NATIONAL COOPERATIVE
HIGHWAY RESEARCH PROGRAM REPORT 260

APPLICATION OF STATEWIDE FREIGHT DEMAND FORECASTING TECHNIQUES

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

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AREAS OF INTEREST:

PLANNING
FORECASTING
SOCIOECONOMICS
USER NEEDS
(HIGHWAY TRANSPORTATION)
(RAIL TRANSPORTATION)

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C.

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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FOREWORD

By Staff
Transportation
Research Board

This report will be most useful to states that undertake freight planning activities on a recurring basis and will be of special interest to state and regional planners having responsibility for the analysis of freight transportation services. Most freight planning techniques developed in the past have been designed for national or regional analyses; therefore, this research was initiated to modify, demonstrate, and document those techniques for state-level applications. The methodology presented herein is based on actual studies conducted in various states, thus ensuring a practical approach for addressing typical freight transportation issues. This report along with *NCHRP Report 177* and *NCHRP Report 178*, which document freight data requirements, provide a comprehensive reference and guide for state freight planning studies.

Participants at the TRB Conference on Statewide Transportation Planning, held on February 21-24, 1974, identified a critical research need for the development of better planning techniques and data sources for statewide freight planning activities. Shortly after the Conference, NCHRP Project 8-17 was initiated to assess and document freight data requirements, and the results were published in 1977 as *NCHRP Report 177* and *NCHRP Report 178*.

Attention then turned from data needs to the development of improved planning techniques that would have general applicability. While several freight forecasting techniques were available, they either were too data intensive for general use or were too oriented to national-level analyses for application at the state level. NCHRP Project 20-17 was conducted to identify and specify multiregional and state freight demand forecasting techniques that could be applied using readily available data. Based on this research, conducted by Cambridge Systematics, Inc., Project 20-17A was initiated to develop a generalized technique for use by state transportation agencies.

Roger Creighton Associates, Inc., had completed freight planning studies for several states just prior to the initiation of Project 20-17A. Drawing on that experience, as well as their work on NCHRP Project 8-17, the research team developed a systematic approach for other states to follow in conducting similar analyses.

The resulting freight demand forecasting technique represents a compromise between specificity and flexibility. Even though a highly structured, step-by-step technique initially seemed like an ideal objective, the need to be responsive to widely different applications and varying data resources dictated a more generalized process than was originally envisioned. However, the general nature of the overall technique is offset by the specificity of its individual components. For example, a truck costing model was developed as part of this research providing a new analysis tool for freight planning studies.

The technique requires the transportation planner to (1) define the problem, (2) structure the technique to address that problem, and (3) simplify and adapt both the problem and the technique to produce results within applicable fiscal, time, and data resource constraints. Following these three preliminary steps, the analysis is completed using the customized freight demand forecasting technique. The technique will be straightforward to most state transportation planners, but it does require some experience with and background knowledge of freight transport. Familiarity with urban and statewide transportation planning processes is also helpful because the technique follows the traditional analysis sequence—freight generation, freight distribution, mode split, and traffic assignment.

The technique can be used to (1) develop current or future estimates of freight flows by highway, rail, and water; (2) forecast freight volume shifts among modes; and (3) provide origins and destinations by commodity within a corridor or region at the sub-state, state, or multi-state level. A user manual is provided, supplemented by three case examples illustrating the usefulness of the method in addressing state-level problems. Each example describes in considerable detail how the technique was applied to the particular problem. While some data came from national data sets, most were obtained from state or local sources and represent the kinds of secondary data generally available.

Developing the capability to conduct effective freight planning activities is a new and difficult challenge for many states. Having trained and experienced personnel, becoming knowledgeable with this and other freight planning techniques, developing a state-level data base of commodity or vehicle flows, rates, and costs, and keeping abreast of the changes taking place both with the state's economy and the transport industry in general are all major parts of this challenge. While a substantial commitment of time and resources is required, the type of freight-planning decisions and issues confronting state governments dictates the need for comprehensive and objective analyses. It is expected that the results of this research will be of value in conducting these analyses.

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The research reported herein was performed under NCHRP Project 20-17A by Roger Creighton Associates, Inc. Mr. Frederick W. Memmott, vice president of RCAI, was the principal investigator. Other contributors to the study were Mr. Daniel Gealt, Transportation Planner, Mr. Russell H. Boekenkroeger, Jr., Senior Transportation Planner, Mr. George J. LaRue, Transportation Planner, and Mr. Roger L. Creighton, president, all of RCAI. (Mr. Boekenkroeger and Mr. LaRue are now with Computervision, Inc., and Wang Laboratories, Inc., respectively.)

APPLICATION OF STATEWIDE FREIGHT DEMAND FORECASTING TECHNIQUES

SUMMARY

This report was prepared at a time when major changes were taking place in the transport industry. A recessionary economy combined with rail and motor carrier deregulation had led to (1) greatly intensified competition among carriers, stemming in part from increased pricing and market entry freedom; (2) a proliferation of new, customized services, including carrier ability to tailor services and rates to closely meet the needs of individual shippers; (3) deterioration in the economic health of many long-established common carriers; and (4) less information being available to the public sector (i.e., through the regulatory process) with which to plan or monitor changes taking place in the supply of, demand for, and the price and quality of transport services being offered.

Despite the thrust of deregulation, the purpose of which was to lessen government intervention and involvement in freight transport, it appears that state interest in freight-related matters is increasing. Although driven in part by interest sparked by light density rail line abandonments and highway maintenance problems accentuated by the use of longer, heavier trucks, the underlying motivations are broader. State DOTs are increasingly accepting the idea that their responsibilities are not solely confined to the state highway system, but include the larger arena of freight transport services being provided by the different modes. States are recognizing the need for better management and coordination of transport resources -- and, hence, the need for better freight planning -- irrespective of whether the infrastructure and services are provided by the public or private sectors.

Given the largely private character of freight transport, planning undertaken by state DOTs is far different from that associated with making physical improvements to the state highway system. In freight planning, the emphasis is on early identification and resolution of problems. It involves working with the carriers to ensure that no economic sector, group, or substate area will be seriously disadvantaged through changes in the type and cost of services being offered. It is not primarily capital oriented, although it may involve state investment in facilities or equipment. Occasionally, it might involve subsidies to retain essential services.

Past Efforts to Address the Problem

Prior to the commencement of this research project, a number of state DOTs had begun to conduct studies requiring freight demand forecasts to address various freight-related issues and problems. These were relatively new activities for many state DOTs; in the past, their concerns had focused primarily on highway transportation and particularly on planning for capital facilities.

Over the years, state DOT ability to carry out freight-oriented studies has been adversely affected by (1) a lack of freight-flow data at the national and state levels in a form that could readily be used for forecasting purposes and (2) a lack of readily available freight demand forecasting techniques that states could directly apply. Given the paucity of appropriate data and analysis techniques, states felt that they were not able to address adequately emerging problems such as the impacts of deregulation, shifts in the economic base of an area brought about by transportation system changes, anticipated changes in transport rate structures, energy availability and price changes, service changes, and so forth. Although techniques and data bases had been developed by others, they had not been widely applied by states nor had they been fully tested. Furthermore, most of the existing techniques and data bases were not developed for application at the state level and, therefore, required further adaptation to make them suitable for use by state DOTs.

Past and Current NCHRP Research

Initial work in freight planning is documented in NCHRP Reports 177 and 178, which focus on the freight data required for statewide transportation systems planning. NCHRP Report 177 provided a detailed assessment of existing freight issues and identified the data required to apply related analysis techniques. The companion document, NCHRP Report 178, contained a user's manual presenting a detailed catalog of existing data sources, methods for obtaining missing data, and guidelines for data collection and management activities by state DOTs.

The first phase of NCHRP Project 20-17 identified freight transportation issues that need to be addressed by demand forecasting techniques and proposed a comprehensive research approach to develop a spectrum of such techniques. However, because of limited funding, it was not possible to undertake the extensive development required to develop this capability. Instead, the scope of the current project (20-17A) was redefined to limit continuing work to the demonstration of an existing technique for immediate application by states through the preparation of a user's manual supplemented by case study examples. Extensive development work was not envisioned; rather the technique was to be based on the current state of the art. The specifications called for a technique which, at a minimum, would (1) develop freight flows by highway, rail, and water for the current year; (2) forecast the likely annual freight volumes and shifts among the modes over the short term (five years or less); and (3) provide origins and destinations by commodity within a corridor or region at the substate, state, or multistate level. The technique must use generally available data and methods, with modification if necessary, to facilitate application to specific problems. The end-product was to be a usable freight demand forecasting technique supplemented by several case studies illustrating the application of the technique. Both the technique and the case examples were to be documented in a self-contained user's manual for general application at the state level.

Research Objective and Approach to Meet Changing State Needs and Data Resources

The objective of NCHRP project 20-17A is to demonstrate the applicability of a freight demand forecasting technique for direct use by state DOTs.

In pursuing this goal, it soon became apparent that the immediate action technique desired by states for freight demand forecasting purposes had to be adapted largely from similar procedures being used for other purposes. Relatively little research work was currently being undertaken in developing freight demand techniques, nor were significant breakthroughs anticipated in the near future. Thus the technique was not expected to overcome the manifest limitations and constraints of present methodologies, but rather be a conduit for supplying information and relevant examples.

In spite of the findings and needs identified in NCHRP Reports 177 and 178, the data resources available to states for freight planning purposes were found not to have improved much in recent years. Given the current federal focus on deregulation and decreasing governmental expenditures, it seems likely that the amount of secondary data to be made available to states through federal programs will decrease. This is in part offset by improving working relationships between the public and private sectors, which in the past has often resulted in required data being made available to states from private sources -- hence, emphasis in this project was shifted away from reliance on traditional, public sector, secondary data sources.

It also became apparent that the emerging problems identified earlier had not materialized to the degree originally expected. For example, deregulation does not seem to have resulted in any significant loss of common carrier service to smaller communities, nor has it placed shippers located therein at any greater economic disadvantage than previously experienced. Likewise, spiraling energy prices and shortages have abated as the worldwide demand for petroleum products has slackened. This is not to suggest that freight problems *per se* have disappeared; rather that the character of the problems likely to be addressed by states in the near future differ from those identified in the research problem statement -- hence emphasis was placed on application flexibility.

It is important to recognize that these shifts in emphasis do not represent any major change to the research approach as originally laid out. They illustrate the changing character of freight planning likely to be undertaken by state DOTs and the need for maximum flexibility and adaptability in the ensuing technique.

Results of the Research

The product of this research project is the freight demand forecasting technique presented in the user's manual. This technique is designed to meet a wide range of potential freight-oriented planning needs, such as:

1. Addressing facility, service, or regulatory problems.
2. Conducting project or program studies having a modal, facility, or commodity type orientation.
3. Assessing state policies toward infrastructure investment, required services, costs, and maintenance of competition.
4. Preparing freight components of statewide master plans.

The overall technique is divided into four phases: (1) freight generation, (2) freight distribution, (3) mode division, and (4) traffic assignment. The main inputs are present and future economic activities (base and forecast year vehicle or commodity flows) and present and future mode service, cost, and price (rate) characteristics for rail, truck, and inland waterway transport. In most applications, the full technique need not be employed. Nor will all of the identified inputs generally be required. A series of subtechniques, of which most have previously been used for freight planning purposes, represent the "building blocks" of the technique. In designing the technique, the researchers sought:

1. As much application flexibility as possible in view of the diverse freight issues and problems likely to be faced by states in the future.
2. Making the technique as user-oriented as possible. The technique will not become an integral part of statewide transportation planning unless the user readily comprehends and understands how the technique can be applied.
3. Adaptability to the varying amounts and quality of data available in different applications. Although the lack of secondary freight flow data has been and will continue to be a perpetual problem, most applications can be undertaken readily if the planner (1) is resourceful in seeking out and adapting appropriate secondary data obtainable from government sources, carriers, and shippers and (2) structures the technique to meet the constraints imposed by available data resources. By allowing flexibility in data inputs, greater adaptability is provided to the planner in marrying the application and data resources.
4. The use of a structured approach incorporating the major independent variables affecting freight demand. The alternative was using direct forecasting techniques, which provide less flexibility. Such techniques focus only on a single aspect of the relationship between economic activity, mode choice, commodity flows and cost and service factors.

The technique was applied to three case examples to illustrate its general applicability. The examples are: (1) the New York Barge Canal Marketing Study, (2) the Montana Grain Subterminal Study, and (3) an informal examination of RoadRailer Service in the Buffalo to New York City Corridor. The complete case examples are included in the user's manual in Chapter Six.

Findings

A pervasive finding of the NCHRP Project 20-17A research is the continuing immature and fragmented state of the art of freight planning. The present lack of freight demand forecasting techniques at the state level stems from numerous causes, among which are the following:

1. Until recently, a limited need or desire by states to undertake freight-oriented studies.
2. State legislation and financial impediments to implementing transport policies or undertaking capital projects involving the nonhighway modes.
3. Unavailability of a freight data base, and the lack of interest in assembling such a data base in view of its potentially limited use.
4. The lack of understanding of the impact that changes in traffic on the rail or waterway systems have on highway system truck traffic and especially on highway maintenance and capital investment needs.

There are other reasons why states have been reluctant to become involved in freight planning. One of the major ones is divided responsibility not only between federal and state governments, but more so between government and private enterprise. Consequently, there remains a great deal of uncertainty as to the proper role for state government in this field. Another reason is preoccupation with the modes and systems over which states have full control. Limited staff and fiscal resources also hinder involvement in areas beyond those of direct responsibility.

The foregoing situation is slowly changing, however, as states become increasingly involved in issues relating to truck use of the state highway system. The advent of the 3R and 4R Acts several years ago gave a major impetus to freight planning for those states faced with substantial light density rail line abandonments. The alternatives to light density line retention in some cases meant increased heavy truck volumes on roads not capable of handling this added traffic without upgrading. Much of the interest generated in retaining the rail infrastructure remains, even though federal rail planning and project funds have recently diminished.

Although the freight demand forecasting technique will handle many potential applications, users should recognize that occasionally the scope of the intended issue or problem will be too broad (or narrow or specific), or the available data too limited, to permit full use of the presented technique. While the technique will make it somewhat easier for states to tackle freight-oriented problems, companion requirements include development of the data resources necessary to support the technique, and the mandate and motivation to address freight problems.

Present State Capabilities: Highway Mode. Even though states are largely responsible for the highway system, the development of forecasting techniques and data bases specifically dealing with truck movements over the highway system has been slow. In most states, the collection of truck traffic flow data, and the preparation of demand forecasts, is treated as an appendage to similar data collection and forecasting being done for passenger vehicles, rather than as a related, but separate, data set. Automobiles do comprise the large majority of vehicles in the traffic stream. This, coupled with the inability to easily separate automobiles and trucks when using automatic traffic-counting equipment (and the consequent necessity to count and classify trucks manually), has mitigated against developing separate data bases for trucks and automobiles. In most states, current and historical vehicle flow data by truck size (i.e., axle and wheel configuration, but not weight) is available from classification and volume counts taken on a periodic basis at sample locations. Data on truck gross and net vehicle weights, however, are usually not available except at a very limited number of locations, typically stations included within FHWA's biannual truck-weighing program. Up until recently, the field work involved in collecting truck weight data has been extremely labor intensive; states have not been receptive to extending the truck weighing program beyond that mandated by the FHWA program due to doubts as to the cost effectiveness and value of such data in meeting their immediate capital program needs. Although such data provide information on equivalent annual load applications, these data are usually not extended to other highway segments. Thus information on vehicle loadings by highway segment is generally not available for the system as a whole.

Many states have permanent weigh stations that are regularly used to weigh trucks for enforcement purposes. Usually, the weight data obtained are not retained in a form adaptable to statistical analysis and summarization. Although most states maintain manual records of the trucks weighed and citations issued, the researchers are not aware of any automation of the record-keeping process, such as using terminals tied into the state DOT's central computer. Nor are data on the vehicle's origin or destination and type and weight of the commodities being carried usually collected. Inasmuch as the lack of data pertaining to truck movements is particularly crucial to developing a freight demand forecasting capability, one solution would be to install computer terminals to access the commodity flow and weight data being generated by an existing program, even though the location of the weigh stations may not be ideal from a statistical standpoint. In doing so, there may be some institutional problems requiring resolution, such as the separation of administrative (data gathering) from enforcement activities. Recognizing that the availability of adequate truck movement data is unlikely through government, carrier, or industry sources, because of the fragmentation of the motor carrier industry and the ubiquitous use of heavy trucks, the importance of capitalizing on existing data resources becomes quite apparent.

In most states, future truck volumes are forecast as a percentage of aggregate traffic volumes for both existing and proposed facilities. The truck percentage typically applied to total traffic is usually determined from historical data rather than from any detailed examination of economic growth or projected truck movements. Thus, the forecasts made are prepared using trend extension forecasting techniques rather than by relating observed volumes with present economic activities and, then, preparing forecasts based on projections of economic activity. Consequently, state DOT personnel often do not consider the resulting forecasts to be very reliable.

Because the relationship between vehicle weight and pavement deterioration has not been well understood, states have in the past expressed only a limited interest in collecting and using vehicle weight data. Thus, truck weight data are typically not used in forecasting rehabilitation or maintenance needs, even though the volume and weight of heavy vehicles do affect pavement life. This appears to be changing, however, as states develop improved pavement management systems.

The limited capability for undertaking truck-oriented freight demand forecasts stems more from the lack of a data base rather than from any inability to devise suitable truck traffic forecasting techniques. This will be rectified as state DOTs develop necessary data bases and forecasting techniques; the responsibility for doing this clearly rests with state DOTs.

Present State Capabilities: Nonhighway Modes. Most of the limitations listed previously also apply to the nonhighway modes. With perhaps the exception of railroad branchline studies, states tend to develop data bases and techniques strictly on an *ad hoc* basis. For nonhighway mode applications, states are largely dependent on secondary data obtained through federal agency programs or supplied directly by carriers or shippers. Development of a comprehensive data base for the nonhighway modes is likely to occur in only a few states. Other states will limit the freight data collection to (1) conducting specialized surveys of particular activities (e.g., shippers' surveys in connection with branchline abandonments) or (2) assembling commodity flow information from secondary sources. When undertaking freight planning, most states will apply techniques developed by others, such as those being developed by this research project, rather than on developing forecasting techniques themselves.

The Emerging Framework. The emerging framework for conducting and managing statewide transportation planning by state DOTs is diagrammed in Figure S-1. This shows statewide transportation planning as being organized into two parts:

- Substantive content -- that which deals with the different modes; their physical and service properties; the way people, vehicles, and freight move over different systems; how well they function; and how they can be improved.
- Management content -- that which is concerned broadly with implementation, from the setting of policy and communications to detailed programming of projects and the monitoring and surveillance of system performance.

The substantive content of statewide transportation planning is a highly technical activity that in the past, has usually led to the publication and adoption of a comprehensive, long-range master plan. Most often, the preparation of these plans was done by an organizational unit detached from the state DOT's day-to-day operations. This reflected the magnitude of the undertaking and the highly specialized character of the work involved.

However, in recent years, greater planning staff efforts have been directed by states towards the management rather than the substantive content of statewide planning. While the management content does have its technical aspects, the emphasis is mainly on staff support of the DOT director or commissioner in policy-level decision-making and program monitoring and surveillance for the purpose of better managing the existing state transportation system. Technical work more often involves policy analysis, analysis of problems having a relatively limited scope, and communications (oral and written) rather than the preparation of a comprehensive, long-range master plan.

The framework shown in Figure S-1 contrasts with the older linear conception of statewide transportation planning that prevailed between 1965 and, say, the mid-1970s. Under that concept the dominating idea was to produce a good technical plan, whether for one mode or all modes, and then to implement that plan. The then prevailing concept was that in order for the plan to be good, it had to be comprehensive and be developed on a systems basis. The latter was a carryover of the urban area 3-C process applied at the statewide level. Implementation, programming, and communication came after the technical work, and were treated by planners as components of plan implementation.

The new framework treats the management content of statewide transportation planning as being at least an equal partner. In many states, it will dominate. This framework recognizes that the day-to-day work of policy planning, communications, programming, monitoring, and surveillance are integral parts of planning processes and perhaps the most important emphasis areas during the 1980s. Furthermore, it recognizes that states are already acting along these lines, and staff assignments are less likely to be geared towards producing older style comprehensive master plans than they are to providing direct support to the DOT director.

Implications Relative to Freight Planning. The implications arising from emerging changes in the substance and content of statewide transportation systems planning vis-a-vis freight planning are these:

Substantive Content of Statewide Transportation Planning

Modes

highway (auto/truck)
rail
aviation
port/waterway
pipeline
bicycle/moped
bus (intercity; rural)

Levels of planning:

systems planning
corridor (project) planning
* preliminary engineering
* engineering design
* planning for operations of existing systems or services
assistance to local/county/regional transportation planners

As a process

data collection
forecasts
goal specification
preparation of alternative plans
testing
evaluation

Management Content of Statewide Transportation Planning

Policy Analysis

financial
regulation
shared policies (e.g., land use)

Communications

with State Administration
with Legislature
with public

Programming

Monitoring/Surveillance

Miscellaneous

operations management studies
energy
environment

* Not functions of DOT planning staff, but part of the typical "Action Plan" process.

Figure S-1. Framework for Statewide Transportation Planning

1. Freight issues and problems in most states stem from the impacts that potential changes in truck flows, sizes, and weights could have on the state highway system. These changes, in turn, affect highway system capital investment needs, maintenance requirements, cost allocation among users, and highway finance. This highway orientation stems from the fact that state DOT responsibilities first and foremost must be directed towards maintaining and improving highway facilities already under state jurisdiction.

2. In considering the nonhighway modes, the primary concerns of most states are the impact that changes in the use of these modes could have on the highway system and secondarily the impact that changes in the cost or services provided by these modes have on the state and/or local economy.

3. State DOTs are more likely to use their limited staff resources in addressing specific issues or problems requiring immediate attention rather than developing freight components of a statewide master plan. Recent applications indicate that states are becoming increasingly pragmatic by focusing efforts on those portions of the transportation system for which they have direct responsibility, and are less willing to undertake freight-oriented planning that could be construed as being the responsibility of the private sector.

4. Inasmuch as future applications are unknown, the freight demand forecasting technique developed under this research project must be adaptable to a wide variety of different applications and situations. A relatively fixed and static technique will not fully meet state needs. This reinforces the "building block"

approach used whereby components can be assembled and used on an as-needed basis. Many applications do not require demand forecasts in a traditional sense, but rather involve comparisons between proposed alternatives and a base condition or case. Frequently, the question to be answered is "What would happen if...?"

5. Even if a forecast is desired, usually it is for a relatively short time period. Sophisticated forecasting techniques per se are really not required, because the limiting factor is the ability to forecast economic activity.

6. Although a freight demand forecasting technique is vitally important to states, by itself it cannot provide the desired capability to analyze freight-related issues and problems. Equally important is the maintenance of adequate data bases, including better information on present and projected truck flows, vehicle weights, and pavement structure and conditions.

Conclusions

Freight Demand Forecasting Technique. Because flexibility and adaptability were paramount considerations, the structure of the technique was purposely generalized. This requires the user at the outset to (1) define the problem, (2) structure the technique to address that problem, and (3) concurrently simplify and adapt both the problem and the technique to produce the desired product within applicable fiscal, time, and data resource constraints. Once done, the user then carries out his customized freight demand forecasting technique. The result is that the user's manual lacks some of the specificity normally associated with a detailed procedural manual. This, however, is offset by the level of detail shown in the included subtechniques.

The user's manual contains over two dozen subtechniques. The majority of them are not unique to freight planning and stem from other areas of transportation planning, as well as from other disciplines. The three modal costing subtechniques, the shipper costing model and the rate estimating models pertain only to freight planning. These subtechniques are probably the portions of the user's manual that will be used most often by state DOTs. It is expected that further development of these subtechniques will occur over time both as a result of refinements brought about by usage and from the need for keeping these subtechniques current. Before using these techniques, users should make necessary adjustments to default values and other input parameters so that the subtechniques reflect current conditions. Thus, users must not consider the subtechniques as being fixed, but as evolving over time.

While the technique is designed to handle a wide range of potential freight-oriented applications, its general applicability can only be established through user experience. Appreciable field testing has been done both through the three case examples, as well as through applications of portions of the technique by the researchers in other freight planning studies. The experience gained to date indicates that the technique is flexible and adaptable to a wide range of applications. However, it is not a universal panacea for all freight-planning needs. Users must be alert not to try and apply the technique in situations where it will not work. As a general rule, the greater the specificity of the application and the completeness of available data resources, the easier it will be to apply the technique.

Freight planning is an extremely broad field. The user's manual is not intended to be a complete text on freight planning or demand forecasting. It is virtually impossible to package the subject in one document or as a single comprehensive technique. Freight planning expertise is not something that can be individually acquired without appreciable effort (i.e., through independent study and experience). Urban planning experience is helpful, but is not a direct substitute for this acquired expertise.

Data Resources. Although there are substantial quantities of secondary data available at the national level for freight planning purposes, the quality and suitability of the data for use at the state or substate level planning is generally poor. By the same token, although much has been written about the inadequacies of available freight data and its adverse effects on state DOT ability to carry out freight studies, and the need for the federal government to improve both the quality and comprehensiveness of public sector freight data resources, states should not anticipate much future improvement in the data resources made available at the national level. The demand for better data is simply not strong enough to offset the costs involved. Thus, users will typically have to make do with what is available, or turn to other than published sources to meet their data needs.

As the case examples in the user's manual illustrate, often some very good data sets are available from other governmental agencies, shippers, and carriers. All-too-often, such resources are not fully exploited by users. While one can never truly get away from data problems, sufficient data can generally be found or assembled if the user is resourceful. Also important is maintaining good working relationships between state DOTs, shippers, and carriers to facilitate information exchange for freight planning purposes. Users must recognize that occasionally quantitative analysis may not always be possible because of the unavailability of suitable data or time and cost considerations involved in assembling required data sets. One pitfall users should avoid is spending too much time attempting to surmount data problems, or trying to perfect the available data, instead of focusing on the application itself. Users must accept the fact that the desired quality attributes are not always available and that they must (1) assemble, synthesize, substitute, or otherwise adapt available data from other sources to develop estimates for missing data, and (2) make estimates and exercise professional judgment when faced with the absence of data. Users should utilize sensitivity analysis to supplement and strengthen the answers obtained, especially when the data resources being used are weak or possibly inaccurate.

One of the greatest needs and opportunities for improving available data resources is through obtaining vehicle and commodity flow information on medium and long-distance truck movements on a regular basis. This is an appropriate area for greater state activity than has been exercised in the past. Creation of a truck-oriented commodity or vehicle movement data base would greatly improve state DOT capabilities for undertaking freight planning activities.

Application by States. The technique will only be useful to those states that choose to undertake freight planning. Because not all states are interested in doing this, the technique has a somewhat limited audience.

Originally, it was hoped that the technique would be simple enough for virtually anyone to apply. However, in making the technique flexible and adaptable to different applications, a highly structured and detailed technique simply was not possible. Thus, some of the desired simplicity has been lost. Although the technique will be straightforward to experienced transportation planners, it does require the user to have experience with and background knowledge of freight transport. Familiarity with the urban and statewide transportation planning processes is also most helpful.

Both the Staggers Rail Act and the Motor Carrier Act of 1980 have substantially changed the character of freight transport. The greater freedom afforded in setting rates present major ramifications in terms of obtaining reliable data on transport charges. Not only is there far more temporal change, but also less information is publicly available as shippers increasingly resort to contract and negotiated rates. Thus, states will find it harder to assemble accurate rate information, and thus, may be forced to use cost rather than rate based approaches. In view of this situation, the researchers anticipate that the costing subtechniques contained in the user's manual will be increasingly important to states in conducting freight planning studies.

States should consider assembling their own commodity flow data base if they plan on undertaking freight planning on a recurring basis. The user's manual describes how this may be accomplished by supplementing existing secondary sources with information on truck movements. The freight demand forecasting technique will not be particularly useful unless it is supported by adequate data resources.

In addition to computerizing the freight data base, states should also consider installing the costing models on the agency's central computer (or on microcomputers). In this way, states will have instant capability to cost out movements by rail, truck, or water. States may also elect to assemble a data base providing information on the physical characteristics, use, and condition of facilities used for freight transport and to develop the capability to perform network assignments. These latter computer tools, however, are not as important as the ability to cost out transport movements.

States must also keep up with what is happening with freight transport both on the national scene and locally within the state. It is particularly important to know the various types of services being provided and the carriers involved, and the economic health of the industry. The more background state DOT personnel have, the easier it will be for them to apply the freight demand forecasting technique as well as to know whom to contact for information and data.

States will find that the technique will become easier to use as staff members gain experience in applying it to different problems. In spite of the encouragement offered in this document, freight planning is not an easy process and it can really only be gained through practice and experience. If it were otherwise, there would have been little need for this research project.

CHAPTER ONE

INTRODUCTION

PURPOSE

This user's manual is a guide for conducting studies that involve or require freight demand forecasts. The technique is designed to handle a wide range of potential freight-oriented applications, such as:

1. Addressing facility, service or regulatory problems.
2. Conducting project or program studies having a modal, facility, or commodity type orientation.
3. Assessing state policies toward infrastructure investment, required services, costs, and maintenance of competition.
4. Preparing freight components of statewide master plans.

The manual presents an overall process or methodology to be followed in conducting such studies along with appropriate subtechniques. Through text, diagrams, and illustrative case examples, this manual describes the means by which users can apply the subtechniques to examine problems and issues at the systems, network, or corridor levels for multistate, state, and sub-state areas.

The overall process and subtechniques both reflect the pragmatic approach used in developing this manual -- emphasis on substantive knowledge and understanding of the problem by the user from which practical quantitative solutions can readily be derived, rather than on methods largely rooted in economic theory or mathematical modeling.

DESIGN OF THE TECHNIQUE

Desired Attributes

Early on, the researchers concluded that the resulting technique should at a minimum:

1. Base freight traffic projections on economic activity rather than on trend extrapolation.
2. Utilize vehicle or commodity flow data rather than vehicle count or density data alone.
3. Be sensitive to changes in the relative costs of, and prices charged by, the rail, truck, and inland waterway modes.
4. Allow changes to factor inputs, such as vehicle size and/or capacity, fuel costs, energy intensity, cost of capital wage rates, etc.
5. Calculate both efficiency and distributional benefits.
6. Allow for the incorporation of public policy factors, as needed.
7. Provide comparisons among alternatives and to a base case.
8. Allow the user to estimate resulting impact on the highway system in terms of vehicles, loadings, and changes in pavement service life.

Design Parameters and Principles

Given the objectives of the project and the foregoing attributes, the technique was designed to satisfy the following requirements and constraints.

Application Flexibility. Because there is no prescribed set of problems or issues that states may wish to address, the technique had to be adaptable to a wide range of potential applications. In essence this means that neither the variables nor the end products of the technique can be defined *a priori*. Thus the freight demand forecasting technique must be specifically tailored to the application at hand. Although states would probably prefer a highly structured, step-by-step technique where essentially all that is required of the user is to supply the specified data inputs, such a technique cannot be developed if application flexibility is to be achieved. The researchers, therefore, opted for a more generalized technique that retains a capability of being applied under widely different situations and for varying purposes. In applying the developed technique, the user is required to (1) define the problem, (2) structure the technique to address that problem, and (3) concurrently simplify and adapt both the problem and the technique to produce the desired products and answers within applicable fiscal, time, and data resource constraints. Once this is done, the user then carries out his customized version of the freight demand forecasting technique.

User-Familarity. If the technique is to be practical for state use, it must not only be easy-to-use, but must build on the previous knowledge and experience of state DOT personnel. This has been accomplished by (1) structuring the technique so that it parallels the well-known urban transportation planning process and (2) carefully selecting component subtechniques. Even so, users should be aware that the subtechniques selected generally (1) were not designed for state or local applications, (2) have diverse and sometimes incompatible data requirements, (3) are not being maintained by any governmental agency for use by others outside the developing agency, and (4) in most cases were not intended for inclusion within a larger freight demand forecasting technique, such as is presented in this user's manual. Criteria used in selecting component subtechniques included (1) the need to establish a complete and integrated overall technique, (2) general usefulness and past utilization of the subtechnique in freight planning, (3) public availability, and (4) general simplicity and understandability of the subtechnique. In preparing the user's manual, the researchers have deliberately chosen not to (1) make the freight demand forecasting technique simply be a compendium of models developed by others or (2) select models developed primarily in a research environment and employing mathematical techniques or computer programs that tend to be unfamiliar or unavailable to state personnel. This is not to suggest that more sophisticated subtechniques could or should not be employed, but rather their usefulness depends on the level of staff training and experience available to state DOTs. Unless state personnel feel comfortable with a method, it will not be used. Hence, emphasis was placed on simplicity.

Adaptability to Varying Data Resources. In the past, state DOTs have been generally self-sufficient in obtaining the data needed for planning capital facilities. Either already available traffic data are used, or agency personnel go out and directly collect such additional data as may be necessary. However, when dealing with freight problems involving nonhighway modes, it is usually not practical for states to directly collect such data. Although some national-level freight-flow data sets are available, these generally have only limited applicability to state and local level problems. Thus, states are dependent on shippers or carriers for a large portion of their data needs. Because the availability of appropriate data sets directly affects the choice of subtechniques, decisions on whether to use a subtechnique or not must be made concurrent with the determination that the necessary data are available from published sources or can be obtained readily from other organizations. The importance of this is borne out by the experience of the researchers on this project. One of the case examples was initially selected without a thorough enough investigation as to the availability of vehicle flow data. This case example later had to be abandoned when it became apparent available that movement data were not comprehensive enough to perform quantitative analysis without undertaking additional field work. Because data availability depends on the unique circumstances surrounding the application, users must never assume that suitable data will be available, but must carefully determine the amount and quality of required data concurrently with selecting subtechniques.

Using a Structured Approach. A structured approach is one based on the concept of freight demand as being (1) derived from underlying economic activities and (2) subject to intramodal and intermodal competitive forces. It is the approach the researchers have used in this manual. The alternative is to use direct forecasting or "single-step" techniques to estimate the quantity of interest based on derived relationships between the forecast quantity and available estimates of economic activities or changes in transportation service. Such approaches are not presented because they focus on a single aspect of the relationship between (1) economic activity, (2) commodity flows, (3) mode choice, and (4) cost and service factors while disregarding other aspects. Although direct forecasting techniques can, in principle, incorporate all of the independent variables found in the structured forecasting approach, users are typically forced by the constraints of empirical model building to limit the number of variables being considered. Depending on state DOT objectives, the freight issue at hand, and the time and data resources available, the user must determine at the outset which variables to address and which to deemphasize or ignore. In con- trast, a structured approach provides the flexibility needed when neither the variables nor the end-products can be defined a priori. It also provides the ability to handle multiple variables simultaneously.

BASIC STRUCTURE

The overall technique is divided into four phases, as shown in Figure 1: (1) freight generation, (2) freight distribution, (3) mode division, and (4) traffic assignment. Thus, the technique is conceptually similar to the urban transportation planning process.

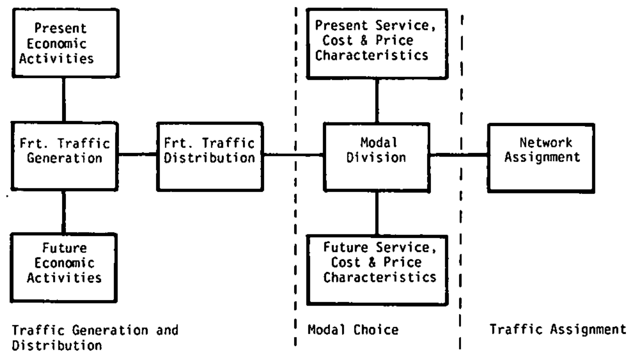

Figure 1. Freight Demand Forecasting Technique: Major Phases.

Although the structure is similar, substantial differences do arise in both application and data resources available to states. Some of the major differences are:

1. Unit of Measure. Rather than vehicle or person trips made on an average weekday, the basic unit is freight or commodity flows expressed in tons or vehicle equivalents made over an extended period of time, say a year.
2. Replication of Universe. In urban studies, the full universe of travel within, into/out of, and through the study area is replicated, whereas such is usually not possible with freight studies.
3. Data Dependency. In urban studies, trip generation and distribution are often simulated. Simulating freight movements is far more difficult, given the multiplicity of commodities each having their own unique distribution pattern and attributes. Thus freight studies have a higher dependency on data -- particularly commodity flow data.
4. Data Collection. In urban studies, states have the option of obtaining travel data directly, rather than relying upon available secondary data. In freight studies, the option of obtaining traffic generation and distribution data directly is not practical unless the study scope is limited.
5. Forecasts. In urban studies, forecasts of future traffic largely reflect expected population and income change for the study area, whereas in freight studies, forecasts must reflect the broader, national and state economies as well as technological changes.
6. Mode Choice Complexity. In urban studies, mode choice generally reflects vehicle availability and comparative time or cost, whereas in freight studies it reflects service factors as well. Procedures for modeling mode choice where service is a major consideration are not well developed.
7. Focus. In urban studies, the main product or focus is on vehicle flows over highway and transit networks. In freight studies, the change in modal use and resulting shipper and carrier costs are very often more important than vehicle volumes on the modal networks. Vehicle flows are particularly relevant when impacts upon pavement structure or the surrounding environment are involved.
8. Redundancy. In urban studies, various crosschecks are typically made to ensure that the results being obtained are representative of actual conditions. In freight studies, there is less opportunity for using redundancy given the amount and quality of the data typically available. This makes independent verification or crosschecking of the results obtained more difficult, and thus places greater re-

sponsibility upon those conducting the study to ensure that the data and techniques used in reaching study conclusions are reasonable and defensible.

The implication of this is that even though the basic phases are similar, the specific techniques will differ appreciably from those used by planners in solving urban transportation problems. The technique presented is more complex than its urban counterpart because of (1) the lack of a prescribed set of problems and issues to which the technique will be applied, (2) the customized nature of the resulting products, and (3) the need to adapt the technique to widely varying data resources and the inability of users to collect required data directly.

ORGANIZATION OF THIS MANUAL

A chapter is provided for each major element of freight demand forecasting:

- Chapter Two: Defining the Problem
- Chapter Three: Freight Traffic Generation and Distribution
- Chapter Four: Modal Division
- Chapter Five: Traffic Assignment
- Chapter Six: Case examples illustrating the application of the technique.

CHAPTER TWO

DEFINING THE PROBLEM

INTRODUCTION

The starting point in any application is:

1. First, defining the problem.
2. Second, structuring the freight demand forecasting technique to address that problem.
3. Concurrently, simplifying and adapting both the problem and the technique to produce the desired products and/or answers within applicable fiscal, time, and data resource constraints.

Since states may elect to address a wide range of problems or issues, appreciable flexibility and adaptability had to be incorporated into the design of the technique. The underlying premise was that the technique could not be rigidly specified in advance, because neither the variables nor the products can be determined a priori. Thus in applying the technique, the user must tailor the technique to the application (and vice versa) before becoming immersed in the computational detail involved in carrying out the application. This chapter provides guidance on accomplishing this.

DEFINING THE PROBLEM

Before attempting to apply the technique, the user should first take time to fully determine the parameters and constraints both affecting and shaping the application at hand. The secondary objective is to reduce the scope of the application, to the maximum extent possible, while retaining the capability to provide desired answers. The greater the effort spent initially in defining the problem, the easier it will be for the user to apply the technique and obtain meaningful results.

Specifically, the user should look for, and identify or decide on, the following.

General Parameters

The user should identify the general parameters or overall dimensions of the application, which include:

1. Physical and cultural aspects, defined by identifying affected (1) geographic space, (2) transport infrastructure, and (3) shippers and receivers constituting the universe of interest. The spatial dimension can be multistate, statewide, substate, or corridor. Infrastructure can include all facilities or be limited to particular transportation modes, routes, and services. The universe of shippers and receivers can include all or, alternatively, be a subset delineated by (1) establishment size, (2) shipment sizes, (3) commodity type, or (4) total volume (weight) of shipments or receipts made over a selected time period.
2. The general orientation, which can be modal (primary emphasis is on a single mode, although comparisons may be made with other modes), commodity (emphasis is on a single or limited number of commodities or types of freight), or specific facility (emphasis is on changing traffic and its impacts).
3. The modes, transport facilities, and services presently being used and expected to be used in the future. Modal definitions should not be limited by their traditional classifications (i.e., rail, truck, inland waterway), but rather the user should explicityl recognize any significant variations in intramodal services, shipment sizes or competition between modes or mode combinations.
4. The commodity or commodities and related shipment sizes presently being transported or expected to be transported in the future.
5. The alternative futures, scenarios, or conditions to be examined in comparison with a base year.
6. The regulatory environment surrounding the problem at hand, both at present and in the future.

In examining the general parameters of the problem, the user must simultaneously sort out what is important and must be incorporated into the technique from that having little effect and, hence, can be dropped from further consideration.

Major Tasks to be Accomplished

In considering the desired products or answers, the user should decide whether the application necessitates:

1. Preparing forecasts of commodity production and consumption (or freight shipped and received) in addition to assembling comparable base year information. Wherever appropriate, production and consumption forecasts prepared by others should be used. If not available, such forecasts must be prepared by the user.
2. Preparing forecasts of vehicle or commodity flows or distribution in addition to assembling comparable base year information. In most cases, the user must prepare such forecasts.
3. Dividing commodity flows among competing modes or services based on anticipated or hypothesized changes in the type, price or cost of the services offered along with assembling similar information on base year modal shares.
4. Determining commodity or vehicle flows over each modal network. If detailed information on segment volumes is required, determining whether the size of the area, complexity of the modal network, and required level of detail dictates that a computerized process be used to assign traffic to modal networks.
5. Determining the impacts of changes in commodity or vehicle flows on the use of the highway system and resulting capital and maintenance needs to be supplied by government. Such impacts include (1) changes in truck volumes, sizes and weights, (2) changes in pavement loadings, (3) changes in anticipated pavement service life, and (4) direct and indirect effects of vehicles on other highway system users as well as on the adjacent environment.

By determining the general parameters and major tasks that must be accomplished, users have largely defined the problem or application while beginning the process of customizing the technique to the application.

Analytical Choices

The user should now consider whether to:

1. Measure performance in (1) economic, (2) physical, or (3) impact terms. Economic performance involves estimating and weighing the benefits and costs accruing from each alternative future, scenario or condition being tested in comparison with the base case. A comprehensive framework covering total system economics can be used or, alternatively, a more restrictive framework limited to (1) changes in the cost incurred by shippers and receivers, (2) relative profitability to the carriers providing the transport service, or (3) costs avoided or incurred by government. Physical performance involves measuring and comparing commodity or vehicle flows. Impacts are simply the projected effects of anticipated changes in vehicle flows in comparison with the base case and relevant standards.
2. Estimate modal shares based on selecting the mode or service minimizing prices charged or unit costs. Underlying premises are that (1) rates reflect carrier market share competition versus profit maximization, and thus reflect service differences, versus (2) the unit costs of the movement, which provide a better indication of long-term prices because such costs reflect the relative efficiencies of the competing carriers.
3. Adopt a physical distribution or a transport economics orientation in determining modal shares. The former includes costs associated with inventory carrying, warehousing, packaging, shipping and receiving in addition to transport charges to the shipper or receiver (revenues to the carrier) used by itself in the more conventional transport economics approach.
4. To cost or price movements on a one-way or round trip basis, with the latter accounting for differences in backhaul revenue and vehicle/vessel utilization.
5. To optimize locations or flows in addition to, or in place of, determining the costs and revenues of different alternatives.

Users should recognize that the analytical choices made above dictate, in part, which subtechniques must be employed.

Resulting Product

The user should finally consider the resulting product, which includes:

1. Contents of the output record, which for each unique movement usually includes an (1) origin, (2) destination, (3) mode, (4) commodity type, (5) commodity flow, (6) vehicle equivalents, (7) carrier revenues, and (8) shipper or receiver costs. This manual presumes that most users will elect to use computers in summarizing data. It does not imply the need for a large mainframe computer; most of the computations presented herein can be made with a microcomputer (e.g., a TRS-80, Apple II, or IBM Personal Computer) or even be done manually.
2. Contents and layout of the various summary tables describing the efficiency benefits and impacts of individual alternatives in comparison with the base case.
3. Written analyses formatted to meet management requirements and providing the specific answers being sought.

SIMPLIFYING THE PROBLEM

Concurrent with structuring the technique is the need to simplify the problem; that is, scaling down the total freight universe to only that portion needed to address the problem. Simplification involves the following steps:

1. Reviewing and accepting simplifying premises and assumptions.
2. Defining the geographic area of interest.
3. Aggregating data.
4. Focusing only on those economic sectors necessary and appropriate to the problem.
5. Determining transport characteristics to be examined.
6. Adjusting the scale of the application to that for which data are readily available.

Simplifying Premises and Assumptions

Most short-range problems can be appreciably simplified if the user is willing to accept the following premises and assumptions:

1. Aggregate freight demand is price and service inelastic. Most economic activities producing significant quantities of freight are resource based or tied to a given location by its investment in plant, equipment, and employees. In the short run, such producers have no option but to transport their freight irrespective of the cost or quality of the transport service supplied. Although locational changes do occur, such tend to be the outcome of a variety of factors, only one of which is transportation.
2. Freight traffic generation is independent of the factors determining the division of traffic among the modes. In the short run, production and marketing decisions are made independently of mode choice decisions.
3. Modal division is dependent on the price and service characteristics of the individual modes. Where service is not a major factor, modal division can be simulated by comparing modes on a price or cost basis. When service is a factor, modal division can be simulated by comparing logistics costs.
4. Freight traffic forecasts are dependent upon the anticipated amount and location of economic activities. Since the economy generates freight, changes in freight generation and distribution must stem from changes in the location and intensity of economic activity. Thus, the ability to forecast freight flows can inherently be no better than the ability to predict changes in the national, state and local economies.
5. Changes in the composition of freight traffic should be implicitly recognized, although the user can usually ignore such trends for short-run forecasts. Even though little consistent change has taken place in the average length of haul for all modes (spatial dimension), changes in industrial structure and technology have resulted in diminished commodity use (weight dimension). Consequently, freight volumes are growing increasingly more slowly relative to the gross national product (GNP) and other economic measures. As an economy matures, it tends to economize on its use of commodities.
6. Products produced by agriculture, manufacturing, and mining establishments will eventually be transported and consumed. Thus, commodities produced equal freight shipped. Variables, such as changes in inventory levels, product shrinkage, loss, and so forth, can be ignored. (The above will not be true for some agricultural products that may partially be consumed on-site or stored for long periods awaiting higher market prices).

Defining the Geographic Area of Interest

In most statewide transportation studies, state boundaries logically delimit the study area. Unfortunately, such areal units do not work well in freight studies because a large portion of freight flows are interstate. Given the economic interdependence of states, a regional, if not national, study area is often more appropriate.

1. If a statewide freight study is being undertaken, the immediate study area will usually be defined by state boundaries. If significant economic activity is concentrated adjacent to state borders, it may be desirable to extend the immediate study area boundaries to include this activity. Equally important is the tributary area formed by shippers or markets located in surrounding states. Users should consider a two-tier approach whereby freight activity is defined at a finer level of detail within or adjacent to the state and at a coarser level of detail for neighboring or remaining states (and, if necessary, adjacent countries).
2. Rather than focusing on geography in defining tributary areas, users should consider specific economic centers or markets. For example, the study area for an agricultural transport study might include the crop or vegetable-growing areas of the state and the principal out-of-state markets for the resulting agricultural products.
3. Data availability is a strong factor in determining study area limits. Because disclosure regulations limit the availability of most secondary economic data to the county level at best, study area and subarea boundaries should be coincident with county boundaries (or their equivalent in New England). Thus, the county itself becomes the smallest common "building block" typically used in freight studies.
4. Finally, the size of the study area should be kept as small as the application and data resources will permit.

Aggregating Production and Consumption or Movement Data

If more disaggregated secondary data are available, the user has the choice of retaining the geographic detail or aggregating up to the county level. Supplementary information is readily available by which to aggregate port, railroad station, or city and town level data upward to the county level. Unless the application involves such localized facilities as railroad branchlines, grain elevators, ports, and terminals, and the commodity flow data being used is reasonably comprehensive and complete, data should be aggregated to the county level.

Economic Sectors of Interest

If the application encompasses all freight movements, it will include movements within and between the following economic sectors: agriculture; manufacturing; mining; contract construction; transport and public utilities; finance, insurance and real estate; retail trade; wholesale trade; services; government; and consumers. Only a few of the economic sectors listed above generate significant freight volumes (see Figure 2), but most sectors receive freight. The main producing sectors include agriculture, manufacturing, and mining. Major consuming sectors include agriculture, manufacturing, mining, contract construction, transport and public utilities, retail and wholesale trade, services, government, and consumers.

If the application permits, the user should concentrate or restrict study efforts to freight movements originating from as few economic sectors as possible, keeping in mind that commodity flow data are really only available for agricultural, manufacturing, or mining activities.

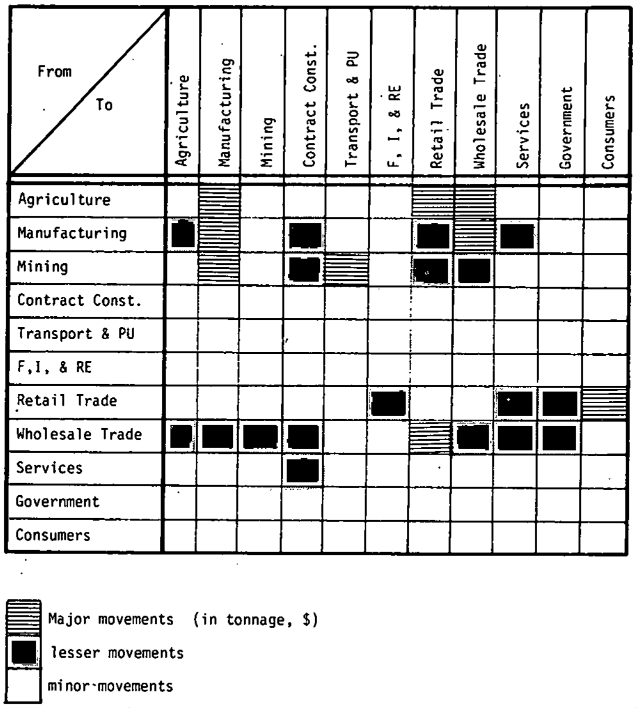

Figure 2. Economic Sectors Generating Significant Freight Volumes.

Transport Characteristics of Interest

Further simplification can be achieved by focusing on limited modes or services. Although all sectors are dependent on motor carrier transport, the use of rail, waterways, and other specialized modes is largely restricted to products produced by the agricultural, manufacturing, and mining sectors. Users should be aware that different types of services are offered by the various modes and that interservice competition may be more relevant than intermodal competition.

1. Again, if the application permits, reduce the scope of the study to those products and movements for which competing modes are service and price competitive.
2. Similarly, limit the scope of the study to shipments of certain sizes or characteristics deemed competitive or otherwise important to the study.

Data Availability

Users must accept the fact that adequate data are rarely available, and be prepared to:

1. Assemble, synthesize, substitute, or otherwise adapt available data from other sources to develop estimates for missing data.
2. Make estimates and exercise professional judgment when faced with a partial absence of data.
3. Use sensitivity analysis to supplement and strengthen technique findings, especially when the data resources being used are weak or possibly inaccurate.
4. Reduce the scope of the application down to the level for which data are available or can be replicated.

Users might best start by establishing:

1. What data are available?
2. What is its intended use?
3. What are its major shortcomings and problems?
4. What effect do such-related problems have on the expected findings?
5. What can be done to guard against misleading or wrong conclusions?

By the time the user reaches this point, practical considerations will take precedence over what may have originally been intended.

STRUCTURING THE TECHNIQUE

The freight demand forecasting technique presented in Figure 1 is divided into four phases: (1) freight generation, (2) freight distribution, (3) mode division, and (4) traffic assignment. The main inputs are present and future economic activities (base and forecast year vehicle or commodity flows) and present and future mode service, cost, and price (rate) characteristics for rail, truck, and inland waterway transport. In most applications, not all of the foregoing phases will be employed. Nor are all of the listed inputs typically required. The user must next decide which of the phases and inputs are mandated by the problem at hand.

To do this, the user must establish whether the application requires preparing forecasts, dividing traffic among the modes, assigning traffic to simulated networks, or determining resulting impacts. If any one of these tasks is not required, the application can be appreciably simplified, as shown in Figure 3.

PHASE OPTIONS

Assuming that the user has (1) defined and simplified the problem (to the extent that this can be done reasonably) and (2) determined which phases must be employed, the next step is to select appropriate phase options.

Freight Traffic Generation and Distribution Options

The product of freight traffic generation and distribution will be one or more commodity flow matrices. A matrix is always prepared for the base case situation.

The need for additional matrices depends on the alternatives being evaluated (i.e., the extent to which the application involves alternative futures, scenarios, or conditions). These terms are defined as follows:

1. Futures. Projected increases or decreases in shipments, receipts, and commodity or vehicle flows, over time. Usually accompanied by changes in distribution patterns. Changes stem from factors unrelated to transport system infrastructure, rates, or

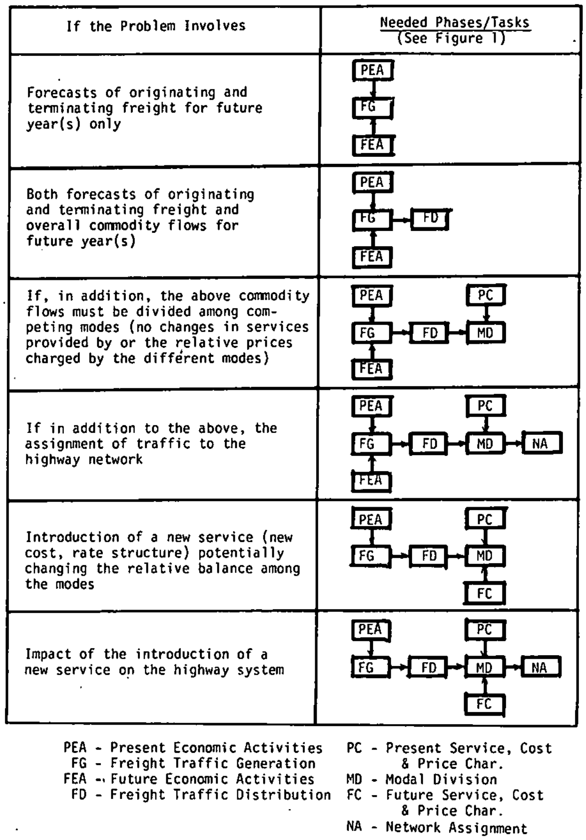

Figure 3. Structuring the Application.

services (i.e., changes in production, consumption, or market shares). Requires preparation of a futur year commodity flow matrix in addition to the base year matrix.

2. Scenarios. Hypothesized changes to transport system infrastructure, rates, or services, the intent of which is to make the transport system more efficient. Usually accompanied by changes in modal use and, hence, flows, revenues, and costs. Because shipments, receipts, and flows do not change, the base case commodity flow matrix would be used.

3. Conditions. Hypothesized constraints or limitations placed upon system use or revenue and cost structures, the intent of which is to determine changes in modal use, flows, revenues, and costs. Because shipments, receipts, and flows do not change, the base case commodity flow matrix would be used.

Although it is possible that two or more of the foregoing situations occur simultaneously, the majority of applications are simpler and involve only one of the above.

Options *per se* do not really exist in preparing a base year matrix because it is a required product. It comes down to determining how to supplement or extend existing vehicle or commodity flow data to attain a matrix representative of the freight universe being examined. If comprehensive quality traffic flow data are available, the work required may be minimal (i.e., selecting movements originating, terminating or passing through study area, summarizing by county, etc.). If such data are not available, the user may also have to (1) update existing commodity flow data to represent the selected base year; (2) combine multiple data sources, recognizing the possibility, and need, to correct for voids and duplications; (3) approximate movements for nonreported modes or services through field surveys or by using other secondary data, estimates, and judgment; and (4) use simulation techniques to help estimate freight shipments, receipts, and flows.

Options involved in preparing future year commodity flow matrices also do not exist. In most cases, the future year matrix will be developed from the base case matrix by (1) applying growth factors to base year commodity production and consumption data (or freight shipped and received), and (2) then adjusting and balancing vehicle or commodity flows using a synthetic distribution process.

Modal Division Options

The overall process shown in Figure 4 is entirely straightforward. It subdivides into three main components:

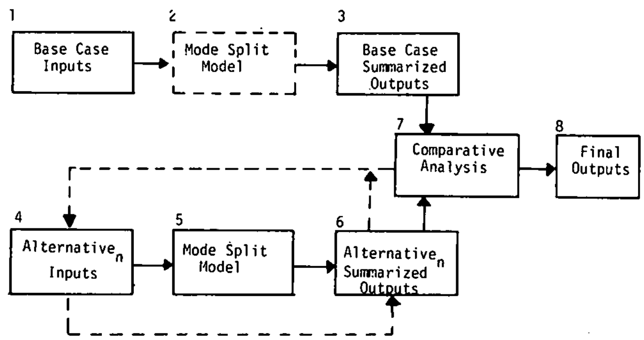

Figure 4. Modal Division Process.

1. Summarizing base case commodity (or vehicle) flows, carrier costs and carrier revenues/shipper costs. Usually information is available on the mode utilized, thus making application of a mode split model unnecessary. Often base case commodity flow data is used to develop such a model or to test the reliability of an existing "off-the-shelf" model.

2. For each alternative being considered, dividing commodity flows among competing modes using a mode split model, and then summarizing resulting flows, costs, and revenues.

3. Performing selected consistency tests to insure the reasonableness of the results obtained from the mode split model, and then preparing final outputs.

Users may elect to add to or combine the components shown. Variations will occur depending on (1) the number of alternatives being considered; (2) whether the user elects to make the modeling process recursive; and (3) the amount of intermodal competition present or anticipated, which may permit partial bypassing of the mode split model.

Figure 5 provides further details on modal division options. The inputs available to the user largely determine the methodology options that can be used. All options require commodity (or vehicle) flow data, however.

1. If only unit cost data (2) are available, Methodology A must be selected. Outputs will then

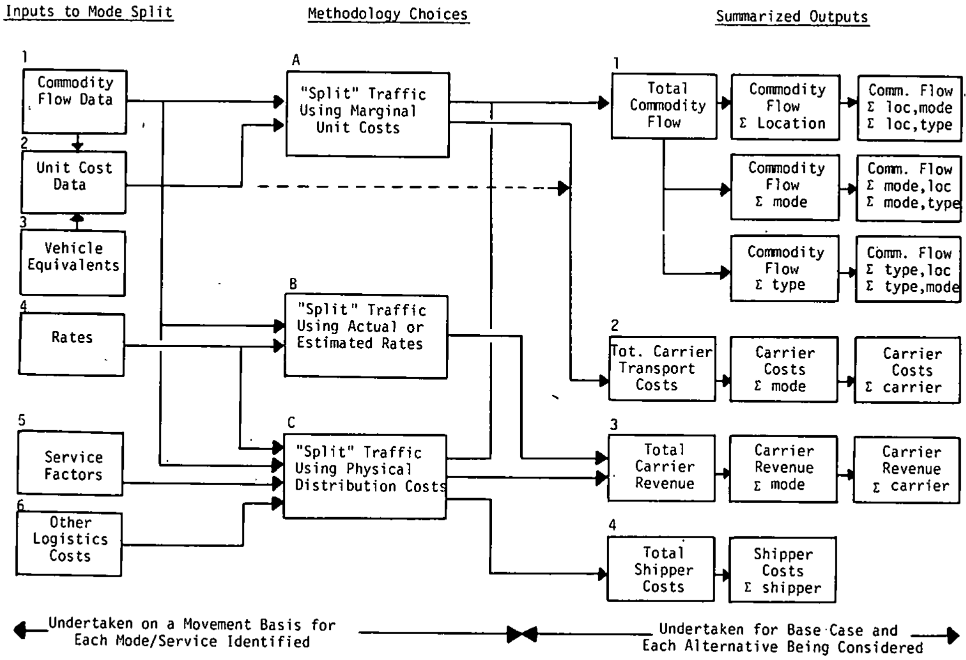

Figure 5. Modal Division Options.

be limited to commodity flow (1) and carrier transport cost (2) summaries.

2. If only rates (4) are available, Methodology B must be selected. Outputs will then be limited to commodity flow (1) and carrier revenue (3) summaries.

3. If both unit cost data (2) and rates (4) are available, either Methodology A or B can be used. Commodity flow (1) and carrier transport cost (2) and carrier revenue (3) summaries will then be produced.

4. If data are available from shippers on their other logistics costs (6), Methodology C can also be used.

Figure 5 also shows various summarized output options. Users can obtain:

- Estimated commodity flows in terms of:
  - totals
  - subtotals by
    - location (origin, destination, and origin-destination pair)
    - mode
    - type (STCC category or equivalent)
  - detail
    - mode within location
    - type within location
    - location within mode
    - type within mode
    - location within type
    - type within mode
- Estimated vehicle flows, that are similar to the above. Vehicle flows can be estimated by dividing commodity flows by vehicle equivalents, taking into account vehicle sizes and utilization of the available weight or bulk capacity of the vehicle.
- Carrier transport costs, including
  - totals
  - subtotals by mode and/or carrier

  Transport costs can be expressed in total dollars or as a cost per mile (kilometer) or a cost per unit quantity (e.g., ton, bushel, gallon). Transport costs can also be subdivided into their fixed and variable components.
- Carrier revenues, including
  - totals
  - subtotals by mode and/or carrier

  Carrier revenues can likewise be expressed in total dollars or as a revenue per mile (kilometer) or a revenue per unit quantity.
- Shipper costs, including
  - totals
  - subtotals by shipper (or shipper group)

  Shipper costs include logistic costs in addition to transport charges (carrier revenues).

The foregoing outputs could be produced for the base case and each alternative being considered. On the basis of their knowledge of the application at hand, users should carefully review the list to determine those products that are important. Since computer programming is often required to produce such products, users should be aware of the manpower and time implications involved in producing outputs in the first instance and the degree to which they will be used in analysis and decision-making.

Figure 6 shows the final outputs. Before producing tables that in effect compare or highlight differences between the base case and each alternative (or between alternatives), users should consider the need for performing consistency tests. Although many checks could be devised, one of the most important checks is comparing unit rates and costs (on a movement basis) or total revenues and costs (on a modal or carrier basis) to ascertain their general reasonableness. It is unlikely that a carrier will continue to provide service when it is inherently unprofitable. Similarly, it is unlikely that a carrier will reap huge profits from a particular movement if there is competition. If these traits are being indicated by the mode split model, it may be necessary to change the premise and opera-

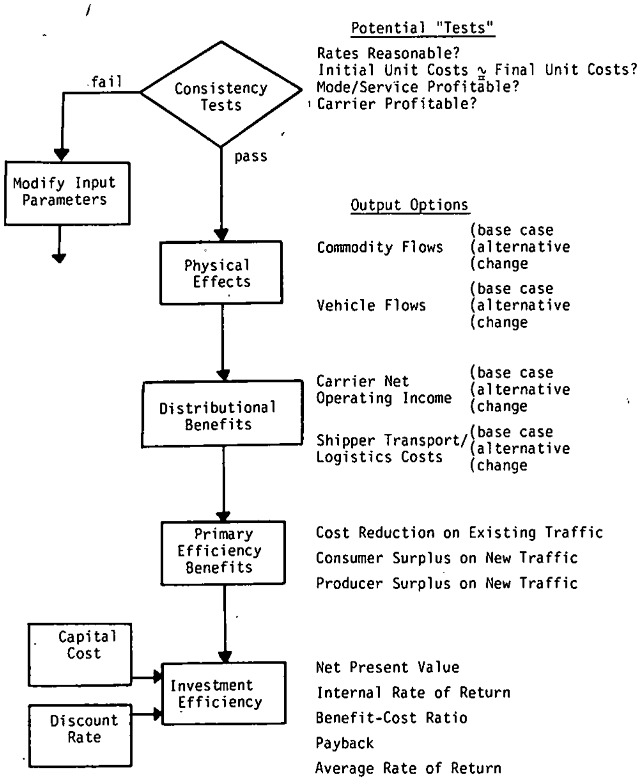

Figure 6. Final Outputs.

tion of this model to obtain more realistic results. Modal utilization should show a general relationship to the rates being charged by competing modes. Otherwise, reasonable replication of real world conditions is not being obtained. Unless the results being obtained are reasonable and logical, the conclusions reached will be suspect.

The remainder of Figure 6 shows various options, including:

- Physical effects, which are primarily changes incommodity and vehicular flows.
- Distributional benefits, which are primarily changes in net carrier operating income or changes in shipper transport or logistic costs.
- Efficiency benefits, which include cost reduction on existing traffic, consumer surplus on new traffic, and producer surplus on new traffic.
- Investment efficiency, which takes into account project capital cost and an appropriate discount rate (if capital investment is being contemplated).

Traffic Assignment Options

The overall process illustrated in Figure 7 is similar to that presented previously. It subdivides into four main components:

- Converting commodity flows into vehicle flows, if not already done in estimating carrier costs.
- Assigning the resulting traffic to modal networks.
- Estimating changes in vehicle/vessel volumes and loadings expected to occur on a segment basis.

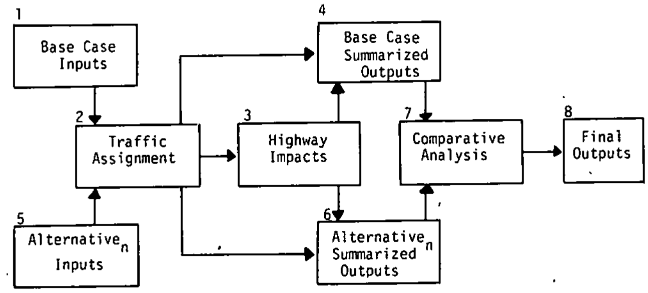

Figure 7. Traffic Assignment Process.

- For highway segments, estimating expected changes in pavement service life on a segment basis.

Some of the subtechniques that typically would be used, such as coding of modal networks and assigning traffic thereto, measuring the direct and indirect effects of vehicles (e.g., noise levels, air pollution, etc.) on other highway system users and the adjacent environment, determining fossil fuel energy use, and changes in user revenues, are already well known to state DOT personnel or are unique to each state and thus have not been presented in detail in this manual.

Figure 8 provides further details on the options available to the user. Inasmuch as states are particularly interested in highway system impacts, a comparable methodology to measure and evaluate rail and inland waterway system impacts has not been presented in this manual.

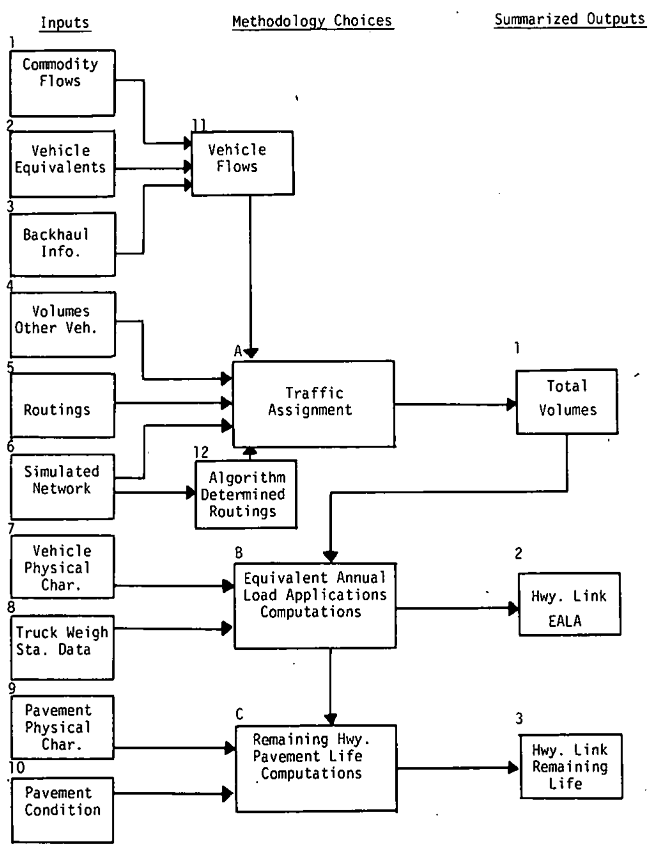

Figure 8. Traffic Assignment Options.

SELECTING APPLICABLE SUBTECHNIQUES

Once the user has (1) defined the problem, (2) conceptually structured the freight demand forecasting technique to address that problem, and (3) simplified and adapted as much as possible both the problem and the technique to meet fiscal, time, and data availability constraints, he is then ready to proceed to the next stage and select applicable subtechniques. Chapters Three, Four, and Five contain subtechniques that have been used or are adaptable to freight demand studies. Table 1 is a cross-reference to assist the user in accomplishing this selection. By starting at the left and working to the right, appropriate subtechniques can be quickly identified.

Table 1. User's Manual Cross-Reference.

PHASE ◄──► USER DECISIONS ◄──► DATA/SUBTECHNIQUE — PAGE

CHAPTER THREE

PHASE	USER DECISIONS			DATA/SUBTECHNIQUE	PAGE
Freight Generation and Distribution	Base Year Commodity Flow Matrix	Commodity Flow Data Available	Census-Type O/D Data	Using Secondary Data	19
				Using Primary Data	19
			Sample O/D Data	Using "Assembled" Data Base	20
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CHAPTER FOUR

PHASE	USER DECISIONS			DATA/SUBTECHNIQUE	PAGE
Modal Division	Mode Split Model	Carrier Costs	Rail	Rail Form A	45
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CHAPTER FIVE

PHASE	USER DECISIONS			DATA/SUBTECHNIQUE	PAGE
Traffic Assignment	Not Req'd				N/A
	Assignment Required	Manual			Note 1
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1. Standard manual accounting.
2. Can be adapted to a highway traffic assignment program, or a special purpose assignment program can be developed.

CHAPTER THREE

FREIGHT TRAFFIC GENERATION AND DISTRIBUTION

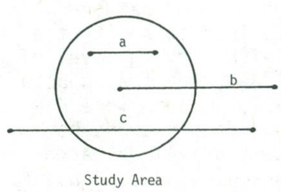
INTRODUCTION

Normally, traffic generation and distribution are thought of as separate phases. When commodity flow data are used to estimate base year traffic origins, destinations (terminations) and flows, these phases are combined. When simulation techniques are employed to estimate these outputs, freight generation and distribution are treated separately.

Irrespective of whether commodity flow data or simulation techniques are employed, the product is the same -- one or more commodity or vehicle flow matrices analogous to the trip tables produced in urban transportation planning studies. One matrix represents the base case. The others, developed from the base case matrix, represent future years.

Freight traffic generation involves estimating the amount and location of originating and terminating freight moving externally to the establishment. It can include the full universe of freight movements or, more typically, is restricted to a subset of movements delineated by (1) geography (i.e., an area from within which the freight must originate and terminate), (2) economic sector or industry inclusion, typically by Standard Industrial Classification (SIC) codes, (3) size of establishment (e.g., minimum number of employees), (4) commodity types, typically by Standard Transportation Commodity Codes (STCC), (5) distance of shipment (i.e., intercity rather than local), and (6) transport modes or services used. This reduces both the number of establishments and movements contained within the universe being examined, and thus makes the application more manageable.

Freight traffic distribution involves estimating vehicle interchanges or commodity flows between the origins and destinations identified under freight traffic generation. Figure 9 shows the classification of typical movements or interchange patterns. Because states are not economic entities by themselves, a large portion of the movements encountered in freight studies will originate or terminate outside of the state. Thus, freight studies readily become regional or national in scope because of the ubiquitous character of freight transport. If traffic flows over a transportation network are of interest, users must also account for traffic passing through the state as well as internally originating or terminating traffic.



a. Origin and Destination within Study Area (local traffic).

b. Origin or Destination within Study Area

Domestic	Foreign*
internal/external shipments to other states	export
external/internal receipts from other states	imports

c. Origin and Destination Outside of the Study Area (through traffic)

* May or may not pass through international terminals (i.e., ports, airports) located within the study area.

Figure 9. Dichotomy of Movements.

The techniques presented in this chapter are based on the concept of using commodity flow data to estimate freight generation and distribution. The few statewide freight studies performed to date have used this approach (7). Simulation techniques would be used only if vehicle or commodity flow matrices could not be developed from existing data. Use of simulation techniques depends on (1) the availability of suitable production, consumption, and distribution data from which commodity flows can be approximated, and (2) acceptance of simplifying premises appropriate to short-range freight demand forecasting.

Although data-based and simulation approaches are both presented, the distinction between the two is not particularly clear-cut. In a data-based approach, the user either structures the application to match the commodity flow data available or expands the data base to meet the requirements of the application. In a simulation approach, the user replicates freight generation and distribution by applying unit shipments and receipts and distribution patterns derived elsewhere to the application. Both data-based and simulation approaches produce a commodity flow matrix.

DEVELOPING THE BASE CASE COMMODITY FLOW MATRIX

If vehicular origin-destination or commodity flow data are available to the user, that data should be used as the basis of the base year commodity flow matrix. Even though the data may be far from complete and thus is initially unsatisfactory, they can often be modified or supplemented by other data to produce a satisfactory product. For reasons that will become apparent, use of existing data is preferable to approximating freight generation and distribution using simulation techniques, because such techniques generally cannot replicate effectively local conditions. Even when available commodity flow data appear to be satisfactory, independently prepared freight generation estimates are advisable to verify the quality of the data.

Using Census-Type Origin-Destination Data

Secondary census-type origin-destination data will occasionally be available to the user as a consequence of other programs or activities. The form of the data can be vehicle equivalents (e.g., truckloads, carloads, bargeloads) or as commodity flows. Vehicle equivalents can be converted to flows if commodity identification (e.g., STCC code) and shipment weight or volume are supplied along with vehicle counts. If census-type data are available, they should be used. Users may want to first verify the quality of the data rather than to assume the data to be satisfactory. By comparing commodity flow totals with independently established industry-wide totals and commodity, locational, and shipper subtotals, voids or omissions (if any) can be identified and modifications be made. Similarly, where data overlap or redundant information is available, the user should identify the "hardest" or most reliable information to use in the application.

If the application is small enough, census-type commodity flow data can be collected by conducting a shipper's survey or by obtaining comparable information through direct contacts with carriers or shippers. Although primary data collection may often appear impractical from a time and cost standpoint, shippers' surveys can be more cost- effective than attempting to supplement incomplete data or to simulate freight generation and distribution using secondary sources. If the application involves a limited number of commodities or establishments, a shipper's survey should at least be given serious consideration. Extensive field work might not required; shippers sometimes are willing to provide manual or computerized summaries of their freight shipments and receipts on request.

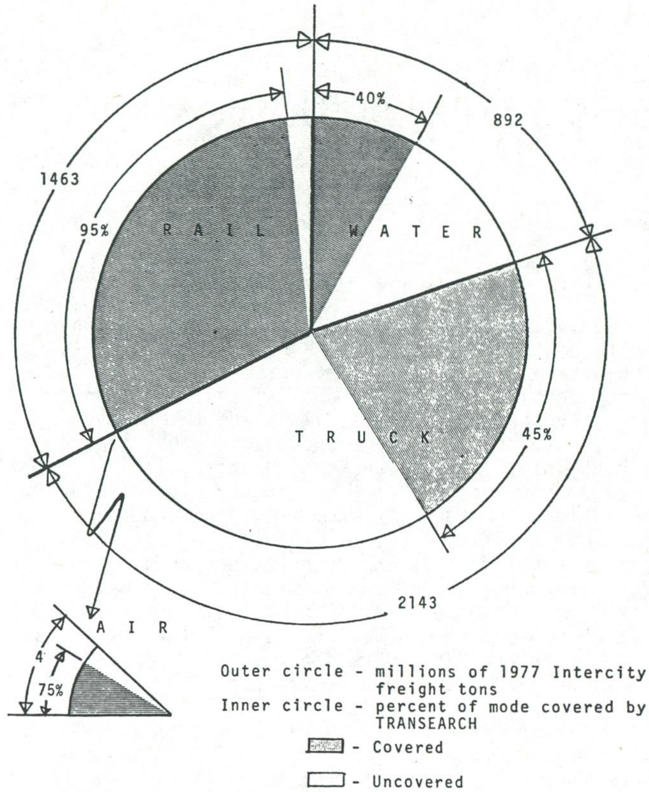
Using Sample Origin-Destination Data

Virtually all of the secondary vehicle or commodity flow data collected by government agencies are samples of larger universes. Sampling is used because it is impractical or too costly to collect and process such data on a census basis. Important secondary information sources for vehicle or commodity flow data include:

1. The Census of Transportation (more specifically, the Commodity Transportation Survey) (17).
2. The ICC/FRA One Percent Waybill Sample (23).
3. The Domestic and International Transportation of U.S. Foreign Trade (18).
4. USDA Fresh Fruit and Vegetable Unload Reports (14,15).
5. The National Motor Transport Data Base (1).

Although data from the foregoing sources are readily available to states, either in published form or as computerized files, none are complete enough by themselves for general purpose applications. Greater utility will be achieved when the sources are combined and adjusted to represent a common year. Users can do this themselves or alternatively use a data base that has already been assembled by others, such as a federal agency or a private organization.

One such commodity flow data base is Transearch, a proprietary computerized information service marketed by Reebie Associates (8). The Transearch universe covers virtually all rail movements plus movements of manufactured goods by truck, water, and air. Omitted are water and highway movements of commodities, such as grain, livestock, forest products, products of mines, and movements from warehouses or distribution centers, for which commodity flow data are unavailable on a national scale. Even though Transearch does not include bulk commodity flows, some of this information (e.g., grain flows) is available from other sources (4). Transearch, whose universe includes approximately 60 percent of the total intercity freight market (see Figure 10), was developed primarily to help transportation planners or traffic managers understand the composition of specific freight flows, to highlight traffic



Source: Reebie Associates, Transearch Reference Manual (1978) p.20.

Figure 10. Transearch Coverage of Intercity Freight Flows.

opportunities, and to assess a mode's relative market performance.

The current Transearch data base, developed from the 1979 waybill sample, the 1977 Commodity Transportation Survey, the 1976 Import/Export Census, and the 1979 USDA Fresh Fruit and Vegetable Unload reports, has been updated to 1980 by applying Federal Reserve Board Production indices to index tonnages to current levels. Because the listed sources overlap in part, only the data from the more detailed and reliable data sources were retained. In assembling data from the four sources, commodity flows were first disaggregated to the county level to provide a uniform geographic basis. The commodity detail contained varies because of disclosure regulations prohibiting governmental agencies from releasing proprietary data. The proportion of data containing relevant commodity codes increases with the level of aggregation. To deal with varying level of commodity detail in displaying data, Transearch both telescopes and residualizes available data (see Table 2). In addition, the various data sources have been normalized to a single base year. Transearch represents a compromise between achieving national coverage of intercity freight movements while retaining the detail on movement origins and destinations and commodity types necessary for state applications.

Information available from Transearch is in one of two forms: preprints (portions of previously prepared computer reports) or customized printouts. Preprints useful in subarea or corridor applications, include:

Table 2. Dealing with Different Levels of Commodity Detail through Telescoping and Residualizing: Hypothetical Example.

STCC	Description	Telescoped	Residualized
20	Food or Kindred Products	975	175
201	Meat, Fresh, Chilled or Frozen	800	350
2011	Meat, Fresh or Chilled	200	200
2012	Meat, Fresh Frozen	250	150
20121	Carcasses	100	100
			975

The telescoped total for Food and Kindred Products contains all other flows within the STCC 20 family. That is, it represents the sum of STCCs 201, 2011, 2012, and 20121.

The residualized total for Food and Kindred Products does not contain tonnage for any other STCC 20 family commodity. Similarly, STCCs 201, 2011, 2012, and 20121 report residualized flows mutually exclusive of any other summarization. The total of residualized flows within the same family will be equal to the most generalized telescoped total for this family.

In this hypothetical example, the telescoped total for STCC 20 and the sum of the residualized flows in the STCC 20 family equal 975 tons.

Source: Reebie Associates, Transearch Research Manual (1978) p.17.

1. One-way flow reports that display freight traffic moving between business economic areas (BEAs) and include principal commodities and volume by each mode of transport (19). Table 3 is an example of the commodity flow data available through Transearch.

2. Summary area terminal reports that summarize freight traffic flows from or to a specified terminal area. Details include tonnage, mode, and major commodities to all destinations from the origin terminal area or from all origins to the destination terminal area.

3. Commodity reports that rank the top 500 traffic lanes (BEA pairs) for each commodity selected.

Transearch also markets custom services such as:

1. Summarizing commodity flows on a SMSA, production area, or county basis.

2. Adding mileages to permit calculations of ton-miles.

3. Combining coal, grain, and other bulk commodity movements into Transearch.

4. Accessing Transearch through a state agency computer terminal.

5. Forecasting freight production/consumption or commodity flows.

Transearch is not a panacea for all applications, and it cannot provide answers in situations where desired secondary data are unavailable. Its principal value lies in eliminating the need for state DOTs to devote staff time in assembling and normalizing existing data sources. This is particularly advantageous (1) if only occasional use of a commodity flow data base is contemplated or (2) where hardcopy printouts of the data base will suffice. Where more frequent use of the data base is contemplated, or a computerized on-line access capa-

Table 3. Sample Transearch Traffic Flow Data.

TS80-OD --- PAGE NO. 1738

TRANSEARCH

TRAFFIC FLOW DATA NORMALIZED TO 1980 - IN TONS

ORIGIN : BEA 10 BUFFALO NY
DESTINATION : BEA 12 NEW YORK NY

TWO-DIGIT STCC SUMMARY		TOTAL		RAIL		HIGHWAY			AIR	WATER
				CARLOAD	INTERMODAL	FOR HIRE		PRIV/EX		
STCC	COMMODITY	TONS	FCE			TL	LTL			
01	FARM PRODUCTS	29988	1452	0	0	3508	0	26480	0	0
14	NONMETALLIC MINERALS	538	25	0	0	18	0	396	0	124
20	FOOD OR KINDRED PRODUCTS	554790	25847	220947	0	150875	77352	102529	0	3087
22	TEXTILE MILL PRODUCTS	520	41	0	0	0	0	520	0	0
23	APPAREL OR RELATED PRODUCTS	378	21	0	0	37	333	7	0	1
24	LUMBER OR WOOD PRODUCTS	15425	702	0	0	13111	0	2314	0	0
25	FURNITURE OR FIXTURES	12918	2483	1383	0	1191	2170	8174	0	0
26	PULP,PAPER OR ALLIED PRODUCTS	81800	3908	29728	0	29954	8084	13765	0	269
27	PRINTED MATTER	273	14	0	0	174	99	0	0	0
28	CHEMICALS OR ALLIED PRODUCTS	459406	20885	96873	0	295543	45257	21558	164	11
29	PETROLEUM OR COAL PRODUCTS	263341	11970	0	0	99000	3085	12503	0	148753
30	RUBBER OR MISC PLASTICS	14672	1101	5142	0	2498	5928	1104	0	0
31	LEATHER OR LEATHER PRODUCTS	1559	104	0	0	859	312	388	0	0
32	CLAY,CONCRETE,GLASS OR STONE	59146	2809	2005	0	20078	7312	29751	0	0
33	PRIMARY METAL PRODUCTS	196216	8920	8798	0	143602	28823	14891	102	0
34	FABRICATED METAL PRODUCTS	42683	1965	0	0	8295	10712	23182	494	0
35	MACHINERY	23203	1136	11438	0	4669	6170	898	27	1
36	ELECTRICAL EQUIPMENT	40992	1967	0	4372	16417	19559	638	6	0
37	TRANSPORTATION EQUIPMENT	75238	5581	47592	0	368	17663	9604	11	0
38	INSTRUM, PHOTO EQ, OPTICAL EQ	225	12	0	0	225	0	0	0	0
39	MISC MANUFACTURING PRODUCTS	3837	384	1153	0	1184	1500	0	0	0
40	WASTE OR SCRAP MATERIALS	39140	1791	39126	0	0	0	14	0	0
46	MISC MIXED SHIPMENTS	2010	134	0	2010	0	0	0	0	0
	TOTAL	1918298	93252	464185	6382	791606	234359	268716	804	152246

ADDITIONAL STCC DETAIL		TOTAL		RAIL		HIGHWAY			AIR	WATER
				CARLOAD	INTERMODAL	FOR HIRE		PRIV/EX		
STCC	COMMODITY	TONS	FCE			TL	LTL			
01195	POTATOES, OTHER THAN SWEET	3834	174	0	0	0	0	3834	0	0
01210	CITRUS FRUITS	508	23	0	0	508	0	0	0	0
01221	APPLES	5801	264	0	0	0	0	5801	0	0
01227	PEARS	571	26	0	0	0	0	571	0	0
01290	MISC FRESH FRUITS OR TREE NUTS	384	17	0	0	384	0	0	0	0
01318	ONIONS, DRY	8296	415	0	0	0	0	8296	0	0
01333	CABBAGE	2634	132	0	0	0	0	2634	0	0
01334	CELERY	909	45	0	0	0	0	909	0	0
01335	LETTUCE	2054	103	0	0	0	0	2054	0	0

LEGEND : FCE - 40 FOOT FREIGHT CONTAINER EQUIVALENT

bility is desired, states should consider developing their own commodity flow data base rather than relying on Transearch or comparable outside services. Besides saving out-of-pocket costs, the advantages of states developing their own data base include:

1. Eliminating movements which have no bearing on the state.
2. Ability to readily substitute more complete or accurate information available to the state in place of data contained in the assembled data base.
3. Capability for adding information to close major economic sector gaps (e.g., mining, agriculture) or to simulate traffic not well represented by existing secondary sources (e.g., bulk movements by truck or inland waterway).
4. Capability to adjust the file to known control totals, such as for agricultural, industrial, or mining production, port import and export totals, etc.
5. Utility of having a computerized file immediately available for application purposes.

The principal steps involved in assembling a commodity flow matrix from existing data sources are summarized in Figure 11.

<u>Step 1 -- Disaggregate Geographic Data: Movement Origin</u>. Consider first movements involving manufacturing plants. If the data are aggregated at the state level (e.g., as with the Commodity Transportation Survey), they can be disaggregated using data on employment by SIC by county. The underlying premises are:

1. Manufacturing plant output is correlated with the number of employees.
2. All plants in the same industry (i.e., same SIC code) have equal productivity.
3. All plants in the same industry share proportionately in resulting commodity flows.

Thus, for a particular commodity, data aggregated at the state level can be apportioned to counties using county and state employment data for the relevant industry:

$$\begin{matrix}\text{County}\\ \text{Tonnage}\end{matrix} \Rightarrow \begin{bmatrix}\text{State}\\ \text{Tonnage}\end{bmatrix}\begin{bmatrix}\dfrac{\text{County Employment}}{\text{State Employment}}\end{bmatrix}$$

<u>Step 2 -- Disaggregate Geographic Data: Movement Destination</u>. Disaggregating destinations are somewhat more complex because they depend on the characteristics of the receiver rather than the shipper. Again, considering movements involving manufacturing plants, output is shipped not only to other manufacturers but to other economic sectors as well. Thus, information is needed on the historical trading relationships of each industry. An input-output table, such as the 1972 BEA National Input-Output Ta-

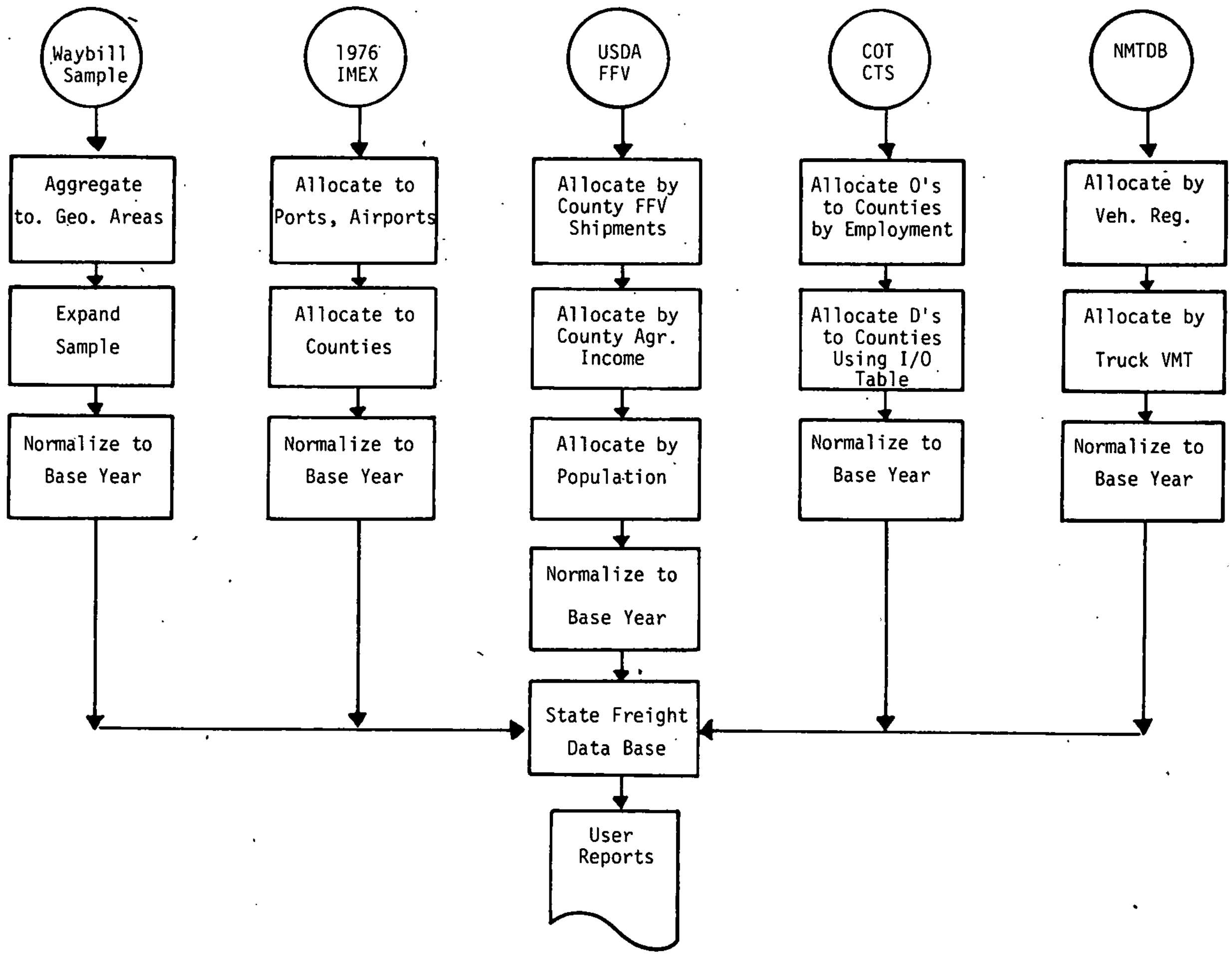


Figure 11. Tasks Involved in Assembling a Commodity Flow Matrix from Secondary Data Sources.

ble or the equivalent, would commonly be used for this purpose (20). Each row expresses the dollar amount of output required from the producing industries by the consuming industries listed in the columns of the table. In using an input-output table, the underlying premises are:

1. Freight shipments are proportional to the dollar outputs contained in the table.
2. All plants in the same industry (i.e., same SIC code) distribute proportionally to the same economic sectors.
3. All receivers in the same industry share in resulting commodity flows.

Since most industries supply portions of their output to other manufacturers as well as to consumers, it is first necessary to apportion their output between manufacturing and nonmanufacturing sectors. States may find it desirable to simplify the allocation process by using population data to allocate the outputs of consumer-oriented industries. Similarly, county farm income can be used as the basis for disaggregating commodities, such as machinery and fertilizer, supplied to the agricultural sector. Table 4 provides two examples of disaggregating production/consumption or commodity flow data from state to county level of detail.

Step 3 -- Expand the Sample. In most cases, sample expansion will have already been done by the agency responsible for collecting the data. The major exception is the waybill sample. Although nominally a one-percent sample, multiple car shipments included on a single waybill introduce errors which cause the sample to vary from one percent. The ICC's Quarterly Report of Freight Commodity Statistics, which reports carloads by 2-digit STCC code, can be used to adjust for any undersampling or oversampling.

For example, consider STCC Code 37 (transportation equipment). In 1976, the waybill sample included 11,203 carloads and the QCS reported 1,270,413 carloads. The factor to use in expanding the waybill sample is 1,270,413/11,203 or 113.4.

Step 4 -- Normalize to the Current Year. The secondary sources typically used for freight production and consumption or traffic flow data reflect different years. Thus, they must be normalized to reflect either a common base or the current year. A variety of indices could be used for this purpose, including:

1. Federal Reserve Board's Industrial Production Indices (25).
2. OBERS projections of regional economic activity in the U. S. (21).

In normalizing data, it is important to keep the original data intact and not apply adjustments on top of adjustments.

Step 5 -- Screen Out Overlapping Records. The only significant overlap between the secondary data sources identified is for rail movements of manufactured goods. Table 5 presents the economic sectors and modes for which secondary data typically exist. While some overlaps do occur (e.g., for rail shipments from manufacturers), the lack of data for the agricultural and mining sectors and for the motor carrier modes is more significant. Overlaps can be eliminated by retaining the most detailed and reliable of the data sources. (For the overlap identified in Table 5, the waybill sample data would usually be retained because it is the more comprehensive data source.)

In deciding whether or not to develop their own data base, users are encouraged to:

Table 4. Examples of Disaggregating Data from State to County Level.

Example 1

Desired Flow: Television sets (STCC 3651) from Nassau County, NY, to Cook County, IL.

Reported Flow: 8928 tons from NY to IL reported by the 1972 Commodity Transportation Survey.

Allocation Process:
Estimated Nassau County and New York State employment for SIC 3651 is 985 and 3088, respectively. Television sets are consumer goods, and thus can be allocated using population as the portioning data. Estimated Cook County and Illinois population is 3,200,000 and 7,615,000, respectively.

$$(8928 \text{ tons}) \left[\frac{985}{3088}\right]\left[\frac{3,200,000}{7,615,000}\right] = 1125 \text{ tons of STCC } 3651 \text{ in } 1972.$$

Example 2

Desired Flow: Primary iron and steel products (STCC 3312) from Allegheny County, PA, to Cook County, IL.

Reported Flow: 4,000,000 tons from PA to IL reported by the 1972 Commodity Transportation Survey.

Allocation Process:
Allegheny County's percentage of total Pennsylvania employment for STCC 3312 is 35.7%. Therefore (.357) (4,000,000) or 1,428,000 tons more from Allegheny County to Illinois.

Industries Consuming STCC 3312 as production input in Cook Co.		I/O Table % of STCC 3312 dist. to consuming ind.	Cook Co. % of IL. employment or population	Cook Co. Consumption % (2) X (3)
331	Iron & Steel Products	20.2	80	16.16
3411	Metal Cans	4.6	75	3.45
3441	Fabr. Struct. Metal	4.0	95	3.80
346	Forg. & Stmps., I & S	6.8	60	4.08
3496	Misc. Fab. Wire Prod.	3.8	65	2.47
3711, 3714	Automobiles	5.6	55	3.08
	Population-Related	9.9	47	4.65
	Misc. Industries	45.1	70	31.57
TOTAL		100.0		69.26

Source: Reebie Associates, Transearch Research Manual (1978) pp. 28-31.

Table 5. Coverage by Mode of Transportation.

Economic Sector		Rail	Motor Carriers			Water	Air
			For-Hire	Exempt	Private		
Agriculture	Farm	WB		FFV			
	Forest	WB					
	Other	WB					
Manufacturing		WB, CTS	CTS	CTS	CTS	CTS	CTS
Mining		WB					
Distribution		WB					

WB - One percent waybill sample

CTS - Census of Transportation, Commodity Transportation Survey

FFV - USDA Fresh Fruit and Vegetable Unloads

☐ - Must be obtained locally

▩ - Relatively little traffic

1. Purchase rather than assemble such information in-house unless (1) a number of applications are contemplated, (2) staff and fiscal resources are available to properly maintain a commodity flow data base, and (3) considerable enrichment of the data base is anticipated.

2. Consider supplementing the information available from secondary sources, especially for shipments originating from the agriculture and mining sectors. A mechanism for accomplishing this may already be in place. For example, if permanent truck weighing stations exist, states should consider simultaneously obtaining information on the origin, destination, and commodities in addition to weighing the vehicle for conformance to state load limits.

Simulating Freight Generation

If commodity flow data are not available, such data will have to be simulated. First, freight shipments and receipts must be estimated either from industry production and consumption information, or from other economic data. Then, the generated traffic must be distributed to obtain flows.

In general, freight shipments or receipts can be approximated by converting employment or monetary measures of industrial production and consumption into physical units. If the total value (dollars) is known, the commodity attribute file contained in Appendix B (or the equivalent thereto) can be used to estimate shipments and receipts. If employment data are available, it must first be translated into industrial production or consumption (dollars) by using national or regional productivity data.

Equally important as the mechanics of simulating freight generation is background knowledge and familiarity with the amounts and types of freight being generated and consumed by different economic sectors within the study area. In addition, a general understanding of the types of changes taking place in freight generation as the economy continues to mature is most helpful (6).

Using Industry Production and Consumption Data

Assuming that industry production and consumption data are available, these data can be disaggregated to the county level. The process works reasonably well when:

1. The products involved are few in number, are relatively homogeneous, are readily identifiable in available statistical data, and are transported in significant volumes.
2. The number of establishments shipping or receiving identified products are either few in number or readily aggregated.
3. Aggregate sector or industry information on the identified products produced and/or received within the study area is available.
4. Information exists on which to adjust production outputs to shipments.

This approach will not work well when:

1. Only partial or incomplete information can be obtained on product production or consumption.
2. Information is lacking on the amount and location of out-of-state or out-of-country production and consumption.
3. A valid basis for disaggregating estimates of freight shipments and receipts to counties or their equivalent does not exist.

The following example illustrates how the U.S. Department of Energy (DOS) national and regional coal supply and demand (production and consumption) projections were disaggregated to 173 BEAs, using supplied projections of coal supply and demand (13).

Because coal production data are not collected or aggregated by BEA, the methodology employed disaggregated the regional projections to the county level, which were then aggregated to BEAs. Four steps were involved: (1) estimating coal production on a preliminary basis in each county using a regression-derived equation stating production as a function of known reserves, past production, and coal characteristics, (2) estimating "production share" obtained by dividing the prepared county-level estimates by the sum for all counties in each DOE region, (3) applying the county production share to the regional production projections to obtain normalized forecasts for each county, and (4) summing production forecasts over all counties in each BEA to obtain BEA production forecasts.

A similar procedure was employed to disaggregate projected regional coal demand. Four steps were similarly involved: (1) disaggregating past county coal consumption by coal type and utility/nonutility use, (2) allocating coal consumption by county in the nonutility sector using data on past nonutility coal consumption by type, (3) allocating coal consumption by county in the utility sector using coal-fired generation capacity as a proxy for coal consumption, and (4) summing the county coal consumption projections for both sectors by type and BEA to obtain total BEA coal consumption by type.

As the application is broadened to include other products or economic sectors, the task of determining the types, amounts, and allocation procedure for each product can become quite extensive. In some instances, it will be impractical to estimate freight generation and distribution by assembling and allocating production and consumption statistics.

Using Other Economic Data

Instead of estimating freight generation through industry production and consumption statistics, an alternative approach is to convert employment or monetary measures of industry production and consumption into physical units. The advantage of this approach is that it potentially covers the full universe of freight movements. However, a number of important assumptions do underly the use of economic data to generate freight estimates.

1. The unit tons or value of raw and semifinished goods required to produce a unit ton or value of product remains constant for that SIC group.
2. Output tonnage for a particular industry is proportional to its earnings or employment. This means that all plants within an SIC group have equal productivity.
3. The tonnage of each commodity used in personal consumption is proportional to the population. This means that all persons consume equally irrespective of income or location.
4. Average unit tonnage and value are applicable to all products and commodities contained within that SIC group.
5. County level output tonnage is proportional to county employment in that SIC group. This means that all plants within an SIC group have equal productivity.

The procedure for estimating freight generation is conceptually straightforward. The following subtechnique uses a combination of value added and employment data by SIC code along with an appropriate input-output transactions table to estimate freight generation. An input-output table shows how the production of each industry is distributed among other industries, or concisely what industries consume in producing output. Industry interrelationships are contained in a matrix of technical coefficients that are defined as the amount of one product in dollars used in making one dollar's worth of another product. The matrix of coefficients shows the amount of input required from the industries in each row to produce one dollar's worth of output from an industry in a particular column.

Before applying an input-output transactions table to estimate freight consumption, the user must recognize the constraints and assumptions underlying this approach:

1. Input requirements for each consuming entity, developed on a national basis, are applicable to any state and county. While the application of national technical coefficients to states ignores likely structural differences, comparable data usually do not exist at the state or local level to allow more accurate estimates.
2. Freight consumption estimates cannot be disaggregated beyond the level of detail contained in the input-output transactions table.
3. By using a national input-output table, regional differences in factor prices, which can be significant, are ignored. This can distort the resulting estimates of the physical units consumed. If regional differences are known, the national values contained in the input-output table should be modified accordingly.
4. The technical coefficients contained in the input-output table are based on relatively old data which in some cases have changed over time.

Step 1 -- Obtain Input/Output Table. The inputs required to produce the various outputs are determined by the technical coefficients from an input-output table, for which the 1972 Input-Output Table is presently being used (20).

Step 2 -- Convert Dollar Amounts to Tonnages. Dollar amounts are converted to tonnages using data from Appendix B, the Commodity Transportation Survey (see Table 6), or from other sources.

Step 3 -- Allocate Tonnages. Tonnage shipped and received is allocated to counties using employment and population as the basis for the allocation.

The following example, drawn from the proposed Maryland Statewide Goods Movement Study, illustrates how the above technique can be applied (11). In that study, the input-output matrix consisted of the

Table 6. Approximating Freight Generation Rates Using Census Data.

Commodity Transportation Survey Data 1/		
STCC CODE	COMMODITY	Total Tons Shipped (000)
20	Food and Kindred Products	426,587
201	Meat: Fresh, Chilled, Frozen	42,728
202	Dairy Products	44,372
203	Canned and Preserved Fruits, Vegetables, Seafoods	36,825
204	Grain Mill Products etc.,	109,538

Approx. Freight Generation Rates	
Tons per Employee	Tons per Ave. Establishment
201	16,000
138	9,400
288	11,900
157	15,500
971	36,000

Census of Manufacturers Data 2/					
SIC CODE	INDUSTRY	Total Estab. (No.)	All Emps. (Thousands)	Value Added by Man. ($ millions)	Value of Shipments ($ millions)
20	Food and Kindred Products	26,656	1520.0	56,062.2	192,911.6
201	Meat Products	4,534	309.1	7,478.0	46,276.3
202	Dairy Products	3,731	153.9	5,648.3	26,009.8
203	Preserved Fruits and Vegetables	2,379	234.7	7,684.5	20,332.8
204	Grain Mill Products etc.	3,043	112.8	6,625.6	22,344.2

1/ U.S. Department of Commerce, Bureau of the Census, 1977 Census of Transportation, Commodity Transportation Survey Summary. Washington, DC (1981) Table 5.

2/ U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufacturers, Volume III Geographic Area Statistics, Washington, DC (1981).

twenty-six two-digit SIC codes listed in Table 7. Consuming industries and other entities comprised the 32 items also given in Table 7 and were subdivided into four categories: (1) producing/consuming industries having physical inputs and outputs, (2) consuming industries that consume physical products, but do not produce them (e.g., transportation, power generation, and services), (3) fixed capital formations (i.e., consumption and/or equipment) that use physical products, but whose product is a means for production rather than a product, and (4) personal consumption. Although it is conceptually possible to have 832 different interrelationships, far fewer significant interchanges actually occur, as indicated in Table 8.

Using SIC 37 (transportation equipment) as an example, the inputs required to produce a unit amount of SIC 37 are determined from an input-output table. In this case, Table 9 indicates that SICs 37, 34, 36, and 35 represent the primary inputs and amount to $0.45, 0.22, 0.08 and 0.06 of each dollar's worth of output.

Next, the estimates given in Table 9 are converted to tonnage. This can be done by using data from the U. S. Census of Manufactures, from the Commodity Transportation Survey, and from similar sources. Table 9 relates material cost to the value of shipments and also presents the average value per ton for each manufactured commodity. Because the delivered cost of all input commodities necessary for the production of SIC 37 was $44,171 (from Table 9), and because input commodities represent 58.9 percent of value of shipments (from Table 10), the total value of shipments is $44,171 divided by 0.589 or $74,993 million. Furthermore because the average

Table 7. Producing and Consuming Industries and Entities.

		SIC Code	Description
1.	Agriculture & Fisheries	01	Agriculture
2.		09	Fisheries
3.	Mining	10	Metallic Ore
4.		11-12	Coal
5.		13	Petroleum & Natural Gas
6.		14	Nonmetallic Minerals
7. Producing/Consuming Industries	Manufacturing	20	Food
8.		21	Tobacco
9.		22	Textiles
10.		23	Apparel
11.		24	Wood Products
12.		25	Furniture
13.		26	Pulp & Paper
14.		27	Printed Matter
15.		28	Chemicals
16.		29	Petroleum & Coal Products
17.		30	Rubber & Plastic
18.		31	Leather
19.		32	Sand, Clay, Stone, & Glass Products.
20.		33	Primary Metals
21.		34	Fabricated Metal Products
22.		35	Machinery (except electrical)
23.		36	Electrical Machinery & Equipment
24.		37	Transportation Equipment
25.		38	Instruments
26.		39	Miscellaneous Manufacturing Goods
27. Consuming Industries		40-47	Transportation
28.		49	Utilities
29.		50-89	Services
30. Fixed Capital Formation		15-17	Construction
31.		-	Equipment
32. Personal Consumption			

Source: Simat, Helliesen & Eichner, Inc., "Statewide Goods Movement Study - Task 2: Preliminary Forecast Model," p.11.

Table 8. Input-Output Correspondence.

S.I.C. of Consuming Industry	01	09	10	11/12	13	14	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	Number of Producing Industries
01	x						x								x	x						x					5
09																x											1
10																x						x					2
11/12																x						x					2
13															x	x						x					3
14															x	x						x					3
20	x	x					x		x	x			x		x		x		x		x						10
21	x							x					x		x												4
22	x						x		x				x		x												5
23									x						x		x	x									4
24											x				x	x	x		x		x						6
25							x		x		x	x	x		x		x		x	x	x						10
26						x	x		x		x		x		x	x	x		x	x							10
27									x				x	x	x		x				x				x	x	8
28			x		x	x	x			x			x		x	x	x		x	x	x	x					13
29					x	x	x						x		x	x			x		x						8
30									x				x		x		x		x	x	x						7
31							x		x						x		x	x			x						6
32						x	x						x		x				x	x		x					7
33			x	x		x			x						x				x	x		x					8
34													x		x		x		x	x	x	x	x		x		9
35													x				x		x	x		x	x				6
36												x	x		x				x	x	x	x	x		x		9
37									x		x				x		x		x	x	x	x	x	x			10
38							x		x						x					x		x	x		x		7
39									x				x		x			x		x			x				6
40-47																x											1
49				x	x											x											3
50-89					x											x											2
15-17											x	x							x		x	x	x				6
-																					x	x	x	x			4
Personal Consumption	x	x		x		x	x	x	x	x	x	x	x	x	x	x		x	x		x		x	x			19
	4	2	2	3	4	6	1	2	13	3	6	4	15	2	23	14	12	4	15	12	15	14	9	4	4	1	204

Source: Simat, Helliesen & Eichner, Inc., "Statewide Goods Movement Study - Task 2: Preliminary Forecast Model," p.36.

Table 9. Input-Output Matrix.

Output commodity group 37: Transportation Equipment
Delivered cost of input commodities ($ millions)

Input Commodity	371 Motor Vehicles	372 Aircraft	374 Railroad Equipment	376 Space Vehicles	379 Misc. Transportation Equipment	37 Total	Percent by Input Commodity
22	174	---	---	---	6	180	0.41%
23	1,386	---	---	---	13	1,399	3.17
24	72	---	6	---	53	131	0.30
25	18	14	---	---	24	56	0.13
26	40	1	---	1	8	50	0.11
27	1	8	---	---	---	9	0.02
28	357	58	15	12	6	448	1.01
29	39	24	---	2	---	65	0.15
30	1,264	25	---	15	51	1,355	3.07
32	987	15	-	6	4	1,013	2.29
33	41	196	1	14	5	257	0.58
34	9,420	233	15	43	115	9,826	22.24
35	2,379	155	81	26	53	2,694	6.10
36	2,095	926	35	302	89	3,447	7.80
37	16,127	2,587	227	646	187	19,774	44.77
38	16	164	5	32	---	217	0.49
39	---	---	---	---	10	10	0.02
Subtotal	34,416	4,406	385	1,099	624	40,931	92.66
Not elsewhere classified	2,071	669	161	216	123	3,240	7.34
Total	36,487	5,075	547	1,315	747	44,171	100.00

Source: Simat, Helliesen & Eichner, Inc., "Statewide Goods Movement Study - Task 2: Preliminary Forecast Model," p.32.

value of SIC 37 is $1,572 per ton (from Table 10), the total amount of SIC 37 produced in 1972 was 74,993 million divided by 1,572 or 47,705,000 tons.

The value of each input commodity can then be converted to tonnage, as illustrated in Table 11. These steps are repeated to include all consuming industries and entities, and the results are summarized separately for commodities produced and consumed.

Users should also consider using portions of the regional economic analysis techniques contained in the research agency's final report prepared under NCHRP Project 8-15 in simulating state freight production and consumption (9,10).

Table 10. Relationship between Cost and Volume of Manufactured Commodities (1972).

	All Commodities				Commodities for which Tonnage Data are Available		
SIC	Cost of Materials ($ millions)	Value Added by Mfg. ($ millions)	Value of Shipments ($ millions)	Material Cost (percent)	Tons Shipped (000)	Value of Shipments ($ millions)	Value per Ton
20	$ 79,793.0	$ 35,614.8	$115,051.2	69.4	252,161	$115,051.2	$ 456
21	3,281.1	2,637.2	5,920.2	55.4	1,056	4,083.3	3,867
22	16,499.4	11,715.8	28,063.9	58.8	9,334	18,948.1	2,030
23	14,532.0	13,487.5	27,809.2	52.3	5,166	26,080.0	5,048
24	13,605.7	10,310.2	23,829.1	57.1	68,826	16,237.7	236
25	5,335.1	6,097.1	11,320.3	47.1	9,214	10,583.8	1,149
26	15,240.5	13,064.1	28,261.9	53.9	85,066	27,805.7	327
27	10,044.3	20,209.5	30,146.4	33.3	0	0.0	--
28	25,085.5	32,413.9	57,349.6	43.7	171,266	45,744.2	267
29	22,762.5	5,793.1	28,694.7	79.3	344,420	28,694.7	83
30	9,466.1	11,653.3	20,923.7	45.2	15,760	19,273.9	1,223
31	2,895.4	2,917.2	5,769.5	50.2	1,045	4,696.2	4,494
32	9,062.6	12,586.5	21,537.5	42.1	159,342	19,903.0	125
33	35,708.9	23,258.1	58,429.7	61.1	158,452	56,332.5	356
34	25,197.5	26,945.8	51,739.3	48.7	39,533	50,003.0	1,265
35	29,204.1	37,562.9	65,820.7	44.4	21,818	65,820.7	3,017
36	23,301.3	30,558.2	53,394.0	43.6	14,879	53,394.0	3,589
37	55,767.8	39,790.4	94,704.9	58.9	43,034	67,636.5	1,572
38	5,058.5	10,580.1	15,526.7	32.6	798	8,796.1	11,023
39	5,554.3	6,768.7	12,173.2	45.9	3,440	7,567.8	2,200
	$407,395.4	$353,973.4	$756,466.9	53.9	1,404,610	$646,922.4	$ 461

Source: Simat, Helliesen & Eichner, Inc., "Statewide Goods Movement Study - Task 2: Preliminary Forecast Model," p.34.

Table 11. Tonnage of Input Commodities Required to Produce One Ton of Transportation Equipment.

(1) Input Commodity	(2) Input Value ($ million)	(3) Input Tonnage (000)	(4) Percent of Total Input Tonnage	(5) Ratio: Input Tons ÷ Output Tons
22	$ 180	89	0.24	0.0018
23	1,399	277	0.77	0.0058
24	131	555	1.55	0.0116
25	56	49	0.14	0.0010
26	50	153	0.43	0.0032
27	9	--	--	--
28	448	1,678	4.70	0.0352
29	65	786	2.20	0.0165
30	1,355	1,107	3.10	0.0232
32	1,013	8,104	22.67	0.1699
33	257	722	2.02	0.0151
34	9,826	7,768	21.73	0.1629
35	2,694	893	2.50	0.0187
36	3,447	960	2.69	0.0201
37	19,774	12,579	35.19	0.2637
38	217	20	0.06	0.0004
39	10	5	0.01	0.0001
	40,931	35,745	100.00	0.7492

(2) Source: Table 9
(3) Column (2) ÷ Value per ton from Table 10
(5) Ratios less than 0.01 are considered to be minor.

Source: Simat, Helliesen & Eichner, Inc., "Statewide Goods Movement Study - Task 2: Preliminary Forecast Model," p.35.

Simulating Freight Distribution

When commodity flow data are not available, it becomes necessary to simulate freight distribution using synthetic models. Users should recognize that such techniques provide only rough approximations of actual movements, and thus should only be used when commodity flow data are not available.

Techniques commonly used for simulating flows are trade and gravity models and linear programming. Trade models are a means for apportioning production among consuming areas, or conversely, consumption among producing areas (5). Every producer is presumed to have a market share proportional to his share of total production. Likewise, each consumer is presumed to purchase from each supplier proportional to his share of total consumption. Because the proportional distribution assumption in trade models overstates the average movement distance, such models represent an "upper bound" on resulting freight movements (ton miles). In the gravity model, the flow between producers and consumers is proportional to total shipments and receipts and inversely proportional to the distance or unit cost of transport between the producer and consumer (22). The addition of impedance changes the resulting distribution patterns to favor lesser distance or lower cost interchanges, which in effect replicates real world conditions. Linear programming extends this concept still further through the notion that producers will seek to minimize their transport costs (5). Because the minimization assumption underlying linear programming understates the average movement distances actually occurring, linear programming represents a "lower bound" on resulting freight movements (ton miles).

Selection of a particular distribution subtechnique depends on the characteristics of the specific application. Table 12 provides some general guidance in choosing an appropriate technique. In some cases, it may be necessary to apply different methods within the same application (e.g., use of a trade model to allocate intrastate flows and a gravity model to allocate interstate flows).

Table 12. Applications Appropriate for Different Freight Distribution Methods.

	Freight Distribution Method		
	Trade	Gravity	LP
Commodity Characteristics			
Average length of haul - short or primarily intrastate	x		
- long or primarily interstate		x	
Producers/Consumers Within State -			
numerous producers and consumers		x	
limited producers; numerous consumers	x		
limited producers and consumers	x		
Producers/Consumers nationwide			
numerous producers and consumers		x	
limited producers; numerous consumers		x	
limited producers and consumers		x	x
Study area size - state or portion of state	x		
multistate or national		x	
Commodity classification - broad	x	x	
- narrow (homogeneous)		x	x

The techniques presented have or can be readily be adapted for computer application. Although each of the techniques will produce answers, it is up to the user to determine whether the results are reasonable and "make sense" when compared with such qualitative or fragmentary quantitative information on flows as may be available. Users should keep in mind the following:

1. Except for certain bulk commodities, the cost of transport is only a small portion of the total value of the commodity. Manufacturing specialization and concentration often take precedence over transport cost minimization.
2. Most applications will use aggregate commodity classifications. Thus, individual groups will cover a variety of products. Product differentiation leads to crosshaul movements, some of which will involve long distances.
3. Market competition among producers and suppliers rarely results in transport cost minimization on an areal basis.
4. Mathematical models cannot replicate the unique "who sells to whom" patterns that have arisen for reasons largely separate from transport considerations.

Trade Models

Expressed mathematically:

$$X_{ij} = \frac{C_j(P_i)}{\sum C_j}, \text{ or } X_{ij} = \frac{P_i(C_j)}{\sum P_i}$$

where: X_{ij} = shipment from production area i to consumption area j;
P_i = production in state or county i;
C_j = consumption in state or county j;
$\sum P_i = \sum C_j$

Application of the trade model is illustrated by the following example. Use is made of the hypothesized study area comprised of four producing and consuming counties given in Table 13.

Table 13. Freight Distribution Example.

County Area	Production (millions) (P_i)	Consumption (millions) (C_j)	Distance(miles) to			
			A	B	C.	D
A	10	2	25	30	80	120
B	2	6	30	10	40	90
C	1	3	80	40	15	60
D	3	5	120	90	60	20
TOTAL	16	16				

Note: Distance can either be airline or ground.

Step 1 -- Zones and Distances. Lay out a map showing counties, states, or other areal units comprising the study area. Identify production and consumption centroids in each county or state; these are logically the centers of economic activity or population. Measure, compute, or look up (if distance references are available) the distance from each county or state to every other state; distances can either be airline or over-the-ground.

Step 2 -- Enter Production and Consumption Estimates. County or state freight shipment and receipt estimates prepared earlier are tabulated similar to that shown in Table 14.

Table 14. Trade Model -- Step 2.

From Producing Counties (P_i)		to Consuming Counties (C_j)			
		A 2,000,000	B 6,000,000	C 3,000,000	D 5,000,000
County A	10,000,000				
County B	2,000,000				
County C	1,000,000				
County D	3,000,000				

P_i = 16,000,000 = C_j

Step 3 -- Compute Flows. The flow from County B to County D is computed as:

$$X_{ij} = \frac{C_j(P_i)}{C_j} = \frac{5{,}000{,}000(2{,}000{,}000)}{16{,}000{,}000} = 625{,}000$$

or

$$X_{ij} = \frac{P_i(C_j)}{P_i} = \frac{2{,}000{,}000(5{,}000{,}000)}{16{,}000{,}000} = 625{,}000$$

Similar computations are performed for all rows and columns. The completed tabulation is given in Table 15.

Table 15. Trade Model -- Step 3.

from Producing Counties (P_i)		to Consuming Counties (C_j) A 2,000,000	B 6,000,000	C 3,000,000	D 5,000,000
County A	10,000,000	1,250,000	3,750,000	1,875,000	3,125,000
County B	2,000,000	250,000	750,000	375,000	625,000
County C	1,000,000	125,000	375,000	187,500	312,500
County D	3,000,000	375,000	1,250,000	562,500	937,500

P_i = 16,000,000 = C_j

Step 4 -- Analyze Results. On the basis of the results given in Table 15 and the distances shown in Table 13, the average distance can be computed, which in this example is 62.5 miles. This should then be compared with any existing data or discussed with industry representatives to determine whether such a distance appears reasonable. Inasmuch as a trade model does not consider distance in allocating flows, the average distance will usually be greater than that actually occurring.

Since production and consumption information may only be available for counties within a state, an alternative approach is to aggregate imports and exports as illustrated in the following example.

Step 1 -- Enter Production and Consumption Estimates. In this step, freight shipments and receipts are entered for study area counties. Shipments to and receipts from other states are entered as aggregate amounts, as illustrated in Table 16.

Table 16. Alternative Trade Model -- Step 1.

from Producing Counties/ States (P_i)		to Consuming Counties/States (C_j) A 2,000,000	B 5,000,000	C 3,000,000	D 4,000,000	Exports to Other States 2,000,000
County A	10,000,000					1,333,333
County B	2,000,000					266,667
County C	0					0
County D	3,000,000					400,000
Imports from Other States	1,000,000	142,857	357,143	214,286	285,714	0

P_i = 16,000,000 = C_j

Step 2 -- Compute External Flows. Next, county exports to other states and county imports from other states are allocated, based on total exports and imports, which in this example are 2 and 1 million tons, respectively. Note that the flow from other states to other states is zero. Aggregate production and consumption is 16 million tons.

Step 3 -- Compute Internal Flows. Next, external flows are subtracted from total production and consumption to obtain study area internal shipments and receipts. County-to-county internal flows are then computed in the manner previously described, as illustrated in Table 17.

Table 17. Alternative Trade Model -- Step 3

from Producing Counties/ States (P_i)		to Consuming Counties/States (C_j) A 1,857,143	B 4,642,857	C 2,785,714	D 3,714,286
County A	8,666,667	1,238,095	3,095,238	1,857,143	2,476,191
County B	1,733,333	247,619	619,048	371,428	495,238
County C	0	0	0	0	0
County D	2,600,000	371,429	928,572	557,143	742,857

P_i = 13,000,000 = C_j

Some application hints and notes of caution:

1. Care should be taken to make sure the size of the study area is roughly coincident with the market area for the particular commodity. For example, a multistate or national study area makes little sense if the commodity being studied is sand and gravel, which for the most part is produced and consumed locally.
2. Because no impedance or cost function is incorporated into a cost model, it should only be used in situations where the cost of transport is small in relation to the value of the commodity. The model is best used for distributing commodities within a state or smaller study area.
3. Since a trade model is solely an apportioning method, the results obtained may be significantly different from real world patterns as evidenced through comparisons with commodity flow data.

Gravity Model

Another model often used to estimate flows is the gravity model. Expressed mathematically:

$$X_{ij} = \frac{P_i C_j F_{ij}}{\sum_{j=1}^{n} C_j F_{ij}}$$

where: $F_{ij} = f(t_{ij})$

X_{ij} = shipment from production area i to consumption area j;
P_i = production in state or county i;
C_j = consumption in state or county j;
F_{ij} = friction factor = i/t; and
t_{ij} = impedance, which will usually be distance.

In applying the gravity model to freight distribution, the subtechnique presented is a manual trip-distribution procedure developed originally for passenger transport in urban areas and documented in NCHRP Report 187 (12). Computerized versions of this model can also be used. In adapting the model to freight distribution, several changes have been made. First, the socioeconomic interchange adjustment factor typically included in urban transportation planning applications has been discarded. Second, distance or cost is used in place of travel time for impedance.

The gravity model then simplifies into the following form, which can be applied manually or by using a computer:

$$X_{ij} = R_i C_j F_{ij}$$

where:

$$R_i = \frac{P_i}{\sum_{j=1}^{n} C_j F_{ij}}$$

R is the "production index," which remains constant for each production area. C F is the "attraction factor" for consumption area j. In this version of the gravity model, a production balance is maintained (i.e., the row totals equal the input production for that county or state). On the other hand, the consumption totals for each county or state output will not necessarily match the desired values. To obtain an acceptable balance, an iterative process must be employed to adjust the calculated commodity flows. Several iterations may be required to bring the consumption totals to within 5 to 10 percent of the originally specified values.

Application of the gravity model for freight distribution is illustrated using the example given in Table 13.

Step 1 -- Geographic Delineation. As before, lay out a map showing study area boundaries and the subareas being used for analysis purposes -- counties, states, or some other areal unit. Also identify the logical centers of economic activity or population.

Step 2 -- Enter Freight Shipment and Receipt Estimates. Assume that subarea estimates of commodities shipped and received have been prepared from production and consumption estimates. These estimates would be entered in the freight flow matrix shown in Table 18; a separate form would be used for each unique commodity.

Step 3 -- Enter Impedances. First determine whether to use distance or cost as the basis for estimating impedances. If distances are to be used, measure, compute, or look up (if distances are available in tabular form) the ground or airline distance from each county to every other county or state. If shipping cost is to be used, first determine the mileage and then look up the equivalent rate for that commodity. Distances or costs would be entered into the freight flow matrix as indicated in Table 18. These distances or costs would then be converted to impedances by inverting and raising the number to selected power. Also enter the impedances in the freight flow matrix.

Selecting an appropriate exponent to use in computing the friction factor presently can only be done using a trial and error approach. Since the gravity model has only infrequently been applied to freight distribution, a body of knowledge on appropriate exponent values has not been developed. Users should start with an exponent value of 1.0, and compare the computed average distance with any other data on average distance for similar movements or commodities. Another approach is to compare the computed average distance with that obtained from applying a trade model (should be less) or linear programming (should be higher).

For example, the estimated distance from County B to County D is 90 miles. In this case, the impedance is the inverted distance raised to a power of 1.0 or 0.0111.

Step 4 -- Calculate Attraction Factors, Accessibility Index, and Production Index (First Iteration). The Attraction Factor from County B to County D is:

$$C_j F_{ij} = 0.0111(5{,}000{,}000) = 55{,}556$$

The Accessibility Index for County B is:

$$\sum_{j=A}^{D} C F = 66{,}667+600{,}000+75{,}000+55{,}556 = 797{,}223$$

The Production Index for County B is:

$$R_i = \frac{P}{\sum_{j=A}^{D} C_j F_{ij}} = \frac{2{,}000{,}000}{797{,}223} = 2.5087$$

The foregoing computations would be undertaken for all rows and columns in the freight flow matrix as illustrated in Table 19.

Step 5 -- Calculate Commodity Flows (First Iteration). The commodity flow from County B to County D is:

$$X_{ij} = R_i C_j F_{ij} = 2.5087(55{,}556) = 139{,}374$$

Thus, the total commodity flow for County B is:

$$P_i = \sum_{j=A}^{D} X_{ij} = 167{,}248+1{,}505{,}225+188{,}153+139{,}374$$
$= 2{,}000{,}000$ which matches the desired p_i.

The Commodity flow to County D is:

$$C_j = \sum_{i=A}^{D} X_{ij} = 2{,}325{,}595+139{,}394+299{,}400+1{,}956{,}518$$
$= 4{,}720{,}887$ which is 6% under the desired C of 5,000,000

The foregoing computations would be undertaken for all rows and columns in the freight flow matrix, as illustrated in Table 20.

Because of the structure of this form of the gravity model, the computed shipments for each county must match the initial amount. County consumption totals, however, will not necessarily match the initial value. While within the 5 to 10 percent range for County D, the results obtained for Counties A and B show much greater variance. Thus, a second iteration becomes necessary. To refine the calculated interchanges, consumption totals are adjusted before the second iteration by the ratio of the desired receipts over actual receipts or, for County D, by:

$$\frac{5{,}000{,}000}{4{,}720{,}887} = 1.0591$$

The above computations would be repeated for all consuming counties.

Step 6 -- Recalculate Attraction Factors, Accessibility Index, and Production Index (Second Iteration). This step is a repeat of Step 4, but using the adjusted consumption totals. The Attraction Factor from County B to County D is:

$$C_j F_{ij} = 55{,}556(1.0591) = 58{,}841$$

The Accessibility Index for County B is:

$$\sum_{j=A}^{D} C_j F_{ij} = 27{,}477+977{,}685+81{,}987+58{,}841 = 1{,}145{,}990$$

The Production Index for County B is:

$$R_i = \frac{P_i}{\sum_{j=A}^{D} C_j F_{ij}} = \frac{2{,}000{,}000}{1{,}145{,}990} = 1.7452$$

As before, the foregoing computations would be undertaken for all rows and columns in the freight flow matrix, as illustrated in Table 21.

Table 18. Gravity Model -- Steps 2 and 3.

Production (P_i)	Consumption (C_j): County A 2,000,000	County B 6,000,000	County C 3,000,000	County D 5,000,000	ΣC_j 16,000,000	Accessibility $\Sigma C_j F_{ij}$	Production Index $R_i = \frac{P_i}{\Sigma C_j F_{ij}}$
County A 10,000,000	25 0.04	30 0.033	80 0.0125	120 0.0083			
County B 2,000,000	30 0.033	10 0.1	40 0.025	90 0.0111			
County C 1,000,000	80 0.0125	40 0.025	15 0.067	60 0.0167			
County D 3,000,000	120 0.0083	90 0.0111	60 0.0167	20 0.05			
ΣP_i 16,000,000							

Table 19. Gravity Model -- Step 4.

Production (P_i)	Consumption (C_j): County A 2,000,000	County B 6,000,000	County C 3,000,000	County D 5,000,000	ΣC_j 16,000,000	Accessibility $\Sigma C_j F_{ij}$	Production Index $R_i = \frac{P_i}{\Sigma C_j F_{ij}}$
County A 10,000,000	25 0.04 80,000	30 0.033 20,000	80 0.0125 37,500	120 0.0083 41,667		179,167	55.8138
County B 2,000,000	30 0.033 66,667	10 0.1 600,000	40 0.025 75,000	90 0.0111 55,556		797,223	2.5087
County C 1,000,000	80 0.0125 25,000	40 0.025 150,000	15 0.067 20,000	60 0.0167 83,333		278,333	3.5928
County D 3,000,000	120 0.0083 16,667	90 0.0111 66,667	60 0.0167 50,000	20 0.05 250,000		383,334	7.8261
ΣP_i 16,000,000							

Table 20. Gravity Model -- Step 5.

Production (P_i)	Consumption (C_j): County A 2,000,000	County B 6,000,000	County C 3,000,000	County D 5,000,000	ΣC_j 16,000,000	Accessibility $\Sigma C_j F_{ij}$	Production Index $R_i = \frac{P_i}{\Sigma C_j F_{ij}}$
County A 10,000,000	$\boxed{25}$ 0.04	$\boxed{30}$ 0.033	$\boxed{80}$ 0.0125	$\boxed{120}$ 0.0083			
	80,000	20,000	37,500	41,667		179,167	55.8138
	4,465,108	1,116,277	2,093,019	2,325,595	10,000,000		
County B 2,000,000	$\boxed{30}$ 0.033	$\boxed{10}$ 0.1	$\boxed{40}$ 0.025	$\boxed{90}$ 0.0111			
	66,667	600,000	75,000	55,556		797,223	2.5087
	167,248	1,505,225	188,153	139,374	2,000,000		
County C 1,000,000	$\boxed{80}$ 0.0125	$\boxed{40}$ 0.025	$\boxed{15}$ 0.067	$\boxed{60}$ 0.0167			
	25,000	150,000	20,000	83,333		278,333	3.5928
	89,820	538,923	71,856	299,400	999,999		
County D 3,000,000	$\boxed{120}$ 0.0083	$\boxed{90}$ 0.0111	$\boxed{60}$ 0.0167	$\boxed{20}$ 0.05			
	16,667	66,667	50,000	250,000		383,334	7.8261
	130,437	521,741	391,304	1,956,518	3,000,000		
ΣP_i 16,000,000	4,852,618	3,682,166	2,744,332	4,720,887	15,999,999		
	+143%	-39%	-9%	-6%			

Table 21. Gravity Model -- Step 6.

Production (P_i)	Consumption (C_j): County A 2,000,000	County B 6,000,000	County C 3,000,000	County D 5,000,000	ΣC_j 16,000,000	Accessibility $\Sigma C_j F_{ij}$	Production Index $R_i = \frac{P_i}{\Sigma C_j F_{ij}}$
County A 10,000,000	25 0.04	30 0.033	80 0.0125	120 0.0083			
	80,000	20,000	37,500	41,667		179,167	55.8138
	4,465,108	1,116,277	2,093,019	2,325,595	10,000,000		
	32,972	37,590	40,994	44,130		150,686	66.3632
County B 2,000,000	30 0.033	10 0.1	40 0.025	90 0.0111			
	66,667	600,000	75,000	55,556		797,223	2.5087
	167,248	1,505,225	188,153	139,374	2,000,000		
	27,477	977,685	81,987	58,841		1,145,990	1.7452
County C 1,000,000	80 0.0125	40 0.025	15 0.067	60 0.0167			
	25,000	150,000	20,000	83,333		278,333	3.5928
	89,820	538,923	71,856	299,400	999,999		
	10,304	244,421	21,863	88,260		364,848	2.7409
County D 3,000,000	120 0.0083	90 0.0111	60 0.0167	20 0.05			
	16,667	66,667	50,000	250,000		383,334	7.8261
	130,437	521,741	391,304	1,956,518	3,000,000		
	6,869	108,632	54,658	264,781		434,940	6.8975
ΣP_i 16,000,000	4,852,618 +143%	3,682,166 -39%	2,744,332 -9%	4,720,887 -6%	15,999,999		

Step 7 -- Recalculate Commodity Flows (Second Iteration). This step is a repeat of Step 6. Thus, the new commodity flow from County B to County D is:

$$X_{ij} = R_i C_j F_{ij} = 1.7452(58{,}841) = 102{,}690$$

The total commodity flow for County B is:

$$P_i = \sum_{j=A}^{D} X_{ij} = 47{,}953+1{,}706{,}271+143{,}085+102{,}690$$
$$= 2{,}000{,}000 \text{ which again matches the desired } P_i.$$

The commodity flow to County D is:

$$C_j = \sum_{i=A}^{D} X_{ij} = 2{,}928{,}607+102{,}690+241{,}909+1{,}826{,}329$$
$$= 5{,}099{,}535 \text{ which is 2\% over the desired } C_j \text{ of } 5{,}000{,}000.$$

As before, the foregoing computations would be undertaken for all rows and columns in the freight flow matrix, as illustrated in Table 22.

Although the results obtained for County D are acceptable, those for County A and B may still be outside the acceptable range. Thus, in some cases, a further iteration may be undertaken, as illustrated in Table 23.

Step 8 -- Compute Average Distance. The final step is to compute the average distance, which in this example is 56.1 miles. This should then be compared with any existing data or discussed with industry representatives to determine whether such a distance appears reasonable. If the average distance is too high; increase the assigned impedance power (and vice versa).

Some application hints and notes of caution:

1. While the addition of distance and cost does interject greater rationality, it will not necessarily produce superior results to those obtained using a trade model.
2. The gravity model is particularly useful where sizable distance or cost differences exist between producing and consuming counties and states.
3. Usually it will not be possible to "fine tune" the impedance function, because the necessary data to do this will probably not be available.

Successful use of the gravity model depends on the availability of travel or movement data with which to calibrate the model to base year conditions. Although such data are typically available in urban transportation planning studies (or can be approximated through use of exponent values from similar urban areas), comparable base year data usually do not exist for freight studies. Thus, the inability to calibrate because of the lack of a data base and knowledge of what the exponents should be (i.e., an established body of empirically derived knowledge) limits the use of the gravity model in freight applications.

Linear Programming

Another method for simulating freight distribution is linear programming. Expressed mathematically:

minimize $\sum\sum X_{ij} t_{ij}$

such that $\sum X_{ij} = C_j$

$\sum X_{ij} = P_i$

$\sum X_{ij} \geq 0$

where: X_{ij} = shipment from production area i to consumption area j;
P_i = production in state or county i;
C_j = consumption in state or county j; and
t_{ij} = impedance which will normally be a unit distance or cost.

The foregoing linear program is known as the transportation problem, and special linear programming algorithms (e.g., the stepping-stone method) exist for it. It is also possible to use more general algorithms (e.g., the Simplex method). Numerous linear programming computer programs have been written, including several for microcomputers. Linear programming requires the use of computers; the method is not amenable to manual solutions.

The attractiveness of linear programming lies in its underlying premise of economic rationality (i.e., overall transport cost minimization). This premise is sometimes applicable at the firm level, but almost never at the regional level given multiple firms competing for the same markets.

Two characteristics of linear programming limit the applicability of this method. First, the number of movements implied in a linear programming solution is only a fraction of those typically taking place. For a system comprised of n counties or states, the program will produce no more than (2n-1) of the n(n-1) potential intercounty or state flows. Second, crosshauling (i.e., the interchange of a commodity in both directions between two areas) is impossible in a linear programming solution. Crosshauls occur in movement data on account of (1) competition for markets by producers, (2) product differentiation not reflected in the aggregated commodity groupings typically used, and (3) except for bulk commodities, transport costs are a relatively small proportion of total product costs. Very few commodity movements exist without at least some crosshauling.

Other factors affecting the use of linear programming include the fact that (1) unit transport costs are not linear with distance or shipment size and (2) the resulting distributions are extremely sensitive to the estimates of production and consumption. The sensitivity of the linear programming solution is based on differences rather than proportions. In practice, transportation planners employing linear programming for commodity flow modeling have to build "inertia" into the model system to overcome the extreme sensitivity to small variations in inputs to the model.

Table 24 presents the type of flows that would have been obtained, had linear programming been employed with the example used previously. In this case, the average distance is 36.6 miles, which represents a sizable reduction from that computed earlier using trade and gravity models.

DEVELOPING A FUTURE YEAR COMMODITY FLOW MATRIX

The following presumes that the application requires preparation of a future year commodity flow matrix. This can usually be done by starting with and modifying the base case commodity flow matrix.

Selecting an Appropriate Method

Factors affecting the choice of a forecasting method include:

Table 22. Gravity Model -- Step 7.

Production (P_i)	Consumption (C_j): County A 2,000,000	County B 6,000,000	County C 3,000,000	County D 5,000,000	ΣC_j 16,000,000	Accessibility $\Sigma C_j F_{ij}$	Production Index $R_i = \frac{P_i}{\Sigma C_j F_{ij}}$
County A 10,000,000	25 0.04	30 0.033	80 0.0125	120 0.0083			
	80,000	20,000	37,500	41,667		179,167	55.8138
	4,465,108	1,116,277	2,093,019	2,325,595	10,000,000		
	32,972	32,590	40,994	44,130		150,686	66.3632
	2,188,126	2,162,776	2,720,492	2,928,607	10,000,001		
County B 2,000,000	30 0.033	10 0.1	40 0.025	90 0.0111			
	66,667	600,000	75,000	55,556		797,223	2.5087
	167,248	1,505,225	188,153	139,374	2,000,000		
	27,477	977,685	81,987	58,841		1,145,990	1.7452
	47,953	1,706,271	143,085	102,690	2,000,000		
County C 1,000,000	80 0.0125	40 0.025	15 0.067	60 0.0167			
	25,000	150,000	20,000	83,333		278,333	3.5928
	89,820	538,923	71,856	299,400	999,999		
	10,304	244,421	21,863	88,260		364,848	2.7409
	28,242	669,926	59,924	241,909	1,000,001		
County D 3,000,000	120 0.0083	90 0.0111	60 0.0167	20 0.05			
	16,667	66,667	50,000	250,000		383,334	7.8261
	130,437	521,741	391,304	1,956,518	3,000,000		
	6,869	108,632	54,658	264,781		434,940	6.8975
	47,379	749,290	377,004	1,826,329	3,000,002		
ΣP_i 16,000,000	4,852,618 +143%	3,682,166 -39%	2,744,332 -9%	4,720,887 -6%	15,999,999		
	2,311,700 +16%	5,288,263 -12%	3,300,505 +10%	5,099,535 +2%	16,000,003		

Table 23. Gravity Model - Final Iteration.

Production (P_i)	Consumption (C_j): County A 2,000,000	County B 6,000,000	County C 3,000,000	County D 5,000,000	ΣC_j 16,000,000	Accessibility $\Sigma C_j F_{ij}$	Production Index $R_i = \frac{P_i}{\Sigma C_j F_{ij}}$
County A 10,000,000	$\boxed{25}$ 0.04	$\boxed{30}$ 0.033	$\boxed{80}$ 0.0125	$\boxed{120}$ 0.0083			
	80,000	20,000	37,500	41,667		179,167	55.8138
	4,465,108	1,116,277	2,093,019	2,325,595	10,000,000		
	32,972	32,590	40,994	44,130		150,686	66.3632
	2,188,126	2,162,776	2,720,492	2,928,607	10,000,001		
	28,526	36,976	37,262	43,269		146,033	68.4777
	1,953,394	2,532,030	2,551,615	2,962,960	10,000,000		
County B 2,000,000	$\boxed{30}$ 0.033	$\boxed{10}$ 0.1	$\boxed{40}$ 0.025	$\boxed{90}$ 0.0111			
	66,667	600,000	75,000	55,556		797,223	2.5087
	167,248	1,505,225	188,153	139,374	2,000,000		
	27,477	977,685	81,987	58,841		1,145,990	1.7452
	47,953	1,706,271	143,085	102,690	2,000,000		
	23,772	1,109,270	74,522	57,693		1,265,257	1.5807
	37,577	1,753,430	117,797	91,196	2,000,000		
County C 1,000,000	$\boxed{80}$ 0.0125	$\boxed{40}$ 0.025	$\boxed{15}$ 0.067	$\boxed{60}$ 0.0167			
	25,000	150,000	20,000	83,333		278,333	3.5928
	89,820	538,923	71,856	299,400	999,999		
	10,304	244,421	21,863	88,260		364,848	2.7409
	28,242	669,926	59,924	241,909	1,000,001		
	8,915	277,317	19,872	86,537		392,641	2.5469
	22,705	706,286	50,611	220,397	1,000,000		
County D 3,000,000	$\boxed{120}$ 0.0083	$\boxed{90}$ 0.0111	$\boxed{60}$ 0.0167	$\boxed{20}$ 0.05			
	16,667	66,667	50,000	250,000		383,334	7.8261
	130,437	521,741	391,304	1,956,518	3,000,000		
	6,869	108,632	54,658	264,781		434,940	6.8975
	47,379	749,290	377,004	1,826,329	3,000,002		
	5,943	123,253	49,681	259,613		438,490	6.8417
	40,660	843,255	339,901	1,776,184	3,000,000		
ΣP_i 16,000,000	4,852,618 +143%	3,682,166 -39%	2,744,332 -9%	4,720,887 -6%	15,999,999		
	2,311,700 +16%	5,288,263 -12%	3,300,505 +10%	5,099,535 +2%	16,000,003		
	2,054,336 +3%	5,835,000 -3%	3,059,924 +2%	5,050,737 +.1%	16,000,000		

Table 24. Linear Programming Model.

from Producing Counties (P_i)		to Consuming Counties (C_j) A 2,000,000	B 6,000,000	C 3,000,000	D 5,000,000
County A	10,000,000	2,000,000	6,000,000	2,000,000	-
County B	2,000,000	-	-	-	2,000,000
County C	1,000,000	-	-	1,000,000	-
County D	3,000,000	-	-		3,000,000

P_i = 16,000,000 = C_j

1. The characteristics of the data used in estimating traffic generation and preparing the commodity flow matrix.
2. The availability of "historical" data either for freight generation or commodity flows.
3. The availability of economic forecasts for the state and substate areas.
4. The level of detail and refinement desired by the user.

Several different approaches can be taken, including:

1. Project future traffic flow directly from base year traffic flow data.
2. Project commodity production and consumption from comparable base year data, and then use these projections to adjust the base year commodity flow matrix to reflect these projections.
3. Use forecasts of income, employment, and population as proxy measures of anticipated changes in production and consumption, and thus use the resulting ratio to estimate changes in production and consumption and to adjust the base year commodity flow matrix.

Forecasting Shipments and Receipts

Although many forecasting methods exist, those of potential use in freight demand forecasting fall into three groups (2): (1) causal methods, (2) time series analysis and projections, and (3) qualitative methods.

Causal Methods

Usually a theoretical model is postulated *a priori*, which is then tested and calibrated against historical data. Once satisfactory agreement has been reached, various extrapolations can be made that then become forecasts. Causal models can range from highly aggregate, using national and state data, to quite detailed disaggregate models requiring specific microeconomic data. The key is establishing valid relationships between the factor to be forecast and other explanatory variables.

Time Series Analysis and Projections

Such methods rely primarily on the observation of patterns and changes in patterns, and thus are heavily dependent on historical data. Their advantage is their simplicity. Their disadvantage is that they make no attempt to explain or relate demand to other stable, predictable causal variables. Such methods are useful so long as stability exists in the phenomena being forecast and sufficient information is available on past performance.

Qualitative Methods

Such methods are built around the use of nonquantitative information, such as expert opinion. Despite their lack of using hard or scientific data, these methods may be quite important in evaluating a situation where little historical data exist or where existing data are questionable or inconsistent.

Tables 25 and 26 summarize the various forecasting methods of potential value in forecasting future year shipments/receipts and commodity flows.

Projecting Commodity Flows

BEA Data and Projections

One rather simple, short range approach is to use BEA historical data and projections prepared for 171 BEA regions to expand a base year commodity flow matrix (24). The results can then be disaggregated to the state and county level.

In using this approach, base year commodity flows of each commodity k from BEA region i to BEA region j are projected to year t by multiplying by the growth rate of industry k in region i between the base year and year t. The resulting raw or uncontrolled flows are then normalized to ensure that shipments grow at the same rate as production at the national level for each industry. This approach is based on three key assumptions:

1. Although labor productivity within an industry may vary among regions, the productivity of one region relative to each other region is maintained. This allows the use of earnings as a proxy for production. Changes in output due to productivity changes may then be determined from the national gross product originating conversion coefficients provided by OBERS.
2. The relationship between the amount of product produced (e.g., tons) and gross output (e.g., dollars) remains unchanged for each industry over the forecast period, both at the regional and national levels. Any percentage change in output implies a corresponding change in shipments.
3. Distribution patterns remain unchanged from the base year. Thus, if Pittsburgh sends 25 percent of its primary metals to Detroit in the base year, it will continue to do so in each projected year. This assumption is clearly violated when major shifts of changes occur in commodity flows between the base and forecast year (e.g., western coal).

In applying this method, it is assumed that a base year commodity flow matrix covering all movements of interest has been prepared.

Step 1 -- Obtain OBERS Earnings Data and Projections. Obtain OBERS earning data for the base year (or as close thereto as possible) and earnings projections (21). It is entirely possible that OBERS data may not be available for the base year. If such is the case, it may be necessary to interpolate between years for which the data are available or the last year for which earnings data are available and the projected earnings for each region to approximate earnings during the base year.

Table 25. Forecasting Techniques: General Description.

Causal Methods Regression Analysis: The ordinary least squares method can be applied to any single-equation model that is purported to capture a one-way flow of causality from a set of independent variables to a dependent one. The dependent variable is the one to be forecast, using the specified historical relationship as the foundation. Econometric Models (Simultaneous Equation Systems): These are systems of independent regression equations that describe some sector or region of economic or transportation activity. As a rule, these models are relatively expensive to develop and operate, but they are more effective in expressing the causalities involved than ordinary regression models and consequently will forecast turning points more accurately. In general, they represent the most attractive and potentially necessary modeling framework to handle regional and statewide commodity flows. Input-Output Models: These reflect the interindustry or interregional flows of goods and services in the regional (or national) economy and its markets. Considerable effort must be expended to use these models properly and additional detail, not normally available, must be obtained if they are to be applied to specific regions. Anticipation Surveys: These surveys of various groups of shippers, carriers, and users of different classes of commodities and freight are quite useful for short range forecasts. The surveys are usually quite brief and are geared to the respondent's immediate decision-making needs. In the case of general consumer surveys, however, the questionnaires are occasionally quite lengthy. Diffusion Indices: A diffusion index is a composite of various business and economic indicators. Its purpose is to capture the general flow or trend of all the leading, coinciding, and lagging indicators normally used to reflect general business conditions. To the extent that the demand for commodities is derived from more aggregate demands, this method could be useful in commodity transport planning. Leading Indicators: A leading indicator is a particular index that has been estimated by the National Bureau of Economic Research to reflect changing aggregate economic conditions by preceding or "leading" the change. It is particularly useful in forecasting turning points in the rate of growth in various categories of economic and monetary data. Economic Base Studies: To some extent, economic base studies are the heart of classical regional location theory. These studies reflect the changing economic and industrial base in local areas and regions. They are extremely useful in capturing the industrial mix of local community and in generating employment information on its industries.	Time Series and Projections, Continued Exponential Smoothing: In some ways this method is merely a special case of the Box-Jenkins method. It assigns progressively higher weights in an exponential fashion to the more recent points of observation in a time series. X-11 Method: Originally developed at the U. S. Bureau of the Census, this method decomposes time series into the classic distribution of trend, cyclical, seasonal, and irregular components. Trend Projections: This in some ways is the simplest forecasting method in usage. The analyst needs only to take an existing series or equation and extrapolate the value of the dependent variable. This extrapolation can be done in many ways; for example, by a range or band of extrapolations, or by applying a known statistical distribution to generate the extrapolation. Motionary Triangles: These are among the most complex of the statistical methods. Essentially, there is a wide range of techniques available for plotting or charting short-range movements in a particular indicator. Some of the movements are calculated with different "triangle" configurations, such that a "breakout" on either side of the apex of the triangle could be forecast.
Time Series and Projections Moving Averages: This method is one of the most basic statistical exercises; it uses quarterly or monthly data ordinarily to generate a moving trend. Box-Jenkins Method: This method assigns probability weights to a series of historical data with the assistance of a quantitative model. It is more cumbersome than using moving averages, but its accuracy in forecasting short-term movements is much higher.	Qualitative Methods Delphi Method: This method is a fairly well defined procedure for using cumulative questionnaires to solicit expert opinions from a group of carefully selected panelists. Market Research Methods: This method uses personal and on-site interviews with shippers, carriers, agencies, and users of commodity transportation. The principal intention is to forecast the longer-range developments or shifts in the flows of commodities or in the contributions of the critical industries. Panel Consensus: This is simply an organized approach to appraising the consensus of a panel of individuals on a specific set of issues. The approach is quite useful to generate fairly quick and accurate short-range predictions. Historical Analogy: This method requires the use of an analyst who is familiar with previous patterns of behavior or who can associate a trend in current events with some historical configuration. One must be very cautious, however, about its use in forecasting. Visionary Forecasts: Quite often, it is valuable to hire a reputed "visionary" in the field, someone who has a track record of providing feasible insight to a particular problem or issue. In a sense, this method is a control or an anchor against which other methods' forecasts can be compared. Factor Analysis: This is the most mathematical method among the set of qualitative ones. It incorporates the preferences of individuals and experts by ranking their views either with cardinal or ordinal measures. The end product is a set of important "factors" or attributes that are regarded as explaining a particular event. Source: Bruck, H.W., Kneafsey, J.T., and Roberts, P.O., "A Methodological Approach to Commodity Flow Analysis in the State of California." MIT Urban Systems Laboratory, Cambridge, MA (1974).

Step 2 -- Compute Regional Growth Rates by Industry. OBERS projected earnings are used to develop regional growth rates for application to base year commodity flows. Growth rates are simply projected year earnings divided by base year earnings. Because such data or projections may not be entirely amenable to direct use, one or more of the following adjustments may be required:

1. Suppression of Historical Data. Because of the suppression of certain historical earnings data at the BEA-industry level, it may not be possible to calculate growth rates for some regional industries for estimating the missing information. Since OBERS projections are basically extrapolative, missing base year earnings can often be estimated by "backcasting" from future projected earnings levels. For example, given 1980 and 1985 projected earnings for industry 1 (E_1^{80}, E_1^{85}):

a. Calculate annual growth rate:

$$r = \left[\frac{E_1^{85}}{E_1^{80}}\right] - 1$$

b. Calculate a correction factor that accounts for differential industry growth rates at the national level to account for changing growth trends (base year = 1972):

$$\frac{g_{1,72/80}}{g_{1,72/80}}$$

where: $g_{1,72/80}$ = national growth rate from base year to 1980

$g_{1,80/85}$ = national growth rate from 1980 to 1985

Table 26. Forecasting Techniques Application.

	ACCURACY	APPLICATIONS	DATA REQUIREMENTS	GENERAL REFERENCE
Causal Methods				
Regression Analysis	Usually quite good	To any single equation model with one-way causality	Usually more than 10 observations: either time series, cross-sectional, or pooled data	J. Johnston, Econometric Methods (New York: John Wiley & Son, 1963); Henri Theil, Principles of Econometrics (New York: John Wiley & Son, 1971)
Econometric Models (Simultaneous Equation Systems)	Very good	To capture interactions within more complex systems	Not less than above	M. Evans, Macroeconomic Activity: Theory, Forecasting and Control (New York: Harper & Row, 1969)
Input-Output Model	Fairly good	To capture regional economic impacts and interaction	Detailed data at the SIC 2-digit level at minimum	W. Leontief, Input-Output Economics (New York: Oxford University Press, 1966)
Anticipation Surveys	Fair	To reflect intentions of shippers	Questionnaires or on-site surveys	Survey Research Center, University of Michigan
Diffusion Indices	Fair	To reflect current business trends	Secondary sources	U.S. Department of Commerce
Leading Indicators	Fair	To reflect aggregate business indicators	Secondary sources	National Bureau of Economic Research
Economic Base Studies	Good	To capture short-term changes in industrial composition	Local or regional data	H. Richardson, Regional Economic Analysis (New York: John Wiley & Son, 1972)
Time Series and Projections				
Moving Average	Poor	General statistical checks	Quarterly or monthly data	A. Hadley, Introduction to Business Statistics (San Francisco: Holden-Day, Inc., 1968)
Box-Jenkins Method	Fair	Assigns smaller errors to historical data with a mathematical model	Quarterly or monthly data	Box-Jenkins, Time Series Analysis: Forecasting and Control (San Francisco: Holden-Day, Inc., 1970)
Exponential Smoothing	Poor	Simply weights recent data points more highly	Quarterly or monthly data	Any general statistics text
X-11 Method	Good	Decomposes time series into seasonal, trend, cyclical and irregular elements	At least 12 quarters of data	U.S. Bureau of the Census
Trend Projections	Variable	Extrapolating an equation	Variable	- -
Motionary Triangles	Fairly good	To predict short-term movements based on "technical factors	Monthly data	Bache & Co., Statistical Reports

Table 26. Forecasting Techniques Application Continued.

	ACCURACY	APPLICATIONS	DATA REQUIREMENTS	GENERAL REFERENCE
Qualitative Methods				
Delphi Method	Fair	To collect expert opinion from a panel of specialists; uses cumulative questionnaires	Tabulation of views; consensus of opinion; rankings	Motor Vehicles Manufacturers Association
Market Research Methods	Good	To forecast longer range developments, especially in shifts of commodity flows	Personal interviews	Consumer Survey Center, University of Michigan; Report to SCAG, 1974 (by MIT)
Panel Consensus	Fair	To check with experts' views	Mail questionnaire; or 1 day meeting	--
Historical Analogy	Poor	To relate present or future events to historical	Long-term historical data	--
Visionary Forecasts	Variable	To evaluate alternative future scenarios, without the existence of necessary data	A set of realistic future scenarios	--
Factor Analysis	Good	To attempt rankings of subjective characteristics or attributes of commodities	Rankings of attributes plus computer program	J. Johnston, *Econometric Methods* New York: John Wiley & Son (1963)

Source: Bruck, H.W., Kneafsey, J.T., and Roberts, P.O., "A Methodological Approach to Commodity Flow Analysis in the State of California." MIT Urban Systems Laboratory, Cambridge, MA (1974).

c. $$E_i^{72} = E_i^{80}(1+rc)^{-8}$$

2. Agricultural Growth Rates. Fluctuations in regional earnings due to local weather conditions and market prices lead to unstable regional growth rates with normal calculation procedures. Base year earnings can be very low or exceed projected year earnings. Such local fluctuations, which reflect changes in price and proprietors' earnings as well as physical output changes, are inappropriate for long-term projections. Substitution of rates more representative of likely long-term growth are often necessary.

3. Transshipment Regions. If the true origin differs that contained in the commodity flow matrix, then a different growth rate may have to be used. For example, ore flows from the Cleveland BEA probably originate in the Duluth BEA, and are only transshipped from water to rail at the Ohio BEA. Projections of these flows by the growth rate of metallic mining in Cleveland (if any actually occur) would be inappropriate. In such cases, the growth rate at the actual origin should be substituted. Similarly for imported commodities, the national average growth rate should be used in place of that occurring at the origin port.

4. Low Production Industries. Although earnings in all industries in all regions are projected, OBERS considers some of them too small for reliable projection. Although such data are omitted from published OBERS reports, they appear on the magnetic tape output. In these cases, national average growth rates should be used.

Step 3 -- Compute National Growth Rates by Industry. National growth rates by industry are required to normalize the uncontrolled flows to ensure that projected regional flows are compatible with national projections by industry. National growth totals are based on OBERS projections of the gross product originating in each industry. This measure is superior to direct use of unadjusted OBERS industry earnings projections because it adjusts for industry specific productivity changes that alter output/earnings ratios over time and accounts for relative price trends between industries as well.

Although OBERS publishes gross-product earnings conversion factors (historical and projected) for mining and manufacturing industries, these data are not provided for agriculture, forestries, and fisheries. The following can be used to derive national output projections for agriculture. First, develop a correspondence between the value of agricultural output in constant dollars and agricultural earnings for historical and projected years in which both data items are available in supplemental OBERS data. Then apply this ratio to the earnings projections for the forecast years to develop output growth rates.

Step 4 -- Disaggregate BEA Regional Commodity Flow Projections to States and Counties. An allocation procedure based on employment can be used for this purpose.

Fratar Growth Factor Model

Although developed for use in urban transportation studies and most commonly used in extrapolating origin-destination matrices over relatively short forecast periods, the Fratar model can also be applied in freight studies. Using this model, the distribution of future shipments from zone i is proportional to the present commodity flows from zone i modified by the growth factors in the zones under consideration.

$$CF^{\alpha}_{ij} = CF^{o}_{ij} f_i f_j \frac{l_i + l_j}{2}$$

$$f = \frac{S_i^{\alpha}}{S_i^{o}}, \quad f = \frac{R_i^{\alpha}}{R_i^{o}}$$

$$l_i = \frac{S}{\sum_{j=1}^{x} CF_{ij} f_i}, \quad l_j = \frac{R}{\sum_{i=1}^{x} CF_{ij} f_j}$$

where: CF^{α}_{ij} = commodity flow for the alternative (future year);

CF^{o}_{ij} = commodity flow for the base case;

f_i, f_j = zonal growth factors;

S_i, S_j = shipments from zone i for base case and alternative;

R_i, R_j = receipts at zone j for base case and alternative;

(Subject to the constraints $S = \sum CF_{ij}$ and $R = \sum CF_{ij}$.)

An interative process is usually required to satisfy the above constraints. The Fratar model has been computerized. See Computer Programs for Urban Transportation Planning for a more complete discussion of the theory and mathematical formulation of this model (22).

RESULTING PRODUCT

The resulting product from Freight Traffic Generation and Distribution is a series of hardcopy or computerized records consisting of the following fields for the base case and each alternative future, scenario, or condition being examined:

- Origin County or State
- Destination County or State
- Commodity Type: 2, 3, 5 digit STCC code or the equivalent.
- Flow: Weight (tons) or Volume (gallons, bushels)
- Flow: Number of Vehicles.
- Modes Utilized: above flows divided among competing modes, services, or mode combinations.

One record is prepared for each movement having an unique origin, destination and commodity type. Users have the option of preparing separate records for the base case and each alternative or future year being considered, or to include them together in the same record. The foregoing records can then be summarized to produce various tables, such as those indicated as follows:

Quantity Summarized	Table Rows	Table Columns
• Total Commodity Flow	Origin	Destination
• Commodity Flow by STCC Code	Origin	Destination
• Total Vehicle Movements	Origin	Destination
• Vehicle Movements by Commodity Type	Origin	Destination
• Originating Traffic	Origin	Commodity Type
• Terminating Traffic	Destination	Commodity Type
• Originating Vehicles	Origin	Commodity Type
• Terminating Vehicles	Destination	Commodity Type

Records can be summarized to produce geographic (state, substate, or study area), commodity, and mode totals.

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CHAPTER FOUR

MODAL DIVISION

INTRODUCTION

Modal division is the process of "splitting" commodity movements among competing modes. For modal division to take place, the following prerequisites are necessary:

1. The physical capability for intermodal competition must exist (i.e., presence or convenient access to a rail line or inland waterway system segment either directly or in combination with truck transport).
2. Carriers either already or capable and willing of providing shippers with a choice of services differentiated by price and service quality.
3. Commodity types, shipment sizes, and a length of haul conducive to transport by competing modes or services.

If these prerequisites are not present, modal division per se is not relevant and this phase reduces down to estimating modal costs and revenues -- if required as a product of the application.

Much of past research in freight demand forecasting has been devoted to modeling the mode choice decision-making process. Most models use comparative transport cost, price (i.e., rates), or logistics cost (total cost to the shipper) as the primary means for dividing traffic among competing modes. This in itself is a simplification on how decisions are actually made, because the choice among modes is the result of a combination of economic and service factors. Since costs or rates typically form the basis for modal division, this chapter is largely devoted to techniques for obtaining or estimating unit costs and rates. Such cost and rate information is also essential in determining the underlying economics of the present or proposed movement.

MODE SPLIT MODELS

Through the years, a number of analytically and empirically-derived mode split models have been developed. The premise underlying these models is that firms seek to minimize either out-of-pocket or logistics costs associated with transporting raw materials and products. With analytical models, the cost function is specified in advance, thus allowing the selection of the optional transport mode or service. With empirical models, shipper or industry cost functions are derived through data-based estimates of shipper or industrial behavior. Although these models can be used by states, most were developed in a research environment, and consequently have only been used to a limited extent in addressing practical problems. An appreciable body of literature does exist on these models, but available documentation is often less-than-adequate in aiding others apply the model. A summary of mode split models has previously been developed and is included in NCHRP Report 177. Also see the references and selected bibliography at the end of this chapter (1-22).

Users can readily construct their own analytical mode split model. Such a model can be nothing more complex than a comparison between the costs of, or prices charged by, competing modes, with the traffic being assigned to the least cost mode. However, users must first choose between a physical distribution (logistics) or transport economics approach. If the latter is selected, users must further decide whether the resulting model will use rates (charges to shipper) or unit costs (incurred by carriers) in dividing commodity movements among competing carriers. The underlying logic is straightforward, as indicated below:

- Mode split model using marginal unit costs:
  Let c_b = base case unit cost (to carriers)
  c_a = alternate unit cost (to carriers)
  If $c_a < c_b$, assign traffic movement to the alternative mode; otherwise assign movement to the base case mode.

- Mode split model using actual or estimated rates:
  Let r_b = base case rate
  r_a = alternative rate
  If $r_a < r_b$, assign traffic movement to the alternative mode; otherwise assign movement to the base case mode.

- Mode split model using physical distribution costs:
  Let s_b = base case unit cost (to shippers)
  s_a = alternate unit cost (to shippers)
  where: s = transport logistics cost + non-transport logistics costs = $c_l + c_{nl}$
  c_l = rate + unit loss and damage + unit pick-up and delivery.
  c_{nl} = unit order cost + unit storage cost + unit inventory + unit carrying cost in-transit + unit stockout cost.
  If $s_a < s_b$ assign traffic movement to the alternative mode; otherwise assign movement to the base case mode.

The foregoing logic presumes choosing between two modes or services. However, the concept can readily be extended to include additional modes or services.

The mode split model assigns all of the traffic to the mode having the least cost or rate regardless of the magnitude of the cost or rate difference. Given known indifference to small variations in unit costs or rates, users may wish to incorporate constraints on an "all-or-nothing" assignment approach. One method for doing this is to establish a zone of indifference within that competing modes or services would share the traffic proportionally. Alternatively, the user can predefine a point at which diversion from an existing mode or service is presumed to take place, or place limits on the amount of diversion or the maximum market share possible for different modes or transport services. While such logic will reduce the sensitivity of modal division to small unit price or cost differences, they should reflect observed behavior and thus would not be implemented arbitrarily. On condition that appropriate data are available, the user can also develop diversion curves governing the assignment of traffic to competing modes and/or services on the basis of their relative prices or costs.

Users can also use various empirical models, such as the (1) disaggregate multinomial logit, (2) aggregate multinomial logit, and (3) aggregate translog (2-5,7,10-19). These models have not been included as subtechniques, because they employ mathematical techniques and computer programs that tend to be unfamiliar or are unavailable to state DOT personnel. Users potentially interested in using these models should obtain copies of the listed references and communicate directly with the researchers involved for further information.

Regardless of which model is chosen, it will perform no better than the quality of the input data, which are unit costs or prices. Hence the emphasis in this chapter on developing unit costs and rates.

UNIT COSTS

Virtually all the larger carriers have developed extensive costing systems for strategic planning and internal management purposes. These systems are tailored to meet the specific needs of individual carriers, and thus vary greatly in design and sophistication. Neither these systems nor the products produced therefrom are generally available to states except for information introduced into the record at regulatory proceedings.

Consequently, the public sector has had to develop its own cost-estimating systems. Development of such systems has been uneven; in the rail area, the Interstate Commerce Commission's need for a system that would produce comparable cost data led originally to the development of "Rail Form A" in 1939. Since then, this methodology has become the standard, recognized rail costing tool for regulatory-oriented applications and is being widely used by others to estimate the costs associated with rail movements. Recent legislation has resulted in the development of the Uniform Rail Costing System (URCS) as a replacement of Rail Form A for use by the public and private sectors.

Analogous public sector techniques for costing truck and inland waterway movements do not exist. As part of this research project, a computerized truck costing system comparable in detail to URCS has been developed. Procedures have also been presented for costing barge movements on the inland waterway system and for determining logistics or distribution costs from a shipper's perspective.

The costing subtechniques presented must be applied correctly. In particular, the user must recognize that:

1. The resulting unit cost will never be a single "true" cost, but only an estimate.
2. Costs can be measured in a variety of ways, any one of which can be correct under the particular circumstances of the application.
3. Unit costs will vary appreciably within the carrier or within the mode, depending on location, financial condition and management expertise of the carrier and the specific movement being costed.
4. The unit costs chosen must be compatible with the application at hand.
5. Unit costs will vary over time, thus making it necessary to determine the time period on which the unit costs are based, and to update these costs to reflect the desired time period.

The user should also recognize that the unit cost data available to the public sector will always be limited. First, government is not providing the transport service and thus is dependent on common and private carriers for necessary data. Second, carriers provide data in response to requirements laid down by regulatory agencies. Because of potential competitive difficulties stemming from inadvertent release of proprietary data, regulatory agencies generally treat such data confidentially, only releasing carrier data in aggregated or summary form. Consequently, detailed information describing how such unit costs were derived, or indicating exactly what the data represent or include or apply to, is typically unavailable.

The following sections present specific subtechniques for estimating unit rail, truck, barge, and physical distribution costs. Where appropriate, alternative techniques have been presented.

Rail Costs

Only one generally recognized and accepted costing system is available for public use. Up until recently, this has been Rail Form A. The Railroad Revitalization and Regulatory Reform Act of 1976 inaugurated major changes in railroad regulation by shifting to reliance on competition and cost-based rate making in place of governmental intervention. The Act directed that the Commission develop new and more accurate accounting and cost systems to replace those currently being used. This requirement was further strengthened by passage of the Staggers Rail Act of 1980, which established a number of cost-based standards defining the scope of the Commission's rate jurisdiction. The Act restricted affected parties from protesting rate actions unless it could be shown that a carrier's revenues exceeded its variable costs by a prescribed percentage, and it specifically called for the calculation of those costs "using Rail Form A methodology (or an alternative methodology adopted by the Commission in lieu thereof)." In response, the Commission incorporated prior efforts into an overall program to replace the old Uniform System of Accounts and Rail Form A with a new accounting and costing system. The new accounting system was developed in 1977 and put into operation in 1978. The Commission completed research and analysis on a new costing system in 1981, and proceeded to solicit general public comment on this system by publishing the Preliminary 1979 Rail Cost Study (29). Final release and full implementation of the replacement costing system took place in early 1983. While both costing methodologies take the same conceptual approach, URCS provides a number of tangible improvements designed to make the replacement system far more useful and flexible in both regulatory and nonregulatory applications. Both Rail Form A and URCS focus on transport costs incurred by railroads; related costs such as inventory, packaging, storage, etc., incurred by shippers are not included.

Rail Form A

Although maintenance of Rail Form A was discontinued several years ago, final release of the movement costing portions position of URCS did not occur until after this manual was essentially completed. A brief description for Rail Form A has been retained for reference purposes, even though URCS will eventually supersede Rail Form A in virtually all applications.

Rail Form A is basically a manual system. Application starts with Commission-developed carload unit costs given in Table 3 of the Rail Carload Cost Scales (32), a sample of which is reproduced as Table 27. In 1977, these costs were developed for the following seven geographical areas, or "territories."

- Region I - New England Region
- Region II - Official Territory, excluding New England and Conrail
- Region III - Official Territory (Regions I and II including Conrail)
- Region IV - Southern Region
- Region V - Western District, excluding Mountain Pacific and Trans-Territory
- Region VI - Mountain Pacific and Trans-Territory
- Region VII - Western District (Regions V and VI)

Each railroad has been assigned to one of the foregoing regions. Using the carload unit cost information given in Table 27, rail costs can be estimated as follows:

COST = Way Train Cost + Through Train Cost + Terminal Cost

COST = (VWTCOST + LHCOST)WTMILES + (VTTCOST + LHCOST)TTMILES + (VTERMCOST + CTERMCOST)

where: COST = unit carload cost, ¢/cwt;
VWTCOST = variable way train cost, ¢/cwt-mile;
LHCOST = linehaul cost (Table 27, Col.8), ¢/cwt-mile);
WTMILES = way train miles = total miles - through train miles, miles;
VTTCOST = variable through train cost, ¢/cwt-mile;
TTMILES = through train miles, miles;
VTERMCOST = variable terminal cost, ¢/cwt;
CTERMCOST = constant terminal cost (Table 27, Col. 9), ¢/cwt;
VWTCOST = (WTLHCAR)/(SS) + WTLHCWT;
VTTCOST = (TTLHCAR)/(SS) + TTLHCWT; and
VTERMCOST = (TERMCAR)/(SS) + TERMCWT.

in which VWTCOST = variable way train cost, ¢/cwt-mile;
WTLHCAR = variable way train linehaul cost (Table 27, Col. 4), ¢/car-mile;
SS = shipment size per car, cwt;
WTLHCWT = variable way train linehaul cost (Table 27, Col. 5), ¢/car-mile;
VTTCOST = variable through train cost, ¢/cwt-mile;
TTLHCAR = variable through train linehaul cost (Table 27, Col.4)¢/car-mile;
TTLHCWT = variable through train linehaul cost (Table 27, Col.5)¢/car-mile;
VTERMCOST = variable terminal cost, ¢/cwt;
TERMCAR = variable terminal cost per car (Table 27, Col. 6), ¢/car; and
TERMCWT = variable terminal cost per cwt (Table 27, Col. 7), ¢/cwt.

As an example of the above, assume a 30-ton carload (600 cwt) moving 350 miles in a general service unequipped box car in Region II. Further assume the mileage divides into 50 way train and 300 through train miles.

VWTCOST = (62.84106/600) + 0.03310 = 0.13784

VTTCOST = (50.82029/600) + 0.02001 = 0.10471

VTERMCOST = (17087.59/600) + 0.048 = 28.527

COST = (0.13784 + 0.01970)50 + (0.10471 + 0.01970)300 + (28.527 + 3.029)

= 7.877 + 37.323 + 31.556 = 76.756¢/cwt or $15.35/ton

Table 27. Rail Form A Example: Carload Unit Cost (Table 3).

Table 3. CARLOAD UNIT COST (IN CENTS) BY TYPE OF TRAIN AND BY TYPE — Region II Excluding Conrail

LINE NO.	TYPE OF EQUIPMENT (2)	EMPTY RETURN RATIO (3)	VARIABLE EXPENSES LINE-HAUL PER CAR-MILE (4)	VARIABLE EXPENSES LINE-HAUL PER CWT.-MILE (5)	VARIABLE EXPENSES TERMINAL PER CARLOAD (6)	VARIABLE EXPENSES TERMINAL PER CWT. (7)	CONSTANT EXPENSES LINE-HAUL CWT.-MILE (8)	CONSTANT EXPENSES TERMINAL PER CWT. (9)
	AVERAGE TRAIN							
1	BOX-GENERAL UNEQUIPPED	0.64	52.09998	0.02141	17087.590	0.048	0.01970	3.029
2	BOX-GENERAL EQUIPPED	0.87	65.92049	0.02141	17045.086	0.048	0.01970	3.029
3	BOX-SPECIAL	0.99	74.41040	0.02141	18396.074	0.048	0.01970	3.029
4	GONDOLA-GENERAL	0.79	58.11925	0.02141	18396.074	0.048	0.01970	3.029
5	GONDOLA-SPECIAL	1.10	69.35333	0.02141	18396.074	0.048	0.01970	3.029
6	HOPPER-OPEN GENERAL	0.87	58.47516	0.02141	18396.074	0.048	0.01970	3.029
7	HOPPER-OPEN SPECIAL	1.01	63.28319	0.02141	18396.074	0.048	0.01970	3.029
8	HOPPER-COVERED	1.04	66.76047	0.02141	18396.074	0.048	0.01970	3.029
9	STOCK	1.03	60.52354	0.02141	18396.074	0.048	0.01970	3.029
10	FLAT-GENERAL	0.88	59.67319	0.02141	18396.074	0.048	0.01970	3.029
11	REFR-MEAT-MECHANICAL	0.92	81.92412	0.02141	12177.992	0.048	0.01970	3.029
12	REFR-O/T MEAT-MECH.	0.85	81.31334	0.02141	12177.992	0.048	0.01970	3.029
13	REFR-MEAT-NON MECH.	0.89	76.03201	0.02141	12177.992	0.048	0.01970	3.029
14	REFR-O/T MEAT-NON MECH.	1.01	77.33133	0.02141	12177.992	0.048	0.01970	3.029
15	TANK 10,000-18,999 GALLONS	1.06	74.41040	0.02141	12177.992	0.048	0.01970	3.029
16	TANK 28,000-31,999 GALLONS	1.06	83.93507	0.02141	12177.992	0.048	0.01970	3.029
	WAY TRAIN							
17	BOX-GENERAL UNEQUIPPED	0.64	62.84106	0.03310	17087.590	0.048	0.01970	3.029
18	BOX-GENERAL EQUIPPED	0.87	81.84219	0.03310	17045.086	0.048	0.01970	3.029
19	BOX-SPECIAL	0.99	93.68123	0.03310	18396.074	0.048	0.01970	3.029
20	GONDOLA-GENERAL	0.79	70.63829	0.03310	18396.074	0.048	0.01970	3.029
21	GONDOLA-SPECIAL	1.10	84.67903	0.03310	18396.074	0.048	0.01970	3.029
22	HOPPER-OPEN GENERAL	0.87	70.32895	0.03310	18396.074	0.048	0.01970	3.029
23	HOPPER-OPEN SPECIAL	1.01	76.25952	0.03310	18396.074	0.048	0.01970	3.029
24	HOPPER-COVERED	1.04	81.31430	0.03310	18396.074	0.048	0.01970	3.029
25	STOCK	1.03	71.77713	0.03310	18396.074	0.048	0.01970	3.029
26	FLAT-GENERAL	0.88	72.07408	0.03310	18396.074	0.048	0.01970	3.029
27	REFR-MEAT-MECHANICAL	0.92	100.29253	0.03310	12177.992	0.048	0.01970	3.029
28	REFR-O/T MEAT-MECH.	0.85	100.31027	0.03310	12177.992	0.048	0.01970	3.029
29	REFR-MEAT-NON MECH.	0.89	91.59351	0.03310	12177.992	0.048	0.01970	3.029
30	REFR-O/T MEAT-NON MECH.	1.01	91.95320	0.03310	12177.992	0.048	0.01970	3.029
31	TANK 10,000-18,999 GALLONS	1.06	89.49234	0.03310	12177.992	0.048	0.01970	3.029
32	TANK 28,000-31,999 GALLONS	1.06	104.22105	0.03310	12177.992	0.048	0.01970	3.029
	THROUGH TRAIN							
33	BOX-GENERAL UNEQUIPPED	0.64	50.82029	0.02001	17087.590	0.048	0.01970	3.029
34	BOX-GENERAL EQUIPED	0.87	64.02357	0.02001	17045.086	0.048	0.01970	3.029
35	BOX-SPECIAL	0.99	72.11450	0.02001	18396.074	0.048	0.01970	3.029
36	GONDOLA-GENERAL	0.79	56.62775	0.02001	18396.074	0.048	0.01970	3.029
37	GONDOLA-SPECIAL	1.10	67.52742	0.02001	18396.074	0.048	0.01970	3.029
38	HOPPER-OPEN GENERAL	0.87	57.06290	0.02001	18396.074	0.048	0.01970	3.029
39	HOPPER-OPEN SPECIAL	1.01	61.73720	0.02001	18396.074	0.048	0.01970	3.029
40	HOPPER-COVERED	1.04	65.02655	0.02001	18396.074	0.048	0.01970	3.029
41	STOCK	1.03	59.18277	0.02001	18396.074	0.048	0.01970	3.029
42	FLAT-GENERAL	0.88	58.19574	0.02001	18396.074	0.048	0.01970	3.029
43	REFR-MEAT-MECHANICAL	0.92	79.73573	0.02001	12177.992	0.048	0.01970	3.029
44	REFR-O/T MEAT-MECH.	0.85	79.05006	0.02001	12177.992	0.048	0.01970	3.029
45	REFR-MEAT-NON MECH.	0.89	74.17802	0.02001	12177.992	0.048	0.01970	3.029
46	REFR-O/T MEAT-NON MECH.	1.01	75.58929	0.02001	12177.992	0.048	0.01970	3.029
47	TANK 10,000-18,999 GALLONS	1.06	72.61353	0.02001	12177.992	0.048	0.01970	3.029
48	TANK 28,000-31,999 GALLONS	1.06	81.51820	0.02001	12177.992	0.048	0.01970	3.029

Table 3. Carload Unit Costs by Types of Train and By Types of Equipment 1/, Other Than TOFC Cars 2/

Region II

(Costs shown in cents per service units)

Line No.	Type of Equipment (2)	Empty Return Ratio (3)	Variable expenses Line-Haul Per Car-mile (4)	Variable expenses Line-Haul Per cwt. mile (5)	Variable expenses Terminal Per carload 3/ (6)	Variable expenses Terminal Per cwt. (7)	Constant expenses Line-Haul Per cwt. mile (8)	Constant expenses Terminal Per cwt (9)
	Car Ownership Costs							
49	Box-general service unequipped ...	xxx	16.82086	xxx	5949.680	xxx	.00205	.419
50	Box-general service equipped	xxx	18.96890	xxx	5907.176	xxx	.00205	.419
51	Box-special service	xxx	20.18618	xxx	6218.078	xxx	.00205	.419
52	Gondola-general service 4/.......	xxx	18.15739	xxx	6218.078	xxx	.00205	.419
53	Gondola-special service 4/.......	xxx	21.30197	xxx	6218.078	xxx	.00205	.419
54	Hopper open-general service 4/...	xxx	18.96890	xxx	6218.078	xxx	.00205	.419
55	Hopper open-special service 4/...	xxx	20.38902	xxx	6218.078	xxx	.00205	.419
56	Hopper covered	xxx	20.69334	xxx	6218.078	xxx	.00205	.419
57	Stock	xxx	20.59190	xxx	6218.078	xxx	.00205	.419
58	Flat-general service	xxx	19.07033	xxx	6218.078	xxx	.00205	.419
59	Refrigerator meat mech	xxx	xxx	xxx	xxx	xxx	.00205	.419
60	Refrigerator Other mech	xxx	xxx	xxx	xxx	xxx	.00205	.419
61	Refrigerator meat non-mech	xxx	xxx	xxx	xxx	xxx	.00205	.419
62	Refrigerator Other non-mech	xxx	xxx	xxx	xxx	xxx	.00205	.419
63	Tank-10,000-18,999 gallons	xxx	xxx	xxx	xxx	xxx	.00205	.419
64	Tank-28,000-31,999 gallons	xxx	xxx	xxx	xxx	xxx	.00205	.419

See pages 126 and 127 for footnotes.

Source: Interstate Commerce Commission, Rail Carload Cost Scales 1977, Statement No. 1C1-77, pp. 22.

Adjustments can be made to the values contained in Table 27 to reflect different operating conditions. Procedures for making such modifications are presented in the text and appendixes of the publication; Rail Carload Cost Scales 1977. Typical adjustments include:

1. Adding intra-terminal and inter-terminal switching costs per car, constant and variable, where appropriate.
2. Utilizing shortline rather than actual distances, and applying a circuity factor.
3. Adjusting line-haul, car-mile and cwt-mile costs to reflect train weight (weight of trailing tons), number of locomotive units, and wages where different from regional averages.
4. Removing private car rental costs included in Table 27.
5. Adjusting car-mile costs for differences in rail car tare weight.
6. Adjusting terminal costs to reflect differences in special services.
7. Adjusting switching costs per carload to reflect known engine switching minutes per loaded car.
8. Deducting interchange switching costs if the movement involves only one railroad.
9. Deducting switching costs if no intertrain or intratrain switching service is required.
10. Changing the ratio of empty to loaded car-miles from regional averages for particular car types.

Rail Form A data were last published for 1977. The data can be updated by multiplying the unit costs by ratios issued by the Commission or developed by the user using standard industry indices. For example, the user could apply the following Commission-issued ratios to obtain costs for the first and second quarters of 1980:

Month/Year	Official Territory	Southern Region	Western Region
January 1980	1.241	1.251	1.272
April 1980	1.258	1.277	1.301

Uniform Rail Costing System (URCS)

URCS is a complex set of computerized procedures that transforms reported railroad expense and activity data into estimates of the cost of providing specific services. It includes (1) assemblage of an initial data base of expense and activity information, (2) the development of cause and effect relationships and the calculation of unit costs, and (3) the application of those unit costs to the movements of specific shipments. Physically, URCS consists of three computerized phases that draw together the various information elements required to calculate the costs of providing rail services. The computer programs provide a framework within which these data can be organized, analyzed, and applied to railroad traffic. The principal output of the methodology is a set of unit costs. Inasmuch as various publications describing URCS are available, no attempt has been made in this manual to describe in detail the underlying theory or the major components comprising this system (25-31,33,34).

Users will be able to obtain from the Commission a separate modularized interactive program that applies the URCS developed unit costs to estimate variable and fully allocated costs for specific movements. This "movement costing program" has been written in a form that allows users to install the program and supporting data files on their own computer system or to access it via a terminal by timesharing arrangements with commercial vendors.

To use the movement costing program, the user first selects the data base files (termed Worktable E) for the applicable regions and carriers. Once this has been done, the user then accesses the costing program and enters movement parameters in response to program queries. The user then has the opportunity to modify any costing factors for which more specific information is available. For efficiency of data entry, these parameters are grouped into three sets:

1. The Minimal Parameter Set. This set contains the basic shipment descriptors required to cost out a movement. The user first specifies the region or carrier, segment short line miles, and movement type for each region or carrier (see Table 28). The program then queries the user for type and number of cars, type of movement, car ownership, commodity, and type and weight of the shipment (tons).

Table 28. Contents of the Minimal Parameter Set.

Region or Carrier	Up to Four 1/
Short Line Miles	(Miles)
Movement Type	(OT, OD, RD, RT, OR, IA, IR) 2/
Car Type	One of 18 3/
Number of Cars	(Cars)
Type of Movement	(1) Individual (2) Multiple (3) Unit Train
Car Ownership	Railroad (R) or Private (P)
Commodity Type	One of 66 by STCC code
Weight of Shipment	(Tons)

1/ Region*

- II Official Territory excluding Conrail
- III Official Territory including Conrail
- IV Southern Region
- V Western District excluding Mountain Pacific and Trans-Territory
- VI Mountain Pacific and Trans-Territory
- VII Western District (Regions V and VI)

* Region I, which was previously the New England Region, has been discontinued.

2/ Movement Type

- OT Originated Terminated
- OD Originated Delivered
- RD Received Delivered
- RT Received Terminated
- OR Open Routing
- IA Intraterminal
- IR Interterminal

3/ Car Type

1. Box, General Service Unequipped (40 ft.)
2. Box, General Service Unequipped (50 ft.)
3. Box, General Service Equipped
4. Gondola, General Service Unequipped
5. Gondola, General Service Equipped
6. Hopper, Covered
7. Hopper, General Service
8. Hopper, Open Special Service
9. Refrigerator, Mechanical
10. Refrigerator, Non-Mechanical
11. Flat, TOFC
12. Flat, Multi-Level
13. Flat, General Service
14. Flat, Other
15. Tank, Less than 22,000 Gallons
16. Tank, More than 22,000 Gallons
17. Freight, All Other
18. Freight, Average

2. The Normal and Special Parameter Sets. These sets contain a large and diverse group of costing factors that are frequently modified when computing the costs of different movements (see Table 29). The program queries the user for the normal and special parameter input codes (1-63 as shown in Table 29) for those parameters which the user chooses to modify. After the user has made the desired modifi-

Table 29. Contents of the Normal and Special Parameter Sets.

Input Code	Parameters
1.	Circuity Factor
2.	Tare Weight
3.	Loaded/Empty Car-Mile Ratio
4.	Spotted/Pulled Ratio
5-7	No. of Locomotives 1/
8-10	Weight of Train 1/
11-13	Crew Wages 1/
14-16	Actual Miles 1/
17	Number of Industry Switches
18	Number of Interchange Switches
19-23	Car Days 2/
24-26	Car Days per Loading and Unloading 3/
27-31	Car Miles 2/
32-36	Number of Cars 2/
37-41	Switch Engine Minutes 2/
42	Miles Between Intratrain & Intertrain Switch
44	Car Miles per Car Day
45	Actual Charge per Car Mile
46	Actual Charge per Car Day
47	General Overhead Ratio
48	Car Days Running
49	Car Days in Yard
50	Accessorial Services (Y or N)

1/ Separately for Through, Way, and Unit Trains

2/ Separately per Industry Switch, Interchange Switch, Intertrain & Intratrain Switch, Intraterminal Switch and Interterminal Switch.

3/ Separately for industry, intraterminal, and interterminal.

Input Code	Parameters
51	Ton miles, Lake Transfer Service
52	Tons at Coal Marine Terminals
53	Tons at Ore Marine Terminals
54	Tons at Other Marine Terminals
Multi-Level Flat	
55	Number of Automobiles
TOFC/COFC Service	
56	Number of Trailer Units
57	Number of Trailers per Car
58	Plan Number 1/
59	Line Haul Miles per Trailer Day
60	Trailer Days for Origin/Terminated Event
61	Refrigerated Trailer (Y or N)
62	Tare Weight of Trailer
63	Loaded/Empty Ratio of Trailer

1/ The TOFC plans commonly in use today are:

Plan 1 - Railroad carriers trailers owned by motor common carrier, ramp-to-ramp.

Plan 2 - Railroad carries its own trailers under its own truck competitive tariffs and furnishes pick-up and delivery services.

Plan 2¼ - Similar to Plan 2 except railroad provides either pickup or delivery service only, but not both.

Plan 2½ - Similar to Plan 2 except railroad performs ramp-to-ramp service only; does not furnish pickup and delivery service.

Plan 3 - Railroad carries trailers owned or leased by shipper, ramp-to-ramp, at published rates.

Plan 4 - Railroad carries trailers owned, leased or paid for by the shipper on cars also owned, leased or paid for by the shipper.

Plan 5 - Railroad carries its own or motor common carrier trailers under through billing at joint rail-truck rates.

cations, the program can provide a listing of the values for all parameters for each region or carrier.

Once the user has specified and/or verified the input data, the costing program is executed. The unit costs, costing factors, and movement descriptors are processed through an extensive series of equations to develop cost estimates. After computing basic train-mile statistics, the program sequentially develops the variable costs for each segment of railroad operations: line haul, terminal, freight car, specialized services, and loss and damage. Total variable costs per shipment are developed by summing the individual components, and the constant cost ratio is then applied to derive a fully allocated cost.

Output from the program is available to users in one of two forms. The user can choose either a brief listing of the variable and fully allocated costs of the shipment, or a more complete report comprised of a listing by region (carrier) of all inputs, intermediate calculations, and a summary of shipment costs on both a variable and fully allocated basis. The extensive detail in this version of the output report enables the user to develop a greater understanding of the movement and trace the specific cost impacts caused by altering key movement parameters.

In applying either Rail Form A or URCS, users should:

1. Talk with shippers, railroad company officials, and others knowledgeable of rail operations, to obtain specific "operations-oriented" information needed in support of rail costing.
2. Use the Handy Railroad Atlas of the United States, The Official Railway Guide, and company timetables to determine rail distances (36).
3. Seek to replicate the real world situations as closely as possible. Users should supply specific inputs for normal parameter set inputs, wherever possible, and not rely on default values.
4. Adjust the Rail Form A or URCS data to reflect current costs or the chosen base year using cost indices. Both methodologies use data that are at least two years old.

Truck Costs

Fragmentation of the motor carrier industry coupled with governmental reliance on competition to control rates and services has not generated the same need for a public sector truck costing system as has traditionally existed for rail. In fact, a public sector motor carrier costing system does not exist. Since the ability to cost truck movements is essential to virtually all freight demand forecasting applications, a truck costing subtechnique has been developed as part of this research project.

Truck Costing Subtechnique

The subtechnique presented updates and extends a model originally developed by the AAR (43) to include shorter haul trucking. The AAR model is oriented towards long-haul (over 150 miles), linehaul truckload movements; consequently, it did not include terminal costs, pick-up and delivery, or local cartage costs (provision has been made to include such costs). Both models assign costs primarily on a mileage-related basis, using unit values derived from the National Motor Transport Data Base and other sources. The subtechnique has been implemented through a computer program written in USCD Pascal for use on an Apple II microcomputer. The program has two main options: one that will compute costs interactively on an individual movement basis and the other that handles multiple runs for the purpose of developing cost curves. The second option was not intended as a technique by itself, but rather to produce the series of cost and distance graphs reflecting differences in the differences in the type of trucking, equipment ownership, trailer type, and miles driven per year to be used as the basis of a quick-response manual technique. Although designed as a stand-alone program, the principles and equations used can be incorporated into a mode split computer program involving other modal cost computations. Additional documentation of this model, including operating instructions, is contained in Appendix A. Also see the references and selected bibliography provided at the end of this chapter (37-56).

General Description of the Subtechnique

The detailed version of the subtechnique estimates the per-mile cost contributions for the following 16 component costs:

- Insurance
- Driver Wages and Benefits
- Driver Expenses
- Fuel
- Overhead
- Licenses and Permits
- Ton-mile Taxes
- Federal Highway User Taxes
- Tractor Capital Cost
- Tractor Maintenance
- Tractor Tire Cost
- Trailer Capital Cost
- Trailer Maintenance
- Trailer Tire Cost
- Stop and Delay Cost
- Terminal Cost

The foregoing components are then combined to produce the following estimates:

- Truckload Cost
- Cost-Headhaul
- Cost-Deadhead
- Per Ton Cost
- Per Hundredweight
- Per Mile Cost
- Per Ton-Mile Cost

The subtechnique makes use of up to 35 variables. The user must provide the following eight inputs:

- Equipment ownership (company or driver-owned)
- Miles driven per year
- Total round-trip miles
- Headhaul miles
- Headhaul average payload (tons)
- Equipment type
- Fuel Price ($/gallon)
- Fuel Consumption (miles/gallon)

The user then can interactively change any of the remaining 27 variables or use supplied default values. To the extent that this is done depends on the application at hand and the specific information available to the user. Once inputs have been entered or reviewed, the program computes and sums component costs and prints out the results.

Input variables are given in Table 30 along with the allowed range of values and typical default values. Figure 12 shows the basic structure of the subtechnique. Sample output is shown in Table 31. This table gives the component and total costs obtained when costing on an individual movement basis.

Table 30. Allowed Values for Program Variables.

Variable	Units	Value Min	Value Max	Default
Owner of Equipment	integer	0	1	0
Annual Mileage	miles	5	300,000	100,000
Roundtrip Dist.	miles	300	20,000	2,000
Headhaul Dist.	miles	150	10,000	1,000
Load	tons	1	75	21
Equipment Type	integer	0	9	1
Fuel Cost	$/gal	30	500	75
Fuel Mileage	mpg	1	10	4.8
Corporate Interest Rate	%	3	30	12.5
Investment Tax Credit	%	0	20	10
Marginal Income Tax Rate	%	17	70	20
Owner Operator Interest Rate	%	3	35	15
Insurance/Cost Year	$	0	10,000	5,000
Driver Wage/Year	$	0	40,000	22,000
Driver Expense/Year	$	0	8,000	3,500
Overhead/Year	$	0	10,000	3,500
License-Permit Cost/Year	$	100	5,000	1,200
3rd Structure Tax/Mile	¢	0	15	0.5
Fed. Hwy. User Tax/Year	$	0	1,000	210
Trailer Price	$	0	50,000	11,500
Trailer Economic Life	years	3	12	8
Trailer Salvage Value	$	0	15,000	3,750
Trailer Tax Life	years	1	10	8
Trailer Tax Salvage	%	0	50	10
Trailer Tire Price	$/set	0	3,000	1,150
Trailer Tire Life	miles	50	250,000	170,000
Trailer Maintenance	(¢/mi or $/yr)	0	10,000	1.5
Tractor Price	$	0	100,000	60,000
Tractor Economic Life	years	3	12	5
Tractor Salvage Value	$	100	30,000	12,000
Tractor Tax Life	years	1	8	4
Tractor Tax Salvage	%	0	50	10
Tractor Tire Price	$/set	500	8,000	1,700
Tractor Tire Life	miles	50	300,000	200,000
Tractor Maintenance	(¢/mi or $/yr)	0	30,000	9.0

The subtechnique is highly dependent on the quality of the input data. Such data not only vary, depending on location, firm, and characteristics of the particular movement, but they also are constantly changing because of inflation. Thus, the user is encouraged to contact local trucking firms to obtain up-to-date information and to adjust truck costing model inputs accordingly. The critical variables (miles per year, length of haul, equipment type, vehicle ownership and cargo weight) must be carefully estimated, because they have a significant impact on the resulting unit costs.

Component Cost Calculations

The following describes how individual component costs are calculated:

Insurance Cost per Mile is apportioned based on annual insurance costs and mileage. This typically includes public liability and damage, collision, cargo, and bob-tail insurance. It varies appreciably by region and vehicle ownership, as well as by type of operation. Some companies self-insure.

Driver Wages and Benefits are computed either by apportioning the annual salary and fringe benefit package by mileage or on a per-mile and per-hour basis. This may include the wages and benefits paid to a helper.

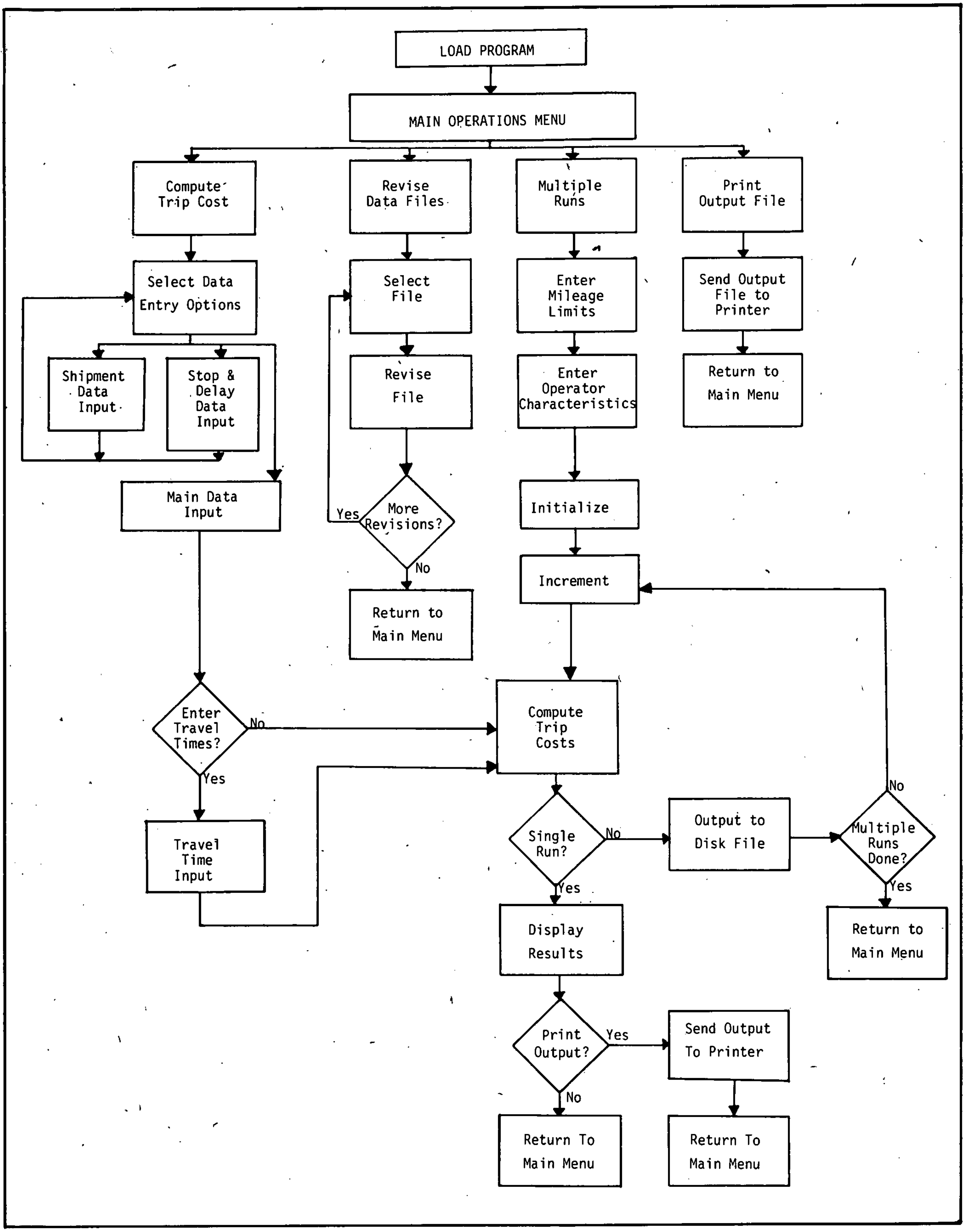

Figure 12. Functional Block Diagram of the Truck Costing Program.

Table 31. Sample Truck Costing Subtechnique Output.

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** TRIP DATA **

ORIGIN	DESTINATION	COMMODITY	WEIGHT (POUNDS)	<---DISTANCE TRAVELLED IN MILES---> HEADHAUL	ROUNDTRIP	DEADHEAD	<---SPEED IN MPH---> HEADHAUL	DEADHEAD	NUMBER OF STOPS
PHL	CHI	20 371 30	48825.0	982.00	2088.00	1106.00	49.93	56.72	3

** TIME FUNCTIONS **

TRANSIT TIMES IN HOURS HEADHAUL	DEADHEAD	<-----STOP AND DELAY TIMES IN HOURS------> LOAD	UNLOAD	WAIT	OTHER
19.67	19.50	2.75	2.00	1.42	0.00

** SHIPMENT DATA **

SIZE OF SHIPMENT	DENSITY LB/CU-FT	AVG LOAD (POUNDS)	NUMBER OF TRUCKLOADS
97.65 TONS	20.000	48825.0 LIMITED BY WEIGHT	4

** COMPONENT COSTS PER TRUCKLOAD **
(CENTS PER MILE &)
(PERCENT OF TOTAL)

<----------------FIXED COSTS---------------->

INSUR ANCE	OVER-HEAD	LIC & PERMIT	FED HUT	TRAC COST	TRLR COST
5.00	3.50	1.20	0.21	22.81	7.66
4.53%	3.17%	1.09%	0.19%	20.68%	6.95%

<----------------VARIABLE COSTS---------------->

DRIVER WAGE	DRIVER EXP	FUEL COST	3RD ST TAX	TRAC TIRE	TRAC MAINT	TRLR TIRE	TRLR MAINT	STOP COST	TERM COST
22.00	3.50	23.96	0.50	1.45	9.00	0.80	1.50	2.64	4.55
19.95%	3.17%	21.72%	0.45%	1.31%	8.16%	0.73%	1.36%	2.40%	4.13%

** TOTAL COSTS **
(PER TRUCKLOAD)

PER MILE	ROUNDTRIP	HEADHAUL	DEADHEAD	TON-MILE	CWT	TON
$ 1.1028	$ 2302.69	$ 1082.97	$ 1219.72	$ 0.0961	$ 4.72	$ 94.32

Driver Expenses are computed either by apportioning estimated annual subsistence and lodging expenses by mileage or are entered as a lump sum for the specific movement.

Fuel Cost is computed by dividing the fuel price per gallon by average fuel consumption per mile.

Overhead Cost is apportioned based on estimated management, office and terminal expenses, the number of tractor-trailer units operated, and annual mileage.

License and Permit Cost involves entering directly the sum of applicable state fees.

Ton-Mile Taxes are entered directly as a rate for states having ton-mile taxes.

Federal Highway User Tax is entered directly as a fixed amount per year.

Tractor and Trailer Capital Cost involves applying a six-step process (done separately for tractors and trailers).

1. Compute the net present value of the investment tax credit, which is the vehicle purchase price times the appropriate rate. Rates depend on the tax life of the equipment and the tax laws in effect when the vehicle was purchased.
2. Compute the net present value of the salvage, which is the excess of the resale value over the tax salvage multiplied by the capital gain portion of the tax rate, and then discounted to present value based on economic life and an appropriate interest rate.
3. Compute the net present value of the tax shield from depreciation. This is computed by taking the summation of present values of annual tax savings produced by depreciation over the tax life of the vehicle.
4. Compute the net present value of the capital cost, which is the vehicle purchase price less the results of steps 1 through 3 and divided by one minus the tax rate.
5. Compute the annual capital outlay. This can be estimated by applying an annuity formula to the results of step 4 to spread the capital cost over the economic life of the vehicle.
6. Compute the capital cost per mile, which is simply the annual capital outlay from step 5 divided by the annual mileage.

Other Costs consist of miscellaneous costs, such as loading and/or unloading the vehicle at terminals and broker fees for owner-operators divided by the round trip miles.

Summary Cost Computations

The following paragraphs describe how summary costs are calculated.

Shipment Cost represents the sum of the component costs multiplied by the larger of: (1) shipment weight divided by the maximum payload rounded up to the next vehicle, and (2) shipment weight divided by the density of the cargo divided by the maximum volume of the vehicle rounded up to the next vehicle.

Truckload Cost represents the sum of the component costs.

Cost-Loaded Miles are computed by multiplying the truckload cost by the proportion that loaded miles are of round-trip miles.

Cost-Unloaded Miles represent the difference between truckload and the loaded miles costs.

Loaded Miles/Round trip Miles represent the ratio of loaded miles divided by the round-trip miles.

Per-Ton Cost represents the loaded miles or round trip cost divided by the payload.

Per-Hundredweight Cost represents the per-ton cost divided by 20.

Per-Mile Cost represents the loaded miles or round trip cost divided by the loaded miles distance.

Per Ton-Mile Cost represents the per ton cost divided by the loaded miles distance.

Percent Fixed Costs (costs considered fixed over the short term) include insurance, overhead, licenses and permits, ton-mile taxes, Federal highway user taxes, and the capital cost of the tractor and trailer. These costs are computed as the sum of the component costs divided by total per-mile costs.

Percent Variable Costs (costs considered variable) include driver wages and benefits, driver expenses, fuel, tractor and trailer maintenance and tire costs, and other costs. These costs are computed as the sum of the component costs divided by total per-mile costs.

Truck Cost Estimating Curves

To aid users not having access to a suitable microcomputer, a set of truck cost estimating curves has been developed. Movement costs for more than 1,700 typical truck trips were computed. These trips covered headhaul distances from 50 to 2,000 miles and annual use from 80,000 to 160,000 miles. Fifteen operating scenarios were selected to allow reasonable estimation of costs for a large segment of the trucking industry. The scenarios cover nine basic trailer types, which enable the user to estimate costs for most of the commodities transportable by truck. Beyond differentiation by trailer type, a further breakdown by type of carrier has been made to account for differing interest rates and equipment prices. An industry average value of percent-loaded-miles is used for each carrier/trailer combination. Each trailer type has associated with it typical terminal costs.

The computed trip cost figures were then plotted on a cost-per-mile (in dollars) versus headhaul distance (in hundreds of miles) basis. The resulting truck curves allow the user to quickly estimate the cost per mile for a specific trip or to establish a range of costs that would apply to a particular type of trucking service. The curves were developed using input values representative of trucking industry costs during the first half of 1982.

Component steps involved in applying the subtechnique are the following.

Step 1 -- Determine Vehicle Ownership, Driver, and Equipment Types Appropriate to the Application. Figure 13 shows the structure of the motor carrier industry. Drivers can be company employed (either unionized or nonunionized) or be independent owner-operators. Van types vary appreciably, although the cost estimating curves illustrate the more prevalent types.

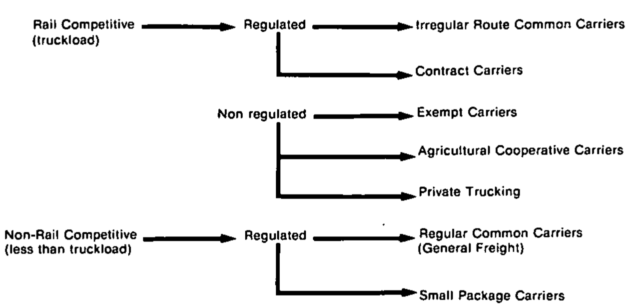

Figure 13. Structure of the Motor Carrier Industry.

Step 2 -- Determine Annual and Headhaul Mileage. Users must estimate approximate annual mileage as well as determine headhaul mileage from a Standard Highway Mileage Guide or the equivalent (50).

Step 3 -- Determine Cost per Mile. Use of the truck cost estimating curves is shown in Figure 14. The example shown assumes a van-type trailer hauled by a regulated carrier. If the annual mileage was 80,000 and the headhaul distance 500 miles, the resulting cost would be approximately $1.80 per mile.

Step 4 -- Apply Desired Adjustments. Typical adjustments include changes in (1) terminal costs, (2) percent loaded miles, (3) fuel cost and fuel economy, and (4) overall costs (inflation). Each is described below:

- Terminal Cost Adjustment

$$COST_a = \frac{\text{Fixed + Variable}}{\text{Costs/Mile}} + \frac{\text{Terminal}}{\text{Cost/Mile}}$$

$$= COST_o + \frac{TCOST_a - TCOST_o}{HHDIST}$$

where: $COST_a$ = adjusted unit cost, \$/mile;
$COST_o$ = original unit cost, \$/mile;
$TCOST_a$ = adjusted terminal cost, \$;
$TCOST_o$ = original terminal cost, \$; and
HHDIST = headhaul distance, miles.

If the terminal cost was $95 instead of $200, the resulting adjustment would be:

$$COST = 1.80 + \frac{95-200}{500} = \$1.59/\text{mile}$$

- Percent Loaded Miles Adjustment

$$COST = \text{Fixed + Variable Costs/Mile} \quad \text{Change in \% Loaded} \quad + \text{Terminal Cost/Mile}$$

$$= \left[COST - \frac{TCOST_a}{HHDIST}\right] \frac{\% LM_o}{\% LM_a} + \frac{TCOST_o}{HHDIST}$$

where: % LM = original % loaded miles; and
% LM = adjusted % loaded miles.

If the percent loaded miles was 75 rather than 84 percent, the resulting adjustment would be:

$$COST = 1.80 - \frac{200}{500}\ \frac{84}{75} + \frac{200}{500} = \$1.97/\text{mile}$$

- Fuel Cost and Economy Adjustment

$$COST = \left[\frac{\text{Fixed + Variable Costs/mile} \quad \Delta\text{Fuel Cost/mile}}{\text{\% Loaded Miles}}\right] + \text{Terminal Cost/mile}$$

$$= \left[COST_o - \frac{TCOST_o}{HHDIST}\right] \frac{HHMILES}{TMILES}\left[\frac{FC_a}{MPG_a} - \frac{FC_o}{MPG_o}\right] + \frac{TCOST_o}{HHDIST}$$

where: TMILES = total distance, miles;
FC = adjusted fuel cost, \$/gallon;
MPG = adjusted fuel consumption, mpg;
FC = original fuel cost, \$/gallon; and
MPG = original fuel consumption, mpg.

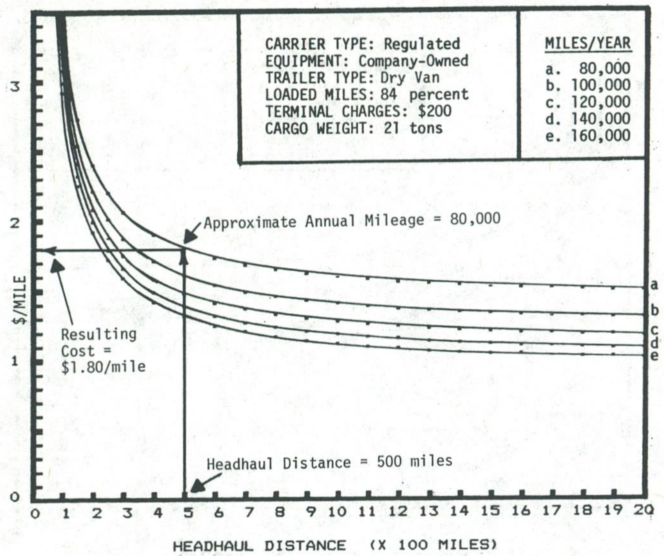

Figure 14. Sample Use of Truck Cost Estimating Curves.

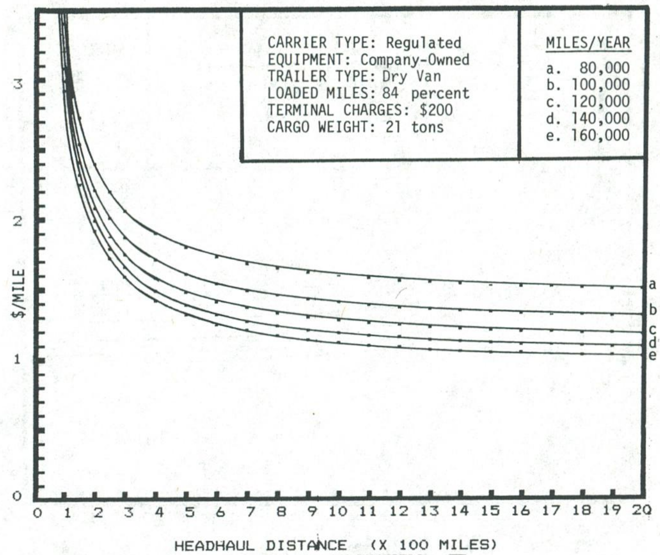

Figure 15. Truck Cost Estimating Curve #1.

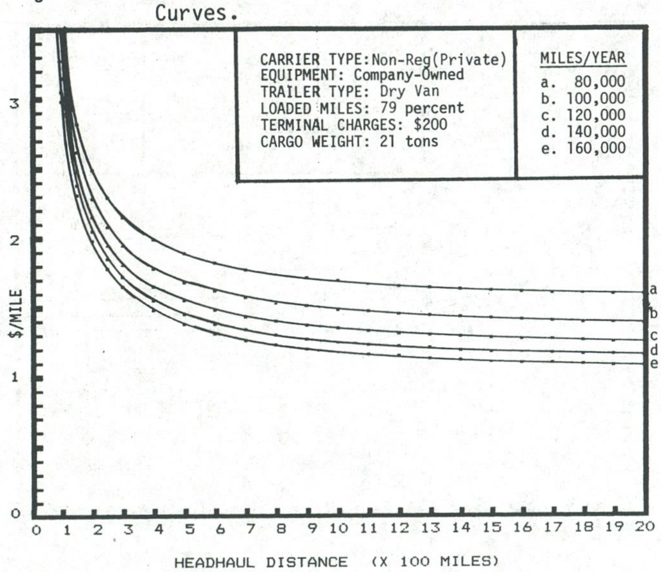

Figure 16. Truck Cost Estimating Curve #2.

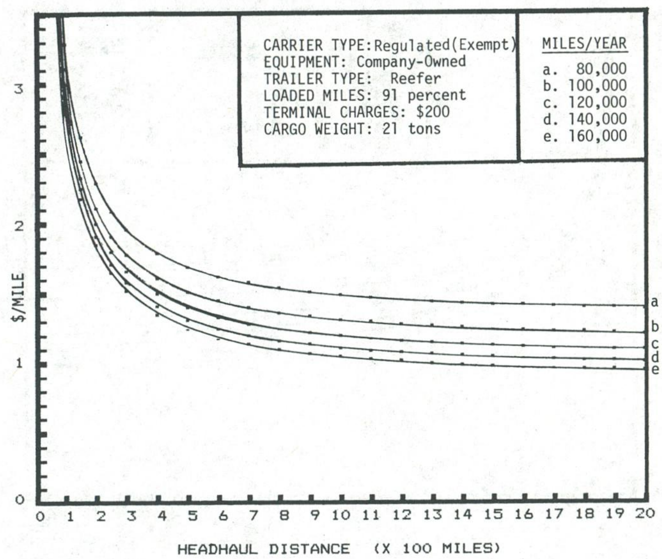

Figure 17. Truck Cost Estimating Curve #3.

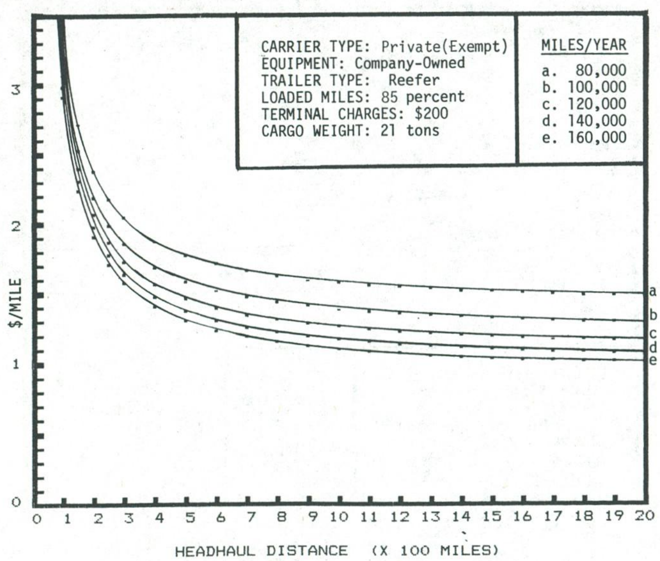

Figure 18. Truck Cost Estimating Curve #4.

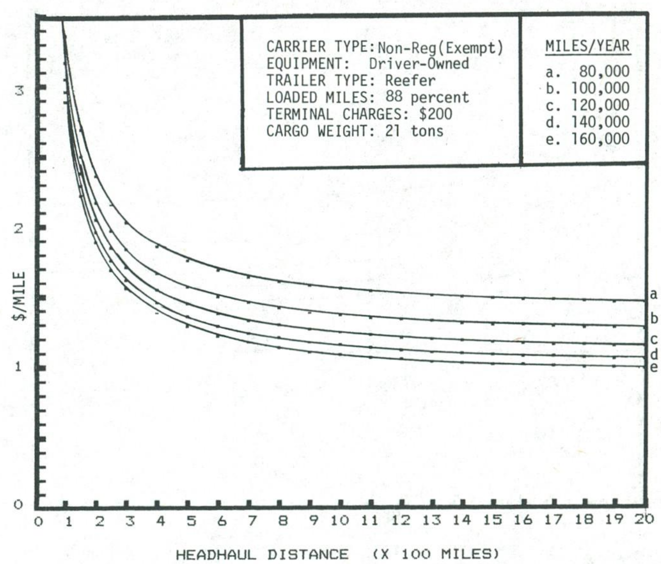

Figure 19. Truck Cost Estimating Curve #5.

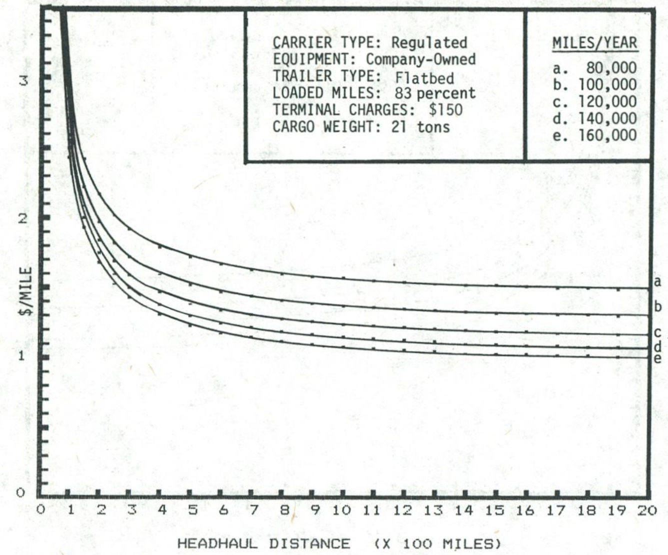

Figure 20. Truck Cost Estimating Curve #6.

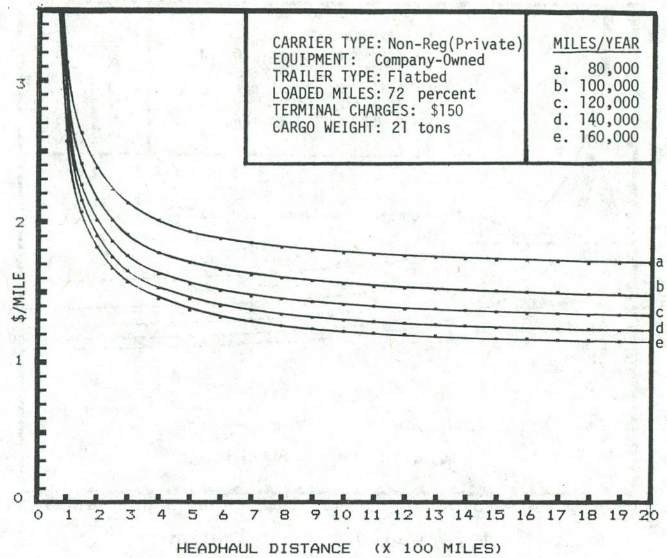

Figure 21. Truck Cost Estimating Curve #7.

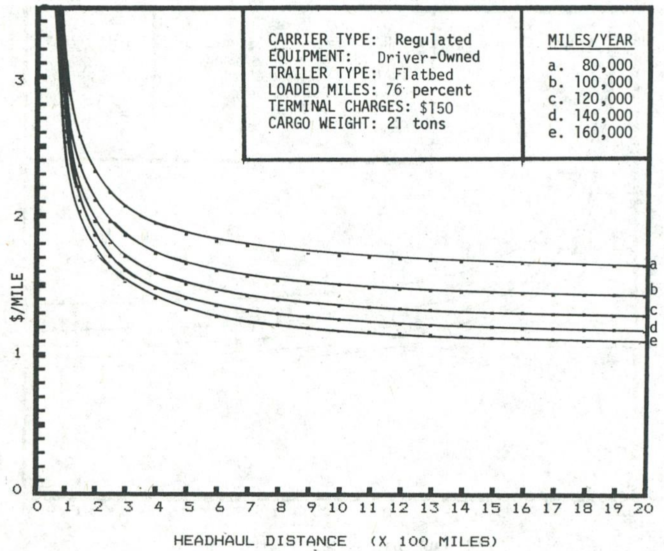

Figure 22. Truck Cost Estimating Curve #8.

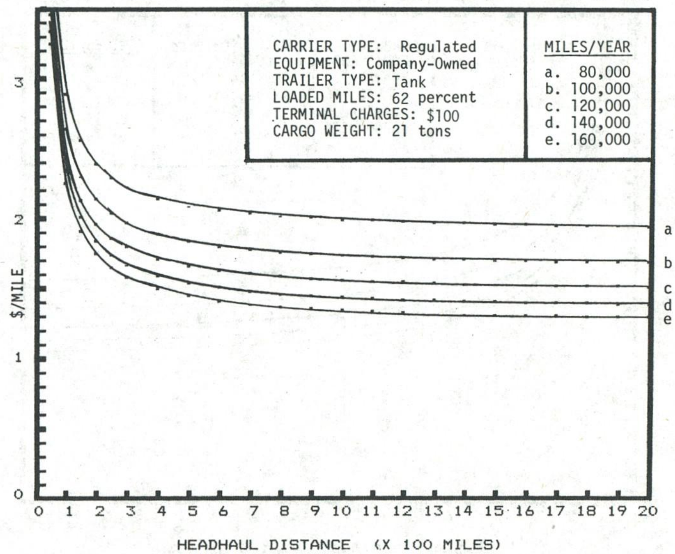

Figure 23. Truck Cost Estimating Curve #9.

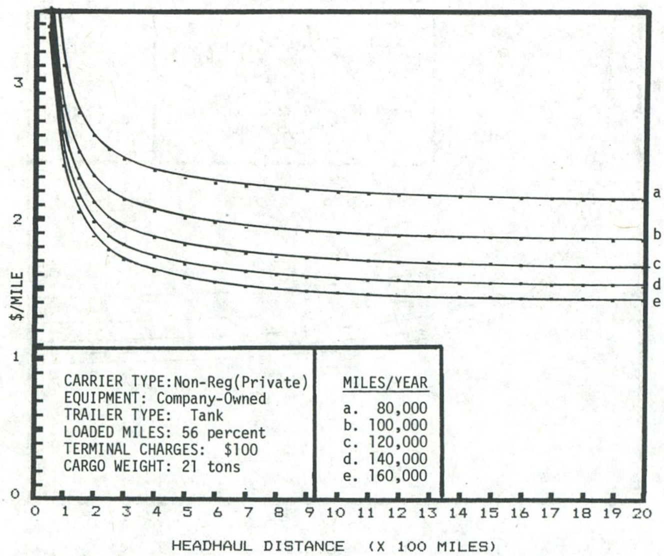

Figure 24. Truck Cost Estimating Curve #10.

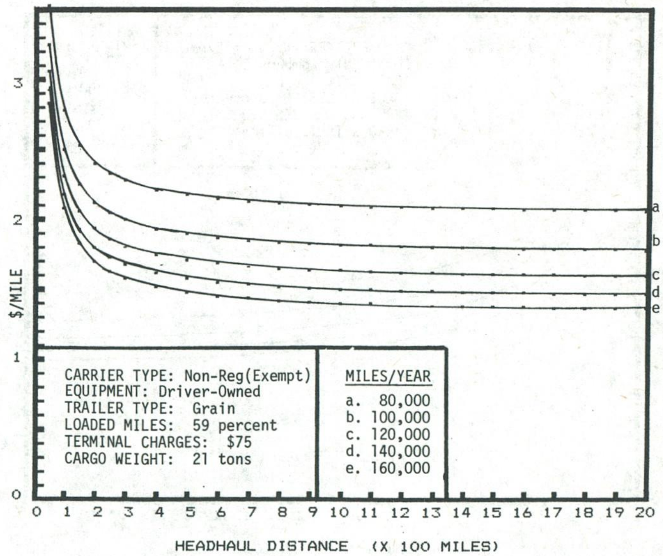

Figure 25. Truck Cost Estimating Curve #11.

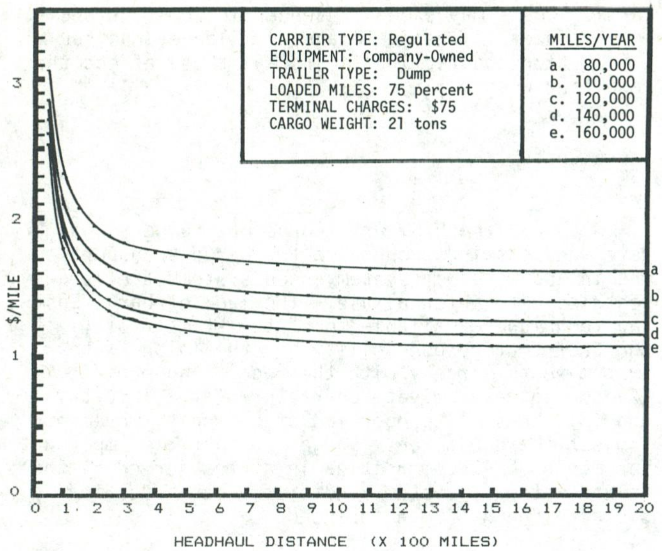

Figure 26. Truck Cost Estimating Curve #12.

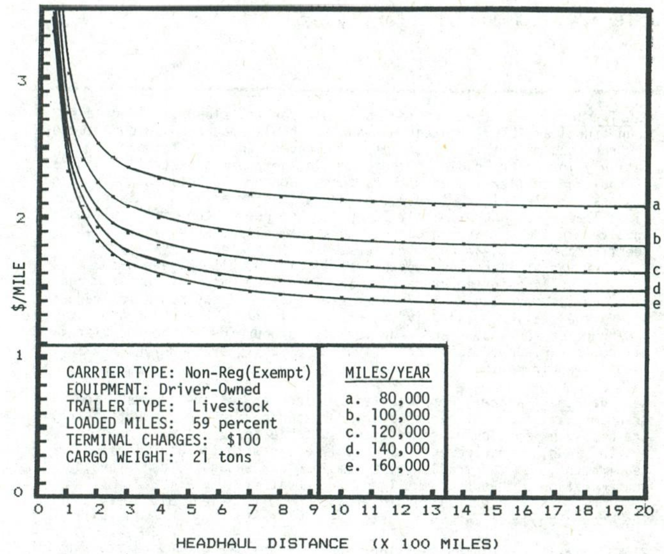

Figure 27. Truck Cost Estimating Curve #13.

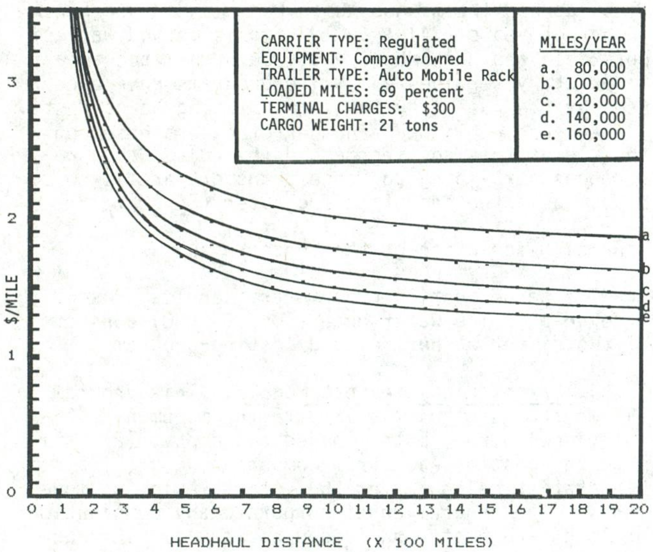

Figure 28. Truck Cost Estimating Curve #14.

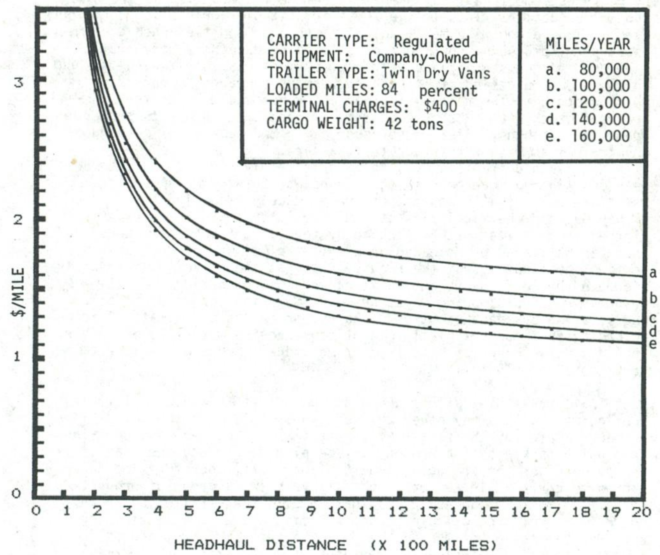

Figure 29. Truck Cost Estimating Curve #15.

If the cost of fuel was \$1.29 instead of \$1.15 and fuel consumption was 4.2 mpg rather than 4.8 mpg, the resulting adjustment would be:

$$COST = 1.8 - \frac{200}{500}\,\frac{500}{595}\,\frac{1.29}{4.2} - \frac{1.15}{4.8} + \frac{200}{500} = \$1.88$$

- Inflation Adjustment

$$COST = \text{Fixed + Variable Costs/Mile} \quad \text{1 + Change in Inflation Rate}$$

$$= COST\ (\ 1 + IRATE\ )$$

where: IRATE = annual inflation rate.

If inflation increased 6 percent:

$$COST = 1.80\ (1 + 0.06) = \$1.91/\text{Mile}$$

The truck cost-estimating curves are presented in Figures 15 through 29. Table 32 describes the principal trailer types and presents the values used in preparing the curves.

In applying the truck costing technique, users should:

1. Use the cost estimating curves (or the equivalent equations) for generalized applications, and the interactive computer application for costing specific movements.
2. Carefully determine the characteristics of the operation being modeled. This can be done by talking with shippers, motor carriers and others knowledgeable of the industry to establish equipment types, operating practices, and changes to default unit cost values.
3. Adjust the unit costs or the cost-estimating curves to represent current costs or those of the chosen base year.
4. Recognize that the profit margins are small in the motor carrier industry, and that estimated

Table 32. Common Trailer Types.

Van Trailers. Van trailers are used both for truckload (TL) and less-than-truckload (LTL) shipments of nonperishable, packaged, manufactured, or processed materials loaded to produce evenly distributed and relatively low floor loadings. For example, a tandem-axle trailer with a 42-foot van trailer loaded with cartons of paper products so as to reach a gross vehicle weight of 80,000 pounds will show an evenly distributed floor loading of approximately 1.1 psi. Because of the diffficulties involved in loading and unloading, bulk commodities are only infrequently carried in van-type trailers.

New van trailers cost approximately $14,000 with 8-year old trailers selling for an average of $5,250. Terminal costs of $200 are based on (1) four men at $10/hour taking three and two hours to load and unload the trailer, respectively, or (2) a lift truck and operator at $28/hour for four hours and a driver at $13/hour for six hours. Terminal costs vary appreciably depending on commodity type and any special loading requirements.

Refrigerated Trailer. Refrigerated trailers or reefers are used to transport all forms of packaged or processed perishable products. They are also used for moving commodities suitable for van trailers. Van trailer loading requirements also apply along with the additional requirement that the trailer must remain clean enough so as to avoid contamination with subsequent loads of foodstuffs.

New refrigerated trailers cost $30,600 with 8-year old units costing around $8,900. Terminal costs are similar to those of van trailers.

Flatbed Trailer. Flatbed trailers are available in several different designs, each one optimized for a particular type of loading. Flatbed designs range from the specialized container chassis (essentially a flatbed trailer with no floor) to the dropframe or gooseneck types used by heavy equipment haulers. The most common flatbed type is the simple wood floor design. This trailer type is suitable for hauling containerized freight along with most typical flatbed commodities such as lumber, pipe, steel products, construction materials, machinery, and crated manufactured goods. A flatbed trailer derives its longitudinal strength solely from the design of its center beam as compared to van trailers which distribute their loads to the center beam as well as the sidewalls and roof of the van. Because of the greater strength of its center beam, the flatbed trailer is not subject to the same floor-loading constraints as van or refrigerated trailers.

New flatbed trailers sell for approximately $10,400 and used 8-year old flatbeds can be sold for around $5,130. Terminal costs associated with flatbed operations vary widely depending on the type of payload and the facilities at individual terminals. Generally, flatbed commodities must be handled by fork lift trucks or cranes, and thus can be loaded or unloaded in a matter of minutes. Most of the terminal cost comes from the requirement that the driver must securely tie down the load to prevent shifting and loss of damage. The tie-down may require blocking, bracing, covering with canvas or plastic, and securing by means of strips, chains, or cables. Estimated loading/unloading cost for a typical load of construction materials or lumber includes three hours of lift truck time and six hours of driver time for a total of $150.

Tank Trailer. Tank trailers are constructed with a wider variety of configurations than any other trailer type. This multitude of designs is necessitated by the fact that the trailer is not merely a container into which packages of a product may be placed. Indeed the trailer is the package for the product. Tank trailers must, therefore, be designed to carry a single, or at best, a very small group of product types. In most instances, contamination of a tank trailer by an incorrect product type will force an extensive and expensive cleaning and decontamination of the tank and all valves, fittings, and piping. Some common designs include heated asphalt tanks, refrigerated milk tanks, large capacity LP gas tanks, highly specialized low temperature liquified gas carriers (e.g., liquid nitrogen tanks), and the widely used 8,000-gallon uninsulated tank. The cost curves developed for tanker operations are based on the common 8,000-gallon uninsulated tank trailer.

A representative new 8,000-gallon uninsulated tank trailer was priced out at $25,200. Used 8-year old units sell for approximately $13,000.

Grain Trailer. This is a specialized trailer that is used to haul bulk grain. Typical trailers have a capacity of 900-1100 bushels. A new grain trailer was priced at $14,200; a used 8-year old unit sells for approximately $7,100. Terminal costs were estimated at $75.

Dump Body. This is a specialized trailer that is used to haul bulk commodities such as coal. A new dump body trailer was priced at $22,100; a used 8-year old unit sells for approximately $12,000. Terminal costs were estimated at $75.

Livestock Trailer. This is a specialized trailer whose use is obvious. A new livestock trailer was priced at $17,000; a used 8-year old unit sells for approximately $4,100. Terminal costs were estimated at $100.

Autorack Trailer. This is a specialized trailer whose use is also obvious. A new autorack trailer was priced at $25,000; a used 8-year old unit sells for approximately $8,800. Terminal costs were estimated at $300.

Twin Vans. Cost includes a dolly unit for second trailer, in addition to the twin trailers. New twin vans plus dolly were priced at $32,500; used units sell for approximately $15,900. Terminal costs were estimated at $400.

carrier costs may exceed revenues in some instances.

5. Carefully estimate annual mileage, backhaul utilization and terminal costs, as these affect the resulting costs.

Barge Costs

Although the U.S. Army Corps of Engineers has developed costing techniques for barge transport on the inland waterway system, such systems are largely restricted to internal use. The lack of barge costing techniques available to states stems from (1) the fact that responsibility for the inland waterway system rests largely with the Federal government, (2) the largely private character of the industry and (3) the small proportion of commodity movements subject to regulation. Barge transport is important for moving bulk commodities in states served by the inland waterway system, and thus a barge costing subtechnique has been included.

Barge Costing Subtechniques

The subtechniques presented are based on a manual barge costing method which has been in use for a number of years (74). In 1977, this method was computerized and has subsequently been marketed as a proprietary service (73). The programs have been used by the rail industry in estimating barge costs. The AAR has published a number of papers based on the use of this costing method (57-63). Other references pertaining to barge transport are likewise provided at the end of this chapter (64-79).

General Description of the Subtechnique

The barge costing proprietary service presently offered by Price Waterhouse (Impact-2000) consists of two different but related costing programs:

1. Barge Trip Rate/Cost Module. This program allows the user to (1) simulate the movements of an individual barge, both, loaded and empty, (2) estimate the cost of each trip component, and (3) assemble statistical data for the entire series of movements. The program can incorporate any combination of loads and empty and loaded backhauls. Through use of percent of tariff and time contingency variables, adjustments can easily be made to reflect changes in transit time and towing charges.
2. Barge Roundtrip Costing Module. This program estimates the cost of barge movements using both dedicated and general towing services for the specified movement. It assumes (1) an empty backhaul, (2) towsize and towload remain constant for the entire length of the movement, (3) towboat horsepower remains constant, (4) one commodity type with same loading and unloading times, and (5) equipment utilization elsewhere (e.g., leased) if not required for revenue service.

The inland waterway network incorporated into the above programs includes the Mississippi and its navigable tributaries and the Gulf Intercoastal Waterway (East and West). Port names, waterway section identification, and milepost are contained in the reference manuals for each program.

Both programs make use of essentially the same inputs. The user is required to supply the following inputs (unless otherwise designated):

- Loaded or Empty (BTCS program only)
- Net Tons per Barge
- Terminal Time: Origin

Table 33. Sample Output from the Barge Trip Costing Program.

LOADED ST. LOUIS MO TO NEW ORLEANS LA *LOADED*

****************************** ** **************************

SPECIFICATIONS FOR THIS ROUTE

COMMODITY: CORN		LOADED BARGE TONS:	1350	PERCENTAGE OF TARIFF:	110.0%
FUEL TAX (PER GALLON):	$0.04	PRODUCT VALUE PER TON:	$120.00	TERMINAL TIME-ORIGIN (HOURS):	125
BARGE INITIAL INVESTMENT:	$250000	TIME CONTINGENCY FACTOR:	1.100	TERMINAL TIME-DESTINATION (HOURS):	125
OVERSIZED BARGE: NO					

GENERAL TOWING SERVICE TRIP DATA AND COSTS

TOTAL TRANSIT TIME (W/O TCF):	304.84 HOURS
TOTAL TRANSIT TIME (W/ TCF):	335.32 HOURS
TOTAL INTERCHANGE TIME:	48.00 HOURS
TOTAL TRANSIT TIME (W/ TCF) + INTERCHANGE TIME:	383.32 HOURS*
TOTAL TERMINAL TIME:	250.00 HOURS
TOTAL ONE-WAY TIME (W/ TCF):	633.32 HOURS**
TOTAL ONE-WAY TON-MILES:	1401435.0
TOTAL ONE-WAY TRIP MILES:	1038.1

	$/BARGE	$/TON
TERMINAL COSTS-ORIGIN:	2524.50	1.87
TERMINAL COSTS-DESTINATION:	6007.50	4.45
DELIVERY COST TO ORIGIN:	0.00	0.00
RESHIPMENT COST FROM DESTINATION:	0.00	0.00
PRODUCT HANDLING LOSS:	405.00	0.30
BARGE CLEANING COST:	150.00	0.11
ADDED INVENTORY COST	0.00	0.00
ADDED STORAGE-ORIGIN:	0.00	0.00
ADDED STORAGE-DESTINATION:	0.00	0.00
ON-TOW ASSIST:	90.00	0.07
OFF-TOW ASSIST:	90.00	0.07
CARGO INSURANCE:	54.00	0.04
FLEETING CHARGES:	125.00	0.09
MISCELLANEOUS SWITCHES:	90.00	0.07
MISCELLANEOUS INSURANCE:	0.00	0.00
MISCELLANEOUS CHARGES:	0.00	0.00
USER FEES (NI):	121.50	0.09
BARGE OWNERSHIP COSTS:	4422.83	3.28
TOWING COST:	9072.00	6.72
TOTAL COST	23152.33*	13.88*

EMPTY MINNEAPOLIS MN TO LA CROSSE WI *EMPTY*

****************************** ** **************************

SPECIFICATIONS FOR THIS ROUTE

COMMODITY: EMPTY		LOADED BARGE TONS:	0	PERCENTAGE OF TARIFF:	110.0%
FUEL TAX (PER GALLON):	$0.04	PRODUCT VALUE PER TON:	$0.00	TERMINAL TIME-ORIGIN (HOURS):	0
BARGE INITIAL INVESTMENT:	$250000	TIME CONTINGENCY FACTOR:	1.100	TERMINAL TIME-DESTINATION (HOURS):	0
OVERSIZED BARGE: NO					

GENERAL TOWING SERVICE TRIP DATA AND COSTS

TOTAL TRANSIT TIME (W/O TCF):	579.53 HOURS
TOTAL TRANSIT TIME (W/ TCF):	637.48 HOURS
TOTAL INTERCHANGE TIME:	92.00 HOURS
TOTAL TRANSIT TIME (W/ TCF) + INTERCHANGE TIME:	729.48 HOURS*
TOTAL TERMINAL TIME:	250.00 HOURS
TOTAL ONE-WAY TIME (W/ TCF):	979.48 HOURS**
TOTAL ONE-WAY TON-MILES:	0.0
TOTAL ONE-WAY TRIP MILES:	155.1

	$/BARGE	$/TON
TERMINAL COSTS-ORIGIN:	0.00	0.00
TERMINAL COSTS-DESTINATION:	0.00	0.00
DELIVERY COST TO ORIGIN:	0.00	0.00
RESHIPMENT COST FROM DESTINATION:	0.00	0.00
PRODUCT HANDLING LOSS:	0.00	0.00
BARGE CLEANING COST:	0.00	0.00
ADDED INVENTORY COST	0.00	0.00
ADDED STORAGE-ORIGIN:	0.00	0.00
ADDED STORAGE-DESTINATION:	0.00	0.00
ON-TOW ASSIST:	90.00	0.00
OFF-TOW ASSIST:	90.00	0.00
CARGO INSURANCE:	0.00	0.00
FLEETING CHARGES:	0.00	0.00
MISCELLANEOUS SWITCHES:	90.00	0.00
MISCELLANEOUS INSURANCE:	0.00	0.00
MISCELLANEOUS CHARGES:	0.00	0.00
USER FEES (NI):	8.74	0.00
BARGE OWNERSHIP COSTS:	5094.37	0.00
TOWING COST:	672.20	0.00
TOTAL COST	6045.31*	0.00*

TRIP CIRCUIT ANALYSIS

**** ******* ********

LE	ORIGIN	DESTINATION	TONS	LOADED MILES	EMPTY MILES	TON MILES	$/BARGE	LOADED $/PNT	LOADED M/TM	EMPTY C/BM
L	ST. LOUIS MO	TO NEW ORLEANS LA	1350	1038.1	.0	1401435.0	23152.33	13.88	16.52	0.00
L	NEW ORLEANS LA	TO MINNEAPOLIS MN	1350	1710.0	.0	2308500.0	28482.54	16.52	12.34	0.00
E	MINNEAPOLIS MN	TO LA CROSSE WI	0	0.0	155.1	0.0	6045.31	0.00	0.00	897.69
L	LA CROSSE WI	TO GALVESTON TX	1350	1742.0	.0	2351700.0	31574.19	18.49	13.43	0.00
E	GALVESTON TX	TO ST. LOUIS MO	0	0.0	1224.1	0.0	9203.65	0.00	0.00	751.87
L	ST. LOUIS MO	TO NEW ORLEANS LA	1350	1038.1	.0	1401435.0	23152.33	13.88	16.52	0.00
E	NEW ORLEANS LA	TO MINNEAPOLIS MN	0	0.0	1710.0	0.0	11459.20	0.00	0.00	670.13
L	MINNEAPOLIS MN	TO GALVESTON TX	1350	1897.1	.0	2561085.0	33670.23	19.74	13.15	0.00
E	GALVESTON TX	TO ST. LOUIS MO	0	0.0	1224.1	0.0	9203.65	0.00	0.00	751.87
L	ST. LOUIS MO	TO NEW ORLEANS LA	1350	1038.1	.0	1401435.0	23152.33	13.88	16.52	0.00
E	NEW ORLEANS LA	TO MINNEAPOLIS MN	0	0.0	1710.0	0.0	11459.20	0.00	0.00	670.13
L	MINNEAPOLIS MN	TO GALVESTON TX	1350	1897.1	.0	2561085.0	33670.23	19.74	13.15	0.00
E	GALVESTON TX	TO ST. LOUIS MO	0	0.0	1224.1	0.0	9203.65	0.00	0.00	751.87
								W/AVG $/PNT	W/AVG M/TM	W/AVG C/BM
TRIP CIRCUIT TOTALS			9450	10360.5	7247.4	13986675.0	253428.84	26.82	18.12	439.29

TOTAL MILES 17607.90

Source: Smith, M.L., Jr., Price Waterhouse

- Origin Name
- Origin Section
- Origin Milepost
- Destination Name
- Destination Section
- Destination Milepost
- Towboat Horsepower (BCS program only)
- Barge Investment
- Barge Type Code
- Interest Rate
- Terminal Time: Dest.
- Commodity
- Interchange Time
- Users Fee Tax ($/gallon)
- Percent of Tariff
- Pressurized or Non-Pressurized Cargo
- User Fee Routine (BTCS program only
- Required Rate of Return

Optional variables, which focus on other cost components, include the following:

- Oversize Barge Indicator. Applies to barges longer than 200 ft or wider than 35 ft. Shipper presumed to pay 200 percent of empty return rate on such barges.
- Product Density, in lbs/cu ft.
- Cubic Capacity, barge cu ft.
- Product Value, in $/ton.
- Horsepower Ratio. Ratio of tow tonnage to towboat horsepower. If not entered, program uses default values of 3.5 and 2.3 for nonpressure and pressure cargoes, respectively.
- Time Contingency Factor, percent increase in transit time to allow for contingencies.
- Terminal Costs-Origin. Loading and other costs in $/ton.
- Terminal Costs-Destination. Unloading and other costs in $/ton.
- Cargo Insurance, in $/ton.
- Cost of holding inventory in storage at origin and destination and while in-transit.
- Added Storage-Origin, in $/ton.
- Added Storage-Destination, in $/ton.
- Barge Cleaning, in $/barge.
- Product Handling Loss. Product lost during loading and unloading procedures, in $/ton.
- Delivery Cost to Origin. Transport from actual origin to origin dock, in $/ton.
- Reshipment Cost to Destination. Transport from destination dock to final destination, in $/ton.
- On-Tow Assist, in $/barge.
- Off-Tow Assist, in $/barge.
- Fleeting Charges, in $/barge.
- Miscellaneous Switches, in $/barge.
- Miscellaneous Insurance, in $/ton.
- Miscellaneous Charges, in $/ton.

The operation of both programs is similar. In computing barge movement costs, the program first estimates the transit time by segment using computed mileage over the inland waterway system and average upstream or downstream speed. Segment times are summed along with user-provided interchange and terminal time estimates. These time estimates along with unit costs or tariff rates are then used to compute barge ownership and towing costs. These costs are then summed along with various other unit component costs provided on a per ton or per barge basis (after appropriate multiplications have been made). Tables 33 and 34 give sample outputs from the two programs.

Rather than rely solely on proprietary services, users may desire to develop their own barge costing

Table 34. Sample Output from the Barge Costing Program.

```
                              CINCINNATI OH                 TO ST. LOUIS

                                    COMMON SPECIFICATIONS FOR THIS ROUTE

HORSEPOWER OF TOWBOAT:          5000   PRODUCT DENSITY (LB/CU FT):       0.0   CUBIC FT CAPACITY PER BARGE:             0
INITIAL BARGE INVESTMENT:    $233600   PRODUCT VALUE PER TON:          $0.00   PRESSURIZED CARGO:                      NO
NET TONS PER BARGE:             1500   AVERAGE TOWLOAD(TONS):          18000   HORSEPOWER RATIO:                    3.000
COMMODITY: COAL                        TERMINAL TIME-ORIGIN(HOURS):       72   TERMINAL TIME-DESTINATION(HOURS):      120
FUEL TAX(PER GALLON):          $0.04   TIME CONTINGENCY FACTOR:        1.000   OVERSIZED BARGE:                        NO
TOTAL INTERCHANGE TIME:           96   TOTAL ONE-WAY MILES:            690.7   PERCENTAGE OF TARIFF:                100.0

   DEDICATED TOWING SERVICE SPECIFICATIONS AND RESULTS        GENERAL TOWING SERVICE SPECIFICATIONS AND RESULTS
   MAXIMUM EXPECTED ANNUAL TONNAGE:              346592       MAXIMUM EXPECTED ANNUAL TONNAGE PER BARGE:             23733
   DEDICATED ROUTE TIME:                                      GENERAL ROUTE TIME:
     EMPTY(HOURS):                   118.37                     EMPTY(HOURS):                   166.37
     LOADED(HOURS):                  324.11                     LOADED(HOURS):                  372.11
     TOTAL(HOURS):                               442.48         TOTAL(HOURS):                                 538.48
   TERMINAL COSTS-ORIGIN(PNT):                  $  0.00       TERMINAL COSTS-ORIGIN(PNT):                    $  0.00
   TERMINAL COSTS-DESTINATION(PNT):             $  0.00       TERMINAL COSTS-DESTINATION(PNT):               $  0.00
   CARGO INSURANCE(PNT):                        $  0.00       CARGO INSURANCE(PNT):                          $  0.00
   ADDED INVENTORY(PNT):                        $  0.00       ADDED INVENTORY(PNT):                          $  0.00
   ADDED STORAGE-ORIGIN(PNT):                   $  0.00       ADDED STORAGE-ORIGIN(PNT):                     $  0.00
   ADDED STORAGE-DESTINATION(PNT):              $  0.00       ADDED STORAGE-DESTINATION(PNT):                $  0.00
   BARGE CLEANING COST(PNT):                    $  0.00       BARGE CLEANING COST(PNT):                      $  0.00
   PRODUCT HANDLING LOSS(PNT):                  $  0.00       PRODUCT HANDLING LOSS(PNT):                    $  0.00
   DELIVERY COST TO ORIGIN(PNT):                $  0.00       DELIVERY COST TO ORIGIN(PNT):                  $  0.00
   RESHIPMENT COST FROM DESTINATION(PNT):       $  0.00       RESHIPMENT COST FROM DESTINATION(PNT):         $  0.00
   OTHER MISCELLANEOUS COSTS(PNT):              $  0.00       OTHER MISCELLANEOUS COSTS(PNT):                $  0.00
   USER FEES:                                                 USER FEES:
     EMPTY(PNT):                   $  0.05                      EMPTY(PNT):                   $  0.05
     LOADED(PNT):                  $  0.08                      LOADED(PNT):                  $  0.08
     TOTAL(PNT):                                $  0.13         TOTAL(PNT):                                  $  0.13
   BARGE OWNERSHIP COST:                                      BARGE OWNERSHIP COST:
     EMPTY(PNT):                   $  0.51                      EMPTY(PNT):                   $  0.72
     LOADED(PNT):                  $  1.41                      LOADED(PNT):                  $  1.62
     TOTAL(PNT):                                $  1.92         TOTAL(PNT):                                  $  2.34
   TOWING COST:                                               TOWING COST:
     EMPTY(PNT):                   $  3.41                      EMPTY(PNT):                   $  1.81
     LOADED(PNT):                  $  9.30                      LOADED(PNT):                  $  5.24
     TOTAL(PNT):                                $ 12.71         TOTAL(PNT):                                  $  7.05

 TOTAL DEDICATED COST:                                      TOTAL GENERAL COST:
   TOTAL EMPTY(PNT):               $  3.97                    TOTAL EMPTY(PNT):               $  2.58
   TOTAL LOADED(PNT):              $ 10.79                    TOTAL LOADED(PNT):              $  6.94
   TOTAL(PNT):                                  $ 14.76*      TOTAL(PNT):                                    $  9.52*
```

Source: Smith, M.L., Price Waterhouse

program. The computational routines underlying in the above programs can readily be adapted to such use. The more difficult part is assembling necessary unit cost data.

The following paragraphs describe in some detail the components of a simplified, manual barge costing subtechnique, shown in Figure 30, which enables the user to approximate barge costs. It can be applied to any inland waterway.

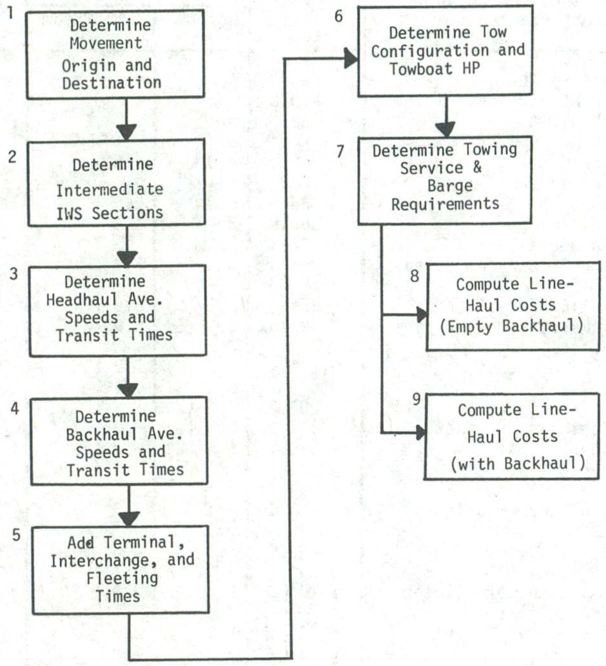

Figure 30. Barge Costing Subtechnique.

Transit Time

Transit time estimates are based on (1) identifying the inland waterway system segments involved in the movement, (2) determining segment distances, and (3) converting estimated distances into time, based on average upstream and downstream speeds. Figure 31 and Table 35, along with mileage information obtained from a reference source such as <u>Inland Waterway Mileages</u>, provide the means for preparing such estimates (<u>66</u>). The subtechnique does not require information on the number of locks or the time delay likely to be encountered at each lock, because this has already been incorporated into average upstream and downstream speeds. If desired, average speeds can also be computed using variables affecting average speed (i.e., stream speed, towboat speeds under different loads, lockage times, lock delays, etc.) (<u>65</u>).

Component steps involved in estimating transit time are as follows.

<u>Step 1 -- Determine Movement Origin and Destinations.</u> The first step is to determine the inland waterway system section and milepost of the movement origin and destination using a waterways mileage reference directory.

<u>Step 2 -- Determine Intermediate Inland Waterway System Sections.</u> Also using Figure 31 and Table 35, identify any intermediate sections used along with the section mileage. For all sections traversed,

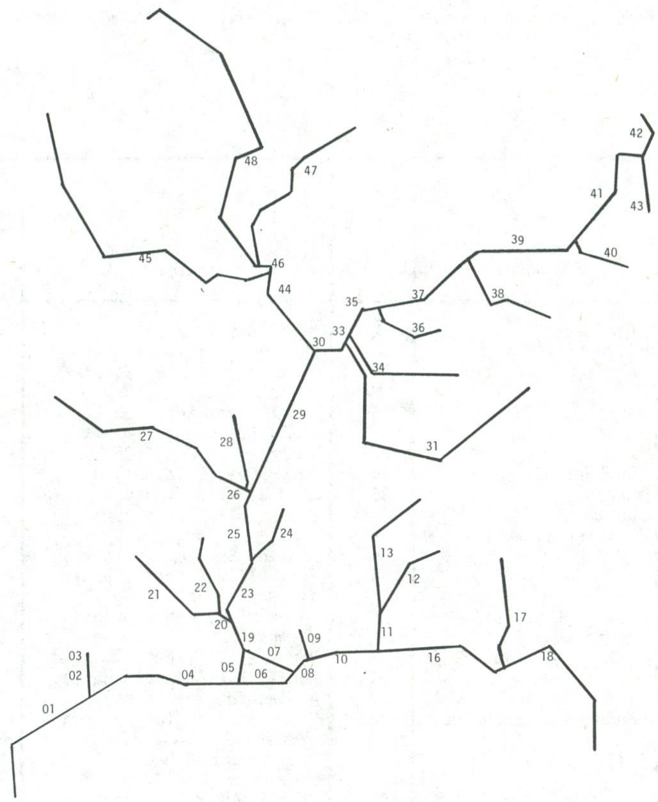

Figure 31. Schematic Diagram Showing Inland Waterway System Sections.

users would then determine the total mileage involved and whether the movement is in the upstream or downstream direction.

For example, consider a movement originating at Cincinnati (MP 75.5) and terminating at St. Louis (MP 180.0):

Section	No.	River	Up/ Down Stream	Segment Milepoints Down-Stream	Up-Stream	Distance (mi)
Originating	39	Ohio	Down	0.0	276.1	75.5
Intermediate	37	Ohio	Down	0.0	227.1	227.1
Intermediate	35	Ohio	Down	0.0	128.2	128.2
Intermediate	33	Ohio	Down	0.0	13.9	13.9
Intermediate	30	Ohio	Down	0.0	46.6	46.6
Terminating	44	U.Miss	Up	0.0	195.3	180.0
				Total Distance		671.3

<u>Step 3 -- Determine Headhaul Average Speeds and Transit Time.</u> Average upstream and downstream speeds are also included in Table 35. To compute average transit time, the distances developed in Step 2 are divided by the appropriate average speeds.

For example, average downstream speed on the Ohio River is 6.2 mph and upstream speed on the Upper Mississippi is 5.0 mph. Thus, transit times are estimated to be 79.2 and 36.0 hours for the Ohio and Upper Mississippi Rivers, respectively.

<u>Step 4 -- Determine Backhaul Average Speeds and Transit Time.</u> Step 3 is repeated for the reverse direction. For example, average downstream speed on the Upper Mississippi is 7.0 mph and upstream speed

Table 35. Summary Information on Inland Waterway Segments.

River	Section	Downstream Junction or Location	Upstream Junction or Location	Length (mi)	Average River Travel Speed(MPH)	
					Upstream	Downstream
Alabama	12	Mobil R @ MP 75.0	Montgomery AL	295.0	5.2	6.8
Allegheny	42	Ohio R @ Pittsburgh	West Monteray, PA	79.0		
Apalachicola 1/	17	Gulf Intracoastal Waterway-East	Columbus, GA	262.3		
Arkansas 2/	26	Lower Miss. Sect. 25 @ MP 16.8	White River Jct.	9.8	4.0	5.5
	27	White River Junction	Catoosa, OK	438.0	4.0	5.5
Cumberland	34	Ohio River @ Smithland, KY	Celina, TN	380.9	3.7	4.4
Green 3/	36	Ohio River @ Evansville, IN	Bowling Green, KY	187.1		
Gulf Intracoastal Waterway-West	01	Brownsville, TX (west)	Houston Ship Channel (east)	341.0	5.2 (E)	6.9 (W)
	04	Houston Ship Channel (west)	Port Allen Cutoff (east)	254.2	5.2 (E)	6.9 (W)
	06	Port Allen Cutoff (west)	Lower Miss. @ New Orleans (east)	95.0	5.2 (E)	6.9 (W)
Gulf Intracoastal Waterway-East	08	Lower Miss. @ New Orleans (west)	Pearl River (east)	40.4	5.5 (W)	7.2 (E)
	10	Pearl River (west)	Mobil Ship Channel (east)	93.2	5.5 (W)	7.2 (E)
	16	Mobil Ship Channel (west)	Apalachicola R. (east)	217.8	5.5 (W)	7.2 (E)
	18	Apalachicola R (west)	Tampa, FL (east)	310.3	5.5 (W)	7.2 (E)
Houston Ship Channel	02	Gulf Intracoastal Waterway-West	Houston, TX	52.8		
Illinois 4/	47	Upper Miss. @ Sect. 46 MP 22.6	Chicago (Lake Michigan)	333.4	4.1	4.8
Kanawha	40	Ohio River @ Gallipolis	Gauley Bridge, WV	97.0	3.5	4.0
Kentucky	38	Ohio River	Beattyville, KY	254.8		
Mississippi-Lower	07	New Orleans, LA	Port Allen Cutoff (Baton Rouge)	134.0	5.0	12.0
	19	Port Allen Cutoff	Red River (Old River)	71.1	5.0	12.0
	23	Red River (Old River)	Yazoo River	136.2	5.0	12.0
	25	Yazoo River	Perthshire, MS.	130.7	5.0	12.0
	29	Perthshire, MS.	Ohio River @ Cairo	344.1	5.0	12.0
Mississippi-Upper	44	Ohio River @ Cairo	Missouri River	195.3	5.0	7.0
	46	Missouri River	Illinois River	22.6	5.0	7.0
	48	Illinois River	Minnesota River @ Shakopee	646.9	5.0	7.0
Missouri	45	Upper Mississippi	South Sioux City	730.5	3.5	10.0
Mobile	11	Gulf Intracoastal Waterway-East	Alabama River	75.0		
Monongahela	43	Ohio River @ Pittsburgh	Fairmont, WV.	127.4		
Ohio	30	Mississippi River @ Cairo	Tennessee River	46.6	4.8	6.2
	33	Tennessee River	Cumberland River	13.9	4.8	6.2
	35	Cumberland River	Green River	128.2	4.8	6.2
	37	Green River	Kentucky River	227.1	4.8	6.2
	39	Kentucky River	Kanawha River	276.1	4.8	6.2
	41	Kanawha River	Allegheny and Monongahela Rivers @ Pittsburgh	265.6	4.8	6.2
Ouachita	22	Black River	Camden, AR	351.0	4.0	6.0
Pearl	09	Gulf Intracoastal Waterway-East	Bogalusa, LA	66.4		
Port Allen Cutoff	05	Gulf Intracoastal Waterway-West	Lower Miss.(Baton Rouge)	60.7	5.2	6.9
Red	21	Lower Mississippi	Shreveport, LA	180.0	4.0	6.0
Tennessee	31	Ohio River @ Paducah, KY.	Knoxville, TN	647.7	5.8	7.0
Tombigbe	13	Mobile River	Black Warrier R.	172.0	5.2	6.8
Trinity	03	Houston, TX	Liberty, TX	78.2		
White	28	Arkansas R.	Newport, AR	255.0	4.0	5.5
Yazoo	24	Lower Mississippi	Greenwood, MS.	170.0	4.0	5.5

1/ Also includes Flint and Chattahoochee Rivers

2/ Also includes San Bois Creek and Verdigris River

3/ Also includes Rough and Barren Rivers

4/ Also includes Des Plaines River, Chicago Sanitary and Ship Canal, Chicago River: South Main, and North Branches, and Calumet-Sag Channel on the Ohio River is 4.8 mph. Thus, backhaul transit times are estimated to be 25.7 and 102.4 hours for the Upper Mississippi and Ohio Rivers, respectively.

Step 5 -- Add Terminal, Interchange, and Fleeting Times. Terminal times vary according to the commodity being moved. Commodities such as petroleum, which can be pumped, require less loading and unloading time than commodities such as coal, iron, and steel, which require significantly more handling.

Appropriate terminal loading and unloading times should be added to the transit times computed previously. Such information can be obtained from barge or terminal operators or, in the absence of specific data, from Table 36.

Table 36. Terminal Loading/Unloading Times.

COMMODITY	LOADING (Hours)	UNLOADING (Hours)
Petroleum Products	18	24
Liquid Bulks	24	24
Chlorine	50	78
Coal	72	120
Grain	72	72
Iron & Steel	120	120
Salt, Bulk	72	72

Source: Smith, M.L., "Barge Operations and Costs," (unpublished study, Missouri Pacific Railroad, 1968)

If the tow is in general service, interchange time should be added where appropriate. Interchange time represents the slack time spent waiting for a more economically sized towboat to move barges through Cairo, IL, or Port Allen, LA, the principal interchange points. An approximate value of 48 hours (in each direction) can be used for interchange time.

If desired, a time allowance could also be included for (1) handling and sorting barges alongside termi- nals, (2) transporting barges to and from midstream, and (3) adding or breaking barges to and from tows. Separate towboat equipment is often employed to perform river terminal tasks characteristic of general towing service.

For example, if the commodity was coal, 144 hours would be added as terminal time and 96 hours for interchange at Cairo, IL. Resulting fronthaul and backhaul transit times would then be 235.2 and 248.1 hours, respectively.

Towboat and Barge Unit Costs

Both towboat and barge costs are calculated on an hourly basis using the following component costs:

Towboat Costs

- Fuel and Lubricating Oil
- Capital (loan repayment)
- Return on Equipment
- Labor
- Administration
- Maintenance
- Insurance
- Miscellaneous
- Stores and Supplies

Barge Costs

- Capital (loan repayment)
- Return on Equipment
- Maintenance
- Insurance
- Miscellaneous
- Stores and Supplies
- Administration

Tables 37 and 38 give average towboat and barge costs as a function of horsepower and type, respectively, for 1980. Table 39 gives the typical size of towboats in use on different river sections, and the resulting net tons per tow. Table 40 gives common barge types and sizes. Table 41 gives coverage waterway costs per ton-mile for selected rivers in 1980. Component steps involved in determining an appropriate tow consist and computing towboat and barge costs are as follows:

Table 37. Towboat Costs.

Capital Costs

Vessel HP	Initial Cost ($ X 10^6)	Loan Amount ($ X 10^6)	Hourly Loan Cost	Hourly ROE	Total Capital Cost	Total O&M Cost	Total Hourly Cost
1100	0.6	0.525	9.21	1.08	10.29	102.18	112.47
1200	0.7	0.613	10.74	1.26	12.00	104.55	116.55
1600	0.9	0.788	13.82	1.62	15.44	135.16	150.60
1800	1.0	0.875	15.35	1.80	17.15	146.65	163.80
3200	2.5	2.188	38.38	4.51	42.89	242.91	285.80
3600	2.6	2.275	39.92	4.68	44.60	264.30	308.90
4300	3.0	2.625	45.54	5.41	50.95	294.38	345.33
6500	4.5	3.938	69.09	8.11	77.20	440.87	518.07

Hourly Operating and Maintenance Costs

Vessel HP	Fuel & Lube Oil Cost	Labor	Adm.	Maint.	Ins.	Misc.	Stores & Supplies	Total O&M
1100	51.72	41.00	4.74	2.05	1.37	0.68	0.62	102.18
1200	53.39	41.00	4.65	2.39	1.60	0.80	0.72	104.55
1600	74.80	41.00	12.29	3.08	2.05	1.02	0.92	135.16
1800	84.44	41.00	3.42	2.29	1.14	1.03	13.33	146.65
3200	149.89	51.25	8.56	2.85	5.71	2.57	22.08	242.91
3600	168.59	51.25	24.03	8.90	5.94	2.97	2.67	264.30
4300	201.03	51.25	27.08	10.27	6.78	3.39	3.08	294.38
6500	304.17	61.50	39.76	15.41	10.27	5.14	4.62	440.87

Note: Costs shown are based on a 100 percent loaded return. Equipment replacement costs were used in determining towboat capital costs (1980).

Source: Maritime Administration, Computrans Barge Costing Methodology.

Table 38. Barge Costs.

Capital Costs

Type	Initial Cost ($ X 10^6)	Loan Amount ($ X 10^6)	Hourly Loan Cost	Hourly ROE	Total Capital Cost	Total O&M Cost	Total Hourly Cost
Nonpressurized (1500 ton hopper)	0.25	0.219	3.84	0.45	4.29	2.18	6.47
Pressurized (2500 ton tank)	2.00	1.75	30.70	3.61	34.31	17.33	51.64

Hourly Operating and Maintenance Costs

Type	Adm.	Maint.	Ins.	Misc.	Stores & Supplies	Total O&M
Nonpressurized (1500 ton hopper)	0.20	0.86	0.57	0.29	0.26	2.18
Pressurized (2500 ton tank)	1.58	6.85	4.57	2.28	2.05	17.33

Note: Costs shown are based on a 100 percent loaded return. Equipment replacements were used in determining barge capital costs (1980).

Source: Maritime Administration, Computrans Barge Costing Methodology.

Table 39. Typical Tows by River Segment.

Towboat HP	Net Tons per Tow: Nonpressure Commodities 1/	Net Tons per Tow: Pressure Commodities 2/
900	3200	2100
1100	3900	2500
1200	4200	2800
1600	5600	3700
1800	6300	4100
2400	8400	5500
3200	11200	7400
3600	12600	8300
4300	15100	9900
5600	19600	12900
6500	22800	15000

1/ 3.5 net tons lading per towboat horsepower, rounded to nearest 100 net tons.
2/ 2.3 net tons lading per towboat horsepower, rounged to nearest 100 net tons.

River Segment	Towboat Horsepower									
	800 900	1100 1200	1600	1800	2400	3200	3600	4300	5600	6500
Allegheny		X		X						
Arkansas	X	X								
Black Warrier & Tombigbee				X		X				
Cumberland	X			X						
Green		X								
GIW: West 1/	X	X		X	X	X	X			
GIW: East	X	X	X							
Illinois	X	X		X	X	X	X			
Kanawha				X						
Mississippi										
Upper		X		X	X	X				
Lower	X	X		X	X	X	X	X	X	X
Missouri 2/					X	X		X		
Monongahela		X								
Ohio				X	X	X		X		
Tennessee		X		X	X	X				

1/ Length restriction of 1,180 ft can reduce towload.
2/ Draft restriction reduces towload by one third.
Source: Smith, M. L., "Barge Operations and Costs," (unpublished study, Missouri Pacific Railroad, 1968).

Table 40. Frequent Barge Types and Sizes.

Barge Type	Dimensions (ft.) L X W X D	Design Cap.(tons)	Usable Cap.(tons) 1/
Open Hopper	175 X 26 X 9 2/	1000	900
	195 X 35 X 9 3/	1500	1350
	195 X 26 X 9 4/	1115	960
	290 X 50 X 9	3000	2900
Covered Hopper	175 X 26 X 9	1000	900
	195 X 35 X 9	15000	1350
Tank	175 X 26 X 9	1000	900
	195 X 35 X 9	1500	1350
	290 X 50 X 9	3000	2900
Deck	110 X 26 X 6	350	350
	130 X 30 X 7	900	900
	195 X 35 X 8	1200	1200

1/ Usuable capacity averages 90 percent of design capacity due to water conditions and loading practices.

2/ Designated "standard" sized barge.

3/ Designated "jumbo" sized barge.

4/ Designated "stumbo" sized barge. Used on narrow, congested waterways.

Source: Smith, M.L., Jr., "A Model for Barge Cost Optimization," unpublished Masters Thesis, University of Missouri, Rolla, MO (1977).

Step 6 -- Determine Tow Configuration and Towboat Horsepower. For each river section traversed, determine the typical tow configuration and associated towboat horsepower. Select the largest tow configuration and towboat horsepower common to all river segments using Tables 39, 40, and 41.

For example, the typical towboat on the Ohio and Upper Mississippi Rivers has 4300 and 3200 hp, and corresponding tow configurations are 11 and 9 nonpressurized barges, or 15,100 and 11,200 net tons of cargo, respectively. Since the tow configuration and towboat horsepower selected must be appropriate to all river sections traversed, a tow configuration of 9 barges and a towboat having 3200 hp would be selected as the largest practical towboat and tow for this movement.

Step 7 -- Determine Towing Service and Barge Requirements. Starting with (1) the annual movement, (2) selected tow configuration, and (3) round-trip transit time, determine the number of round trips required to complete the movement and the appropriate towing service to be used.

For example, assume that the annual movement between Cincinnati and St. Louis is 240,000 tons, and that it takes 72 hours to load or unload barges at both the origin and destination. If jumbo hopper barges (1350 tons/barge) were used, 12,150 tons can be carried per round-trip using a 9-barge tow. Thus, 19.8 or 20 round-trips annually would be required to transport 250,000 tons. Round-trip time consists of 115.2 hours fronthaul, 128.1 hours backhaul, and 144 hours loading and unloading. If the tow can be operated 350 days per year, a total of 21.7 or 21 round-trips are possible. Given the close match between supply and demand, dedicated towing service would be appropriate for this movement.

If the annual movement was 60,000 tons, use of dedicated tow and barges would not be practical, because to low utilization. Using general towing service, round-trip time would consist of 115.2 hours fronthaul, 128.1 hours backhaul, 144 hours loading and unloading, and 96 hours interchange at Cairo. Thus, a barge could make 17.4 or 17 round-trips per year. To transport 60,000 tons using barges having a practical capacity of 1350 tons, a total of 2.6 or 3 barges would be required for this movement.

Table 41. Average Waterway Costs per Ton-Mile by Segment (1980).

River Segment	Towboat Size hp	Ave. Crew Size	Ave. Speed Up-stream	Ave. Speed Down-stream	Towboat Cost $/hr	Non-Pressurized Cargo: No. of Barges	Barge Cost $/hr	Tons	$ Up-stream	$ Down-stream	Pressurized Cargo: No. of Barges	Barge Cost $/hr	Tons	$ Up-stream	$ Down-stream
Allegheny	1800	8	3.7	4.4	163.80	3	19.41	4200	0.0118	0.0099	1	51.64	2700	0.0216	0.0183
Arkansas	1100	8	4	5.5	112.47	3	19.41	3900	0.0088	0.0064	1	51.64	2500	0.0169	0.0123
Black Warrier & Tombigbee	3200	10	5.2	6.8	285.80	9	58.23	11200	0.0059	0.0045	3	154.92	7400	0.0145	0.0088
Cumberland	1800	8	3.7	4.4	163.80	4	25.88	6300	0.0081	0.0068	2	103.28	4100	0.0176	0.0148
Green & Barren	1200	8	3.7	4.4	116.55	3	19.41	4200	0.0088	0.0077	1	51.64	2800	0.0150	0.0126
Gulf Intercoastal Waterway: West	3600	10	5.2	6.9	308.90	7	45.29	10000	0.0068	0.0051	3	154.92	8300	0.0108	0.0081
Gulf Intercoastal Waterway: East	1600	8	5.5	7.2	150.60	4	25.88	5600	0.0057	0.0044	2	103.28	3700	0.0125	0.0095
Illinois	3600	10	4.1	4.8	308.90	10	64.70	12600	0.0072	0.0062	4	206.56	8300	0.0152	0.0129
Kanawha	1800	8	3.5	4.0	163.80	4	25.88	6300	0.0086	0.0075	2	103.28	4100	0.0186	0.0163
Mississippi Upper Sec.	3200	10	5	7	285.80	9	58.23	11200	0.0061	0.0044	3	154.92	7400	0.0119	0.0085
Mississippi Lower Sec.	6500	12	5	12	518.07	17	109.99	22800	0.0055	0.0023	6	309.94	15000	0.0110	0.0046
Missouri	4300	10	3.5	10	345.33	11	71.17	10700	0.0111	0.0039	4	206.56	6600	0.0239	0.0084
Monongahela	1200	8	3.7	4.4	116.55	3	19.41	4200	0.0088	0.0077	1	51.64	2800	0.0150	0.0126
Ohio	4300	10	4.8	6.2	345.33	11	71.17	15100	0.0058	0.0045	4	206.56	9900	0.0116	0.0090
Tennessee	4300	10	4.8	7.0	345.33	9	58.23	11200	0.0064	0.0053	4	206.56	9900	0.0129	0.0107

Average Costs per Ton-Mile by Segment (1980)

Step 8 -- Compute Linehaul Costs (Empty Backhaul). Using the time estimates from Step 7 and assuming an empty backhaul, linehaul costs for the fronthaul and backhaul portions of the movement can now be computed.

For example, assuming dedicated towing:

$$\text{COST} = \text{RTTIME}\ \frac{[\text{TBCOST} + \text{NOBARGE}(\text{BCOST})]}{\text{NOBARGE}(\text{BCAP})}$$

where: COST = unit cost by barge, $/ton;
RTTIME = roundtrip time, hours;
TBCOST = towboat unit cost, $/hour;
NOBARGE = number of barges;
BCOST = barge unit cost, $/hour; and
BCAP = practical capacity of a barge, tons.

In this example

$$\text{COST} + 387.3\ \frac{285.80 + 9(6.47)}{9(1350)} = \$10.97/\text{ton}$$

Were general towing used instead, a towing rate for the section would be applied against the section miles traveled and tonnage. For example consider a movement from Houston to Cincinnati:

Section No.	Section Miles	Rate Loaded Mills/ ton mi.	Charge per Ton	Rate Empty ¢/mi.	Charge per Barge
02	52.8	0.0121	0.64	5.88	310.46
79	312.0	0.0121	3.77	5.88	1834.56
65	724.1	0.0083	6.01	3.14	2273.67
73	435.2	0.0087	3.79	3.94	1714.69
39	75.5	0.0087	0.66	3.94	297.47
Charge per Ton			$14.87		$6430.85

Assuming that a barge carried 1400 tons:

COST = LOADED CHARGE/TON + EMPTY CHARGE/TON
= 14.87 + 6430.85/1400 = $19.46/ton

If a larger or smaller towboat were used for a portion of the movement, or the size of the tow changed significantly, separate computations should be made to reflect the changes in equipment or tow configuration, and the results should be added.

Step 9 -- Compute Linehaul Costs (with Backhaul). Empty backhauls are characteristic of dedicated towing, but not general towing. Backhaul possibilities depend on (1) commodity imbalance (especially, availability of traffic moving in the backhaul direction), (2) commodity compatibility (added time and cost of barge cleaning, if commodities are not compatible), (3) barge compatibility (a factor particularly with tank barges coupled with governmental restrictions on the liquids that can be transported by particular tank barge types), and (4) cost considerations. Because of the high hourly equipment cost of barge transport, waiting times required to obtain backhauls may make such use uneconomic. Table 42 provides summary information on equipment utilization in 1978.

The cost calculations are essentially the same as in Step 8. For example, assume that the barge equipment is fully used on the fronthaul portion of the movement, but only 60 percent used on the backhaul portion.

COST = Fronthaul Cost + Backhaul Cost

$$\text{COST} = \frac{\text{FHTBHOURS}(\text{TBCOST}) + \text{FHBHOURS}(\text{NOBARGE})(\text{BCOST})}{(\text{FHUTIL})(\text{NOBARGE})(\text{BCAP})}$$

$$+ \frac{\text{BHTBHOURS}(\text{TBCOST}) + \text{BHBHOURS})\text{NOBARGE})(\text{BCOST})}{(\text{BHUTIL})(\text{NOBARGE})(\text{BCAP})}$$

Table 42. Barge Utilization by River Segment in 1978.

River Segment	Percent of Barges Loaded			
	Upstream		Downstream	
	Dry Cargo	Tanker	Dry Cargo	Tanker
Allegheny	37	89	72	13
Arkansas	48	61	56	43
Black Warrier & Tombigbee	36	66	79	45
Cumberland	70	98	47	5
Green & Barren	14	100	97	0
Gulf Intercoastal Waterway	51 eastbound	60 eastbound	36 westbound	42 westbound
Illinois	44	71	70	37
Kanawha	44	82	58	71
Mississippi				
Minneapolis to Missouri R.	39	74	79	35
Missouri R. to Ohio R.	32	72	89	43
Ohio R. to Baton Rouge	29	93	91	16
Missouri	48	78	56	54
Monongahela	28	81	76	21
Ohio	51	80	58	30
Tennessee	70	81	40	25

Source: USACOE, Waterborne Commerce Statistics, (1978)

$$\text{COST} = \frac{115.2(285.80) + (307.2)(9)(6.47)}{(1.0)(9)(1350)}$$

$$+ \frac{128.1(285.80) + (320.1)(9)(6.47)}{(0.6)(9)(1350)}$$

$$= 4.182 + 7.579 = \$11.76/\text{ton}$$

Since the origin and termination of a backhaul movement may be different from the fronthaul movement, the round-trip time of the total movement may be greater than simply the additional time spent loading and unloading the barge on the backhaul movement.

In applying the barge costing subtechnique users should:

1. Carefully choose the characteristics of the operations to be modeled. This can be done by talking with shippers, river terminal operators, Corps of Engineers officials, and others knowledgeable of the inland waterway industry to establish a representative operation.
2. Obtain new or adjust the unit costs presented to represent current costs or those of the chosen base year.
3. Recognize that the barge industry is heterogeneous in terms of equipment employed, operational methodologies, and services provided, and that the user must tailor the subtechnique to the specific movement and commodity being modeled.
4. Be aware of the reluctance of the industry to provide cost information to states and governmental agencies.
5. Carefully estimate backhaul utilization. An empty backhaul increases ton-mile costs that must be reflected in the rates charged.

Shipper Costs

In recent years, shippers have increasingly recognized that the mode offering the lowest rate may not in fact be the least cost mode, after considering other logistics costs. Thus, costs accruing to shippers typically include:

- Transport Logistics Costs:
  - Rate (transport charges)
  - Loss and Damage (L&D)
  - Pickup and Delivery (PUD)
- Nontransport Logistics Costs:
  - Order Cost
  - Storage Cost
  - Inventory Cost
  - Stockout Cost

The rail, truck, and barge costing subtechniques presented previously in this chapter all replicate the unit costs being incurred by carriers. On the other hand, the shippers' costing subtechnique approaches costs from the shipper's or consignee's perspective. Thus it supplements rather than replaces the subtechniques presented earlier.

Shipper Costing Subtechnique

The shipper costing subtechnique is a simplified version of the AAR Shipper Cost Model, which in turn was based on work done at MIT (80,81,84,85). The model calculates the average cost per unit for each cost element and sums them to find the total cost of shipping by a given mode. It can be readily computerized using a microcomputer or larger computer. Also see the references and selected bibliography provided at the end of this chapter (80-92).

General Description of the Subtechnique

The user must provide the following commodity, volume, shipment, and mode related inputs:

- Value ($/lb).
- Density (lbs/cu ft).
- Storage requirements. Choices include open storage, sheltered storage, refrigerated storage, or freezing.
- Annual volume (tons).
- Mode being used. Choices include rail, truck, barge, or TOFC.
- Distance (miles).
- Shipment size (lbs).
- Rate for shipment size ($/cwt).
- Arrival time probability distribution (if known) or an average travel time (days).

If more specific information is not readily available, the commodity attribute data contained in Appendix B can be used as inputs to the subtechnique.

The user is then provided the opportunity to modify default values, which include:

- Operating days of shipper (days/year).
- Cost per order ($).
- Interest rate (percent).
- Storage costs ($/cu ft/yr).
- Cost of stocking out per day ($).
- Variation in daily use.
- Pick up and delivery charges ($/cwt).
- Loss and damage costs, by mode ($).

Once all inputs have been provided, transport and nontransport logistics costs are then computed and summed.

$$\text{Total Logistics Costs} = \text{Transport Logistics Cost} + \text{Nontransport Logistics Cost}$$

Figure 32 schematically illustrates the subtechnique; component steps involved in estimating transport and nontransport logistics costs are described below.

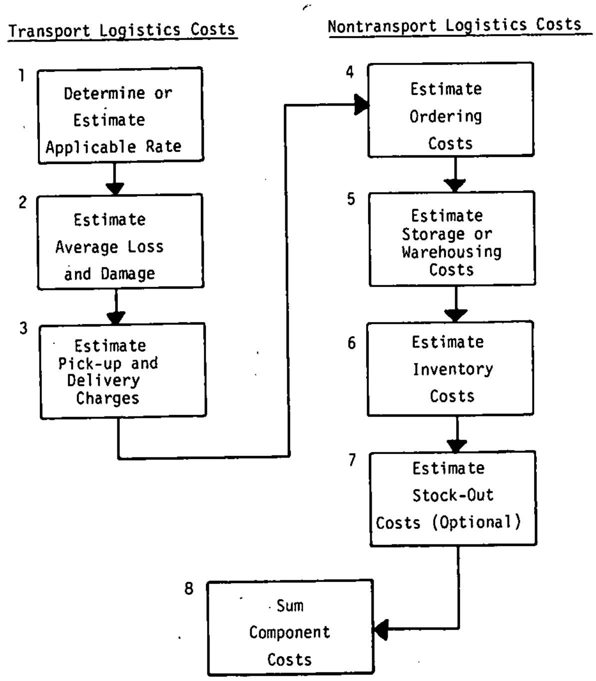

Figure 32. Shipper's Costing Subtechnique.

Transport Logistics Costs

Transport logistics costs are comprised of (1) the rate charged by the carrier, (2) average loss and damage for that commodity and mode, and (3) any pick-up and delivery charges.

Step 1 -- Determine or Estimate Applicable Rate. Rate(s) are exogenous inputs that the user must supply. See the section on rates presented later in this chapter.

Step 2 -- Estimate Average Loss and Damage. Loss and damage costs are based on the percentage of the shipment lost or damaged. They can be estimated using the following equations:

$$L\&D = (PCT)(SS)(VAL)$$

where: L&D = loss and damage, $;
PCT = percent of shipment lost or damaged;
SS = shipment size, lbs); and
VAL = value of commodity, $/lb).

$$PCT = TLD/TONS$$

where: TLD = total tons lost or damaged; and
TONS = shipper's annual tonnage.

Previous research into loss and damage (92) has resulted in several regression equations for estimating total tons lost or damaged. For Barge and TOFC, an appropriate value for the variable PCT would be 0.0001 (0.0002, if temperature control or freezing is required).

$$\text{Rail TLD} = 0.0251(\text{TONS})^{.8384}(\text{DEN})^{-.8542}(\text{VAL})^{-.1216}\ 1.0257(\text{TEMP})$$

$$\text{Truck TLD} = 0.0175(\text{TONS})^{.5811}(\text{DEN})^{-.2051}(\text{VAL})^{-.3963}\ 0.4369(\text{TEMP})$$

where: TLD = total tons lost or damaged;
TONS = shipper's annual tonnage;
DEN = density of the commodity, lbs/cu ft;
VAL = value of the commodity, $/lb; and
TEMP = 1 if temperature control or freezing protection is required; 0 if not.

Step 3 -- Estimate Pick-Up and Delivery Charges. Depending on the particular situation, pick-up and delivery costs may or may not be applicable. In general, pick-up and delivery should be added when:

1. Bulk commodities originate or terminate at a location physically distant from a rail line or inland waterway river terminal. Examples include coal hauled from a mine to a tipple using a truck and grain hauled by farm truck to a country elevator for transport to market by grain truck, rail, or barge.
2. The vehicle used for pick-up and delivery is usually smaller from that used for linehaul transport. Examples include less-than-truckload (LTL) movements and parcel delivery services.

Pick-up and delivery charges may be treated as an exogenous input, if separate rates or charges exist for such services, or be costed out as a separate mode or transport service. Inputs can either be on a per shipment or unit cost basis.

Non-Transport Logistics Costs

Nontransport logistics costs are comprised of costs associated with (1) ordering, (2) storage, (3) capital carrying in inventory, (4) capital carrying in transit, and (5) stock out.

Step 4 -- Estimate Ordering Costs. Because shippers often do not know what their ordering costs are, constant value (e.g., $20) should be used.

Step 5 -- Estimate Storage or Warehousing Costs. Storage costs can be estimated using the following equation:

$$STOR = \frac{(AVEINV)(WHSECT)}{(DEN)} - ORDERS$$

where: AVEINV = average inventory or shipment size, whichever is higher, lbs;
DEN = commodity density, lbs/cu ft;
WHSECT = warehousing cost, $/cu ft/yr; and
ORDERS = number of orders.

$$ORDERS = YRDAYS/CYCLEN$$

where: YRDAYS = operating day of shipper; and
CYCLEN = cycle length of shipper (days) or shipment size divided by average daily use.

Previous research has developed the following approximate values for storage costs ($/cu ft/yr).

- Open Storage $0.24
- Sheltered Storage $0.68

- Temperature Control $0.81
- Freezing $1.20
- Security $0.34 additional if commodity has a value greater than $5.00.

Much research has centered on the optimal reordering point, taking into account (1) the daily variation in requirements for a commodty, (2) the arrival time of alternative modes, and (3) the costs of "stocking out." For most applications, a simple estimate of reordering frequency is sufficient.

Step 6 -- Estimate Inventory Costs. Inventory costs can be estimated using the following equation:

$$INVCOST = CCINV + CCTRNST$$

where: INVCOST = total inventory cost;
CCINV = capital carrying in inventory;
CCTRNST = capital carrying in transit;
CCINV = (AVEINV)(VAL)(IR); and
CCTRNST = (SS)(VAL)(IR/365)(AVE)
in which: IR = interest rate, annual %; and
AVE = average transit time, days.

Step 7 -- Estimate Stock-Out Costs (Optional). Sometimes, the consequences of running out are far more severe than the value of item or commodity itself. Thus the unreliability of the transport service must often be considered at the shipper level. However, for areawide studies, inclusion of a stock-out cost is not recommended, because it depends on information that is not readily available.

Step 8 -- Sum Component Costs. Component costs computed in previous seven steps are summed to estimate a total shipper's cost (transport + nontransport logistics costs).

In applying the subtechnique, users should:

1. Be sure that the application is appropriate. The subtechnique is most useful where intermodal competition presently exists and substantial cost and service differences exist between the modes competing for the movement. The subtechnique is not effective when modal division largely reflects rate differences.

2. Recognize that the subtechnique was originally designed for applications at the shipper level and that the data inputs must be simplified for areawide applications.

3. Make sure the data inputs required are available or can be reasonably approximated before actually applying the subtechnique.

UNIT RATES

Completely separate from unit costs are the rates charged for specific transport services. Rates may be supplemented by charges for special or accessorial services and by penalties assessed. Rates, charges, and penalties, taken together, represent carrier income. Rates can be (1) derived from published tariffs, (2) supplied by shippers or consignees, or (3) estimated using secondary data or approximating equations. The availability of rate data, which depends to a large extent on the type of carriers involved, is summarized in Table 43.

No analytical technique applies in researching tariffs to find the applicable rate or in seeking such information from shippers or consignees. However, techniques do exist for approximating rates. Generally, acquisition of the actual rates is preferable to estimating rates.

Users must recognize the resulting changes brought about by deregulation in terms of the avail-

Table 43. Availability of Rate Data.

Carrier Type	Basis	Source	Modes	Comments
Common Carriers	Common carrier legal obligation to charge reasonable rates to all users.	Tariffs published by carriers and rate bureaus, and filed with regulatory agencies.	Most railroads, pipelines, and airlines. Common carrier trucking companies.	Time and effort involved in determining applicable rates may be beyond user's resources.
Contract Carriers	Contract law. Rates negotiated between carrier and shipper.	Non publically. No requirement to release information, although shippers may do so voluntarily.	Trucking companies, barge operators, and rail contract rates (authorized by Staggers Act).	User must rely on direct contacts.
Exempt Carriers	Applies to any carrier transporting exempt commodities (e.g., agricultural products). Rates not regulated.	None publically. Information can be obtained through shippers.	Truck, rail, and most bulk commodities transported by water.	SEE ABOVE
Private Carriers	Shippers transporting own products.	No rates other than those established for internal cost accounting purposes.	Truck, barge	Generally, rate-type information will not be made available.

ability of rate information. Prior to the Staggers and Motor Carrier Acts of 1980, intramodal carriers essentially charged the same rates, varying only in the quality of service provided. With deregulation, carriers are now competing both in terms of service and price. Intensified competition has increasingly resulted in "discounts" and "volume contracts" designed to capture high volume movements. This has led to a tremendous proliferation of rates. Consequently, the user will be less able to rely on historical or even published tariffs as rates continue to fluctuate and additional or different services are offered. Thus, the user must increasingly depend on direct contacts with carriers and shippers in order to obtain information on current rates.

Obtaining Rates from Tariffs

In the past, the most accurate and reliable rate information was that obtained directly from tariffs. Given the present volatality of rates, coupled with increasing reliance on discount and contract rates, this may no longer be true. Thus, the user must first decide whether tariff rates are generally being used as such by shippers and carriers. If so, the user must then decide whether the effort involved in locating the tariff rate is warranted. Working with tariffs is practical only if a relatively few movements or commodities are of interest.

In addition, trade associations and transportation specialists often publish summaries for specific commodities and geographic areas. Although such summaries do not replace tariffs, they are usually far more convenient to use.

When seeking rates for the same movement by different modes, the rate clerk must ensure that the services provided are comparable. Differences sometimes arise concerning equipment ownership (e.g., use of shipper or carrier-owned equipment) and origin and destination points if other than the shipper's or consignee's loading docks. For example, in comparing motor carrier and TOFC service, it may be necessary to include local cartage costs if the TOFC plan requires customer pick-up and/or delivery.

The following illustrates the steps a rate clerk would go through in searching for a specific tariff rate.

Step 1 -- Classification. Review the classification (Uniform for rail and/or National for motor) and find the proper nomenclature for the commodity, shipment size, and volume class rating.

Step 2 -- Locate Tariff. Next check in a tariff index to find the tariff covering the commodity between the specified origin and destination.

Step 3 -- Check Tariff. Check the tariff to identify the specific commodity and rate between the specified origin and destination.

Step 4 -- Further Investigation. Because there may be lower rates, check the tariff for any alternate provision that would reveal another rate in the same tariff or one in a class tariff. If so identified, search out any such provisions to determine whether other rates are allowable.

Step 5 -- Origin or Destination Not Specified. If the origin or destination is not specifically identified in the tariff, determine the larger areas to which the more specific points might be attached for rate purposes.

Step 6 -- Specified Commodity Rates Not Found. If specified commodity rates cannot be found, refer to a Rate Basis Tariff to find the origin and destination points and associated base points. Using the base points from the Rate Basis Tariff, go to the applicable tariff to find a rate basis number. Using the class rate tariff and rating table, line up the rating with the rate base number. This will establish the base rate for the classified commodity.

Step 7 -- Supplements. In searching tariffs, the rate clerk must check every supplement of every classification and tariff in use to determine whether any applicable changes have been made. The rate clerk must make sure that the tariff is currently in use and has not been superseded by a reissue of the tariff.

Step 8 -- Contract Rates or Discounts. To make matters even more complex, the rate clerk must determine whether the movement is large enough to potentially qualify for contract rates or discounts. Since contract rates and discounts will generally not be made available to public agencies, the reductions possible initially will have to be inferred from comparable situations.

Because of the intricacies involved in locating and understanding appropriate tariffs, freight rate determination is best performed by specialists.

Alternatively, if the number of rates desired is not too large, such information can often be obtained from shippers or directly from the carriers. Normally, this represents a more practical way of acquiring rates for long-established commodity movements. However it can lead to mixed results. Often a shipper will not know the rate if it is being paid by the consignee (and vice versa). Occasionally, wrong information will be supplied. This also happens, with carriers, who by law are not responsible for wrong quotations regardless of the form of the communication.

Obtaining Rates from Shippers and Consignees

Published rates do not exist for contract carriers. Here the analyst must rely on direct contacts with carriers and shippers for rate information. Much depends on the arrangements made by the analyst to protect the confidentiality of the information being supplied.

Given perseverance and a willingness to search, information on the rates charged by exempt carriers can usually be obtained. In so doing, the analyst should be alert to the complexities involved in actual situations, a few of which are listed as follows:

1. Often a common carrier (e.g., rail) will establish a set of rates which incidently serves as the basis for comparable rates charged by exempt carriers transporting the same commodity. These competing rates are usually set a few cents per cwt lower than the rail rate.

2. Truck rates for hauling exempt commodities are negotiated and often depend on the "clout" of the individual shipper, the amount and type of competition, and the nature of the haul. Large shippers using trucking on a regular basis often establish the rates that they are willing to pay for particular movements. Rates are also affected by location and the amount of trucking competition. Rates for movements convenient to the Interstate system are generally lower than those involving locations off the beaten path. Also, rates are lower where the competition is intense, be it from firms specializing in hauling exempt commodities, independent owner-operators obtaining loads through truck brokers, or others seeking to offset an empty movement. Shippers sometimes negotiate different rates depending on the timing and character (e.g., fronthaul or backhaul) of the movement. Thus, the analyst often will be confronted with a large variety of situa-

tions resulting in a range of rates that at best are difficult to determine. This situation can be simplified by focusing on the prevailing rates for non-premium, fronthaul movements.

3. In areas where intensive competition exists, the rates charged will approximate costs. A high degree of turnover exists among the independents, indicating the marginal nature of the business. In many applications, the use of truck costs as a proxy for rates may produce the desired level of accuracy.

Rate Estimating Equations

In many cases, there will neither be the time nor fiscal resources to search out the tariffs for appropriate rates, or to undertake extensive direct contacts with carriers or shippers. In such cases, the user has to resort to less rigorous means.

Revenue Data

One alternative is to substitute revenue data. Sources of data do exist for both rail and truck, which summarize the revenues received for groups of shipments or for individual carriers. These data can be arranged and manipulated in various ways to develop generalized rate curves. The advantage of this method is that it depicts rates on an average systemwide basis fairly accurately and at relatively low cost. Its disadvantage lies in the fact that very few commodity rates can be classified as average. In fact, wide differences do exist in freight rates which, on a local basis at least, would not be reflected in rate curves developed on a proxy basis. Also, such data usually tend to be out-of-date.

Nevertheless, estimated rates developed in this manner are useful for systemwide analysis in that they are relatively accurate and factually based. Use of such estimates for corridors or subsystem analysis is not recommended, because specific commodity types, shipment size, or competition play a large role in rate determination.

Rate Equations

Another approach is to generate rates using models developed for this expressed purpose. A number of researchers have attempted to derive functional relationships based on variables such as commodity type, distance, shipment size, density, and value. These efforts have achieved mixed success. The results obtained are reasonable when used in generalized system studies, but are probably not satisfactory for use in more narrowly defined applications. Rates produced through rate equations are approximations at best, and should be used only if rate information cannot be found from other sources. The following presents sample regression equations for estimating rates from waybill data collected over several years and indexed to 1981 (87,89,91):

- Private Truck

$$RATE = \frac{(84.32 + 0.7487(DIST)(NTRK))}{0.6(WGHT)}$$

- LTL Truck

$$\ln(RATE) = 5.45 + 0.305 \ln(DIST) - 0.166 \ln(BRKM) - 0.156 \ln(SS) + 0.0233 \ln(VAL) - 0.169(DEN)$$

- Truckload

$$RATE = \frac{(219 + 0.76 + DIST)NTRK)}{WGHT}$$

where: RATE = rate, \$/lb;
DIST = distance, miles;
SS = shipment size, lbs;
VAL = value of commodity, \$/lb;
DEN = density of commodity, lbs/cu ft;
NTRK = larger of the following two values:
W = SS/45,000 lbs; and
CUBE = (SS/DEN)/ 3200;
WGHT = SS if SS $\leq$ 45,000 lbs, or
= (SS/1.02) if SS $>$ 45,000 lbs; and
BRKM = DIST/500 if DIST $>$ 500 miles, or
= 0 if DIST $\leq$ 500 miles.

- TOFC, Single Trailer (Shipment Size 40,000 lbs)

$$\ln(RATE) = 3.38 + 0.37 \ln(DIST) + 0.423(BRKM) + RGDUM$$

- TOFC, Double Trailer (Shipment Size 40,000 lbs)

$$\ln(RATE) = 3.54 + 0.443 \ln(DIST) + 0.401(BRKM) + RGDUM$$

where: ln(RATE) = TOFC charges per shipment;
DIST = distance, miles;
BRKM = ln(DIST/500) if DIST 500 miles,
= 0 if DIST 500 miles; and
RGDUM = regional variables for originations in ICC territories

Territory	Single Trailer	Double Trailer
Official	- 0.253	- 0.242
Southern	- 0.195	- 0.296
Western	- 0.118	- 0.186
Southwestern	- 0.0653	- 0.164

Pick-up and delivery charges of \$150 for single trailer, TOFC and \$300 for double trailer TOFC are added after the calculation.

- Rail-Single Carload (Shipment Size $<$ 200,000 lbs)

$$\ln(RATE) = 8.89 + 0.438 \ln(DIST) - 0.633 \ln(SS) + 0.166 \ln(VAL) + 0.177(G) + 0.311(BRKM) + 0.423(BRKM) + 0.213(LIQ) + REGDUM$$

- Rail-Multiple Carload (Shipment Size $>$ 200,000 lb)

$$\ln(RATE) = 2.2 + 0.59 \ln(DIST) - 0.856 \ln(SS) + 0.87 \ln(VAL) - 0.196 \ln(DEN) + 0.829(LIQ) + 0.311(P) - 0.368(PRIV) - 0.146(BD) - 0.062(DD) + REGDUM$$

where: ln(RATE) = rate, ¢/cwt;
DIST = distance, miles;
SS = shipment size, lbs;
VAL = value of commodity, \$/lb;
DEN = density of commodity, lbs/cu ft;
G = 1 if commodity is a gas, and 0 otherwise;
LIQ = 1 if commodity is liquid, and 0 otherwise;
P = 1 if commodity is a particulate, and 0 otherwise;
PRW = 1 if rail cars are privately owned, and 0 otherwise;
BD = 1 if shipment begins at a dock, and 0 otherwise;
DD = 1 if shipment ends at a dock, and 0 otherwise; and
REGDUM = regional delivery variables:

Originating Territory	Single Carload	Multiple Carload
Official	-0.0198	0.406
Southern	-0.203	-0.175
Western	-0.0135	0.115
Southwestern	-0.178	0.158

- Barge

$$\ln(RATE) = 1.158 + 0.316 \ln(DIST) + 0.384\ (BRKM) + 0.0759 \ln(VAL) - 0.271(P)$$

where: ln(RATE) = rate, ¢/cwt;
DIST = distance, miles;
BRKM = ln(DIST/500) if DIST 500 miles, and 0 if DIST 500 miles;
VAL = value of commodity, $/lb; and
P = 1 if commodity is a particulate; and 0 otherwise.

RESULTING PRODUCTS

Record Format

The record previously created during the trip generation and distribution phase has been further divided as a result of developing and applying (1) a mode split model, (2) actual or estimated rates and shipper, and (3) carrier cost equations. The resulting product from Modal Division is a record consisting of:

- Origin county or state.
- Destination county or state.
- Commodity type (2, 3, 5 digit STCC cord or equivalent).
- Flow: (Weight) tons or Volume (gallons, bushels).
- One or more of the following cost functions, including separate records for the following components (if applicable): pick-up, linehaul, delivery, and terminal costs.

Mode/Service Identification
Carrier
Vehicle Equivalents
Empty Return Ratio
Distance
Carrier Unit Cost (loaded)
Carrier Total Cost (loaded)
(loaded and empty)
Unit Charges (Rates)
Total Charges
Other Logistics Cost (transport)
(nontransport)
Ton Miles
Vehicles Miles (loaded)
(loaded and empty)

One record is prepared for each mode-movement combination (i.e., records having a unique origin, destination, commodity type, and actual or selected mode or mode/service combination). If necessary, they can be further subdivided by component modes (mode combinations only). Separate records are prepared for the base case and each alternative being considered. Actual mode applies to the base case only, whereas the selected mode summarizes the results from using a mode split model and thus applies to the alternative future, scenarios, or condition being examined.

As indicated, multiple cost functions such as (1) the applicable rate, (2) total carrier revenue for the movement, (3) carrier unit and/or total cost, and (4) the shipper's unit and/or total cost can be included on the resulting record. If carrier unit or total costs are desired, commodity flows must be converted to vehicle flows using the vehicle equivalents subtechnique presented in Chapter Five. Distance inputs come either from a distance matrix or from coding modal networks and summing distances therefrom. A utilization factor can also be included to calculate overall costs (loaded and empty).

Tabular Summaries

Base case and alternative records can be summarized separately in a variety of ways, as indicated previously in Chapter Two. A few of the many possible summaries are identified as follows:

Quantity Summarized	Table Rows	Table Columns
• Transport Costs and Charges by Origin	Origin	Transport Charges and Costs
• Transport Costs and Charges by Mode	Mode	Total Transport Charges and Costs
• Transport Costs and Charges by Mode	Mode	Unit Transport Charges and Costs
• Ton-Miles by Origin	Origin	Ton-Miles by Mode and Total
• Vehicle Miles by Origin	Origin	Vehicle Miles by Mode and Total
• Traffic Division Among Modes	Origin	Tons by Mode (including percent)

In addition, the anticipated change in commodity and vehicle flows, carrier income and costs, and shipper costs between the base case and each alternative can be computed. This can be done either on a unit or a cumulative basis.

Economic Benefits

Primary Efficiency Benefits

Using the output records, the efficiency benefits of an alternative can also be computed. Such benefits are defined as additions to community welfare resulting either from introducing a new product or service or from making an existing product or service more efficient (i.e., consume fewer resources). Primary efficiency benefits are those attributable to changed transport costs and rates, and can be estimated using the following equation (99):

$$(B_\alpha - B_o)_t = \underbrace{q_o(c_o - c_\alpha)}_{\text{Term 1}} + \underbrace{1/2(p_o - p_\alpha)(q_\alpha - q_o)}_{\text{Term 2}} + \underbrace{(p_\alpha - c_\alpha)(q_\alpha - q_o)}_{\text{Term 3}}$$

where: $(B_\alpha - B_o)_t$ = the gain in benefits from changed transport rates and costs of alternative a over a base case (alternative o), and q, c, and p are the unit commodity flows, unit costs, and unit rates, respectively.

- term 1 = cost reduction on existing traffic;
- term 2 = consumer surplus on new traffic; and
- term 3 = producer surplus on new traffic.

Distributional Benefits

The distribution of economic benefits among the different parties or groups is also an important consideration, and is accomplished by calculating the benefits or disbenefits accruing to each group. The distribution of benefits and disbenefits identifies who gains and who loses, and by how much, from each alternative under consideration. Affected groups typically include:

1. Shippers and consignees (whoever pays the shipping charges).
2. Carriers.
3. Government (different levels).

In the case of the first two groups, the benefits represent the change in net income (revenues less costs) between the base case and alternatives under consideration. Benefits attributable to government stem either from changes in user charges or tax revenues, or the capital expenditures incurred to maintain and operate transportation facilities built with public funding.

Investment Efficiency

Techniques typically used to evaluate capital projects include:

1. Discounted payback -- how soon the project will pay back its cost.
2. Net present value -- whether the project will be profitable, and how profitable.
3. Internal rate of return -- percent return on the investment.
4. Benefit-cost ratio -- whether the project offers "positive" returns (i.e., a benefit-cost ratio greater than one).

The investment efficiency of a proposed capital expenditure can be computed using the output records and any of the foregoing techniques. The first three are generally used by private industry in evaluating plant and equipment capital investments. The latter is primarily used by public agencies in assessing transportation system investments. For further details on applying these techniques, users should consult a recognized text providing methods and examples evaluating capital investments (97,98, 100,101).

Benefits and costs that occur in the future must be discounted. The rate of interest or discount rate employed should reflect the rate of return the funds would enjoy if invested elsewhere. On federal projects, the Office of Management and Budget sets the discount rate equal to the interest rate which the federal government must pay for short-term borrowings. If costs are computed as constant costs, the selected discount rate would simply be the opportunity cost. Alternatively, the user can estimate the inflated values of benefits and costs for the year in which the benefits will be achieved or costs incurred. In such cases, the discount rate should also include an inflation cost component. Normally, the former method is simpler, although the latter is appropriate when significant variation in the inflation rate of various cost and benefit components is anticipated.

In addition to the discount rate, project life must also be determined. Project life is:

1. The period of time over which the asset is functionally needed.
2. The physical life of the asset.
3. The technological life of the asset (or the period of time before obsolescence would dictate replacing the asset).
4. The period of time over which discounted benefits exceed discounted costs.

Resulting project life may be less than the length of the payback period.

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CHAPTER FIVE

TRAFFIC ASSIGNMENT

INTRODUCTION

Traffic Assignment converts commodity flows into vehicle flows (if not already done as a prerequisite to estimating carrier costs), and then allocates the resulting vehicle interchanges to the transportation system. The process may be used to estimate the traffic load on various segments of a system for a proposed alternative or to simulate present conditions. Optional components include estimating the expected change in truck volumes, pavement loadings, and pavement life on a segment basis, and computing therefrom system changes in energy consumption and user tax revenue.

The basic component, traffic assignment, is carried out for the base case and each alternative being considered. The results are then compared to determine anticipated change. Either manual or computerized techniques (or a combination thereof) can be used in assigning traffic to modal subsystems, the selection of which depends on the complexity of the application and the number of alternatives being analyzed. Usually, the route choices involved with rail, inland waterway, and even intercity highway movements will be obvious. Thus the advantage of using computerized assignment techniques lies not so much in finding the least distance or cost route through a network, but rather in the systematic accounting of vehicle volumes by segment and the calculation of distance or traffic related costs. Computerized highway assignment techniques commonly used in urban transportation studies can be applied with little modification. Such techniques are particularly valuable in assigning motor carrier traffic to the statewide highway system. Manual or simplified computerized techniques often suffice in assigning rail and inland waterway traffic.

Because states are particularly interested in highway system impacts, this chapter focuses primarily on methodologies useful in measuring highway system impacts unique to freight transportation. While changes in highway segment volumes are important, such information by itself provides only limited insight into the effect or impacts that such changes have on the highway itself or the surrounding environment. Thus other techniques are required to assess the impact of changes in traffic volumes. A number of techniques are already available to states to use in measuring the direct effects of vehicles (i.e., noise, air pollution, etc.). Since such techniques have been widely applied by states in determining the impacts of major highway projects and are well documented elsewhere, they have not been included in this manual. Techniques pertaining to the impacts of changes in truck volumes on pavement life are not as well known or documented, and hence are presented in this chapter.

In considering just how far to go in assigning traffic to networks and estimating impacts, the basic choices available to the user are:

1. Whether to undertake traffic assignment at all or only for selected modes (e.g., highway system). Traffic assignment is required if segment-level assessments are contemplated. If segment volumes are not required, traffic assignment per se is not necessary, provided that a distance matrix is available to use in computing cost and revenues.

2. Whether to limit the application to summarizing and comparing vehicular flows on a segment basis. Information on projected changes in traffic volumes do not take into account the larger impact that trucks used for intercity transport have on pavement structure. Users should recognize that in addition to vehicular flows for the base case and each alternative, information is also required on background automobile and truck traffic.

3. Whether to estimate the impact of changed loadings on pavement structure. To do this, use must be made of truck weight data such as that collected periodically by states. Change is measured in terms of 18-kip equivalent annual load applications. Such measurements neutralize differences between vehicle types and weights. Using vehicle count and classification data (or estimates), the relatively limited truck weight data collected at limited locations can be extended to estimate the wheel/axle configurations, tare weights, and vehicle loadings expected to occur at different locations. Because the effects of design strength, pavement age, and past traffic are not included, this approach does not identify expected changes in pavement life.

4. Estimate changes in pavement service life. In addition to the above, this requires as inputs detailed data on pavement condition and structure. If such data are not available, states can substitute the assumptions and default data developed by FHWA for use in highway needs studies.

5. Using network flows to estimate changes in energy consumption on a system basis and/or changes in revenues derived through user taxes.

VEHICLE EQUIVALENTS

Although the process of converting commodity flows into vehicle flows is conceptually simple, it does require (1) determining the equipment and service most likely to be used for individual shipments which, when summed, comprise the total movement, and (2) estimating the weight or volume to be transported by representative vehicles on the fronthaul or backhaul portions of the movement.

Figure 33 shows a subtechnique that can be used to determine vehicle equivalents. The following paragraphs describe component steps.

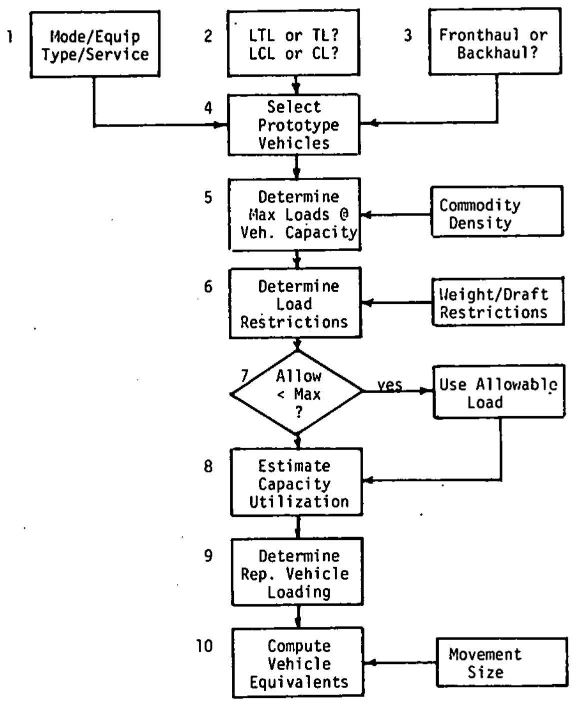


Figure 33. Vehicle Equivalent Subtechnique.

<u>Step 1 -- Mode/Equipment Type/Service</u>. The starting point is selecting the probable mode, vehicle type, and service. Mode determination either is an output of the modal division process or is determined by the nature of the appli- cation. Equipment types can be determined from Table 44 or from discussions with shippers or carriers. Service can be determined from Table 45 or from discussions with shippers or carriers. A general knowledge of shippers, consignees, and the local transport industry is also helpful.

<u>Step 2 -- Truckload, Carload, or Bargeload Shipments</u>. Again, using general information or discussions with shippers or carriers, determine whether the application involves truckload, carload, or bargeload shipments, or less-than-truckload or parcel delivery services. The former increase network volumes, whereas the latter generally can be accommodated within existing vehicles and thus have little effect on network volumes. Factors to consider in examining movement commodity flows include:

1. Probable shipment size and frequency.
2. Value and characteristics of the commodity.

Table 44. Equipment Types.

<u>Railroad Rolling Stock</u>	
<u>Rail Form A Categories</u> 1/	<u>URCS Categories</u> 1/
Box - General Unequipped	Box, 40 ft
Box - General Equipped	Box, 50 ft
Box - Special	Box, Equipped
Gondola - General	Gondola, Plain
Gondola - Special	Gondola, Equipped
Hopper - Open General	Hopper, Covered
Hopper - Open Special	Hopper, Open Top General
Hopper - Covered	Hopper, Open Top Special
Stock	Refrig., Mechanical
Flat - General	Refrig., Nonmechanical
Flat - TOFC	Flat, TOFC/COFC
Refrig.,-Meat-Mechanical	Flat, Multilevel
Refrig.,-O/T Meat-Mechanical	Flat, General Service
Refrig.,-Meat-Nonmechanical	Flat, All Other
Refrig.,-O/T Meat-Nonmechanical	All Other Freight Cars
Tank 10,000-18,999 Gallons	Auto Racks
Tank 28,000-31,900 Gallons	
<u>Motor Carrier Semitrailers</u> 2/	<u>Coastwise Carriers-Barges</u>
Regular Vans	Equipment types are similar to that used by inland waterway carriers, but are larger and built for towing in open waters.
Refrigerated Vans	
Flatbed Trailers	
Moving Vans	
Tanker Vans	
Specialized Trailers	
	<u>Ocean-Going Vessels</u> 4/
<u>Inland Waterway Carriers-Barges</u> 3/	
	General Cargo
Open	Partial Container
Covered	Full Container
Tanker	Barge Carrier
Deck	Neobulk
Pressured	Drybulk
	Combination Carrier
	Liquified Gas Carrier
	Liquified Bulk (Tanker)

1/ Car types shown are those contained in the Rail Form A and Uniform Rail Costing Systems. Railroads utilize a more detailed designation system developed by the AAR. See the <u>Official Railway Equipment Register</u> published quarterly by the <u>National Railway Publication Company</u>.

2/ Trailer types shown are those contained in the National Motor Transport Data Base. Types shown can be further subdivided by trailer size (principally length) or capacity and maximum gross axle weight.

3/ Barge Equipment shown can be further subdivided by size and type of construction (single mall versus mall).

4/ Vessel types shown are those utilized in the report prepared for the U.S. Department of Commerce, Maritime Administration, entitled <u>Merchant Fleet Forecast of Vessels in U.S. Foreign Trade: 1980 - 2000</u>. Vessels vary greatly in terms of their deadweight tonnage, overall length, beam, and maximum draft. See <u>Lloyd's Register of Ships</u>.

3. Number of shippers or consignees included in the movement.
4. Overall size of the movement.

<u>Step 3 -- Fronthaul or Backhaul</u>. Next, determine whether the movement is or will be primarily fronthaul or backhaul to some other movement. Fronthaul movements increase network volumes, whereas backhaul movements increase vehicle utilization, and thus do not substantially change traffic volumes. Factors to consider include:

1. Need for speciallydesigned equipment with which to transport the commodity.
2. Equipment ownership.
3. Organization providing the transport service.
4. Any "imbalance" in commodity flows (i.e., available capacity in the direction of the commodity flow).
5. Distance of the movement.
6. Service requirements.
7. Rates being offered (i.e., those that cover full versus only out-of-pocket costs).
8. Size of the movement in relation to available capacity.

Table 45. Service Types.

Rail Service[1/]	Inland Waterway Carrier Service 8/
Regular Single Car	Common Carriers
Multicar 2/	Contract Carriers
Unit Train 3/	Private Carriers
TOFC/COFC Plan 4/	
Motor Carrier Service 5/	**Ocean Service**
Regular Route Common Carriers	Liner Service (scheduled routes & frequency)
Truckload	Tramp (nonscheduled)
Less-than-Truckload	Private
Package Delivery	
Irregular Route Common Carriers 6/	
Private Carriers 6/	
Exempt Carriers 7/	
Agricultural Cooperatives	

1/ Virtually all rail service is provided by common carriers.

2/ Multicar service refers to two or more carloads moving between a single origin and destination on one waybill. Carloads are handled as a "unit" in way and through trains.

3/ Unit train service refers to a trainload moving between a single origin and destination on one waybill.

4/ TOFC/COFC Plan refers to one of six plans involving trailers or containers handled in intermodal service. Plans differ in terms of equipment ownership and responsibility for providing pickup and delivery services.

5/ Linehaul service using tractors, semitrailers, and full-trailers. Excludes pickup and delivery service or similar movements using two- and three-axle single-unit trucks.

6/ Will include independent owner-operators hauling for common or private carriers as well as carrier or privately owned equipment.

7/ Designation stems from the commodities handled. Any type of carrier can haul exempt commodities.

8/ A further distinction could be made based on the use of dedicated tows (a two moving as an integral unit between origin and destination) and the number of barges and size of towboat used.

Sometimes it is difficult to determine whether a movement is primarily fronthaul or backhaul. In some cases, it may be either. Discussions with carriers and shippers will often help clarify this.

Step 4 -- Select Prototype Vehicles. One purpose of Steps 2 and 3 was to screen out movements that can generally be accommodated using available space in present vehicles and thus do not increase network volumes. Assuming that the movement will result in additional vehicle use, select prototype vehicles based on:

1. Prevailing equipment being utilized for the commodity and type of haul.
2. Financial resources of transport company or firm (e.g., new or used equipment).
3. Known or expected availability of the equipment.
4. Anticipated size, weight, or draft constraints.

Step 5 -- Determine Maximum Loads at Vehicle Capacity. Using (1) the maximum volume and weight capacities of prototype vehicles selected in Step 4 and (2) the density of the commodity being transported, determine the maximum size load that potentially can be carried by the vehicle. Depending on density, vehicles may "cube out" before the maximum weight is reached or, alternatively, "weigh out" before the available capacity is fully used. Commodity densities at the 5-digit STCC level are presented in Appendix B.

For example, a covered hopper rail car has a capacity of 4,750 cu ft and a maximum load capability of 199,000 lbs. If loaded with wheat (density: 60 lb/bu or 47 lb/cu ft), the car could only be filled to 89 percent of its volumetric capacity before the maximum load rating was reached. If this car instead was fully loaded with barley (density: 48 lb/bu or 37 lb/cu ft), the resulting load would be 175,750 lbs or 88 percent of weight capacity of the car.

Step 6 -- Determine Load Restriction. Even if the vehicle can be fully loaded, other route-related restrictions may limit the load that can be accommodated. The next step is to determine applicable restrictions, both physical and legal. For highways (motor carriers), each state has laws governing allowable combinations of full and semi-trailers, maximum overall length, and allowable axle and gross vehicle loads for all or portions of the state highway system. See Overweight Vehicles, Penalties, and Permits -- An Inventory of State Practices (2). Railroads also have established for each rail line a maximum gross weight for car and lading, depending on the condition of the roadbed and the weight and condition of the track structure. See Railway Line Clearances (5). Typical tare weights are given in Table 46. Barge loads may be restricted by the effective draft of the waterway system. Minimum or available channel depth is not the usable or effective navigational depth; allowance must also be made for vessel trim and squat as well as bottom clearance. Several guides are published giving information on controlling depths and clearances at bridges and locks (1).

Table 46. Tare Weight (Tons) for Different Rail Cars.

Type of Equipment	Tare Weight (tons)
Box-general service, unequipped and equipped	30.9
Box-general service unequipped	28.0
Box-general service equipped	36.4
Box special service	41.4
Gondola-general service	29.9
Gondola-special service	31.2
Hopper open-general service	27.1
Hopper open-special service	27.6
Hopper covered	30.5
Stock	23.7
Flat-general service	28.2
Flat-TOFC	33.6
Auto Rack	47.8
Refrigerator-meat mechanical	40.9
Refrigerator-other mechanical	43.9
Refrigerator-meat-nonmechanical	35.2
Refrigerator-other-nonmechanical	31.1
Tank 9,999 gallons and under	24.4
Tank 10,000-18,999 gallons	31.3
Tank 19,000-21,999 gallons	33.7
Tank 22,000-27,999 gallons	37.4
Tank 28,000-31,999 gallons	42.1
Tank 32,000 gallons and over	47.1
All Other	30.1

Source: Interstate Commerce Commission, Rail Carload Cost Scales 1977, p. 137.

Step 7 -- Compute the Maximum Allowable Load. The next step is to compute the maximum allowable load. For motor carriers, this involves apportioning the gross weight among the different axles and determining whether the legal weights and distances between axles are met. If not, the maximum load must be reduced to bring the gross weight down to the legal limits. This may differ from the loadings being reported by shippers, because of a lack of enforcement of weight limits. For rail lines, the maximum load must be reduced to attain the maximum gross weight allowable. For inland waterways, maximum vessel loadings can be determined as follows:

$$SS = CAP1\text{-}12(IFACTOR)(MAXDRAFT\text{-}ACTDRAFT)$$

where: SS = maximum cargo, tons;
CAP = vessel capacity at maximum draft, tons;
IFACTOR = immersion factor, tons/in;
MAXDRAFT = vessel maximum draft, feet; and
ACTDRAFT = maximum allowable draft, feet.

For example, a jumbo barge has a practical capacity of 1,350 tons at a draft of 8.5 ft. The same barge empty has a draft of 1.5 ft. If the effective draft of the waterway segment was 6 ft, the maximum cargo which could be carried by that barge would be:

$$SS = 1350\ 1\text{-}12(16.1)(8.5\text{-}6.0) = 867 \text{ tons}$$

In all cases, either the maximum load must be reduced to the allowable load, or alternative equipment or vessels capable of meeting the physical or legal constraints must be substituted for that originally selected.

Step 8 -- Estimate Capacity Utilization. Once a maximum allowable load has been established, then it is necessary to estimate how this capacity is typically used on an individual shipment basis. In many cases, the typical load will run considerably less than the maximum allowable load, while in other cases, utilization may be at or even above the maximum allowable load. Factors to consider include:

1. The particular commodity involved.
2. The amount of unused "space" in the vehicle.
3. Variation in shipment size and loading practices.
4. The risks involved of damage or delay to the vehicle/vessel from overloading.
5. Likelihood of enforcement and penalties against overweight, if caught.

Step 9 -- Determine Representative Vehicle Loading. The results from Step 7 are applied to the results of Step 8 to determine a representative vehicle or vessel loading.

Step 10 -- Compute Vehicle Equivalents. The fronthaul portion of the total movement is then divided by the representative loading to determine the vehicle or vessel equivalents needed to accommodate that movement.

TRAFFIC ASSIGNMENT TECHNIQUES

The traffic assignment procedure involves the selection by computer of a minimum impedance path between zones and the "accounting" associated with assigning this movement to the identified route segments. To accomplish this, a description of the network is first coded, edited and stored in the memory of the computer. After selecting the minimum impedance path between zones, the computer then proceeds to assign associated movements to the selected routing. Traffic volumes are thus accumulated for each route segment.

In recent years, a number of states have undertaken studies involving statewide traffic assignments. These studies have generally utilized traffic assignment computer programs developed originally for urban areas with only minor modifications to the inputs being necessary to adapt the programs to statewide applications. The following sets of programs or "packages" are available to states having IBM mainframe computers:

1. PLANPAC/BACKPAC. Originally developed by the Bureau of Public Roads (predecessor to the FHWA), "PLANPAC" contains programs for analysis of survey data and trip table building, trip generation, trip distribution, traffic assignment, network evaluation, plotting, and a few utility programs for moving, copying, and dumping data sets. The programs have been widely used by state DOTs and other organizations involved in urban area highway planning. "BACKPAC" contains additional programs of a "backup" character as well as other miscellaneous programs of potential use in freight demand forecasting, such as spider web assignment and statistical analysis packages. An appreciable body of literature is available describing the programs in the PLANPAC/BACKPAC battery and their application in urban transportation planning (11-14).

2. Urban Transportation Planning System (UTPS). Developed by the Urban Mass Transportation Administration, UTPS is a package of computer programs, attendant documentation, users guides and manuals providing state-of-the-art methods for multimodal urban transportation planning. UTPS, which has many of the same capabilities as PLANPAC/BACKPAC vis-a-vis highway traffic assignment, is widely used for applications involving both highway and transit networks. Extensive literature describing UTPS is also readily available describing individual programs and their applications (16-21).

The foregoing sets of programs are useful primarily for assigning freight traffic (i.e., trucks) to highway networks. In addition, analogous simulation models exist for assigning freight traffic to national-level rail and inland waterway networks (7-10). Such models are generally not appropriate for use at the state level, however, and thus are not described in detail in this manual.

Detailed procedures and suggestions for (1) subdividing states into appropriately sized traffic analysis zones, (2) selecting segments and coding a statewide highway network, and (3) adapting the assignment process to the smaller scale network typically employed in statewide planning have been documented elsewhere (13-14). A statewide highway network can be coded with the minimum data required for traffic assignment (i.e., A-node, B-node, speed, distance, and ADT for each segment). Other data fields often included by states are functional class, federal aid class, capacity, DHV/ADT factor, link class, type of facility, rural versus urban section, and route number. The above data fields are oriented towards automobile or total traffic rather than truck traffic. Statewide assignments are usually unrestrained (i.e., no limit is placed on the number of vehicles assigned to any one segment), because few highways outside of urban areas have traffic volumes approaching their capacity.

Only a few of the programs contained in the PLANPAC or UTPS packages would normally be employed. Programs within PLANPAC useful in assigning truck volumes to highway networks include:

1. BUILDHR (or NETWORK), which performs edit and consistency checks on the input link records and writes a sorted file of link and intersection description records (historical record).
2. PRINTHR (or FORMAT), which prints the historical record.
3. BUILDVN, which reads the historical record and computes the minimum paths.
4. PRINTVN, which prints out the minimum impedance paths to allow the user to examine them for logical accuracy.
5. LOADVN, which reads the minimum impedance paths and the zone-to-zone vehicle flow matrix and then routes these flows over the minimum path. As it does so, the program accumulates the volumes by link for all zone-to-zone movements. When all vehicle flow records have been processed, the program reads the historical record file, merges the link volumes with it, and writes out a new, more detailed historical file.
6. PRINTLD, which prepares printed summaries of the assigned link flows. (Alternatively, the program FORMAT could be used).

Comparable UTPS program are:

1. HR, the highway network builder/updater program, which builds an "historical record" from link cards for input to the highway assignment program, UROAD. HR also processes updates to an historical record, inserts node coordinates, and prints the historical record along with messages regarding the correctness of the data. HR optionally produces mechanical or printer plots of the network and associated data.
2. UROAD, the highway analyzer, which performs many of the traditional functions associated with planning a highway system, including pathfinding, "skimming" (time and/or distance and/or toll) and traffic assignment (with or without capacity restraint). Its input is a "historical record" describing the highway network and up to four highway trip tables. The program permits the user to select from a variety of built-in capacity restraint techniques using network equilibrium concepts or alternatively to specify his own methodology. Besides an historical record updated with forecasted link and turn volumes, UROAD outputs optionally include impedance matrices and printouts of selected paths, link loadings and speeds, turn volumes, VMT, VHT and speed summaries by volume/capacity groups, and pollution emission and energy consumption estimates. Mechanical or printer plots of networks, loads, and associated data can be produced optionally.

Before using either of the foregoing assignment packages, users must first decide whether to assign all traffic (automobiles and trucks), truck traffic only, or only applicable truck movements. The first option, which represents a total simulation of flows over the developed network, necessitates developing a zone-to-zone trip table for all automobile and truck movements. The second option similarily requires developing a zone-to-zone trip table for all truck movements. The preparation of such trip tables does entail appreciable work, and may not be practical unless previously done by the state DOT.

In addition to the above assignment packages, less sophisticated approaches based on user-determined routings coupled with computerized segment accounting can also be employed. These are particularly useful when the application involves (1) selected movements or (2) a statewide network and trip tables that have not previously been developed by the state DOT or are out-of-date.

EQUIVALENT ANNUAL LOAD APPLICATION

Users are often interested in estimating equivalent annnual load applications on a segment basis for the base year and each alternative, and then computing the net change in pavement loadings.

Equivalent annual load applications (EALA) can be estimated by:

EALA = (ADT)(%TRKS)(CLF)(18KSAEC)365

where: EALA = equivalent annual 18-kip single-axle load applications;
ADT = average daily traffic;
%TRKS = percent that trucks and combinations are of total traffic (after excluding pickups, panels, and other 2-axle, single-tired vehicles);
CLF = critical lane factor, defined as the percent of vehicles in the right-hand lane:

number of lanes	direction one-way	two-way
2 or 3	100	50
4 or more	80	40

18KSAEC = 18-kip, single-axle equivalent constant. Can be obtained from the W-4 tables of a state's bi-annual truck weight study.

The following example illustrates the application of the subtechnique. A company presently ships 115,000 tons of cement a year in covered hoppers over a rail line which the owning railroad contemplates abandoning. The company is considering shifting to privately owned trucking, using tandem trailers to serve two distribution terminals. Because specialized bulk cement semitrailers will be used, an empty backhaul is contemplated. The state is concerned over the impact that such a shift will have on the highway system. Table 47 provides combined W-4 data for four rural Interstate stations, two of which are on the Interstate route which would be used, if the traffic shifts to truck. Table 48 shows vehicle and classification counts at these four stations. Table 49 correlates axle loads and 18-kip equivalents for both rigid and flexible pavements. Table 50 provides data on the semitrailer-trailer vehicle which will be used for this movement. The Interstate route is for the most part surfaced with portland cement concrete (rigid pavement).

Component steps involved in computing an EALA for this route are as follows:

Step 1 -- Obtain or Estimate the Percent that Tractor/Semitrailers and Combinations are of Total Vehicles. Although average daily traffic volumes (ADT) are typically available for most highway system segments, information on the composition of trucks by type, axle, and tire configuration is much less available. This step consists of obtaining available information and estimating the percent that tractors/semitrailers and combinations are of total vehicles for highway segments where such information is not available.

In this example, the classification count made during the summer of 1981 is two-thirds greater than the ADT value. Because much of this difference can be attributed to passenger cars, the assumption was made that average daily trucks are approximately 80

Table 47. Number of Axles Counted and Eighteen Kip Axle Equivalents at Four Rural Interstate Truck Weight Stations in 1981.

	Single-Unit Trucks	Tractor Semi-Trailer Comb.	Semi-Trailer Trailer Comb.	Truck & Trailer Comb.	All Trucks & Comb.
Total Single Axles Counted	14025	3951	652	153	18781
Total Tandem Axles Counted	242	6714	123	121	7200
Total Axles Counted	14509	17379	898	395	33181
Total Vehicles Counted	7166	3506	155	81	10908
Rigid Pavement P=2.5, D=9"					
18K Eqv.for All Trucks Weighed	85.8	1580.0	54.0	28.4	1748.2
18K Eqv.per 1000 Trucks Weighed	62.5	1690.1	1283.3	1644.2	614.7
18K Eqv.for All Trucks Counted	451.6	5922.4	198.8	132.2	6705.0
% Distribution of 18K Eqv.	6.74	88.33	2.96	1.97	100.00
Flexible Pavement, P=2.5, SN=5					
18K Eqv.for All Trucks Weighed	70.9	970.5	49.3	19.1	1109.8
18K Eqv.per 1000 Trucks Weighed	56.2	1035.0	1190.2	1106.2	394.8
18K Eqv.for All Trucks Counted	404.9	3627.2	184.3	88.7	4305.1
% Distribution of 18K Eqv.	9.40	84.26	4.28	2.06	100.00

Source: South Dakota Truck Weight Study, 1981, Table W-4. Data are for four combined Interstate rural stations.

Table 48. Vehicles Counted at Four Rural Interstate Truck Weight Stations in 1981.

	Sta A	Sta B	Sta C	Sta D	All Sta.	Percent
Cars	5623	4185	4038	4595	18441	62.3
Buses	25	32	22	10	89	0.3
Single Unit Trucks	2364	1458	1700	1644	7166	24.3
Tractor Semitrailer	726	535	1339	906	3506	11.9
Semitrailer Trailer	31	36	64	24	155	0.5
Truck & Trailer	38	5	15	23	81	0.3
Total Traffic	8807	6251	7178	7202	29438	100.0
Total Trucks	3159	2034	3118	2597	10908	
ADT	7666	3730	9826	6240	27462	

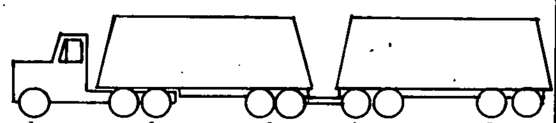
Source: South Dakota Truck Weight Study, 1981 Table W-1

Table 49. Axle Loads and 18-Kip Equivalents.

Axle Loads in Pounds	18-Kip Axle Equivalency Factor: Rigid Pavement P=2.5,D=9"	18-Kip Axle Equivalency Factor: Flexible Pavement P=2.5, SN=5
Single Axles		
Under 3000	0.0002	0.0002
3,000 - 6,999	0.005	0.005
7,000 - 7,999	0.026	0.032
8,000 - 11,999	0.082	0.087
12,000 - 15,999	0.341	0.360
16,000 - 18,000	0.783	0.796
18,001 - 18,500	1.065	1.060
18,501 - 20,000	1.336	1.307
20,001 - 21,999	1.926	1.826
22,000 - 23,999	2.818	2.583
24,000 - 25,999	3.976	3.533
26,000 - 29,999	6.289	5.389
30,000 or Over	11.395	9.432
Tandem Axles		
Under 6000	0.010	0.010
6,000 - 11,999	0.010	0.010
12,000 - 17,999	0.062	0.044
18,000 - 23,999	0.253	0.148
24,000 - 29,999	0.729	0.426
30,000 - 32,000	1.305	0.753
32,001 - 32,500	1.542	0.885
32,501 - 33,999	1.751	1.002
34,000 - 35,999	2.165	1.230
36,000 - 37,999	2.721	1.533
38,000 - 39,999	3.373	1.885
40,000 - 41,999	4.129	2.289
42,000 - 43,999	4.997	2.749
44,000 - 45,999	5.987	3.269
46,000 - 49,999	7.725	4.170
50,000 or Over	10.160	5.100

Source: W-4 Tables.

Table 50. Example Vehicle Characteristics.



Approximate Weights

Tractor less fuel and driver	14,000 lbs
Fuel at 200 gallons	1,600 lbs
Trailers (each)	9,100 lbs
Tandem axle dolly	5,080 lbs
Maximum allowable gross	129,000 lbs
Less tare weight	38,880 lbs
Maximum payload	90,120 lbs

Axle or Tandem	1	2	3	4	5
Weight Distribution					
Tractor	70%	30%			
Trailer		40%	60%	40%	60%
Tandem axle dolly				100%	
Payload		50%	50%	50%	50%
Net Weight					
Tractor	10920	4680			
Trailer		3640	5460	3640	5460
Tandem axle dolly				5080	
Payload		22530	22530	22530	22530
Total loaded	10920	30850	27990	31250	27990
Total empty	10920	8320	5460	8720	5460
18-Kip Equivalents (Rigid Pavement)					
Loaded	0.1	1.3	0.7	1.3	0.7
Empty	0.1	0.01	0.01	0.01	0.01

percent of the trucks reported during the summer of 1981 (1627 vehicles).

Step 2 -- Obtain Truck Weight Study W-4 Data. Most states prepare W-4 data only for a limited number of locations, even though a far more extensive truck-weighing program may be used for weight limit enforcement purposes. Step 2 involves obtaining such truck weight data as are available, and then extending this information to other highway segments using average daily traffic and vehicle classification data or estimates from Step 1.

Because the W-4 data in this example are aggregated for four locations, the data in Table 47 must be allocated to each station. Because Station B is located on the portion of the Interstate affected by the shift to trucks, the 18-kip equivalent for that station can be apportioned on the basis of traffic volumes:

	Sta B	All Sta	Percent
Single unit trucks	1458	7166	20.3
Tractor semi-trailer	535	3506	15.3
Semi-trailer trailer	36	155	23.2
Truck and trailer	5	81	6.2

Step 3 -- Compute Base Case EALA. Base year EALA is first computed for the total traffic mix on a segment basis. If the application involves multiple years, separate EALA estimates are then prepared for the base and each forecast year by segment.

In this example, base year average daily EALA for Station B is estimated in the following manner:

	EALA-4 Sta.	Sta B Percent	Sta B EALA	Adj EALA
Single unit trucks	451.6	20.3	91.9	73.5
Tractor/semi-trailer	5922.4	15.3	903.7	723.0
Semi-trailer/trailer	198.8	23.2	46.2	37.0
Truck and trailer	132.2	6.2	8.2	6.6
Station Total			1049.9	840.1

Step 4 -- Compute Alternative EALA. The next step is to compute the EALA for each alternative, using the vehicle types and equivalents selected earlier. This is then added (or subtracted) from the EALA computed in Step 3.

Table 50 gives the EALA fronthaul and backhaul computations for this example on a per vehicle trip basis. Because the total movement consists of 8 round-trips per day, alternative EALA equals base EALA plus the EALA of the additional vehicles or 840.1 + 33.6 or 873.7 per day.

Step 5 -- Compute Change in EALA. Base case EALAs from Step 3 are then subtracted from the EALAs determined in Step 4 to determine the change in EALA on a segment basis. This can be expressed either as an absolute number or as a percent change.

In this example, the change in daily EALA is 840.1 to 873.7 or 33.6. This represents a 4 percent increase. Such a change may or may not be significant, however, and depends on the impact of the projected change in shortening remaining pavement service life.

CHANGE IN SERVICE LIFE

Although segment-level information on vehicle flows and equivalent annual load applications is helpful, neither directly addresses the issue most keenly felt by states -- changes in highway investment needs. Pavements deteriorate both from aging or weathering and from the loads imposed on them. Increasing either the number of trucks or average loadings shortens pavement life. Whether a projected increase is significant depends on the strength and condition of the pavement structure as well as the magnitude of the additional (or lessened) load placed on the pavement.

In many states, a detailed system-wide study of the present condition and projected remaining life of state highways has not been undertaken, although state action to implement a pavement management system necessitates that information be assembled from which to estimate remaining service life on a segment basis. Included are data on (1) pavement condition, obtained through both surface examination and nondestructive testing of pavement structure (e.g., measuring deflection under prescribed loadings); (2) pavement physical structure, obtained through analyzing of soil conditions and obtaining pavement core samples, and by researching previous construction contracts and maintenance improvements to determine the type and amount of materials used; and (3) present and projected truck traffic and equivalent annual load applications.

Figure 34 shows a subtechnique that can be used to compute the change in service life. The subtechnique was originally developed by FHWA in the late 1960's for use in highway needs studies (23). It is dependent on four inputs:

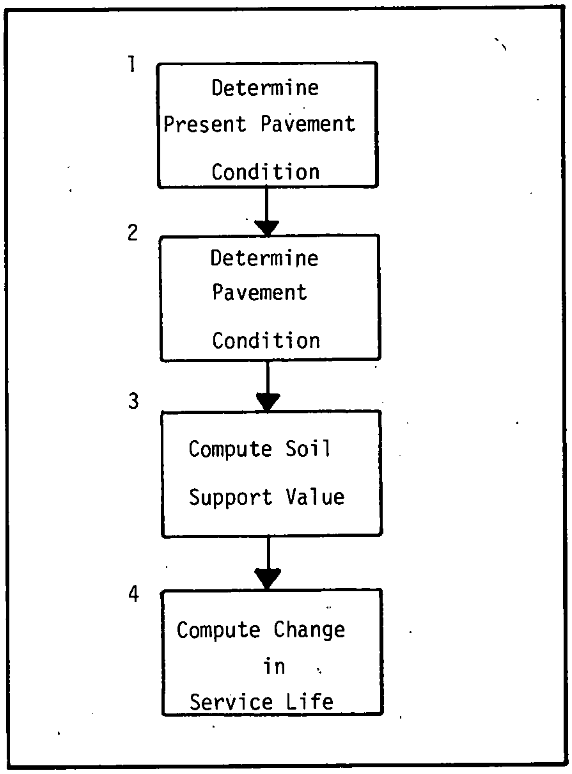


Figure 34. Service Life Subtechnique.

1. Present pavement condition (PSR, PSI or the equivalent).
2. Pavement structure or thickness, expressed as the structural number (SN), slab thickeners (D), or correlation thereto.
3. Number of equivalent annual load applications presently being applied to the roadway.
4. Estimated annual traffic growth (rate).

Many states have their own procedures for determining remaining service life. Such procedures often provide a more precise method for measuring pavement conditions, pavement structure, and soil support value, and thus can be substituted for the subtechnique presented.

The following paragraphs describe component steps.

Step 1 -- Determine Present Pavement Condition. Present serviceability rating (PSR) or present serviceability index (PSI) ratings, if available, should be used. If not available, states should either undertake the field work required to make PSR, PSI, or comparable pavement condition measurements, or develop a correlation between the sufficiency rating scale and the PSR scale so that existing ratings may be utilized, assuming that current sufficiency ratings for pavement condition (excluding geometrics) are available. If recent PSR, PSI, or sufficiency ratings are not available, it is possible to approximate PSR by using Figure 35.

PSR Range	Verbal Rating	Description
5		
	Very good	Only new (or nearly new pavements are likely to be smooth enough and sufficiently free of cracks and patches to qualify for this category. All pavements constructed or resurfaced during previous year should be rated very good.
4		
	Good	Pavements in this category, although not quite as smooth as those described above, give a first-class ride and exhibit few, if any, visible signs of surface deterioration. Flexible pavements may be beginning to show evidence of rutting and fine random cracks. Rigid pavements may be beginning to show evidence of slight surface deterioration, such as minor cracks and spalling.
3		
	Fair	The riding qualities of pavements in this category are noticeably inferior to those of new pavements, and may be barely tolerable for high-speed traffic. Surface defects of flexible pavements may include rutting, map cracking, and more or less extensive patching. Rigid pavements in this group may have a few joint failures, faulting and cracking, and some pumping.
2		
1	Intolerable	These pavements, corresponding to the PSR poor and very poor categories, have deteriorated to such an extent that they are in need of resurfacing.
0		

Source: FHWA, National Highway Functional Classification and Needs Manual.

Figure 35. Approximate PSR Values.

Step 2 -- Determine Pavement Structure. If available, the structural number (SN for flexible pavements) or the slab thickness (D for rigid pavements) should be used. If not available, states can estimate SN or D values by taking core samples or researching previous construction contracts and maintenance improvements to determine the amount and type of materials comprising the pavement structure. If necessary manpower or sufficient time is not available, it is possible to approximate SN and D values by using Table 51.

Step 3 -- Compute Soil Support Value. The soil support value S, required in the evaluation of flexible pavements, is expressed in an abstract scale that can be related to certain soil test procedures. Figure 36 provides approximate correlations for CBR, R-Value, and Group Index.

The roadbed soils of the AASHO Road Test have an S value of 3.0 (21). When the S value for a particular area is either substantially greater (S=6 or more) or less (S=1.5 or less) than the S value measured at the AASHO Road Test, an adjustment must be made to the pavement structure value to account for the difference in performance ability. See Table 52. (It is anticipated that the general soils characteristics of the area under consideration would be compared with those of the AASHO Road Test and that comprehensive soils tests would not be conducted on a segment basis.)

Step 4 -- Compute Change in Service Life. The procedure for accomplishing this is best illustrated by an example. Assume the following situation:

1. Flexible pavement - Medium (SN=3.1 - 4.5).
2. Soil support value - Substantially greater than AASHO (S = 6 or more).
3. Present pavement condition - Fair (PSR or PSI = 2.1 - 3.0).
4. Minimum tolerable condition - PSR = 2.1.
5. Present ADT = 15,000.
6. Percent total trucks and combinations = 12 percent.
7. Number of traffic lanes = 4.
8. Percent vehicles in critical lane = 40 percent.
9. 18-kip single axle equivalent constant = 0.720.
10. Annual traffic growth rate = 4 percent.

First from Table 53, a medium pavement structure (SN=3.1-4.5) with an S value of 6 or more must be increased to a heavy pavement structure (SN = 4.6 - 6.0).

Next, EALA is computed. In this case, EALA = 15,000 x 0.12 x 0.40 x 0.720 x 365 = 189,216.

Next, Table 53 is entered in the general section identified as "Heavy Pavement Structure" and "4 to 6 percent Traffic Growth Rate." Under the column "Pavement Condition-Fair," the ranges of EALA values are searched until the range corresponding to the EALA of 189,216 is found. The years of remaining life in 5-year increments are read directly from the column "Years of Remaining Life" and the line for the EALA range. As illustrated in Table 53 for the example, the years of remaining life are 11 to 15 years.

If the S value in the foregoing example above had been between 1.6 and 5.9, the pavement structure value would not have required adjustment. Consequently, Table 53 would have been entered in the section identified as "Medium Pavement Structure," and the years of remaining life would have been 1 to 5 years.

A similar procedure is followed in determining the years of remaining life for rigid pavements.

ENERGY CONSUMPTION

During recent energy crises, considerable interest was expressed in the energy efficiency or inten-

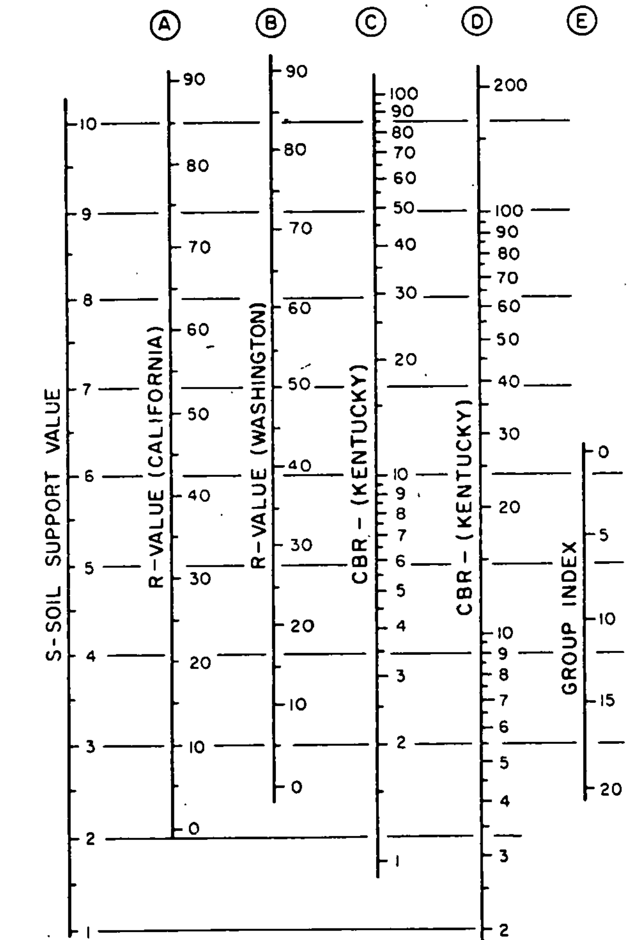
Table 51. Approximate SN and D Values.

Type of Section	SN Range	Flexible Pavement: Surface Type & Thickeners	Flexible Pavement: Base Type & Thickeners	Flexible Pavement: Subbase type & Thickeners	Flexible Pavement: Combined Depth 1/	Rigid Pavement: Range in Pavement Thickeners D
Heavy	4.6-6.0	4" asphaltic concrete	9" crushed stone to PC concrete	4" gravel 2/	> 12"	9.1-11.0 (8" if continuously reinforced)
Medium	3.1-4.5	3" asphaltic concrete	8" gravel to pene-tration macadam	4" gravel	11"-12"	7.1-9.0" (6" if continuously reinforced)
Light	1.0-3.0	Surface Treatment to 2" asphaltic concrete	6" gravel or crushed stone	2" gravel or sand	10" or less	6.0-7.0"

1/ To be used as a guide where only the total depth is known or estimated.

2/ Subbase course not necessary under portland cement concrete base.

Source: FHWA, National Highway Functional Classification and Needs Study Manual



Source: FHWA, National Highway Functional Classification and Needs Study Manual.

Figure 36. Correlation Chart for Estimating Soil Support Value.

Table 52. Adjustment to Pavement Structure Value to Account for Difference in Soil Support Value.

Soil Support Value	Pavement structure value: Light SN = 1.0-3.0	Pavement structure value: Medium SN = 3.1-4.5	Pavement structure value: Heavy SN = 4.6-6.0
1.5 or less	No change	Decrease to light	Decrease to medium
1.6 - 5.9	No change	No change	No change
6.0 or more	Increase to medium	Increase to heavy	No change

Source: FHWA, National Highway Functional Classification and Needs Study Manual

siveness of different modes and services. Thus, one of the products of a freight demand forecasting technique is a capability to produce order-of- magnitude estimates of energy consumption.

Estimating energy consumption can be quite complex, as evidenced by the factors given in Table 54. Accounting for all such factors necessitates the use of vehicle performance simulators, a level of sophistication and detail inappropriate for statewide applications. In lieu thereof, a relatively simple subtechnique using the concept of energy intensity is presented in the following paragraphs.

Energy intensity is simply energy use per unit of productive output (32):

$$EI = \text{Energy Intensity} = \frac{\text{Energy Use}}{\text{Productive Output}}$$

Table 53. Rigid Pavement - Remaining Service Life (Minimum Tolerable Condition - PSR = 2.1).

Table H-1--Rigid pavement-remaining service life (minimum tolerable condition-PSR=2.1)

Pavement thickness	Years of remaining life	Annual traffic growth								
		1 to 3 percent			4 to 6 percent			7 percent and over		
		Pavement condition			Pavement condition			Pavement condition		
		Very good	Good	Fair	Very good	Good	Fair	Very good	Good	Fair
		Present equivalent annual 18-kip single-axle load applications (EALA)								
Light (D=6.0-7.0)	Over 20	Less than 17,999	Less than 10,999	Less than 3,999	Less than 12,999	Less than 7,999	Less than 2,999	Less than 8,999	Less than 4,999	Less than 1,999
	16-20	18,000 to 26,999	11,000 to 14,999	4,000 to 4,999	13,000 to 20,999	8,000 to 11,999	3,000 to 3,999	9,000 to 15,999	5,000 to 8,999	2,000 to 2,999
	11-15	27,000 to 42,999	15,000 to 24,999	5,000 to 7,999	21,000 to 36,999	12,000 to 21,999	4,000 to 6,999	16,000 to 30,999	9,000 to 17,999	3,000 to 5,999
	6-10	43,000 to 92,999	25,000 to 53,999	8,000 to 17,999	37,000 to 87,999	22,000 to 50,999	7,000 to 16,999	31,000 to 80,999	18,000 to 46,999	6,000 to 14,999
	1-5	93,000 or more	54,000 or more	18,000 or more	88,000 or more	51,000 or more	17,000 or more	81,000 or more	47,000 or more	15,000 or more
Medium (D=7.1-9.0)	Over 20	Less than 103,999	Less than 70,999	Less than 21,999	Less than 75,999	Less than 51,999	Less than 15,999	Less than 48,999	Less than 32,999	Less than 9,999
	16-20	104,000 to 150,999	71,000 to 101,999	22,000 to 31,999	76,000 to 119,999	52,000 to 81,999	16,000 to 25,999	49,000 to 87,999	33,000 to 59,999	10,000 to 18,999
	11-15	151,000 to 242,999	102,000 to 164,999	32,000 to 51,999	120,000 to 211,999	82,000 to 143,999	26,000 to 44,999	88,000 to 174,999	60,000 to 118,999	19,000 to 37,999
	6-10	243,000 to 527,999	165,000 to 357,999	52,000 to 112,999	212,000 to 499,999	144,000 to 338,999	45,000 to 106,999	175,000 to 458,999	119,000 to 310,999	38,000 to 97,999
	1-5	528,000 or more	358,000 or more	113,000 or more	500,000 or more	339,000 or more	107,000 or more	459,000 or more	311,000 or more	98,000 or more
Heavy (D=9.1-11.0)	Over 20	Less than 571,999	Less than 382,999	Less than 125,999	Less than 417,999	Less than 279,999	Less than 91,999	Less than 268,999	Less than 179,999	Less than 58,999
	16-20	572,000 to 827,999	383,000 to 553,999	126,000 to 182,999	418,000 to 660,999	280,000 to 441,999	92,000 to 145,999	269,000 to 483,999	180,000 to 323,999	59,000 to 106,999
	11-15	828,000 to 1,338,999	554,000 to 895,999	183,000 to 295,999	661,000 to 1,166,999	442,000 to 779,999	146,000 to 257,999	484,000 to 961,999	324,000 to 643,999	107,000 to 212,999
	6-10	1,339,000 to 2,905,999	896,000 to 1,942,999	296,000 to 641,999	1,167,000 to 2,749,999	780,000 to 1,838,999	258,000 to 606,999	962,000 to 2,524,999	644,000 to 1,687,999	213,000 to 556,999
	1-5	2,906,000 or more	1,943,000 or more	642,000 or more	2,750,000 or more	1,839,000 or more	607,000 or more	2,525,000 or more	1,688,000 or more	557,000 or more

Table H-2--Flexible pavement-remaining service life (minimum tolerable condition-PSR=2.1)

Pavement structure	Years of remaining life	Annual traffic growth								
		1 to 3 percent			4 to 6 percent			7 percent and over		
		Pavement condition			Pavement condition			Pavement condition		
		Very good	Good	Fair	Very good	Good	Fair	Very good	Good	Fair
		Present equivalent annual 18-kip single-axle load applications (EALA)								
Light (SN=1.0-3.0)	Over 20	Less than 699	Less than 499	Less than 99	Less than 499	Less than 299	Less than 99	Less than 299	Less than 199	Less than 59
	16-20	700 to 999	500 to 699	100 to 199	500 to 899	300 to 499	100 to 199	300 to 599	200 to 399	60 to 99
	11-15	1,000 to 1,999	700 to 999	200 to 299	900 to 1,499	500 to 999	200 to 299	600 to 999	400 to 799	100 to 199
	6-10	2,000 to 3,999	1,000 to 1,999	300 to 699	1,500 to 3,999	1,000 to 1,999	300 to 599	1,000 to 2,999	800 to 1,999	200 to 599
	1-5	4,000 or more	2,000 or more	700 or more	4,000 or more	2,000 or more	600 or more	3,000 or more	2,000 or more	600 or more
Medium (SN=3.1-4.5)	Over 20	Less than 30,999	Less than 23,999	Less than 8,999	Less than 22,999	Less than 16,999	Less than 6,999	Less than 13,999	Less than 10,999	Less than 3,999
	16-20	31,000 to 44,999	24,000 to 33,999	9,000 to 12,999	23,000 to 35,999	17,000 to 26,999	7,000 to 9,999	14,000 to 25,999	11,000 to 19,999	4,000 to 7,999
	11-15	45,000 to 71,999	34,000 to 55,999	13,000 to 20,999	36,000 to 62,999	27,000 to 47,999	10,000 to 17,999	26,000 to 51,999	20,000 to 39,999	8,000 to 14,999
	6-10	72,000 to 156,999	56,000 to 120,999	21,000 to 44,999	63,000 to 147,999	48,000 to 113,999	18,000 to 42,999	52,000 to 135,999	40,000 to 104,999	15,000 to 38,999
	1-5	157,000 or more	121,000 or more	45,000 or more	148,000 or more	114,000 or more	43,000 or more	136,000 or more	105,000 or more	39,000 or more
Heavy (SN=4.6-6.0)	Over 20	Less than 356,999	Less than 311,999	Less than 151,999	Less than 260,999	Less than 227,999	Less than 110,999	Less than 167,999	Less than 146,999	Less than 71,999
	16-20	357,000 to 515,999	312,000 to 451,999	152,000 to 219,999	261,000 to 411,999	228,000 to 360,999	111,000 to 175,999	168,000 to 301,999	147,000 to 263,999	72,000 to 128,999
	11-15	516,000 to 834,999	452,000 to 729,999	220,000 to 356,999	412,000 to 726,999	361,000 to 635,999	176,000 to 310,999	302,000 to 599,999	264,000 to 524,999	129,000 to 255,999
	6-10	835,000 to 1,810,999	730,000 to 1,584,999	357,000 to 773,999	727,000 to 1,713,999	636,000 to 1,499,999	311,000 to 731,999	600,000 to 1,573,999	525,000 to 1,376,999	256,000 to 671,999
	1-5	1,811,000 or more	1,585,000 or more	774,000 or more	1,714,000 or more	1,500,000 or more	732,000 or more	1,574,000 or more	1,377,000 or more	672,000 or more

Table 53. Rigid Pavement - Remaining Service Life (Minimum Tolerable Condition - PSR = 2.1). Continued

Table H-3--Rigid pavement-remaining service life (minimum tolerable condition-PSR=2.6)

Pavement thickness	Years of remaining life	Annual traffic growth: 1 to 3 percent, Pavement condition: Very good	Good	Fair	4 to 6 percent, Pavement condition: Very good	Good	Fair	7 percent and over, Pavement condition: Very good	Good	Fair
		Present equivalent annual 18-kip single-axle load applications (EALA)								
Light (D=6.0-7.0)	Over 20	Less than 16,999	Less than 7,999	Less than 2,999	Less than 11,999	Less than 5,999	Less than 1,999	Less than 7,999	Less than 3,999	Less than 999
	16-20	17,000 to 23,999	8,000 to 11,999	3,000 to 3,999	12,000 to 18,999	6,000 to 8,999	2,000 to 2,999	8,000 to 13,999	4,000 to 6,999	1,000 to 1,999
	11-15	24,000 to 38,999	12,000 to 18,999	4,000 to 5,999	19,000 to 33,999	9,000 to 16,999	3,000 to 4,999	14,000 to 27,999	7,000 to 13,999	2,000 to 3,999
	6-10	39,000 to 84,999	19,000 to 40,999	6,000 to 12,999	34,000 to 79,999	17,000 to 38,999	5,000 to 11,999	28,000 to 72,999	14,000 to 35,999	4,000 to 10,999
	1-5	85,000 or more	41,000 or more	13,000 or more	80,000 or more	39,000 or more	12,000 or more	73,000 or more	36,000 or more	11,000 or more
Medium (D=7.1-9.0)	Over 20	Less than 81,999	Less than 44,999	Less than 12,999	Less than 59,999	Less than 32,999	Less than 9,999	Less than 37,999	Less than 20,999	Less than 5,999
	16-20	82,000 to 117,999	45,000 to 64,999	13,000 to 18,999	60,000 to 93,999	33,000 to 51,999	10,000 to 14,999	38,000 to 68,999	21,000 to 37,999	6,000 to 10,999
	11-15	118,000 to 190,999	65,000 to 103,999	19,000 to 30,999	94,000 to 166,999	52,000 to 90,999	15,000 to 26,999	69,000 to 137,999	38,000 to 74,999	11,000 to 22,999
	6-10	191,000 to 414,999	104,000 to 225,999	31,000 to 67,999	167,000 to 392,999	91,000 to 213,999	27,000 to 63,999	138,000 to 360,999	75,000 to 196,999	23,000 to 58,999
	1-5	415,000 or more	226,000 or more	68,000 or more	393,000 or more	214,000 or more	64,000 or more	361,000 or more	197,000 or more	59,000 or more
Heavy (D=9.1-11.0)	Over 20	Less than 441,999	Less than 241,999	Less than 73,999	Less than 322,999	Less than 176,999	Less than 53,999	Less than 207,999	Less than 112,999	Less than 34,999
	16-20	442,000 to 639,999	242,000 to 348,999	74,000 to 107,999	323,000 to 510,999	177,000 to 278,999	54,000 to 85,999	208,000 to 373,999	113,000 to 203,999	35,000 to 62,999
	11-15	640,000 to 1,034,999	349,000 to 564,999	108,000 to 173,999	511,000 to 901,999	279,000 to 491,999	86,000 to 151,999	374,000 to 743,999	204,000 to 405,999	63,000 to 124,999
	6-10	1,035,000 to 2,244,999	565,000 to 1,225,999	174,000 to 376,999	902,000 to 2,124,999	492,000 to 1,160,999	152,000 to 356,999	744,000 to 1,950,999	406,000 to 1,065,999	125,000 to 327,999
	1-5	2,245,000 or more	1,226,000 or more	377,000 or more	2,125,000 or more	1,161,000 or more	357,000 or more	1,951,000 or more	1,066,000 or more	328,000 or more

Table H-4--Flexible pavement-remaining service life (minimum tolerable condition-PSR=2.6)

Pavement structure	Years of remaining life	Annual traffic growth: 1 to 3 percent, Pavement condition: Very good	Good	Fair	4 to 6 percent, Pavement condition: Very good	Good	Fair	7 percent and over, Pavement condition: Very good	Good	Fair
		Present equivalent annual 18-kip single-axle load applications (EALA)								
Light (SN=1.0-3.0)	Over 20	Less than 599	Less than 299	Less than 69	Less than 499	Less than 199	Less than 49	Less than 299	Less than 199	Less than 29
	16-20	600 to 899	300 to 499	70 to 99	500 to 699	200 to 399	50 to 89	300 to 499	200 to 299	30 to 59
	11-15	900 to 1,499	500 to 699	100 to 199	700 to 1,299	400 to 699	90 to 199	500 to 1,099	300 to 499	60 to 99
	6-10	1,500 to 3,199	700 to 1,599	200 to 399	1,300 to 2,999	700 to 1,499	200 to 399	1,100 to 2,799	500 to 1,399	100 to 299
	1-5	3,200 or more	1,600 or more	400 or more	3,000 or more	1,500 or more	400 or more	2,800 or more	1,400 or more	300 or more
Medium (SN=3.1-4.5)	Over 20	Less than 21,999	Less than 14,999	Less than 3,999	Less than 15,999	Less than 10,999	Less than 2,999	Less than 9,999	Less than 6,999	Less than 1,999
	16-20	22,000 to 31,999	15,000 to 21,999	4,000 to 5,999	16,000 to 25,999	11,000 to 16,999	3,000 to 4,999	10,000 to 18,999	7,000 to 12,999	2,000 to 3,999
	11-15	32,000 to 51,999	22,000 to 34,999	6,000 to 9,999	26,000 to 44,999	17,000 to 29,999	5,000 to 8,999	19,000 to 37,999	13,000 to 24,999	4,000 to 7,999
	6-10	52,000 to 112,999	35,000 to 75,999	10,000 to 22,999	45,000 to 106,999	30,000 to 71,999	9,000 to 20,999	38,000 to 97,999	25,000 to 65,999	8,000 to 19,999
	1-5	113,000 or more	76,000 or more	23,000 or more	107,000 or more	72,000 or more	21,000 or more	98,000 or more	66,000 or more	20,000 or more
Heavy (SN=4.6-6.0)	Over 20	Less than 207,999	Less than 170,999	Less than 66,999	Less than 151,999	Less than 124,999	Less than 48,999	Less than 97,999	Less than 79,999	Less than 30,999
	16-20	208,000 to 300,999	171,000 to 246,999	67,000 to 96,999	152,000 to 239,999	125,000 to 196,999	49,000 to 76,999	98,000 to 175,999	80,000 to 144,999	31,000 to 56,999
	11-15	301,000 to 486,999	247,000 to 399,999	97,000 to 156,999	240,000 to 423,999	197,000 to 347,999	77,000 to 135,999	176,000 to 349,999	145,000 to 287,999	57,000 to 112,999
	6-10	487,000 to 1,056,999	400,000 to 867,999	157,000 to 339,999	424,000 to 999,999	348,000 to 820,999	136,000 to 320,999	350,000 to 917,999	288,000 to 753,999	113,000 to 294,999
	1-5	1,057,000 or more	868,000 or more	340,000 or more	1,000,000 or more	821,000 or more	321,000 or more	918,000 or more	754,000 or more	295,000 or more

Table 54. Factors Affecting Energy Consumption.

Mode	Vehicle-Related Factors	Roadbed and Operational Factors	Load Factors
Rail	Size and weight of the rail car (ratio of net to gross tonnage). Type and size of the locomotive. Fuel consumption rate in gal per hp-hr or gal per ton-mile.	Number of trains operated. Track profile and curvature. Maximum operating speed. Number of slow orders. Sections having reduced speeds.	Train size. Mix of empty and full cars. Commodity weight carried per car. Ton-miles (metric ton-kilometres) shipped, by commodity type. Empty return ratio. Commodity weight carried per truck.
Truck	Type and size of truck. Fuel consumption rate in gal per hp-hr or gal per ton-mile.	General route profile. Average operating speed. Number of stops required. Number of speed changes.	Empty/return ratio. Commodity weight carried per vehicle. Ton-miles (metric ton-kilometres) shipped, by commodity type.
Port/ Inland Waterway	Type and size of vessel. Condition of hull. Fuel consumption rate in gal per hp-hr or gal per ton-mile.	Speed of river currents (upstream and downstream). Vessel operating speed and draft. Circuity between origin and destination.	Empty return ratio. Commodity weight carried per vehicle. Ton-miles (metric ton-kilometres) shipped, by commodity type.

Source: NCHRP Report 177, p. 122

While conceptually simple, past research has produced a widely divergent set of values for the different freight modes. This variation stems from (1) changes in modal operating characteristics and equipment over time, (2) variations in inclusiveness, especially that relating to energy used for purposes not directly related to linehaul transport, (3) density and characteristics of the commodities being shipped, (4) level of aggregation employed by the researcher, and (5) differing values used in translating energy use (e.g., gallons, kwh) into corresponding British thermal units.

Before using published energy intensity values, users should determine how the values were originally calculated and whether they are compatible with the intended application. In applying energy intensity values, users should:

1. Recognize that a change in total demand for a given mode will have differing effects on demands within the components of that mode. When such changes occur, use of the base case EI value is no longer applicable. The EI for the alternative being considered must be computed using the new mix of component activities within that mode and any changes in efficiency that may have occurred as a result of changes in the scale of operations.
2. When making intermodal comparisons, the data should be normalized for transit time, quality of service, and modal circuities. Although it may not be possible to quantitatively normalize the data for the first two factors, the user must recognize that considerable differences may exist that could have a major impact on the estimates produced. Such comparisons should be made using actual route miles (or airline distance times an appropriate circuity factor), and be done on a disaggregated basis, thereby reflecting competitive segments, commodities, and shipment lengths. Use of commodity and service specific EI values is highly recommended. Inclusion of indirect energy consumption (e.g., for supporting infrastructures and operational facilities) should also be considered.

Before undertaking energy intensity calculations, users are encouraged to review various publications providing details on the calculations themselves and the underlying data resources (25-36).

USER TAX REVENUE

Assuming that estimates of energy consumption (in gallons) have been developed, the potential change in revenues derived from per gallon user taxes can be readily estimated. Such estimates may not closely match state revenue data, however, because the larger carriers often purchase significant quantities of fuel from terminals in other states. Changes in sales tax revenue can similarly be estimated from estimates of energy consumption.

RESULTING PRODUCT

Provided that the user desires information on vehicle flows over the transportation network, and thus has (1) reduced the transportation network to a series of segments, (2) converted base case and alternative commodity flows to vehicle equivalents, and (3) assigned vehicle equivalents to a network, the resulting product of Traffic Assignment is a record consisting of:

- Segment or Link Identification
- Traffic -- Reported (all movements)
  - -- Base Case Only (selected commodities or movements)
  - -- Alternative Only (selected commodities or movements)
  - -- Reported + (Alternative-Base Case)

- Optional: EALA - Base Case
  - Alternative

  Remaining Service Life -- Base Case
  -- Alternative

  Energy Consumption -- Base Case
  -- Alternative

  User Tax Revenues -- Base Case
  -- Alternative

One record is prepared for each segment identified. The user has numerous options, such as (1) to include different modes, (2) to use manual or computerized methods, and (3) for the highway network, to compute equivalent annual load applications, estimate remaining service life, or approximate energy consumption and user tax revenues on a segment basis.

Once the above record has been assembled, segment and system level summaries can be readily prepared showing base case and alternative totals as well as projected change. If so desired, the results can be plotted provided that coordinates have been included in the resulting record.

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CHAPTER SIX

CASE EXAMPLES

INTRODUCTION

Previous chapters have provided the user with guidance in defining the problem, structuring the technique to address the problem, and simplifying and adapting both problem and technique to meet applicable constraints. A variety of subtechniques have been provided for use in addressing different phases and components. The subtechniques presented are conceptually simple and straight-forward. Some can be applied manually; others are best done using a computer. In most cases, specific examples have been provided to illustrate how the subtechniques can be applied.

The purpose of this chapter is to illustrate the application of the technique by using several case examples. In reviewing the examples, users should recognize that the individuality of freight planning applications makes it unlikely that any case example can directly serve as a model for similar on-going work. Most applications will necessitate innovativeness and resourcefulness on the part of the user.

It is important to keep in mind also that an in-depth explanation of the choices made among candidate analytical methods and/or data sources has not been included, because it would not be relevant to most readers. A sensitivity analysis of the results to the assumptions made or computational process employed has not been shown, even though such testing is commonly done, because of the the length and complexity of the examples. However, users are encouraged to include a sensitivity assessment when applying the freight demand forecasting technique. Finally, comparisons of the results obtained with similar studies have not been attempted because of the uniqueness of the case examples.

GENERAL DESCRIPTION

The first two case examples are abridgements of previously completed studies undertaken by the researchers. While it can be argued that a post-study application of the technique does not provide a true test or "shakedown" of the technique, the availability of commodity flow, cost, and rate data reduced the time and effort that would have been required had the application started "from scratch." In both cases, the conclusions reached were borne out by subsequent events.

The third case example, which was expressly undertaken for this project, was an informal examination of Roadrailer service in the Buffalo-New York City corridor. The case example chosen involves examining volume, rate and cost structures of the service to estimate the point at which services become competitive with trucking, and thus can survive on a self-sustaining basis. Roadrailer is a dual-mode semi-trailer having flanged wheels which can be assembled into trains for linehaul movement over the rail system. It is similar to TOFC (trailer-on-flat-car) except that it obviates the need for the flat car. Its main competition is trucking. The Buffalo-New York City corridor was chosen by the Bi-Modal Corporation (the operator of the service) to demonstrate the feasibililty of intermodal services between markets 200-800 miles apart. (Approximately 73 percent of the national market for containerizable commodities lies within this distance range.)

Most of the computations illustrated by the case examples can be done with minicomputers or microcomputers. The latter are becoming increasingly available within government because of their low price and performance. A number of the applications could be done using commercially available generic software, such as VisiCalc or dBASE II. Otherwise, custom programming using BASIC or USCD Pascal would have to be employed. Because of compatibility problems stemming from different manufacturers' hardware and software, various operating systems, language variants, and differences in disk storage capabilities and formats, application specific software developed for a particular microcomputer may not be readily transportable to other machines. At the present time, relatively little public sector or proprietary software is available expressly for freight demand forecasting purposes. Nor are all applications appropriate for microcomputers (e.g., a main frame computer is required for rail costing using URCS).

CASE EXAMPLE A -- EXPECTED CHANGES IN COMMODITY FLOWS ON THE NEW YORK STATE BARGE CANAL SYSTEM

The Barge Canal Marketing Study

This case study was developed from the report, Barge Canal Marketing Study: Technical Report, and related data, worksheets, and notes prepared by Roger Creighton Associates Incorporated for the New York State Department of Transportation in 1978. Component tasks of the study included, among others, (1) determining actual and potential canal commodities through secondary sources and a shippers' survey; (2) computing transport costs (from the shipper's perspective) via the different modes, including terminal handling costs; and (3) identifying the transportation, economic and other benefits and impacts of increased utilization of the New York State Barge Canal System. Exhibits 1 and 2 show the location of the Barge Canal and the counties adjacent or contiguous to the canal system and connecting waterways.

Although centered on barge transport, the original study did require a corresponding in-depth examination of the rates and costs for canal-potential bulk commodity movements then being made by competing modes --pipeline, rail, and truck. The study focused heavily on petroleum product movements because (1) most of the traffic on the canal system consisted of petroleum products, and (2) there was a general lack of other high-volume bulk commodity movements susceptible to canal transport. The study involved determining changes in commodity flows, modal use, and shipper costs resulting from improving or modernizing all or portions of the canal system in comparison with continuation of the present facility as it currently exists. It did not require estimating the future production or consumption of commodities that might be transported via the canal system, because significant changes in the traffic base were not expected to occur. The original study focused primarily on economic rather than on physical changes or impacts; thus, preparation of simulated highway, rail or waterway networks and the computer programs needed to compute distances, determine minimum paths, and account for commodity and vehicle flows was not undertaken.

Purpose and Intent of the Case Example

This case example is designed to illustrate the general applicability of the freight demand forecasting technique. Beyond this, it illustrates its usefulness in situations where the study scope is constrained, such as in this case where the orientation was (1) modal, (2) largely economic rather than simultaneously being physical or impact-oriented, and (3) directed towards one particular group, which in this case were shippers rather than the carriers or government. The example can be classified as either a regional or a corridor study. It uses data typically available to state agencies, or obtainable from secondary sources or through contacts with shippers and carriers. While state-prepared waterway-based studies may not be all that common, since the Corps of Engineers has jurisdiction over

Exhibit 1. New York State Barge Canal System.

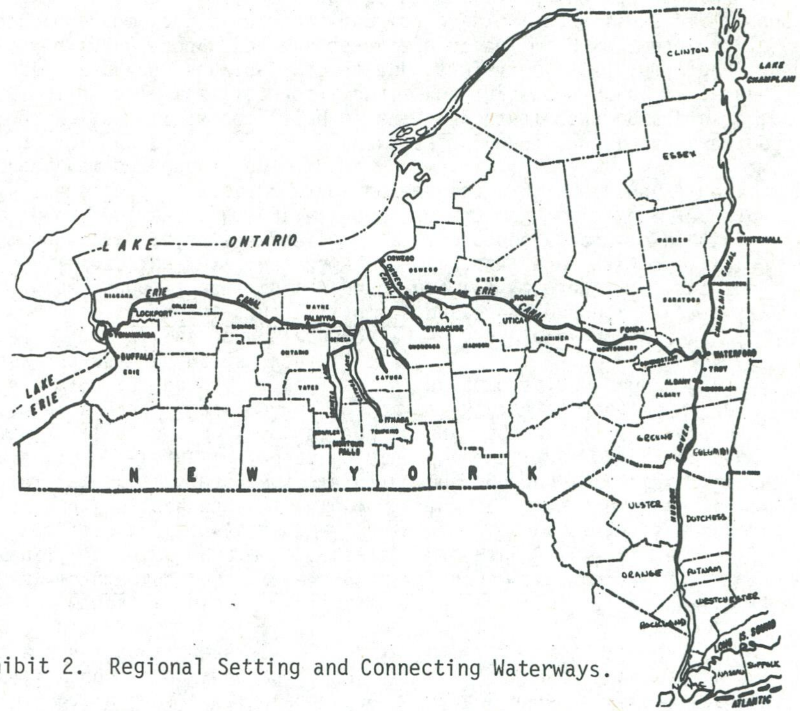
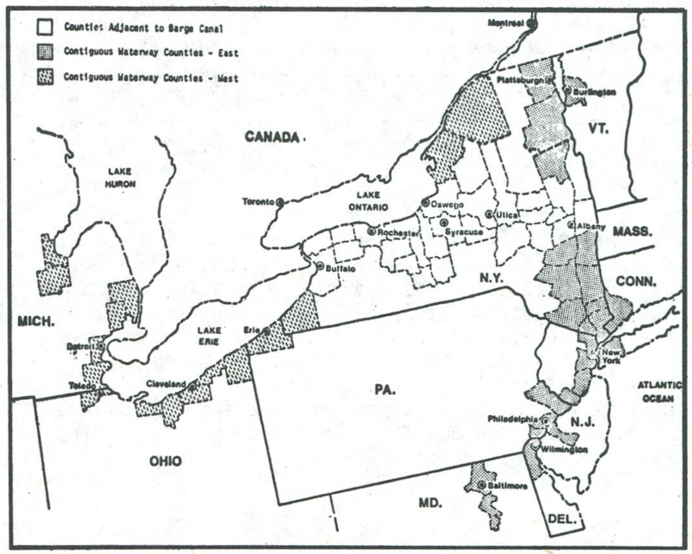


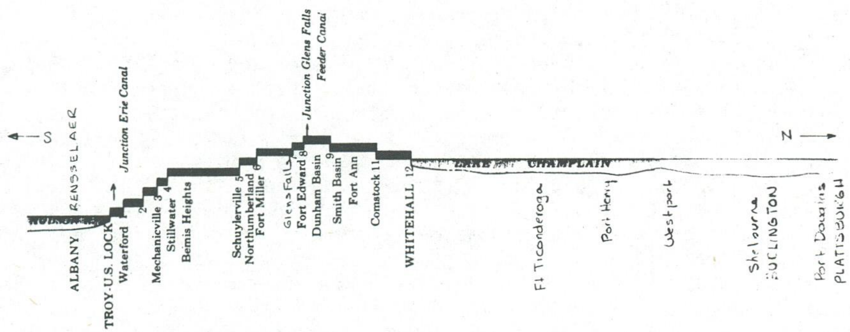
Exhibit 2. Regional Setting and Connecting Waterways.



most waterways in the United States, its larger purpose is to demonstrate how to go about assembling data and preparing commodity flow and unit cost and rate data, which can then be used to determine modal diversion and resulting costs and revenues. It also illustrates the specialized character and commodity nuances often encountered in freight demand studies.

The original study included up to eight different mode/physical configuration alternatives and divided the canal system into five market areas. Because the purpose of the case example is to illustrate how to apply the technique rather than to fully replicate the original data sets and computations, the case example has purposely been narrowed to one market area and five alternatives. The market area chosen includes the Hudson River between New York Harbor and the Troy Lock and Dam, the Champlain section of the Barge Canal, and Lake Champlain. Exhibit 3 provides a profile of the Champlain section. Although the traffic base of the Champlain section is exclusively petroleum products, other dry and liquid bulk commodity movements were transported in the past and thus represent potential traffic.

Exhibit 3. Profile of the Champlain Section.



The case example is based on the premise that a computer was used to perform the computations. Actually, the original computations were performed manually; however, they would have been performed on a microcomputer or minicomputer had such equipment been available at the time the study was conducted.

This case example is organized generally to correspond with the elements of the freight demand forecasting procedure given in Chapters Two through Four of the manual. The user will find that the presentation of each element, although specific to New York, contains concepts, ideas, procedures, equations, data sources, and outputs that should be helpful when undertaking similar work.

Defining the Problem

Stated Objective of the Study

"...first to define the cargo potential and transportation benefits of the NYS Barge Canal System and then, assuming potential exists, to develop an effective canal marketing strategy. Cargo potential and transportation benefits are to be evaluated under two different situations: first, continued operation of the canal without changing the physical dimensions of the locks and waterways, and second, improving or modernizing all, or portions of, the canal system to accommodate larger barges or tows." (Barge Canal Marketing Study: Technical Report, prepared for the New York State Department of Transportation, January 1979.)

General Parameters

1. Area of Interest -- Bulk commodity shippers located in counties contiguous to the NYS Barge Canal System or connecting waterways in the Great Lakes or Eastern Seaboard. Centroids are identified ports. Intermediate points shaping the application are the petroleum terminals or refineries located in Northern New Jersey (Port of New York) and at Albany/Rensselaer.

2. General Orientation of the Problem -- Facility oriented to the NYS Barge Canal, with resulting modal emphasis on barge transport. Overall focus is on changes in total costs (charges) incurred by shippers and consignees as a group in comparison with the existing situation.

3. Modes, Transport Facilities, and Services Utilized -- For highway movements, Interstate Routes 87 and 90 and Route 7 in Vermont; for waterborne movements, the NYS Barge Canal (Erie, Oswego and Champlain Sections), the Welland Canal, the Great Lakes, Hudson River, and the intercoastal waterways along the Eastern Seaboard; for rail, Conrail's east-west mainline through New York State, D&H's mainline from Albany to Rouses Point and branchline to Rutland, and Vermont Railway's line from Rutland to Burlington, VT; and for pipeline, product lines connecting Utica, Syracuse, Rochester, and Buffalo with the petroleum refineries and depots in northern New Jersey and eastern Pennsylvania.

4. Commodities Being Transported -- Since over 90 percent of present traffic on the canal system is petroleum products, commodity was further subdivided into (a) gasoline, (b) kerosene, (c) jet fuel, (d) distillate fuel oil (No. 2&3), (e) residual fuel oil, and (f) bituminous materials or asphalt. Existing nonpetroleum movements were largely cement. Potential nonpetroleum movements were individually identified. Existing minor movements (e.g., machinery) were dropped from consideration.

5. Alternative Futures, Scenarios, or Conditions to be Examined -- Commodity flow matrix comprised of existing canal movements plus potentially divertable traffic; additional "routing" consisting of interconnected tank car service (rail), applicable where (a) individual movements are large enough to take advantage of volume rate, (b) traffic originates from Port of Albany, and (c) physical conditions permit consignee to receive petroleum products by rail; and physical improve-

ments to the lock structures and the canal itself to accommodate (a) larger tows or (b) larger barges.

Major Tasks to be Accomplished (See Fig. 1)

1. Present Economic Activities
2. Freight Traffic Generator
3. Freight Traffic Distribution
4. Present Service, Cost & Price Characteristics
5. Modal Division

Analytical Choices

1. Measure Performance in Economic, Physical, or Impact Terms -- Economic only, because transit time, transit time reliability, or system capacity is not of concern, -- nor was the impact of potentially divertable truck traffic operating over the highway system of particular concern to the state transportation agency.

2. Estimaate Modal Shares on a Unit Price or Cost Basis -- Hypothesized commodity flows are based on the least cost mode as determined through transport rates and logistics charges.

3. Adopt a Physical Distribution or Transport Economics Orientation -- Physical distribution, because (a) storage, inventory, and insurance costs for petroleum products are sizable (the principal commodity), and (b) the demand for petroleum products is out of synchronization with the supply of waterborne transport. Consignees have increasingly chosen a more expensive mode (truck) to minimize total costs.

4. Price/Cost Movements on a One-Way or Round-Trip Basis -- Transport costs were computed on the basis of two-way movements, given the limited possibilities for utilizing available backhaul capacity. This was not expected to change, given the specialized character of the vehicles/vessels involved.

5. Optimizing Locations or Flows -- Not required.

Required Products

1. Record for each movement containing the following information:

- Identification

  a. Origin port along canal or connecting waterway.
  b. Destination port along canal or connecting waterway.
  c. Commodity type (gasoline, kerosene, jet fuel, distillate heating oil, residual fuel oil, asphalt, cement, and other types of bulk commodities) as existing or potential commodities.

- Contents

a. Designation as an existing or potential movement.
b. Commodity flow (in tons or gallons annually).
c. Unit revenues/charges via tug/barge under present conditions, tug/barge with an improved canal, tug/barge using larger barges with a modernized canal, truck, and rail (interconnected tank car).
d. Unit transport costs via tug/barge under present conditions, tug/barge with an improved canal, tug/barge with a modernized canal, truck, and rail (interconnected tank car).

2. Report summarizing the volumes and transport cost savings from using the canal system. In this particular example, separate tables giving transport and distribution cost savings were prepared. Also, savings accruing to petroleum products and other commodities were computed separately. Savings accrue from using water transport when the rates (and other inventory-related charges) are less than via competing modes, irrespective of whether water transport is presently being used.

Simplifying Premises and Assumptions

1. Aggregate demand is price and service inelastic.
2. Modal division solely dependent on logistics costs.
3. Existing refinery/terminal infrastructure unaffected by distributional cost differences. Thus the focus is on distributional movements from refinery or terminal to the jobber or distributor. Linehaul components involving ocean-going or coastal vessels are excluded, along with final distribution from jobber or distributor to retail outlets and consumers.

Data Requirements and Availability

1. Commodity movements being made over the canal system.
2. Commodity movements being made over competitive modes that could potentially be diverted to barge transport.
3. Tug/barge unit costs for several vessel/canal configurations:

  a. Existing equipment and canal cross-section (base case).
  b. Existing equipment used on an improved canal (draft increased from 12 to 15 ft, with no change in width or length of lock chambers.
  c. Ocean-going equipment used on a modernized canal (ocean-going barges or the equivalent used in a canal having locks 70 ft wide, 500 ft long, and 22 ft deep).

Information required to estimate unit costs includes variable and fixed costs, the former on an hourly or daily basis and the latter on an annual basis. Typical variable costs components are (a) wages, (b) fringe benefits, (c) subsistence, (d) fuel, (e) supplies, (f) maintenance and repairs, (g) insurance, and (h) miscellaneous. These would be required separately for the barge(s) and the tug. Typical fixed-cost components are (a) administrative costs, (b) annual depreciation, (c) unscheduled maintenance or overhaul, and (d) a rate of return on the investment.

4. Capital costs for new/used barges and tugs.
5. Typical financing (terms, including interest rate, allowable amount, period of the loan, etc.).

6. Common carrier rates/tariffs for comparable movements by truck, pipeline, and rail.

7. Volume/weight capacities of barges by product type and draft.

8. Loading/unloading rates.

9. Distances between ports along canal system, average speeds on Hudson River, Great Lakes, and along canal sections, and average lockage delays; or average running times between ports as obtained from lockage reports or operating companies.

Preparing Base Case Inputs

Commodity Flows

New York State Department of Transportation, the agency responsible for the operation of the New York State Barge Canal, maintains extensive records on commercial use of the canal system. These "canal trip clearance records" contain data on commodity type, tonnage, transit time between entrance and exit locks, vessel registration, and origin and destination ports. Exhibit 4 summarizes commodity types and tonnages reported for 1977 for the Champlain section of the canal system. (The "full" commodity flow matrix would also include commercial traffic movements over the Erie, Oswego, and Cayuga/Seneca sections as well.) Although the canal system as a whole does carry other commodities, petroleum products are the only significant commodity transported over the Champlain section.

Unit Transport Costs

Unit cost estimates were developed for the different modes. Rail costs were estimated using data contained in Rail Carload Cost Scales-1973, which in turn was derived from Rail Form A data. Truck costs were derived from the ICC publication Cost of Transporting Freight by Class I and II Motor Carriers of General Commodities: 1973. In both cases, the estimates obtained were updated to reflect 1977 costs by using appropriate Bureau of Labor Statistics indexes. Rail and truck unit costs, however, were used only to estimate rates in the absence of shipper or carrier-provided rate data.

The unique physical configuration and operating conditions along the NYS Barge Canal System made it necessary to develop barge unit costs "from scratch." The procedure used in developing these costs is outlined in the following paragraphs. Barge unit costs were initially developed for petroleum product movements, and later extended to include other commodities.

Barge Operations. Tug/barge combinations essentially operate 24 hours per day, seven days per week. While the canal season is only 7 to 7 1/2 months long, much of the equipment is also used for lighterage operations in New York Harbor, and thus an effective season of 300 to 340 days is achieved.

The size of vessels used to carry petroleum products is limited by the physical dimensions of the locks. These dimensions limit vessels to a width (beam) of 43 1/2 ft, a length of 300 ft, a height (clearance) of 15 ft, and an operating depth (draft) of 10 1/2 to 11 1/2 ft, depending on the canal section.

Exhibit 4. Summary Movements Over the NYS Barge Canal in 1977 (Petroleum Movements - Champlain Section)

Destination Port	Origin Port	Petroleum Product (tons)					
		Gasoline	Kerosene	Jet Fuel	Fuel Oil	Residual Oil	Total
Plattsburgh	Albany	101,036	12,496	277	62,618	4,242	180,669
	NYC	25,201		2,150	8,413		35,764
	Rensselaer	2,427			55,263	68,788	126,478
	Staten Is.		2,083		2,026		4,109
	Bayway				10,438		10,438
	Carteret		2,047				2,047
	Linden	11,877	1,900		1,983		15,760
	Newark	2,221					2,221
	Perth Amboy	14,709			8,630		23,339
	Sewaren	16,985	8,140		17,938		43,063
	Weehawken				2,111		2,111
Port Douglas	Rensselaer			1,757			1,757
	Staten Is.			2,288			2,288
	Port Reading			110,780			110,780
Port Henry	NYC	1,046					1,046
	Rensselaer	1,428					1,428
	Staten Is.	1,934	585		4,460		6,979
Westport	Albany	8,119	471		6,443		15,033
Ticonderoga	Albany					1,859	1,859
	NYC					1,817	1,817
	Rensselaer					71,933	71,933
	Staten Is.					1,865	1,865
	Perth Amboy					1,885	1,885
Ft. Ann	Rensselaer				4,076		4,076
	Sewaren		3,982				3,982
Dunhams Basin	Albany				4,538		4,538
Ft. Edward	Albany	12,948	803		11,915		25,666
Glen Falls	Albany	1,505	565		2,279		4,349
Shelburne	Rensselaer	2,334					2,334
Burlington	Albany	88,757	2,862		38,245		129,864
	NYC	11,998			17,060		29,058
	Rochester	5,517			47,047	15,202	67,766
	Staten Is.		6,286		6,023		12,309
	Bayway	2,200			11,765		13,965
	Carteret		2,100		8,377		10,477
	Linden				4,143		4,143
	Newark		1,366		13,852		15,218
	Perth Amboy				35,883		35,883
	Sewaren	23,255	3,602	5,814	12,750		45,421
	Tremley Pt.				7,220		7,220
	Port Reading			11,013	6,434		17,447
TOTALS		335,497	49,288	134,079	411,930	167,591	1,098,385

Source: Waterways Maintenance Subdivision 1977 Annual Report.

There are essentially three vessel combinations presently operating on the canal system:

- Barges ranging in length from 230 to 250 ft used in conjunction with a tug that enters the lock with the barge.
- Barges 295 to 299 ft long used in conduction with a tug. This type of tow is "double-locked;" that is, the barge and tug must pass through the lock separately. This doubles the locking time required.

• Self-propelled barges or motor vessels 295 to 299 ft long.

Because many of the barges used are designed with a draft of 12 to 15 ft, some loss of capacity occurs due to the limited depth of the channel. Product tonnage per vessel varies with vessel capacity and design, and on the Champlain section averages 2500 tons at an effective draft of 10 1/2 ft.

Variable Costs. The starting point is determining the variable costs associated with using particular equipment. The typical barge and tug combination has a crew of six or seven men on the tug and two men on the barge. The larger tug crew is required for a nonautomated tug to facilitate communication between the pilot house and the engine room. Based on the rates shown in Exhibit 5, these manning requirements resulted in an average daily labor cost (in 1977) of $986 for a tow with an automated tug and $1,125 for a tow with a nonautomated tug. Self-propelled vessels operate with a crew of seven and have a labor cost of $821. Two crews are assigned to each tow, with each crew working one- or two-week shifts on the average. These labor practices and costs were obtained from the labor contract (agreement between Local 333 United Marine Division, ILA, AFL-CIO and Marine Towing and Transportation Employer's Association, Operators of Tugboats and Self-Propelled Lighters -- effective April 1, 1976 through March 31, 1979) covering tug and barge crewmen and from the interviews with operators.

Exhibit 5. 1977 Daily Labor Costs for an Automated Tug with Barge.

Job Classification	Number	Average Daily Rate ($)	Total ($)
Captain	1	146.22	146.22
Mate	1	138.38	138.38
Chief Engineer	1	143.65	143.65
Deck Hands	2	106.97	213.94
Cook	1	106.97	106.97
Captain (Barge)	1	121.87	121.87
Mate (Barge)	1	115.11	115.11
	Grand Total		986.14

In addition to labor costs, variable costs include fringe benefits, subsistence (meals and travel), fuel oil, supplies or stores to operate (i.e., rope, lubricants, etc.), maintenance and repairs, insurance, and other costs. Operators indicated that these costs represent approximately 50 to 60 percent of total variable costs. Using this information, the costs shown in Exhibit 6 were prepared for a typical tug/barge combination.

Fixed Costs. Fixed costs of operating tugs and barges include amortization that includes interest charges and a return on the investment. These factors depend on the capital cost of the vessel,

Exhibit 6. Summary of Variable Hourly Costs.

Category	Tug a/	Barge	Total	Percent
Wages b/	34.34	10.86	45.20	44.5
Fringe Benefits b/	8.20	2.70	10.90	10.7
Subsistence	1.40	.70	2.10	2.1
Fuel Oil	15.00	1.00	16.00	15.7
Supplies	3.10	1.10	4.20	4.1
Maintenance & Repairs	6.00	4.00	10.00	9.8
Insurance	5.00	3.00	8.00	7.9
Miscellaneous	4.30	1.00	5.30	5.2
Total	77.34	24.36	101.70	100.0

a/ Automated.

b/ Factored by 1.10 to account for downtime.

Source: Barge Canal Marketing Study: Technical Report, Tables 2.1 and 2.2.

financing, and the profit goals of the owner. Exhibit 7, which shows fixed costs for typical vessels in 1977, is based on information supplied principally by operators.

Transit and Terminal Times. Present one-way and round-trip transit times were computed between Albany/New York City and various points along the NYS Barge Canal System, as well as to other points on connecting waterways. These times assumed (a) an average speed between locks of 5 mph, (b) an average locking time of 20 min, (c) open water speeds of 8.5 mph, and (d) loading and unloading times of 24 and 35 hr for light and heavy petroleum products. The results, shown in Exhibit 8, were checked against NYSDOT Canal Trip Clearance records to ensure their reasonableness.

Since transit and locking times are a major determinant of unit costs, the possibility of increasing vessel speeds and reducing the number of locks with ocean-going barges was investigated. Operators indicated that a speed of approximately 8 mph was about the maximum that could be achieved in a canal environment. The limiting factor was the beam and draft of the vessel in relation to the cross-sectional dimensions of the canal which (a) creates wave action that cannot be sufficiently dissipated before it reaches the canal banks and (b) the turbulent flow or resistance created by a barge operating at higher speeds which increases horsepower requirements. Based on this, an average speed of 7 mph between locks was used for a modernized canal. A table similar to Exhibit 8 was developed. (Barge Canal Marketing Study: Technical Report, Table 2.6).

Unit Barge Operating Costs. Equations were derived to estimate barge costs. The equation shown below, which is based on an operating draft of 10 1/2 ft, was developed for the Champlain section. (A similar equation based on an operating draft of 11 1/2 ft was developed for the remainder of the canal system.)

$$c_b = \frac{100\ t\ [F_b + V_b]\ f_i}{cap} \qquad (1)$$

where: c_b = barge cost is cents per gallon (product);
t = operating time (hr)

$$t = 2\begin{bmatrix} \text{one-way} & & & & \\ \text{transit} + & \text{loading} + & \text{unloading} + & \text{ballast} + & \text{downtime} \\ \text{time} & \text{time} & \text{time} & \text{time} & \text{allowance} \end{bmatrix};$$

$$F_b = \text{fixed cost} = \frac{\text{annual cost}}{24\ (\text{days operated/year})}\ (\$/\text{hr});$$

V_b = variable cost ($/hr);
f_i = type of product, with gasoline = 0.00308 tons/gallon
jet fuel = 0.00316 tons/gallon
kerosene = 0.00339 tons/gallon
distillate fuel oil = 0.00356 tons/gallon
residual fuel oil = 0.00402 tons/gallon; and
cap = vessel capacity (tons).

For example, unit barge costs for transporting gasoline from Albany to Plattsburgh are:

$$t = 2\ [31 + 7 + 8 + 3 + 6 + 6] = 92 \text{ hrs}$$

$$F_b = \frac{152{,}000}{24(315)} = \$20.11/\text{hr} \text{ assuming average annual costs and operation 315 days/year}$$

$$V_b = \$77.34\ (\text{tug}) + \$24.36\ (\text{barge}) = \$101.70/\text{hr}$$

$$f_i = 0.00308 \text{ tons/gallon}$$

$$cap = 2500 \text{ tons}$$

$$c_b = \frac{100(92)\ [20.11 + 101.70]\ 0.00308}{2500} = 1.38¢/\text{gallon}$$

Depending on the capacity and age of the vessel, financing arrangements, and degree of automation, the unit costs for individual vessels could vary as much as 20 percent from that obtained using the foregoing formula.

Unit Terminal Costs

Heretofore, only linehaul costs have been considered. To complete the unit cost picture, it is also necessary to consider terminal costs.

Terminal operations occur at refineries/terminals located in northern New Jersey and eastern Pennsylvania, at waterfront terminals/tank farms located at or south of Albany and Rensselaer, and at the

Exhibit 7. Range of Fixed Costs in Thousands of Dollars per Year

Item	Combined Tug/Barge Tows				Self-Propelled Barges	
	Oldest	Newest	Average	New Constr.	Average	New Constr.
Administrative Costs	$ 33	$ 33	$ 33	$ 33	$ 33	$ 33
Annual Depreciation	0	60	30	120	37	104
Unscheduled Main.	25	0	15	0	0	0
Rate of Return (Interest Charges)	15	155	74	300	93	260
Total Yearly Fixed Costs	$ 73	$ 248	$ 152	$ 453	$ 163	$ 397
Estimated Present Value	$ 150	$1,550	$ 740	$3,000	$ 925	$ 2,600

Assumptions :

1. Straight-line depreciation for 25 years on new equipment.
2. Average tug (weighted by trips) is 21 years old, oldest built in 1932, newest built in 1966. Average value = $ 350,000; range $ 75,000 - $550,000.
3. Average barge (weighted by trips) is 18 years old, oldest built in 1933, newest built in 1974. Average value = $390,000; range $ 75,000 - $1,000,000.

Source: Barge CAnal Marketing Study: Technical Report, Table 2.3.

distributorships. Regardless of which mode is used, petroleum products are handled at two and possibly all three terminal locations. So long as terminal operations remain common to the modes or routing alternatives being considered, terminal unit cost estimates need not be developed. If such alternatives result in an addition or deletion of a terminal operation, these costs have to be estimated.

A shift from barge originating in northern New Jersey to either rail or truck originating from Albany or Rensselaer could result in an additional terminal operation at Albany if affected oil companies continue to secure their petroleum products from the same source and use the same distribution system. Oil companies do have information on the variable costs of terminal operations. Provided that the volumes involved are small in relation to total terminal throughput (thus not affecting the viability of the terminal operation as a whole), such unit costs can be used. In this case, there was no way of determining whether additional terminal costs would indeed be incurred. Rather than attempting to estimate the volumes involved and separately computing a unit cost for terminal storage and handling at Albany/Rensselaer and

Exhibit 8. One-Way and Round Trip Times to Locations on the Champlain Canal from Albany and New York City.

Destination	One-Way Transit Time (hours)		Round-Trip Time (hours) 1/			
			Origin-Albany		Origin-New York City	
	Alb.	NYC	Light Pet.	Heavy Pet.	Light Pet.	Heavy Pet.
Albany	-	18	-	-	60	71
Mechanicville	3	21	30	41	66	77
Fort Edward	11	29	46	57	82	93
Glens Falls	12	30	48	59	84	95
Whitehall	21	39	66	77	102	113
Ft. Ticonderoga	24	42	72	83	108	119
Port Henry	26	44	76	87	112	123
Burlington	29	47	82	93	118	129
Port Kent	30	48	84	95	120	131
Plattsburgh	31	49	86	97	122	133

1/ Loaded or ballasted for the entire trip. Includes following terminal times (hours):

	Light Pet.	Heavy Pet.	Ballast (Water)
Loading	7	12	3
Unloading	8	14	6

Assumptions: Average speed between locks - 5 mph. Average locking time - 20 min. Speeds on Hudson River and Lake Champlain - 8.5 mph.

Source: Barge Canal Marketing Study: Technical Report, Table 2.5.

linehaul transport between northern New Jersey and Albany/Rensselaer, the difference in the wholesale price of various petroleum products was used to reflect the cost of transport and any additional terminal costs between these two points.

In analyzing the shift that had occurred from barge to truck, it was discovered that a portion of the truckload shipments originating in Albany/Rensselaer was being delivered directly to customers rather than through the distributor's local terminal facilities. This applied to some gasoline deliveries to service stations and to customers capable of receiving distillate or residual fuel oil in truckload quantities. Whether this indeed resulted in a savings in terminal costs depended on whether such deliveries were being made to reduce local distribution and terminal costs or to provide better service to the customer. If direct deliveries allowed the distributor to reduce his terminal costs or even sell the facility, such savings should be reflected in the computations.

In this case, direct deliveries had the effect of reducing the required amount of storage required, but not eliminating the need for the terminal. Such savings were estimated in the following manner. During the interviews, petroleum dealers indicated that the current value of storage terminals was approximately $8 per barrel of storage capacity. Since an oversupply of storage capacity existed in the market area, realization of this "book value" was considered unlikely. Consequently, a factor of 0.75 along with an interest rate of 9 percent was applied to convert this value to a rough market price, from which an annual cost of $0.54 per barrel of storage capacity was derived for the facilities alone. This was then converted to a unit basis by applying an average throughput ratio (annual volume/storage capacity). Using a 2.4 ratio, the unit cost worked out to be 0.54 cents per gallon.

Much depends on judgments made as to the effect that reduced use of terminal storage (through potential sale or dismantling of the infrastructure involved) had on terminal costs. It could be argued that the savings from reduced storage (i.e., less maintenance, taxes, land, etc.) is offset by the higher unit costs resulting from less throughput. It could also be argued that further growth in "terminal by-pass" movements is unlikely, since those facilities capable of receiving truckload deliveries and located within easy trucking distance of Albany/Rensselaer are already using this service.

Unit Charges/Revenues

Information on truck, rail and pipeline rates was obtained from applicable tariffs. Exhibits 9, 10, and 11 summarize truck and rail rates for petroleum products moving from Albany or Rensselaer to locations along the Champlain Canal or on Lake Champlain. Similar information on pipeline rates would have been obtained had these communities also been served by pipeline.

Unit Truck Rates. Exhibit 9 indicates the multiplicity of rates often encountered, and the temporal and volume commitments required on the part of the distributor or consignee to take advantage of these rates. Knowledge of applicable rate structures is valuable in that it permits determining where longer term commitments have been made and the degree of flexibility present in shifting among the different modes. Had the rate structures been known in advance of conducting the survey of petroleum distributors, specific questions could have been asked regarding the utilization of the different discount rates being offered, and thus a more precise estimate of the transport charges being incurred could have been made. Use of the different rates is influenced by purchasing practices. Most dealers make both long-term contractual and spot purchases, with the former being more conducive to volume rates than the latter. This illustrates the importance of at least some understanding of the nature of the particular business and its impact on transport decisions.

In this case, the rates shown in Exhibit 9 represent only a small portion of those contained in the actual tariff. Intrastate application of rates can often be simplified by developing rate equations. In this particular case, one equation was developed to represent virtually all product movements in New York State by truck. Based on the tariff, the derived equation was:

Exhibit 9. Sample Truckload Rates from Freight Tariff No. NY-7A.
(In Cents/Gallons)

Commodity	From Albany, N.Y. to Following Destinations 2/								Tariff Section/Item	Applicable Conditions	Applicable Carriers 3/
	Dunhams Basin	Ft. Ann	Ft. Edward	Glens Falls	Plattsburgh	Port Henry	Ticonderoga	Westport			
Gasoline	2.37	1.60	1.51	1.51	3.99	2.68	2.37	3.12	10/2050	Standard Rate (8000 gal/veh min)	all
	2.13	1.44	1.36	1.36	3.59	2.41	2.13	2.81	1/500	Weekly gallonage 100,000 - 149,999	X2
	2.09	1.41	1.33	1.33	3.51	2.36	2.09	2.75	1/500	Weekly gallonage 150,000 - 199,999	X2
	2.04	1.38	1.30	1.30	3.43	2.30	2.04	2.68	1/500	Weekly gallonage 200,000 - 299,999	X2
	1.99	1.34	1.27	1.27	3.35	2.25	1.99	2.62	1/500	Weekly gallonage 300,000 - 399,999	X2
	1.94	1.31	1.24	1.24	3.27	2.20	1.94	2.56	1/500	Weekly gallonage 400,000 and over	X2
	1.90	1.28	1.21	1.21	3.19	2.14	1.90	2.50	6/900	12 million gallons over 52 consecutive weeks	1,3,5
	1.73	1.17	1.08	1.08	2.93	1.94	1.73	2.27	5/800	60 million gallons over 52 consecutive weeks	X2
Kerosene/ Jet Fuel	2.61	1.79	1.67	1.67	4.41	2.92	2.61	3.39	10/2050	Standard Rate (7000 gal/veh min)	all
	2.09	1.43	1.34	1.34	2.57	1.68	1.53	1.98	6/900	12 million gallons over 52 consecutive weeks	1,3,5
	1.91	1.30	1.21	1.21	3.21	2.10	1.91	2.48	5/800	60 million gallons over 52 consecutive weeks	X2
Distillate Fuel Oil	2.76	1.90	1.79	1.79	4.75	3.14	2.76	3.64	10/2050	Standard Rate (6500 gal/veh min)	all
	2.21	1.52	1.43	1.43	3.80	2.51	2.21	2.91	6/900	12 million gallons over 52 consecutive weeks	1,3,5
	2.01	1.37	1.30	1.30	3.46	2.30	2.01	2.67	5/800	60 million gallons over 52 consecutive	X2

(Footnotes shown at the end of the table.)

Exhibit 9. Sample Truckload Rates from Freight Tariff No. NY-7A. (In Cents/Gallons) Continued.

Commodity	From Albany, N.Y. to Following Destinations 2/								Tariff Section/Item	Applicable Conditions	Applicable Carriers 3/
	Dunhams Basin	Ft. Ann	Ft. Edward	Glens Falls	Plattsburgh	Port Henry	Ticonderoga	Westport			
Residual Fuel Oil	2.88	2.01	1.87	1.87	4.98	3.33	2.88	3.85	10/2050	Standard Rate (6000 gal/veh min)	all
	2.39	1.67	1.55	1.55	3.98	2.66	2.39	3.08	9/1250	5 million gallons annually (6500 gal/veh)	1,4,5,6
			1.58	1.58	3.69				9/1260	35 million gallons annually (6700 gal/veh)	5
				1.14					9/1210	10 million gallons annually (6500 gal/veh)	
							2.25		9/1220	8 million gallons annually (7000 gal/veh)	

1/ Issued by Robert A. Roper, Tariff Issuing Officer for the Bulk Carrier Conference, Inc.

2/ Origins and destinations generally specified on a county basis. Thus included were petroleum terminals located in Rensselaer County.

3/ Applicable Carriers (for the rates extracted from the tariff) Agent, on November 4, 1977, effective December 7, 1977. Tariff gives local and joint specific and mileage rates on petroleum and petroleum products in bulk, in tank vehicles between points and places in New York State.

1. J.A. Carman Trucking Co., Inc.
2. Chemical Leaman Tank Lines, Inc.
3. Fort Edward Express Co., Inc.
4. Frontier Delivery, Inc.
5. A. R. Gundry, Inc.
6. Matlack, Inc.

X Except.

Exhibit 10. Sample Truckload Rates from Freight Tariff MF-ICC 58.

Commodity	From Albany, N.Y. to following Destinations 2/		Tariff Section	Applicable Conditions
	Burlington	Shelburne		
Gasoline	2.85	2.75	1	Standard Rate (7,000 gal/veh min.)
Kerosene/ Jet Fuel	2.85	2.75	1	Standard Rate (7,000 gal/veh min.)
Distillate Fuel Oil	2.85	2.75	1	Standard Rate (7,000 gal/veh min.)
Residual Fuel Oil	3.33	3.31	1	Standard Rate (6,000 gal/veh min.)

1/ Issued by Paul E. Merrill, President, Merrill Transport Company on September 2, 1977, effective October 10, 1977. Tariff gives local commodity rates applying on petroleum products in bulk, in tank vehicles, from points in New York to Vermont and New Hampshire.

2/ Includes petroleum terminals in Rensselaer and adjacent communities as well.

$$r_t = 0.0501\, d^{0.85} f_1\ f_2\ f_3 \qquad (2)$$

where: r_t = truck rate, ¢/gal;
d = one-way distance, miles;
f_1 = type of product, with gasoline = 1.000,
kerosene & jet fuel = 1.098,
distillate fuel oil = 1.177,
residual fuel oil = 1.243;
f_2 = (1 - volume discount); and
f_3 = any rate changes over the applicable time period (none were applied).

For example, the estimated base truck rate for transporting gasoline between Albany and Plattsburgh (160 mi) is:

$$r_t = 0.0501\ (160^{0.85})\ (1.0)\ (1.0)\ (1.0) = 3.74¢/\text{gallon}$$

The interstate rates shown in Exhibit 10 are far simpler, because volume discounts are not indicated. This does not necessarily mean that such discounts do not exist, however.

Unit Rail Rates. The rail rates described in Exhibit 11 are a limited set of specific point-to-point rates. The rates, however, do not indicate the full costs, as potential consignees would first have to invest in an unloading facility (or modify existing pipes, pumps, etc.) and possibly in a rail siding. These particular rates are unusual in that the railroad is leasing the equipment from a private car company. In similar situations, the shipper or consignee is required to provide the cars, which in turn results in per diem and per car mile charges in addition to the published rate.

Exhibit 11. Applicable Rail Rates.

On April 19, 1977, the Delaware & Hudson and Vermont Railways published a joint tariff (D&H Freight Tariff 500, effective May 28, 1977) on volume shipments of petroleum products to encourage use of the rail system for movements between Albany and Burlington. The basic parameters/conditions of this tariff were:

- Thirty million gallons to be shipped during five successive 12-month periods.
- Consignor furnishing an indemnity bond guaranteeing payment in the event that the minimum gallonage requirement was not met for any period.
- Rate applicable with railroad provided tank cars, with 20,000 gallons minimum per car.
- An incentive rate structure initially consisting of:

	Cents/100 gallons
First 30 million gallons in 12-month period	107
Excess over 30 million gallons mileage or per diem paid	95
No mileage or per diem paid	80
Deficit in gallonage during any 12-month period	47

Volume movements began during November 1977, utilizing a fleet of 20 railroad-leased 26,000 gallon tank cars, operated as two 10-car units in weekly turnaround service. The Delaware & Hudson has offered to publish a similar tariff from Albany to Plattsburgh, although no distributors have yet elected to use this service.

In addition to the foregoing volume tariff, the Delaware & Hudson also published (Supplement 9 to Freight Traffic 3-G, effective December 11, 1976) commodity rates of 167 and 155 cents/100 gallons on petroleum products (including residual) and residual fuel oil, respectively, moving between Albany and Plattsburgh. The latter rate applied only on shipments comprised of two or more interconnected tank cars. Minimums of 20,000 and 23,000 gallons per car were also specified.

Unit Barge Rates. Barge rates were not published, but rather negotiated between the barge operators and oil companies or distributors utilizing the service. Rates varied depending on (a) the volume and time period involved, (b) distance, (c) availability and cost of equipment and crews, (d) the degree of competition from other barge operators for that particular movement, and (e) the type of product involved. Since only a limited amount of rate data were obtainable through the interview process, the unit rate data were used to develop a "multiplier" through which barge rates could be estimated from unit costs.

Unit barge rates were estimated using the following equation:

$$r_b = m\, c_b \tag{3}$$

where: r_b = barge rate, ¢/gal;
c_b = unit barge cost (see Exhibits 6 and 7);
m = multiplier = $3.736\, t^{-0.226}$, $m \geq 1.08$;
t = round-trip time or length of the contract period in hrs.

Again using the Albany to Plattsburgh movement, the estimated barge rate would be:

$$r_b = 1.18\ (1.38) = 1.62¢/\text{gallon}$$

The foregoing equation was derived from rate data supplied by petroleum distributors and the unit cost estimates. It reflects the principle that barge operators do seek higher profit margins on smaller or limited duration contracts than the 8 to 10 percent customary on high-volume or long-term contracts. The resulting multipliers are listed as follows:

Round-Trip or Contract Time

Days	2	3	4	5	6	7	8	9	10 and up
Hours	48	72	96	120	144	168	192	216	240 and up
Multiplier	1.56	1.42	1.33	1.27	1.22	1.18	1.14	1.11	1.08

Again using the Albany to Plattsburg movement, the estimated barge rate would be:

$$r_b = 1.18 \times 1.38 \text{ or } 1.62¢/\text{gallon}$$

Other Logistics Charges

The final components to be considered are inventory or logistics charges, which together with unit rates comprise what are often referred to as physical distribution costs. The uniqueness of this particular case example made it necessary to develop inventory costs directly.

One of the disadvantages of the canal system is its limited season and its impact on costs. This causes no significant problems if the demand for transport coincides temporally with the availability of that system. This, however, is not the case with petroleum products. Thus, the cost of maintaining inventory in excess of that required by normal business practices had to be calculated.

In this case, inventory costs were comprised of (a) interest charges on the excess product on hand, (b) insurance on the excess product, and (c) the amortized value of the storage facilities beyond that required by normal business practice. The detention time for excess product associated with barge transport was determined by subtracting the monthly supply from the monthly demand for different products, as illustrated in Exhibit 12. In determining the length of time the product was stored, the assumption was made that distributors would sell surplus products as soon as possible to minimize interest charges. For example, surplus fuel oil accumulated in May (the first inventory-building month) was credited to November and December (the first two inventory-depleting months). Storage times ranged from 4 to 8 months, depending on the product involved.

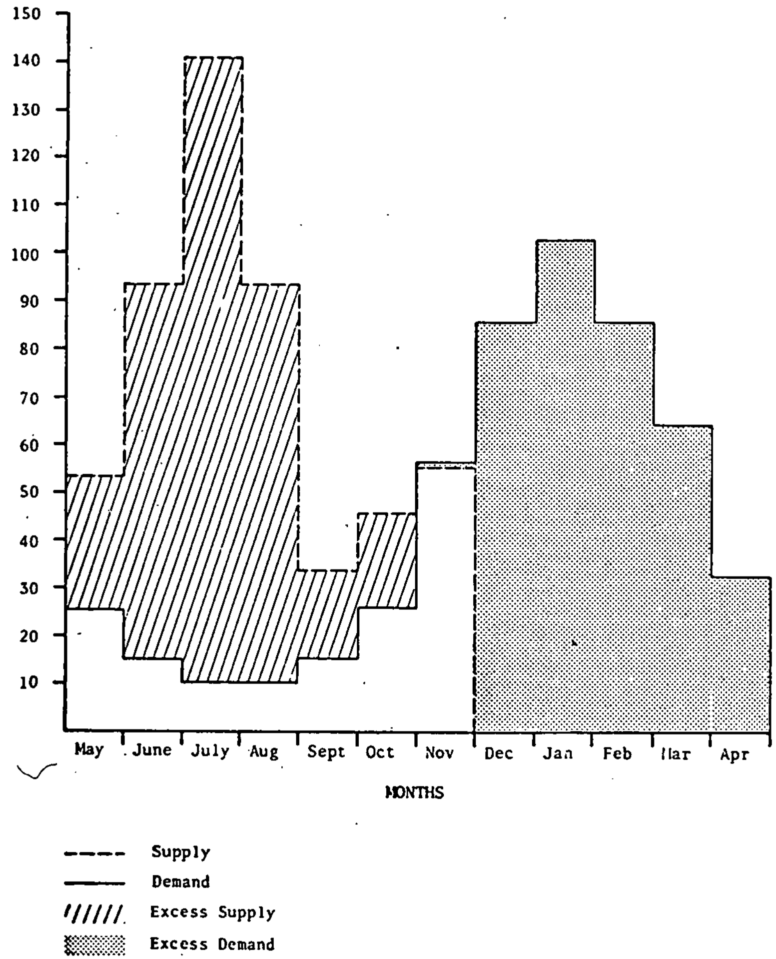
Technically, that proportion of storage capacity beyond that required was that barge transport usable on a year-round basis should be included as part of the added cost of using water transport. Such excess capacity was not considered to be readily marketable, since the rising wholesale cost of petroleum products coupled with increased interest and insurance rates had lessened the economic appeal of keeping large supplies on hand. Consequently, no value was assigned to the cost of storage facilities needed for water transport but not required were the product to be transported by other modes. Distributors having excess storage may still use it because it is a sunk investment and does provide qualitative benefits such as (a) flexibility in purchasing practices, (b) a hedge against inflation, and (c) security against delivery uncertainties, but they are unlikely to build new storage or will shift modes if additional storage should become necessary. Thus, such costs have not been included as a component of physical distribution costs.

Interest costs were estimated by multiplying the unit wholesale price by the interest rate and the average detention time (proportion of the year). Insurance costs were computed by applying a rate to average detention time. Exhibit 13 shows computed per gallon inventory costs for different petroleum products transported via barge.

Inventory costs also occur for the other modes. These costs were estimated by comparing the ratio of the annual product throughput at a terminal to available storage. These ratios, which indicate the length of time a product is held, are shown in Exhibit 14. The greater the turnover, the smaller will be the inventory cost. Inventory costs for pipeline, rail and truck were determined by dividing the inventory costs shown in Exhibit 13 bv the increase in throughput ratio shown in Exhibit 14.

Two other potential components of inventory costs -- interest on transport charges brought about by seasonal delivery by water and incremental inventory costs incurred while in transit (between water and the other modes) -- were considered to be relatively minor and were not included in the cost computations.

Exhibit 12. Temporal Supply/Demand Curve for Distillate Fuel Oil Delivered by Barge to Distributors Located Along the Champlain Canal.



Preparing Inputs for the Alternatives Being Considered

Changes to Commodity Flows

As detailed and accurate as the NYSDOT data were, they only reported actual movements made by barge during 1977. Potential canal traffic would include petroleum movements made by pipeline, rail, and truck as well as other commodities suitable for transport via the canal system.

Exhibit 13. Inventory Costs for Petroleum Products Delivered by Barge.

Product	Wholesale Price in 1977 ($/gal)	Average Detention (months)	Unit Inventory Cost 1/ ($/gal)
Gasoline	0.48	6.3	0.0226
Kerosene	0.405	5.5	0.0166
Distillate Fuel Oil	0.385	6.3	0.0181
Residual Fuel Oil	0.395	6.2	0.0183

1/ Includes insurance and interest costs, the latter at 9 percent annually, for the average detention time indicated.

Source: Barge Canal Marketing Study: Technical Report, Table 2.8.

Exhibit 14. Average Throughput/Storage Ratios for Distributorships.

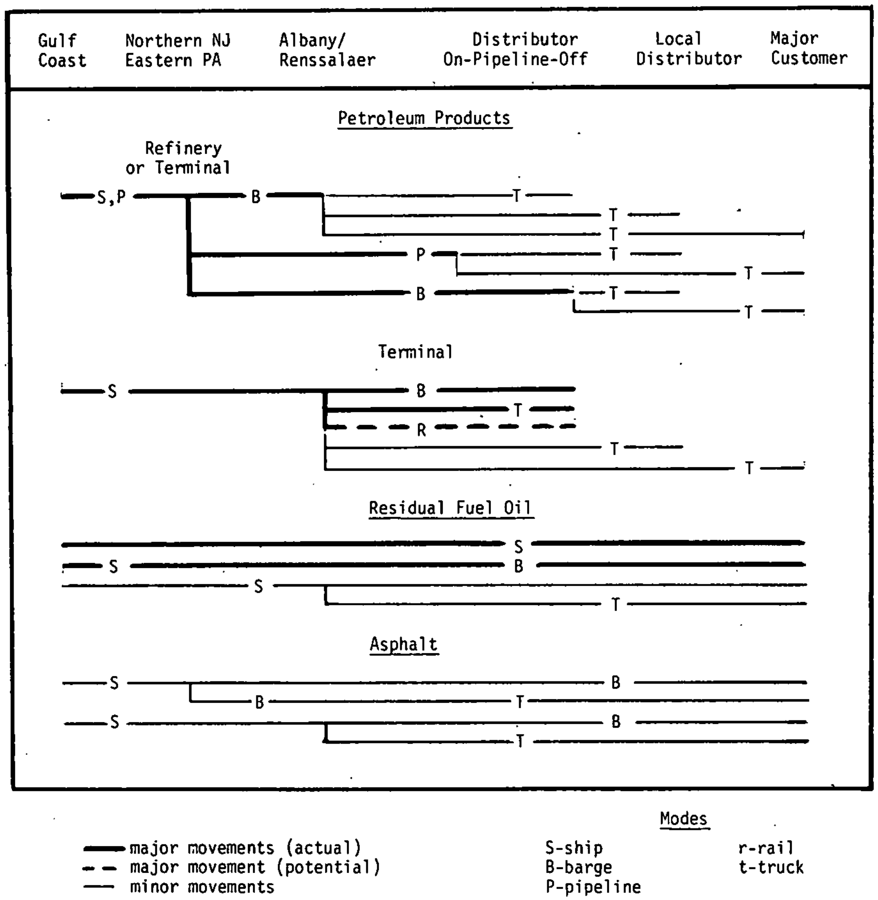
Mode	Throughput/ Storage Ratio	Ratio to Barge	% of Barge
Barge	1.8	1.0	-
Pipeline	6.6	3.7	27
Rail	4.5	2.5	40
Truck	8.0	4.4	23

Source: Barge Canal Marketing Study: Technical Report, Table 2.9.

Considering petroleum products first, either (a) the base commodity flow matrix must be expanded to include information on shipments or movements presently made by other modes, or (b) another data set providing more comprehensive information on petroleum product movements, or alternatively on product sales or consumption, must be used as the basis of the potential commodity flow matrix.

If information on petroleum product movements by other modes had been available for 1977, the base commodity flow matrix could have been extended. Several checks would have to be performed, however. The first would be to identify all potential movements as has been done schematically in Exhibit 15. The second would be to identify all likely shippers and receivers of volume petroleum products. In this case, shippers would logically be oil company refineries or terminals located in northern New Jersey or eastern Pennsylvania, and the receivers would be principally distributors located in counties adjacent to the canal system or on Lake Champlain, rather than dealers or consumers of petroleum products. The third check would be to screen the list of distributors, applying criteria such as shipment size, waterfront location, and annual volume to reduce the list of distributors down to potential users. In this study, it made little sense to include movements having little or no potential for barge transport. The final check would be to identify any major industrial users that might be purchasing petroleum products directly from oil companies. An example of this turned out to be jet fuel for the Air Force base at Plattsburgh, which was purchased under contract from a supplier located in northern New Jersey. In this case, the above checks were not performed, because secondary data were not available for the other modes.

Exhibit 15. Potential Petroleum Movements.



Given that the only commodity utilizing the waterway was petroleum products, the initial thrust was to seek information on petroleum movements being made by truck and rail. A survey was conducted of petroleum distributors located in counties contiguous to the canal and having a storage capacity of 400 thousand gallons or greater to obtain the following information:

- Mode(s) utilized.
- Amount and type of products moved.
- Product origin.
- Transport rates for the different modes.
- Reason(s) underlying the use or nonuse of the canal system.

Petroleum distributors were identified by compiling names from several sources, including:

- Waterways Maintenance Subdivision, NYSDOT.
- National Petroleum News Factbook list of marketing management personnel.
- Members of the Empire State Petroleum Association.
- Members of the New York State Petroleum Council.
- Petroleum companies having pipeline "taps" located on the canal system or Lake Champlain.

A two-stage survey process was used to contact each firm on the consolidated list. First, an introductory letter was mailed to each firm. This was followed by telephone calls. Information obtained was recorded on a survey form shown in Exhibit 16. In cases where distributors were hesitant to provide the requested information over the telephone, survey forms were mailed and follow-up telephone calls were made to ensure receipt of the requested information.

In addition to collecting primary data on petroleum movements by pipeline, rail, and truck, other data sets were considered in estimating potential commodity flows. The choices were secondary data on wholesale or retail sales by firms located in counties contiguous to the canal system or data giving county-level consumption of petroleum products. The former was preferable, because barge movements were usually made from refineries or terminals to wholesale distributors. County-level information on petroleum product sales was obtained from the <u>1972 Census of Wholesale Trade-Petroleum Bulk Stations and Terminals</u> (see Exhibit 17). Exhibit 18 presents the secondary data for counties contiguous to the Champlain section or Lake Champlain.

Exhibit 16. Survey Form for Bulk Liquid Carriers.

GENERAL INFORMATION

Company: ______________________ ☐☐☐☐☐

Mailing Address: ______________________

____

Zip County

Contact person, title:

______________________ Phone Number ______________

Vessel Data

No/ Name ______________ Fully loaded capacity ______________

Replacement Cost ______________ Erie capacity ______________

Champlain capacity ______________

Variable Cost Data For	Annual	Per Operating Hour	Per Operating Day	Other
Wages				
Fringe Benefits				
Subsistence				
Fuel Oil				
Supplies				
Maintenance & Repairs				
Insurance				
Administration & Sup.				
Miscellaneous				
Fixed Cost				
Depreciation				
Interest				
Required Return				

Operating Strategy ______________________

____

____

____

The Census data provided information on 1972 sales for distributors located within the defined counties. This does not mean that the volumes shown are necessarily consumed within these counties -- in fact, it is quite likely that some of these distributors also market to interior counties. Thus the Census data will differ from county-level petroleum product consumption data or estimates.

Because 1977 Census data were not available when the study was originally conducted, adjustments were made to eliminate underreporting and reflect anticipated changes occurring between 1972 and 1977. Exhibits 19 and 20 illustrate how these adjustments were made. Exhibits 21 and 22 show reported distillate and residual movement or sales by county and the resulting estimates of petroleum product movements in 1977. The adjustments, however, do not assume any change in unit consumption of petroleum products brought about by increasing price, smaller and more efficient vehicles, and increased use of wood for heating, and, thus, probably overstate petroleum product consumption. These two exhibits also illustrate the type of discrepancies often encountered when using different data sources. Resolution of such differences may be difficult, because full knowledge of the data is usually lacking. In this case, the NYSDOT data obviously will be less than the other sources, because it represents only a single mode. The Census of Wholesalers data show greater movements than the other sources. In the Barge Canal Marketing Study, neither time nor fiscal resources permitted resolution of the rather large differences noted for some of the counties. In the end, it was necessary to establish movement volumes by edict as shown in Exhibits 21 and 22. Such resolution should take into account the consequences of low and high estimates and themselves be the product of careful reasoning and judgment. Since precise totals were not obtainable and some estimating was necessary, the figures shown were generally rounded to the nearest million gallons. (This also reflects the prevailing petroleum industry practice of measuring flows as volumes rather than by weight.)

Although the estimated movements shown in Exhibits 21 and 22 show only the destination end, the origin end can be replicated easily because all petroleum product shipments moving by truck or rail originate from either Albany or Rensselaer.

Potential canal traffic also includes other dry and liquid bulk commodities (other than petroleum products). Consequently, letters and telephone calls were made to some 206 firms in an attempt to identify New York State produced or consumed bulk commodities for which the canal system might lower transport costs in comparison with the present mode. Exhibit 23 shows the survey form used for this purpose. Interviews with prospective users focused on identifying potential movements and the reasons why the canal system has or has not been utilized in the past. During the conduct of the interviews, potential commodities were screened on the basis of their:

- General adaptability to water transport (low unit value, high volume, low susceptibility to damage from weather or transshipping, low loading/unloading cost).
- Projected amount (multiple barge load amounts).
- Origin and destination (waterfront origination and termination, or at least very close by).

If the commodity appeared promising, more detailed information was sought on the present means of transport and the costs involved. Exhibit 24 lists for the Champlain section the nonpetroleum bulk commodity movements found initially to have the greatest potential

Exhibit 17.

Sample Data from the 1972 Census of Wholesale Trade.

Source: U.S. Department of Commerce, Bureau of the Census, 1972 Census of Wholesale Trade: Petroleum Bulk Stations and Terminals, Table 8 p. 2-96.

TABLE 8. **Gallon Sales to Retailers, Jobbers, and Consumers, by Type of Product—United States, States, and Counties: 1972**—Continued

(Excludes liquefied petroleum (LP) gas bulk stations and terminals)

State and county	All establishments		Establishments reporting gallon sales by type of product							
	Number	Sales	Sales[1]	Gallon sales by product						
				Aviation gasoline	Motor gasoline	Special naphthas	Jet fuels (naphthas or kerosene types)	Kerosene	Distillate fuel oils	Residual fuel oils
		($1,000)	($1,000)	(1,000 gal.)	(1,000 gal.)	(1,000 gal.)	(1,000 gal.)	(1,000 gal.)	(1,000 gal.)	(1,000 gal.)
NEW YORK										
TOTAL	668	2 538 537	2 115 826	69 816	4 660 753	13 725	105 126	265 242	3 709 550	1 974 659
REFINER-MARKETER BULK STATIONS, TERMINALS	298	1 887 232	1 677 765	68 619	4 170 180	13 270	57 279	216 025	2 478 280	953 106
OTHER BULK STATIONS, TERMINALS	370	651 305	438 061	1 195	490 573	455	47 847	49 217	1 231 270	1 021 553
ALBANY COUNTY	14	105 023	102 161	831	227 685	5 703	361	30 593	243 522	37 594
ALLEGANY COUNTY	7	5 126	3 221	75	6 973	-	-	583	1 923	-
BRONX COUNTY	7	120 954	73 617	-	74 146	1	-	2 516	111 903	328 302
BROOME COUNTY	16	50 977	49 373	-	126 219	14	-	10 478	103 159	1 775
CATTARAUGUS COUNTY	9	11 410	9 870	20	20 346	19	-	1 917	6 090	3 826
CAYUGA COUNTY	9	5 596	5 596	-	7 873	8	-	1 364	11 898	-
CHAUTAUQUA COUNTY	14	5 494	4 180	-	9 892	43	-	865	3 252	250
CHEMUNG COUNTY	7	19 305	15 375	-	35 022	1	-	1 157	18 131	-
CHENANGO COUNTY	9	6 380	6 380	-	8 925	-	-	1 465	9 237	-
CLINTON COUNTY	14	41 065	41 065	-	57 057	-	9	17 973	56 402	33 112
COLUMBIA COUNTY	7	7 025	4 819	-	5 033	-	-	698	8 933	-
CORTLAND COUNTY	5	3 597	3 209	-	4 781	-	-	732	4 941	-
DELAWARE COUNTY	11	5 162	5 049	-	11 078	-	-	659	6 170	-
DUTCHESS COUNTY	4	5 483	3 733	-	6 734	-	-	322	5 924	-
ERIE COUNTY	32	153 815	142 681	1 436	413 251	928	14 848	7 593	133 840	61 116
ESSEX COUNTY	7	4 314	4 314	20	4 339	-	-	1 524	5 501	30 411
FRANKLIN COUNTY	11	9 059	8 556	-	13 154	-	-	2 872	10 367	4 382
FULTON COUNTY	6	6 135	6 119	-	9 328	-	-	3 466	4 383	4 767
GENESEE COUNTY	6	10 169	6 557	-	23 207	-	-	1 132	6 505	800
GREENE COUNTY	6	7 125	6 265	-	10 094	-	-	699	16 021	300
HAMILTON COUNTY	-	-	-	-	-	-	-	-	-	-
HERKIMER COUNTY	7	4 619	4 227	64	8 805	-	-	530	5 853	-
JEFFERSON COUNTY	11	10 366	10 168	6	17 764	4	-	3 380	26 186	-
KINGS COUNTY	19	401 997	267 996	223	608 085	3 571	233	40 318	339 644	106 531
LEWIS COUNTY	5	3 375	3 113	20	3 996	-	-	575	5 985	-
LIVINGSTON COUNTY	11	8 354	7 234	-	13 703	-	-	1 603	5 883	270
MADISON COUNTY	10	6 486	6 450	-	10 330	2	112	1 143	6 843	-
MONROE COUNTY	21	101 585	84 936	296	216 341	1 660	4 377	22 683	149 784	6 705
MONTGOMERY COUNTY	11	6 752	5 499	43	7 350	-	-	1 063	12 782	10
NASSAU COUNTY	40	310 483	279 829	54 160	705 485	21	7 197	4 394	502 805	49 577
NEW YORK COUNTY	17	52 422	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)
NIAGARA COUNTY	12	(D)	(D)	-	7 938	-	-	861	25 822	-
ONEIDA COUNTY	21	48 543	47 406	-	97 467	22	-	9 289	74 972	56 343
ONONDAGA COUNTY	24	120 359	102 609	239	285 618	349	2 220	10 306	115 051	10 103
ONTARIO COUNTY	13	11 997	10 015	-	26 636	-	-	3 984	20 742	1 312
ORANGE COUNTY	20	85 831	80 991	643	217 177	104	-	6 480	114 536	248 315
ORLEANS COUNTY	4	3 808	3 346	-	7 475	-	-	325	2 058	-
OSWEGO COUNTY	10	21 853	21 853	-	32 292	2	-	5 931	27 397	1 704
OTSEGO COUNTY	9	12 594	(V)	(V)	(V)	(V)	(V)	(V)	(V)	(V)
PUTNAM COUNTY	1	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)

Exhibit 18.

Bureau of the Census Data on Petroleum Product Consumption in 1972, by County.

Source: Bureau of the Census, 1972 Census of Wholesale Trade, Petroleum Bulk Stations and Terminals, Table 8.

Selected NY and VT Counties	All Est.		Establishments Reporting Gallon Sales by Type of Product (gallons X 10^3)							
	No.	Sales ($ Thousands)	Sales ($ Thousands)	Aviation Gasoline	Motor Gasoline	Special Naphthas	Jet Fuels	Kerosene	Distillate Fuel Oils	Residual Fuel Oils
Clinton	14	41065	41065	-	57057	-	9	17973	56402	33112
Essex	7	4314	4314	20	4339	-	-	1524	5501	30411
Saratoga	4	4749	3224	-	8633	-	-	508	3247	-
Warren	7	3393	2987	-	5377	56	1	1154	5482	-
Washington	9	13433	12926	-	17336	56	-	4424	39450	-
Addison	3	2799	2799	-	5506	-	-	268	2907	-
Chittenden	12	42409	40942	16	77078	32	343	8932	83455	16375

Exhibit 19. Petroleum Product Sales to Retailers, Jobbers, and Consumers.

Selected NY and VT Counties	Reported Sales to Retailers, Jobbers and Consumers in 1972 (gallons X 10^2)							Total Products
	Under-Reporting Adjusted	Auto Gasolene	Jet Fuel	Kerosene	Distillate Fuel Oils	Residual Fuel Oils	Total Distillates	
Clinton	1.000	57057	9*	17973	56402	33112	131441	164553
Essex	1.000	4339	-	1524	5501	30411	11364	41775
Saratoga	1.473	12716	-	748	4783	-	18247	18247
Warren	1.136	6108	1	1311	6228	-	13648	13648
Washington	1.039	18012	-	4597	40989	-	63598	63598
Addison	1.000	5506	-	268	2907	-	8681	8681
Chittenden	1.036	79840	355	9252	86445	16962	175892	192854
							422871	503356

* Note the underreporting of jet fuel sales in Clinton County. This is a consequence of USAF purchases from a supplier located in the New York City area.

Exhibit 20. Estimated Distillate Sales to Retailers, Jobbers, and Consumers.

Selected NY and VT Counties	Est. % Change In Pop.	Estimated Sales to Retailers, Jobbers and Consumers in 1977						Total Distillates (gal X 10^3)
		Gasoline		Kerosene		Dist. Fuel Oil		
		Factor (1)	Est. Sales (gal X 10^3)	Factor (2)	Est. Sales (gal X 10^3)	Factor (2)	Est. Sales (gal X 10^3)	
Clinton	+ 14.1	1.053	60081	1.084	19483	1.084	61140	140713
Essex	+ 1.4	0.937	4066	0.963	1468	0.963	5297	10831
Saratoga	+ 17.4	1.085	13797	1.115	834	1.115	5333	19964
Warren	+ 6.1	0.980	5986	1.008	1321	1.008	6278	13586
Washington	+ 2.8	0.950	17111	0.977	4491	0.977	40046	61648
Addison	+ 8.1	0.999	5500	1.027	275	1.027	2985	8760
Chittenden	+ 7.6	0.994	79361	1.022	9456	1.022	88347	177519
								433021

Notes:

(1) Between 1972 and 1977, per capita gasoline consumption dropped by 7.6 percent (369 to 341 gal/person) Estimated 1977 sales = 1972 sales X 0.924 X population change.

(2) Between 1972 and 1977, percapita kerosene and fuel oil consumption dropped by approximately 5 percent. 30 year mean for New York State ≐ 5900 degree days; July 71 - June 72 = 5837 degree days. Consequently, 1972 data considered indicative of an average heating season. Estimated 1977 sales = 1972 sales X 0.95 X population change.

Exhibit 21. Estimated Distillate Usage by County.

Selected NY and VT Counties	Reported Distillate Movement or Sales (gallons X 10^3)			Estimated Movements by Mode in 1977 (gallons X 10^3)		
	NYSDOT in 1977 1/	COW Adj. to 1977 2/	Survey in 1977 3/	Barge	Rail	Truck
Clinton	149600	140713	146100	148000	-	26000
Essex	7500	10831	5200	7000	-	3000
Saratoga	-	19964	3500	-	-	20000
Warren	1300	13586	2400	3000	-	12000
Washington	11400	61648	10900	13000	-	47000
Addison	800	8760	5500	5000	-	4000
Chittenden	112400	177519	143300	114000	4/	47000
	283000	433021	316900	290000	0	159000

1/ At 325, 305, and 278 gallons/ton for gasoline, jet fuel and kerosene, and distillate fuel oils, respectively.

2/ Census of Wholesalers.

3/ Survey of distributors conducted by Roger CREIGHTON ASSOCIATES Incorporated.

4/ Rail service was initiated in late 1977.

Exhibit 22. Estimated Residual Usage by County.

Selected NY and VT Counties	Reported Residual Movement or Sales (gallons X 10^3)				Est. Movements by Mode in 1977 (gallons X 10^3)		
	NYSDOT in 1977 1/	COW in 1972 2/	NERBC in 1975 3/	Survey in 1977 4/	Barge	Rail	Truck
Clinton	18258	33112	27400	48000	18000	5000	3000
Essex	19840	30411	4300	-	19500	-	3000
Saratoga	-	-	-	-	-	-	-
Warren	-	-	-	-	-	-	-
Washington	-	-	15600	-	-	-	-
Addison	-	-	600	-	-	-	-
Chittenden	3801	16962	2800	4000	4000	-	-
	41899	80485	50700	52000	41500	5000	6000

1/ At 250 gallons/ton.

2/ Census of Wholesalers.

3/ New England River Basin Commission.

4/ Survey of distributors conducted by Roger CREIGHTON ASSOCIATES Incorporated.

for water transport. These movements were then added to those for petroleum movements, thus establishing the commodity flow matrix to be used in determining the cargo potential and transportation benefits of the canal system.

Changes to Unit Costs

In addition to the unit costs developed previously for petroleum products, such costs had to be estimated for other commodities (particularly dry bulks) and for barge operations over an improved or modernized canal system. The latter consisted of:

- An improved canal that required deepening sections of the canal system to approximately 15 ft to accommodate most fully-laden tank barges without change in the length or width of the lock chambers. The objective was to maximize the transport capabilities of existing barge equipment without extensive reconstruction of the canal itself. Infrastructure changes would be limited to lowering lock sills and deepening the canal without widening. (A consequence of this would be the necessity for operating the canal as a reversible one-way facility.)

- A modernized canal capable of handling ocean-going barges. This required replacing existing locks with a lesser number of replacement locks capable of accommodating the barge equipment presently being used in coastal service. Locks would be roughly 70 ft wide by 500 ft long and have a 22 ft depth over sill. Since the major operators were primarily engaged in coastwise and harbor hauling, the use of ocean-going equipment (in lieu of the two and four barge tows that were the original alternatives) would permit equipment interchangeability and operational flexibility. Present lock dimensions necessitate barge sizes unique to the canal system -- equipment that is too small (economically) for coastal and Great Lakes hauling (these barges are larger than the standard or jumbo-sized barges used on the inland waterway system).

Exhibit 23. Survey Form for Potential Users.

COMMODITY ______________ ☐☐☐ (STCC Code)
Value ($/ton or barrel) ________ Transshipment Costs ($/ton or bbl) ________
Estimate of transport costs via the canal system
____

	Destination (State, County)	Quantity (tons or bbl)	Mode	Shipments	Rate	Transit Time
Originating Shipments						

	Origin (State, County)	Quantity (tons or bbl)	Mode	Shipments	Rate	Transit Time
Terminating Shipments						

COMMODITY ______________ ☐☐☐ (STCC Code)
Value ($/ton or barrel) ________ Transshipment Costs ($/ton or bbl) ________
Estimate of transport costs via the canal system
____

	Destination (State, County)	Quantity (tons or bbl)	Mode	Shipments	Rate	Transit Time
Originating Shipments						

	Origin (State, County)	Quantity (tons or bbl)	Mode	Shipments	Rate	Transit Time
Terminating Shipments						

Barge Costs. The automated tug/barge used in the base case was supplemented with the vessel types listed as follows:

Exhibit 24.

Non-Petroleum Commodities Having Barge Potential

Source: Barge Canal Marketing Study: Technical Report, Table 1.23.

STCC Code	Commodity Type	Origin	Destination	Current Mode	Quantity (tons)	Wt. per Carload or Truckload	No. of Shipments Annually
24155	Wood Chips	Ballston Spa	Philadelphia	Truck	16,900	21	805
26111	Pulp	Erie, PA	Plattsburgh	Rail	20,000	85	235
14514	Clay	Georgia	Glens Falls	Rail	32,000	100	320
14716	Crude Sulfur	Cartaret, NJ	Glens Falls	Rail	4,700	89	53
14716	Crude Sulfur	Ohio	Glens Falls	Rail	3,500	88	40
28122	Caustic Soda	Syracuse	Glens Falls	Rail	4,875	98	50
28128	Clorine	Syracuse	Glens Falls	Rail	3,330	90	37
28112	Soda Ash	Solvay	Glens Falls	Rail	5,760	90	64
28199	Inorganic Chem.	Wilm., NC	Glens Falls	Rail	6,100	50	122
28199	Inorganic Chem.	Wilm., NC	Glens Falls	Rail/TOFC	5,500	45	122
28192	Nitric Acid	Parlin, NJ	Glens Falls	Truck	1,563	22	71
28193	Sulfuric Acid	New Jersey	Glens Falls	Rail	2,700	75	36

Vessel Type	Commodity Type	Use on
Existing Tug/Tank Barge	Petroleum products and other Liquid Bulks	Existing and Improved Canal
Drybulk Motor Vessel	Dry bulks	
Tug/Ocean-Going Tank Barge	Petroleum products and other Liquid Bulks	Modernized Canal
Tug/Ocean-Going Hopper Barge (with and without self-unloader)	Dry bulks	

Exhibits 25 and 26 show the variable and fixed costs used for the different vessel types. These in turn were used to generalize Eq. 3, developed earlier for petroleum products, to other vessel types and commodities:

$$c_b = \frac{100\, t\, [F_b + V_b]}{cap} \qquad (4)$$

where: c_b = barge cost, cents per gallon;
t = time, as previously defined, hours;

F_b = fixed cost = $\dfrac{\text{annual cost}}{24 \times \text{days operated per year}}$ (see Exhibit 26);
operations assumed over 315 and 330 days for present and ocean-going petroleum barges and 250 days for dry bulk motor vessels or ocean-going barges.

V_b = variable cost (see Exhibit 25); and

$$\text{cap} = \text{vessel capacity} = \frac{(\text{vessel volume})(\text{product density})}{2000} \quad \text{rated or maximum (tons)} \qquad (5)$$

Exhibit 25. Variable Costs for Selected Vessel Types.

Category	Variable Costs ($/hr)		
	Existing Tug/ Tank Barge	Motor Vessel	Ocean-Going Tug/Barge
Wages	$ 45.20	$ 37.62	$ 45.20
Fringe Benefits	10.90	9.03	10.90
Subsistence	2.10	1.80	2.10
Fuel Oil	16.00	10.00	76.00
Supplies	4.20	2.10	6.00
Maintenance & Repairs	10.00	10.00	10.00
Insurance	8.00	7.50	20.00
Miscellaneous	5.30	5.00	5.30
TOTAL	$ 101.70	$ 83.05	$ 175.50

Source: Barge Canal Marketing Study: Technical Report, Tables 2.2, 2.12, 2.16.

Exhibit 26. Fixed Costs for Selected Vessel Types.

Item	Fixed Costs ($000/Yr)		Existing Ocean-Going Tug/Barge		
	Existing Tug/ Tank Barge	New Dry Bulk Motor Vessel	Tank	Hopper Without Self Unloading	Hopper With Self-Unloading
Administrative Costs	$ 33	$ 33	$ 33	$ 33	$ 33
Annual Depreciation	30	104	240	240	360
Unscheduled Maintenance	15	0	0	0	0
Rate of Return (Interest Charges)	74	260	600	600	900
Total Yearly Fixed Costs	$ 152	$ 397	$873	$ 873	$1293

Assumptions:
1: Straight-line depreciation for 25 years.
2: Rate of return on investment and interest charges combined equal 10 percent of present value.
3: Capacity: Existing Tug/Barge 3,400 tons; 112,000 cu ft
Dry Bulk Motor Vessel 4,400 tons; 153,000 cu ft
Ocean-Going Barge 14,000 tons; 450,000 cu ft

Source: Barge Canal Marketing Study: Technical Report, Tables 2.3 and 2.16.

The end result was one barge costing equation with seven variables: round-trip time (hours); fixed cost ($/yr); vessel utilization (days/yr); variable cost ($/hr); volumatic capacity or cube (cu ft); maximum allowable cargo weight (tons); and product density (lb/cu ft). It can be further reduced to

$$c_b = \frac{t\,f}{\rho} \qquad (6)$$

where: t = time, hours;
f = factor for vessel type (see Exhibit 27); and
ρ = the lessor of the product density or the density at which the vessel cube equals the maximum allowable cargo weight (see Exhibits 27 and 28).

Information on commodity density is often essential in determining whether the vehicle or vessel cube weighs out at capacity. In this example, barges carrying petroleum products are typically weight constrained, whereas those carrying dry bulks could, in many cases, be volume constrained. The effective draft of the Champlain section constrains the weight that can be carried by existing barges, and that deepening of the canal permits vessel capacity to be utilized more effectively.

Terminal Costs. Terminal costs were previously developed for petroleum product movements by barge. Such costs must be extended to cover other liquid and dry bulk commodities. The following reasoning was employed in deriving the transshipment and local delivery costs given in Exhibit 29.

Terminal costs for nonpetroleum liquid bulks were assumed to be identical to that for petroleum products. It was reasoned that the movement would most likely be a reinstitution of one made previously and that existing waterfront storage facilities would be used. Such costs are typically small.

It is unlikely that shippers would make any major investment in new terminal facilities, but rather would use the public terminals already in existence. These terminals, which have fallen into disuse, consist of nothing more than a bulkhead or pier having road access. Potential users must obtain a NYSDOT permit and supply his own labor and equipment. Three component operations are potentially involved: (1) transfer of the dry bulk from vessel to land, (2) loading the truck, and (3) local delivery to the destination. Various methods are possible for unloading barges, including clam shells, conveyors, and vacuum systems. Since the volumes of potential traffic were small and movements were likely to be sporadic, the equipment required would most likely be leased or the user would accept a higher rate for the use of a self-unloading barge or motor vessel. Loading operations would involve using the same equipment or portable conveyors or front-end loaders. Exhibit 29 illustrates the types of data that typically have to be assembled for estimating terminal costs using the following equation:

$$c_{tb} = h + dc_{ld} \qquad (7)$$

where: c_{tb} = approximate dry bulk terminal cost (barge);

h = estimated handling (transfer and loading) cost, $/ton;
d = one-way distance from bulkhead to destination, miles; and
c_{ld} = estimated local delivery cost, $/ton-mile.

Physical Distribution Costs. Inventory costs for other liquid and dry bulk commodities were computed in the same manner as petroleum products. Exhibit 30 shows incremental delivery costs for nonpetroleum products as a function of time in storage beyond that required by normal business practices. Estimates of the amount of excess storage time were made on a case-by-case basis, depending on the temporal demand for the product; estimates ranged from a low of zero (cement) to a high of 6 months (rock salt). Since the numbers were at best order-of-magnitude approximations, no separate estimate of interest charges or insurance costs were made.

Changes to Unit Revenues/Charges

The modal alternatives examined required that additional unit rates be obtained or estimated. These alternatives reflected the possibility of (1) diversion of some barge petroleum product movements to interconnected tank car service, (2) attracting bulk commodity movements back to the canal system, and (3) infrastructure improvements to the locks and canal itself allowing the use of more heavily laden or larger barges, the effect of which would reduce economies leading to lower unit rates.

Additional Rail Rates. Exhibit 25 described the volume rail rate, which at that time had recently been implemented. This rate was extended in Exhibit 31 to include several other movements that potentially could meet the specified annual minimum. Exhibit 31 shows how nonexistent rates can be approximated using selected cost data from Rail Form A. This rate was not applied mechanically because feasibility depended not only on physical proximity to a rail line but also on the availability of, or at least space for, a sufficiently long siding. Given the need to (a) install pumps and other equipment, (b) lease rail cars from private car supplier (in most cases, they would have to be built), (c) build, extend, or rehabilitate a siding, and (d) make the contractual commitment, rail had to be viewed as a specialized service that, at best, would appeal to only a few, high-volume distributors. Other than Burlington, only Plattsburgh was considered to have this potential.

Existing Rail and Truck Rates for Potential Canal Traffic. For liquid and dry bulks identified as potential canal traffic, applicable rail or truck rates were obtained from the shippers as part of the survey process.

Barge Rates for Potential Canal Traffic. No additional rates were required for petroleum product movements located along the Champlain section. However, rates had to be estimated for other commodities. These rates were approximated by the same procedure described previously, by applying a multiplier to estimated unit costs.

Computing System Costs and Revenues

Revenue Equations

Once unit cost or revenue data have been assembled, the remaining work is simply assembling the components. At this point, a careful review and examination of the components were made to identify any

Exhibit 27. Calculated Vessel Type Factors.

Vessel Type	Canal Alternative	Days/Yr Operated	F_b ($ Thousands)	V_b ($/hr)	Cube (Thousands ft^3)	Max. Allow. Cargo Wt. (tons)	Max. P_{rho}	Vessel Type Factor
Existing Tug/Barge	Existing	315	78	101.70	112	2500	45	200
Dry Bulk Motor Vessel	Existing	250	397	83.05	153	3300	43	195
Existing Tug/Barge	Improved	315	78	101.70	112	3400	61	200
Dry Bulk Motor Vessel	Improved	250	397	83.05	153	4400	58	195
Ocean-Going Tug/ Tank Barge	Modernized	330	873	175.50	450	14000	62	127
Ocean-Going Tug/ Hopper Barge Without Self-Unloader	Modernized	250	873	175.50	450	14000	62	174
Ocean-Going Tug/ Hopper Barge With Self-Unloading	Modernized	250	1293	175.50	450	14000	62	174

Exhibit 28. Sample Commodity Densities.

Petroleum Products	Density (lb/ft^3)	Selected Commodities	Density (lb/ft^3)
Gasoline	46	Grains	41
Jet Fuel	47	Chemicals or Allied Products	44
Kerosene	51	Clay, Concrete, Glass, or Stone Products	49
Distillate Fuel Oil	54		
Residual Fuel Oil	60	Coal	70
Asphalt	64	Nonmetallic Minerals	100

* Source for Product Densities by STCC Code (5-digit level): Association of American Railroads, "The AAR Commodity Attribute File," Staff Report 81-13, June 1981.

Exhibit 29. Transshipment and Local Delivery Costs.

STCC Code	Commodity Description	Local Trucking ($/ton-mile)	Bulkhead Handling ($/ton - mile)
01	Farm Products	0.108	0.100
10	Metallic Ores	0.324	0.070
11	Coal	0.324	0.070
13	Crude Petroleum, Natural Gas,or Gasoline	0.065	0.053
14	Nonmetallic Minerals, Except Fuels	0.324	0.078
20	Food or Kindred Products	0.344	0.102
24	Lumber or Wood Products, except Furniture	0.108	0.100
26	Pulp, Paper, or Allied Products	0.124	0.096
28	Chemicals or Allied Products	0.124	0.071
29	Petroleum or Coal Products	0.065	0.068
32	Clay, Concrete, Glass, or Stone Products	0.092	0.078
33	Primary Metal Products	0.096	0.056
40	Waste or Scrap Materials	0.324	0.045

Sources.

1. American Trucking Association, National Motor Freight Classification. Washington, D.C. (February 1977).

2. Trine Transportation Consultants, Trine's Blue Book of the Trucking Industry. Washington, D.C. (1976).

missing pieces and areas where further developmental efforts would be warranted.

Barge Equations. In developing an equation to estimate barge rates (in the absence of such information from consignees), the first product was the following unit cost equation:

$$c_b = \frac{100\, t\, (F_b + V_b)\, f_1}{cap} \quad \text{(in ¢/gallon)} \qquad (8)$$

Exhibit 30. Incremental Inventory Costs for Non-Petroleum Products.

		Storage Time in Months				
		2	3	4	5	6
01	Farm Products	.6	1.9	3.2	4.4	5.7
10	Metallic Ores	.1	.3	.4	.6	.8
11	Coal	.1	.3	.4	.6	.8
13	Crude Petroleum, Natural Gas,or Gasoline	.1	.3	.4	.6	.8
14	Nonmetallic Minerals, except Fuels	.1	.3	.4	.6	.8
20	Food or Kindred Products	2.1	6.2	10.4	14.5	18.4
24	Lumber or Wood Products, except Furniture	.4	1.4	2.2	3.2	4.0
26	Pulp, Paper,or Allied Products	3.0	8.9	14.8	20.8	26.7
28	Chemicals or Allied Products	4.3	13.0	21.6	30.2	38.9
29	Petroleum or Coal Products	.4	1.1	1.8	2.5	3.2
32	Clay, Concrete, Glass,or Stone Products	3.4	10.3	17.1	24.0	30.8
33	Primary Metal Products	2.9	8.6	14.4	20.2	25.9
40	Waste or Scrap Materials	.7	2.2	3.6	5.0	6.5

Original Source: U.S. Department of Transportation, Transportation Systems Center, "Freight Transportation Markets and Service Quality Requirements."Cambridge, MA (July. 1977), Tables 2.3 and 2.4.

Note: Time value, in $/day/ton for 2-digit STCC codes, was multiplied by 1.5 (to convert to 1977 dollars) and by 15, 45, 75, 105, or 135 days to represent storage times of 2, 3, 4, 5, or 6 months, respectively. A further adjustment was made to make these costs comparable to the 9 percent interest rate and 1 percent insurance charge used for petroleum products.

This equation was based on petroleum products moving over the existing Champlain section. (A similar equation was also developed for the remaining portions of the canal system, for which the greater effective draft allows increased vessel loadings.) Equation 9 was then developed to estimate unit rates using the unit cost equation (Eq. 8) as a base:

$$r_b = m\, c_b \quad \text{(in ¢/gallon)} \qquad (9)$$

where: $m = 3.736\, t^{-0.226}$.

Exhibit 31. Estimated Volume Rail Rates.

Destination	Rail Distance (Miles)	Component (cents/100 gallons)			
		Terminal	Linehaul	Total	Comments
Plattsburgh	168	42.5	64.5	107	Offered by D&H
Port Douglas	168	42.5	64.5	107	Estimated
Ticonderoga	101	42.5	38.8	81	Estimated
Ft. Edward	57	42.5	21.9	64	Estimated
Burlington	168	42.5	64.5	107	Existing

Source: Interstate Commerce Commission, Rail Carload Cost Scales: 1977, Statement ICI-77 (November 1979) pp 36.

Fully Allocated Unit Cost for Tank Car 28,000 - 31,000 gallons (single car).

Territory: Official Excluding Northeast Region and Conrail.

Terminal Costs = 9.226 cents/cwt = C_6

Linehaul Costs = 0.08350 cents/cwt mile (average weight trains) or

$$\text{Total Costs} = \frac{14.028\ \text{¢/cwt @ 168 mi}}{23.254\ \text{¢/cwt @ 168 mi}} = c$$

Rail rates were approximated by:

$$r_r = \frac{[C_{tr} + C_{\ell hb}(d_r/d_b)]}{(C_{tr} + C_{\ell hb})}$$

where: r_r = new rail rate;
C_{tr} = terminal cost (rail);
$C_{\ell hb}$ = linehaul cost for base distance;

d_r = new linehaul distance;
d_b = base linehaul distance; and
r_b = published rail rate for base distance.

Equation 8 was later extended to include (a) other bulk commodities, (b) infrastructure changes (i.e., an improved or modernized canal), and (c) other types and sizes of vessels. This resulted in a cost equation of the following form:

$$c_b = \frac{t\ f_b}{\rho} \text{ (in ¢/gallon)} \tag{10}$$

which when combined with Eq. 9, produced the rate equation presented as follows:

$$r = \frac{0.3736\ f\ \ t^{0.774}}{} \text{ (in \$/ton)} \tag{11}$$

The corresponding revenue equation was:

$$R_b = V\ r_b \tag{12}$$

where: R_b = total barge revenue for that movement, $;
V = volume, tons; and
r_b = unit rate, $/ton.

Equation 12 was further extended to include terminal and inventory costs, where appropriate:

$$R_b = V\ [r_b + c_{tb} + c_{\ell b} - \text{dif}] \text{ (in \$/ton)} \tag{13}$$

where: c_{tb} = unit terminal cost (dry bulks only), $/ton;
$c_{\ell b}$ = inventory cost, $/ton; and

dif = differential in the wholesale price of petroleum products if the origin of the movement is northern New Jersey rather than Albany/Rensselaer (petroleum products only).

Truck Equations. A similar rate equation was developed for truckload shipments of petroleum products originating from Albany/Rensselaer:

$$r_t = 0.0501\ d^{0.85}\ f_1\ f_2\ f_3 \text{ (in ¢/gallon)} \tag{14}$$

The corresponding revenue equation was:

$$R_t = \frac{V\, r_t}{100} \qquad (15)$$

where: R_t = total truck revenue for that movement, \$; and
V = volume, gallons.

For truckload shipments of other commodities and for all shipments made by rail, the rates supplied by the potential shipper or consignee were used directly. Although a rate estimating equation could have been developed for interconnected tank car shipments, the limited opportunities for such movements made it more efficient to perform such computations manually rather than as an integral part of the forecasting technique. In such cases, the unit rates would be multiplied by the volumes involved to determine total revenues.

User Options

In this particular application, the user options were limited to computing either transport or distribution cost savings. The difference is that the latter included inventory costs for shipments made by barge. Everything else was "built-in."

Another option that would have been possible had the commodity flow data been disaggregated to the distributor level would have been the use of volume truck rates. Because commodity flow data had been aggregated to the county level, there was no way of determining the extent to which such rates were actually being used.

Mode Split Process

Because the study focused on potential cost savings from using the canal system, the mode split premise adopted was that shippers or consignees capable of being served by truck or barge would choose the least cost mode.

The Computational Process

The process involved computing total transport and distribution charges for each identified movement. One set of computations was made encompassing the base case and each alternative, existing and potential traffic. Inputs to the process included the commodity flow data and other reference data listed as follows:

Commodity Flow Data	Reference Data
Movement origin	Barge time
Movement destination	Highway distance
Commodity type	Rail distance
Density	Petroleum wholesale price difference
Mode	Vessel type factors
Volume	Inventory costs (petroleum products)
Transfer costs (dry bulks)	Local delivery cost (dry bulks)
	Local delivery distance (dry bulks)
	Rate (if supplied)

The basic computational sequence is as follows:

- First identify whether the movement represents existing or potential traffic.
- If the latter, identify the existing mode.
- Next, compute transport and distributional charges for the using either the rate equations or the supplied rate data.

  barge-existing canal
  barge-improved canal
  barge-modernized canal
  truck
  pipeline
  rail-conventional
  rail-interconnected tank cars

- If the movement was of petroleum products and originated in northern New Jersey, add the difference in wholesale prices to the transport and distributional charges computed for truck and rail.
- Identify the least cost mode (separately for transport and distributional charges).
- Prepare an output record containing:

  movement origin
  movement destination
  commodity type
  density
  present mode
  volume
  transport charges (7 different possibilities)
  least cost mode identifier
  distribution charges (7 different possibilities)
  least cost mode identifier

Summarizing and Evaluating Results

The output record described previously was then sorted into market area sequence and the various volumes and revenues were summarized. Since the process (a) involved canal physical configuration alternatives which replaced the existing canal (replaced rather than supplemented the base case), (b) focused on revenues along, and (c) did not account for vehicle movements, the table formats shown in Figure 4 of this manual were not employed.

Exhibits 32 and 33 present comparative transport revenues and volumes for petroleum products over the Champlain section. Exhibit 32 illustrates the differences between actual and expected behavior in terms of mode choice:

- Cost by barge less than competing modes; water transport used.
- Cost by barge less than competing modes; other modes used.

Exhibit 32. Sample Product 1: Cost Savings.

Mode Used	Least Cost Mode	Transport Cost Basis		Distribution Cost Basis	
		Volume Gallons X 10^6	Savings $ Millions	Volume Gallons X 10^6	Savings $ Millions
Barge	Barge	331.5	6.43	215.0	1.91
Alt. Modes	Barge	165.0	1.77	29.0	0.08
Barge	Alt. Modes	-	-	116.5	0.29
Alt. Modes	Alt. Modes	5.0	0.04	141.0	0.83

Source: <u>Barge Canal Marketing Study: Technical Report</u>, Tables 2.25 and 2.27.

Exhibit 33. Sample Product 2: Comparison: Transport and Distribution Cost Savings.

Barge Canal	Potential Traffic Gallons X 10^6	Transport Cost Basis		Distribution Cost Basis	
		Volume Gallons X 10^6	Savings $ Millions	Volume Gallons X 10^6	Savings $ Millions
Existing	501.5	331.5	6.43	331.5	1.62
Improved	501.5	404.5	8.91	370.5	3.10
Modernized	501.5	404.5	11.82	388.5	5.38

Source: <u>Barge Canal Marketing Study: Technical Report</u>, Tables 2.29 and 2.30.

- Cost by barge greater than competing modes; water transport used.
- Cost by barge greater than competing modes; other modes used.

The first case represents the savings being realized from the active use of the canal system. The second case represents the situation where alternate modes are being used even though transport costs would have been less if the movement was made by water. There are many reasons for this including:

- The need for resupply during the winter or spring months when water transport is unavailable.
- An unwillingness to make the capital investment in constructing (or rehabilitating) facilities and equipment needed to take advantage of bulk shipments by water.
- Throughput not high enough to justify the use of rail or water.
- Desire to retain flexibility and purchase petroleum products from alternate sources when the price is right, even though this may result in higher transport costs.

The second case might be thought of as "potential" waterborne traffic.

The third case is basically the complement of the preceding. A number of reasons can be advanced as to why a more expensive mode is being used, including:

- Some distributors may be making transport decisions on price along without considering inventory and terminal costs in reaching their decision.
- Distributors may have a deliberate policy of seeking and maintaining an inventory during the summar months as a hedge against product availability and transport problems during the winter months, even though this results in added expense.
- Inventory costs may be borne by the supplier either through delayed billing practices or retained ownership of the product.
- Institutional lag in changing modes from that which has been historically.

The fourth case represents that portion of the market for which water transportation is essentially noncompetitive. For example, barge transport as it now exists cannot effectively compete against pipelines or short distance movements presently being made by truck.

Exhibit 32 also illustrates the differences obtained when inventory costs are included. Mode choice is more explainable when done on a distribution rather than a transport cost basis.

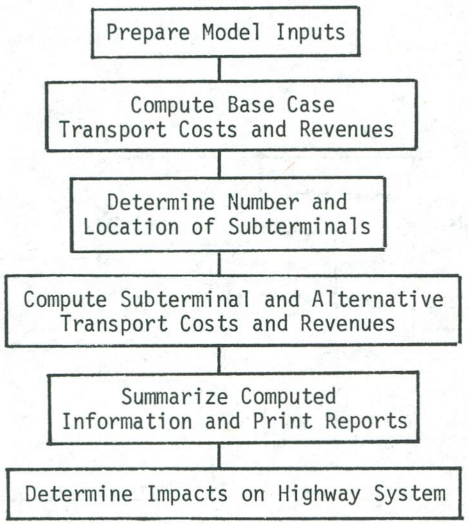
Exhibit 33 illustrates the modal shifts and transport and distribution cost savings that would be expected were the canal improved or modernized. It is a typical product of studies of this type.

CASE EXAMPLE B -- EXPECTED CHANGES IN GRAIN MOVEMENTS

The Montana Grain Subterminal Study

This case study was developed from the report Bulk Freight Grain Transportation System Study and related data, computer printouts, and notes prepared by Roger Creighton Associates Incorporated, Robert Peccia & Associates, and Radermacher & Associates for the Montana Departments of Agriculture, Highways, and Commerce during 1980-1981. The purpose of the study was to determine the economic and institutional feasibility of modernizing Montana's grain transportation system using grain subterminals to gain the efficiencies of centralized collection and unit train freight movements. Feasibility depended on whether the proposed subterminals generated sufficient economic benefits for Montana farmers and elevator operators to overcome the inertia and resistance to major changes in the transport and marketing of grain, and whether elevator operators and other grain shippers would be willing to combine their shipments into unit train quantities bound for a single destination while retaining their independence and competiveness in other areas.

The following diagram shows the basic structure of the freight demand forecasting model developed for use in the grain subterminal study. A model is simply an objective process or technique for estimating transport costs, revenues, and throughputs under different assumptions concerning markets, subterminals, and unit costs and rates. The six main components are:



The first component prepares the data required in applying the model. The basic revenue and cost computations are performed in the second and fourth components. Data for each grain flow are sequentially processed, revenues and costs are computed via the country elevator and the subterminal alternative, and a decision is made between routing all, part, or none of the grain via the subterminal alternative. Grain flow, revenue, cost, distance, and vehicle volume information is then entered onto an output file, which is summarized in the fifth component. These two components represent the heart of the model and can usually be performed simultaneously. The third component involves specifying the number and location of subterminals, which represent the alternatives being considered. For accomplishing this, two methods are possible: one based on using location allocation theory; and the other, on an empirical process. The last component is optional and involves determining highway impacts caused by potential changes in truck volumes in the vicinity of subterminals and along the principal grain hauling routes.

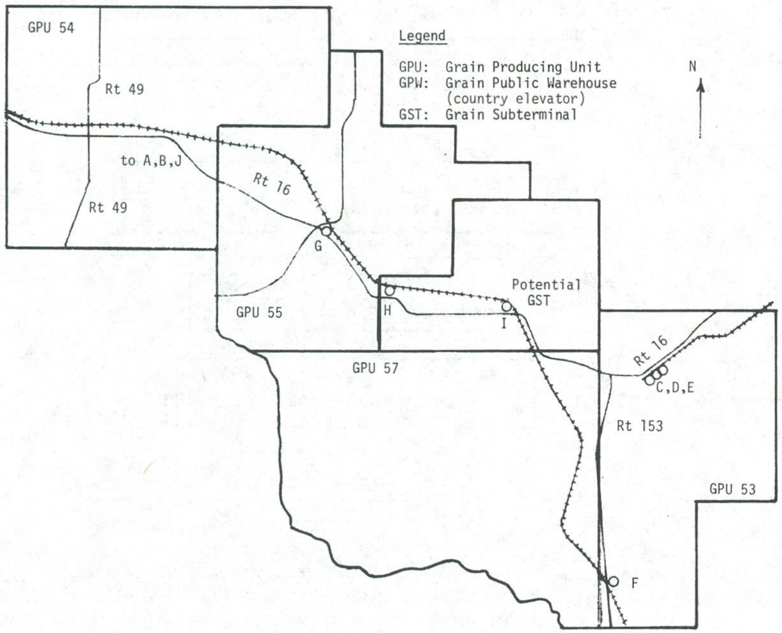
The application of the model in Montana was designed to be simple and straightforward. Such will depend on the options selected. Although not done in this case example, the model can have a recursive structure (i.e., feedbacks can be used to optimize a parameter). This would occur if (1) unit costs or revenues are treated as a function of throughput volumes, or (2) optimal solutions are derived for the number and location of subterminals or elevators. These possibilities are discussed in this case example.

Purpose and Intent of the Case Example

As previously, the case example illustrates the general applicability of the technique. Even though its focus is on a single commodity (i.e., grain, or more specifically export wheat), the example illustrates the use of the technique where a broad, in-depth examination of both economic and impact issues is desired. The former includes computations of efficiency benefits resulting from modernizing the grain transport system as well as the distributional benefits or differential effects on transporters, elevator operators, and the producers. The latter includes estimating changes in truck movements over the state highway system and the effect that such changes are expected to have on pavement life. The study used data already being collected by the state.

The original study included 188 grain producing units, 230 country elevators (or grain public warehouses), and 10 proposed subterminals. Since the purpose of the case example is to illustrate the application of the technique, rather than to replicate the previous work, this example has been reduced down to a single county containing five grain producing units and seven country elevators. Exhibit 34 shows the location of these units or facilities relative to the rail and highway system (main roads only).

Exhibit 34. Map Showing Example GPUs, GPWs, the Proposed GST, Rail Lines and Highways.



In this case example, names and numeric designations have been properly changed to protect the confidentiality of the original data.

The case example is based on the premise that a computer would be used to perform the computations. Although the original computations were performed using a small microcomputer, use of a larger microcomputer or a mainframe computer would have been preferable because of the size and scale of the problem (in terms of geographic coverage of the State and the number of grain-producing units, country elevators, subterminal possibilities, and highway and rail links).

This case example is organized to correspond with the elements of the freight demand forecasting procedure given in Chapter Two through Seven of this manual. The user will find that the presentation of each element, although specific to Montana, contains concepts, ideas, procedures, equations, data sources, and outputs that should be extremely helpful when undertaking similar work.

Defining the Problem

Stated Objective of the Study

"...to determine quantitatively the economic and institutional feasibility of modernizing Montana's grain transportation system using grain subterminals (GSTs) to gain the efficiencies of centralized collection and unit train freight movements." *

General Parameters

1. Area of Interest -- Originating points or grain producing units (GPUs) are subcounty areas for which production statistics are kept by the State of Montana and the United States Department of Agriculture. Intermediate points include the 230 GPWs currently operating in Montana and the proposed grain subterminals. The primary destination for export wheat is the export terminal located in or around Portland, OR. Other destinations include malt houses and flour mills in WA, OR, CA, or MN. Grain producing units covered all but the westernmost counties in Montana.
2. General Orientation of the Problem -- Commodity oriented. Overall focus is on economic benefits accruing to grain growers, transporters, and elevator operators from the implementation and operation of GSTs in comparison with a base situation.
3. Modes, Transport Facilities, and Services Utilized -- Rail movements are made primarily along two east-west lines crossing the State; one through Havre and Shelby in the north, and one through Billings and Helena in the south. Linehaul highway movements are made along I-90, US 2 and 12, and MT 200 to Lewiston, ID, and then by barge to Portland on the Snake and Columbia Rivers. Rail services considered include single and multiple car service (26 and 52 car units, with the latter being a unit train).
4. Commodities Being Transported -- Study limited to the transport of wheat grown in Montana, particularly that moving to export markets through export terminals located at or near Portland, OR.
5. Alternative Futures, Scenarios, or Conditions to be Examined -- Continuation of existing transportation patterns built around country elevators or grain public warehouses (GPWs), and single car rail or truck/barge transport service; adding grain subterminals and unit train service, but keeping GPWs as local collection and marketing points; and adding GSTs and simultaneously phasing out GPWs.

Major Tasks to be Accomplished (See Fig. 1)

1. Present economic activities (i.e., grain production, grain marketed).
2. Freight Traffic Generation.
3. Freight Traffic Distribution.
4. Present Service, Cost & Price Characteristics.
5. Modal Division.
6. Future Service, Cost and Price Characteristics.
7. Network Assignment.

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* Grain Subterminal Study, prepared for the Montana Departments of Agriculture, Highways, and Commerce, August 1981.

Analytical Choices

1. Measure Performance in Economic, Physical or Impact Terms -- Economic, primarily, because transit time, transit time reliability, and system capacity impose no major constraints on the existing system and are not expected to produce major effects under the alternative plans. The potential for accelerated pavement deterioration and associated increases in maintenance costs due to increased truck volumes near the GSTs examined, thus also requiring measurement in physical and impact terms.
2. Estimate Modal Shares on a Unit Price or Cost Basis -- Both, because rates are determined by costs, competition, and the transporter's desire to maximize profits.
3. Adopt a Physical Distribution or Transport Economics Orientation -- Transport economics, because growers seek to maximize profits in their grain marketing decisions, of which logistics costs (e.g., on-farm or country elevator storage costs) are but one component.
4. Price/Cost Movements on a One-Way or Round-Trip Basis -- Two-way, because the cost computations must reflect empty backhauls where these occur.
5. Optimizing Locations or Flows -- Not required in the study, although study could have been expanded to include optimizing GST locations.

Required Products

1. Record for each movement containing the following information:

- Identification

  a. Originating node (GPU).
  b. Destination.

- Contents

  a. Base Case

     - Commodity flow volumes.
     - Linehaul mode.
     - Composite unit cost (including collection, warehouse, and linehaul components).
     - Composite unit rate.

  b. Alternative Scenarios

     - Commodity flow volume.
     - Linehaul mode.
     - Composite unit cost.
     - Composite unit rate.

2. Report summarizing expected economic benefits or disbenefits associated with GST operations. Specifically, tables showing profitability for the hypothesized subterminals, and tables showing potential impacts on grain growers, rail carriers, motor carriers, barge operators, and warehouse operators.
3. Report summarizing expected impacts on the highway network stemming from increased truck traffic in the vicinity of the hypothesized GSTs.

Simplifying Premises and Assumptions

1. Aggregate market demand is price and service inelastic.
2. Modal division solely dependent on transport charges.
3. Study focused solely on grain movements from the grower to the terminal elevator (for export movements). Linehaul components involving ocean-going vessels are excluded along with final distribution.

Types of Supporting Data Required

1. Commodity flows from all GPWs to all destinations via all modes.
2. Rail and highway network descriptions with distances and locations of warehouses.
3. Number and location of hypothesized GSTs, including estimation of GST tributary areas and, by extension, annual GST throughput.
4. Unit costs and revenies for all transport modes. Costs and revenues must be developed for truck, single car rail, and unit train using accepted costing models, published tariffs, and shipper- and operator-provided information.
5. Unit costs and revenues for the different modes, GPWs, and GSTs under several alternatives: existing GPWs (base case), existing GPWs and new GSTs, and new GSTS only. Should include constructions costs, interest, and all operating expenses.

Preparing Base Case Inputs

Grain Production and Market Data

Ample statistics are usually available on the acreage, amount, and value of the feed and food grains produced in a state each year, aggregated at the county, district, and statewide levels. Examination of such data typically reveals: (1) sizable variability in the amount of grain produced from year to year, which usually is a function of natural conditions (e.g., weather) and to a lesser extent economic factors (price, demand), (2) the relatively constant amount of acreage planted or harvested each year, and (3) gradual shifts over time among different agricultural products. Exhibit 35, which summarizes acreage and resulting production of wheat and barley grown in Montana during the 1970's, illustrates these phenomena.

The first major decision the user must make is establishing a control total for the amount of grain produced in a region or a state. This can be based on a recent or typical year, or be arbitrarily chosen to represent average conditions, as was done in choosing 1979 as the case example base year. In this particular year, Montana growers

Exhibit 35. Montana Grain Production During the 1970's.

Year	Wheat (all varieties) Acreage Planted	Wheat Acreage Harvested	Wheat Total Bushels	Barley Acreage Planted	Barley Acreage Harvested	Barley Total Bushels	Total Acreage Planted	Total Acreage Harvested
1970	3,506	3,383	85,167	1,800	1,714	65,132	5,306	5,097
1971	4,516	4,314	112,011	1,740	1,680	58,800	6,256	5,994
1972	4,130	3,704	98,831	1,820	1,707	64,013	5,950	5,411
1973	4,235	4,052	96,714	2,100	2,000	60,000	6,335	6,052
1974	5,020	4,857	120,108	1,370	1,250	37,500	6,390	6,107
1975	5,130	4,975	155,925	1,360	1,300	50,700	6,490	6,275
1976	5,580	5,415	167,295	1,220	1,170	52,065	6,800	6,585
1977	5,400	5,060	130,920	1,650	1,520	55,480	7,050	6,580
1978	5,031	4,840	146,050	1,500	1,375	59,125	6,531	6,215
1979	5,363	5,125	116,475	1,100	1,040	40,560	n.a.	6,165
Ave.			122,950			54,338	6,345	6,047

Sources: Montana Agricultural Statistics - State Series 1867-1976 April 1978.
Montana Agricultural Statistics, Volume XVII December 1978.
Selected County Agricultural Statistics, 1978-1979, March 1980.

Montana Department of Agriculture in cooperation with the U.S. Department of Agriculture, Montana Crop and Livestock Reporting Service.

produced 116.5 and 40.6 million bushels of wheat and barley, respectively. These totals were below the mean value for the 1970's, and thus were conservative.

County-level statistics on grain production are also readily available. However, in this case in this study, such statistics were too aggregate to use in computing transport costs. As part of its larger responsibility to monitor crop acreage and production, the Montana office of the Agriculture Conservation and Stabilization Service made available the crop production data collected by county agents and aggregated to subcounty areal units. Thus, wheat and barley production information was obtained for 44 counties and 194 subcounty areas, subsequently referred to as grain producing units or GPUs (see Exhibit 36. These counties produced 115.1 million bushels of wheat in 1979.

Exhibit 37 illustrates the general destinations of wheat and barley movements in 1979, as reported to the Montana Department of Agriculture by GPWs. This is not, however, a complete accounting of the grain marketed during that year. The primary destinations for wheat and barley were the Pacific North Coast and the interior of Oregon and Washington for both export and domestic shipments, with the latter being consigned to flour mills, feed lots, and malt houses. Wheat destined for Idaho was trucked to Lewiston where it was loaded on barges for movement to Portland or vicinity. Wheat and barley destined for Montana represented shipments to storage elevators for later reshipment to west coast markets. Barley moving to California was destined to feed lots; barley to Minnesota was destined to a malt house. Minor amounts were also shipped to other destinations.

Exhibit 36. Grain Producing Units.

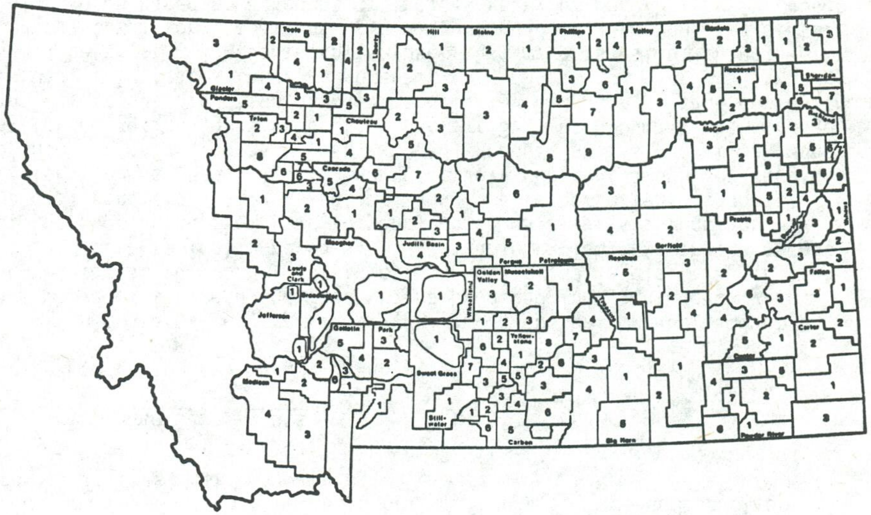


Exhibit 37. 1979 Grain Movements by Destination.

Destination	Wheat Rail	Wheat Truck	Wheat Total	Wheat %	Barley Rail	Barley Truck	Barley Total	Barley %
Pacific North Coast	29,938	5,748	35,686	41	2,843	1,069	3,911	24
Interior Oregon or Washington	18,473	9,114	27,587	32	1,649	632	2,280	14
Idaho	80	9,001	9,081	10	236	656	892	5
California	204	1,851	2,055	2	92	2,964	3,056	18
Colorado	0	41	41	0	303	5	308	2
Utah	9	827	837	1	1	532	533	3
Minneapolis/ St. Paul	1,089	1,100	2,189	3	1,494	541	2,035	12
Duluth/Superior	744	59	803	1	41	29	70	0
Other Minnesota	38	509	547	1	362	27	389	2
Montana	5,196	3,379	8,575	10	1,860	1,095	2,955	18
Total	55,834	31,696	87,531	100	8,932	7,717	16,649	100

Source: Montana Department of Agriculture - Grain Transport Data.

Note: Columns will not add up to totals shown due to the omission of minor movements.

Grain produced is not necessarily grain marketed and transported. The availability of large amounts of storage both in GPWs and, particularly, in on-farm silos provides appreciable flexibility to the grain grower seeking the most advantageous moment to market his product. Other factors affecting marketing (besides price or demand) include the amount retained on-farm for seed or as cattle feed, losses from shrinkage age or spoilage, transport availability, and the need to provide room for future crop storage. Thus the second major decision the user must make is to estimate the aggregate amount or the proportion of grain produced that is actually marketed, recognizing that substantial differences can occur between grain produced and grain marketed from year to year, although over the long run grain consumption must be in balance with grain production. Montana grain reported as being marketed in 1979 includes a portion of the 1979 harvest plus portions of previous years' harvests.

Most of the Montana-produced wheat and barley was marketed by the 230 State or Federal licensed country elevators or GPWs then in existence in Montana. The fairly small portion not marketed through GPWs typically finds its way to markets through "track buyers," who predominantly use motor carriers to transport wheat and barley directly to customers. Unfortunately, little information existed on the amount and destination of grain bypassing GPWs, thus making a complete accounting of grain movements impossible. However, such grain is unlikely to move through subterminals.

Commodity Flows

The case example essentially involves a two-step process: (1) linking GPU-produced grain with GPW throughputs, and then (2) linking these throughputs with market demand. To do this, the user would have to accomplish the following subsidiary tasks:

- Define the boundaries of GPUs; determine associated grain production, and approximate or calculate the centroid locations.
- Determine the total throughput of each GPW.
- Determine the over-the-highway distance between GPUs and nearby GPWs, or assign Cartesian coordinates to each GPU and GPW and compute airline distances, using a circuity factor to approximate over-the-highway distances.
- Estimate the proportion of GPU-produced grain that is actually marketed.
- Allocate GPU-marketed grain among different GPWs.
- Determine markets, associated demand, and mode combinations servicing those markets.
- Determine over-the-rail and over-the-highway distance between GPWs and markets.
- Allocate GPW-handled grain among the different market/mode combinations.

The latter task is all-important. It can be accomplished in one of several ways:

- <u>Using Data Collected on a Systematic Basis by a State Agricultural Agency</u> -- An example of this is Montana's Grain Movement System, which collects commodity flow information on a monthly basis from all elevators licensed by the State. Information is obtained on the volume (bushels), vehicles and mode used (number of boxcars, covered hoppers, and grain trucks) and commodity type (winter, spring and durum wheat, barley, etc.), and destination. Such a system can provide excellent information on present flows provided that (1) a high degree of participation is maintained, (2) periodic audits or checks are conducted to ensure the receipt of accurate information, and (3) the information is afforded the confidentiality mandated by elevator operators and grain companies in supplying the information.
- <u>A Comprehensive Survey of Grain Movements</u> -- Such a survey, if carefully executed, should produce results comparable to the above. It does place a greater immediate burden on elevator operators because it forces them to go back and dig out records covering, say, a one-year period.
- <u>Allocation Models (Entropy Maximizing Models)</u> -- To do this, further information is required on the aggregate use of different modes by market. Application of the model normally requires that two constraints be satisfied: (1) the sum of the commodity flows from the GPW must equal the total throughput of the GPW, and (2) the sum of the traffic received at each market/mode possibility must equal predetermined totals. An iterative process must be used to accomplish this allocation. The impedance function that drives the allocation process (algorithm) usually involves "generalized cost" (i.e., some function representative of cost/distance). Close agreement with observed market patterns may not be achieved, however, given the competition taking place and institutional factors affecting the choice of markets.

In this case example, a combination of data sources was used to estimate GPW throughputs (where necessary) and GPW-to-market commodity flows, because no single source covered all GPWs or grain movements. Component data sources used included.

- Montana's Grain Movement System.
- The Montana Wheat and Marketing Research Commission's records on bushels of wheat and barley for which assessments were paid to the Commission.
- A mailout-mailback survey of all GPWs conducted in June 1980.
- Aggregated carload data for both origins and destinations, as prepared by the Burlington Northern.
- Disaggregate traffic data by station, as provided by the Milwaukee Road.

The methodology fashioned to reconcile differences among data sources exploited the positive attributes of each of the available sources, relying on reasoning, professional judgment, and knowledge of grain operations in Montana to derive reasonable estimates in the face of conflicting or missing data. Exhibit 38 illustrates how this was done.

Once GPW throughputs were estimated, it was then possible to apportion GPU production to GPWs. It can be done by either:

Exhibit 38. Reconciling Grain Movement Data.

Attributes of Available Data Sources	
Source	**Attributes**
Grain Movement System (GMS)	Generally used for distributing flows among modes and markets. Not considered as reliable as other sources for GPW throughputs. Discrepancies generally traceable to underreporting during particular months of year. Historical GMS data used in absence of 1979 data.
Wheat Commission (WC)	WC totals generally higher than GMS; considered more reliable since GPWs act as collection agents for Wheat Commission assessments and were presumed to maintain accurate records.
Special Survey (s)	Totals generally similar to WC; used in absence of WC data.
Railroad Data	Used in absence of other data. Disaggregate data, where available, used in determining GPW movements by railroad.

Utilization of the Data Sources

Data Available from Sources	No. GPWs	Data Used to Establish GPW Throughputs	Data Used for Mode and Market Distribution
GMS, WC, S	139	WC or S, whichever higher	GMS
GMS, WC	48	WC	GMS
GMS, S	8	S	GMS
WC, S	11	WC or S, whichever higher	Historical GMS or comparable GPW
GMS	5	GMS	GMS
WC	9	WC	Historical GMS or comparable GPW
S	3	S	Same as above
None	7	RR and historical GMS	Historical GMS

- <u>A subjective approach</u>, based on (1) intuitively defined tributary areas for each GPW, (2) characteristics of the local highway system, and (3) knowledge of traditional trading/commerce patterns. The process consists of linking GPW throughput with GPU production starting first with GPUs located closest to GPWs and then extending the process to those located further away. It may become necessary to allocate GPU production among two or more GPWs. Since GPU production is presumed to be greater than GPW throughputs, a second iteration would consist of proportionally allocating GPU production to GPWs.
- <u>An optimizing approach</u> using linear programming to minimize transport distances or costs between GPUs and GPWs. This can be done either by using airline distances computed from assigned coordinates or by using measured over-the-road distances between GPUs and GPWs.

The first method is basically a cut-and-try process that may result in some imbalances between grain produced by GPUs and handled by GPWs. The second method may result in greater farm-to-elevator distances and some illogical movements caused by the need to absolutely tie together grain marketed by GPUs and handled by GPWs. Each has its advantages and disadvantages; neither will work perfectly. The former was used in Montana.

A formally coded highway network comprised of links and nodes is not essential for the purpose of linking GPU-produced grain with GPW throughputs. However, if the user is interested in changes in truck volumes on the local highway system, it becomes desirable to use a tree-building program to determine the minimum path between GPU and GPW and to assign grain flows to the highway system after conversion to truck equivalents. Usually, distance would be used in the minimum path algorithm, although either time or cost could similarly be used.

Exhibit 39 presents a portion of the commodity flow matrix developed for the grain subterminal study. It represents the "end product" after GPU production has been balanced against GPW throughputs. Exhibit 40 shows corresponding over-the-road distances from GPUs to GPWs and highway and rail network distances from GPWs to various markets. (These data will be further used in illustrating the various calculations and products from applying the freight demand forecasting technique.)

Unit Transport Costs

Unit cost estimates were developed for the different modes. Farm and grain truck costs were estimated in part using outputs from the AAR's Truck Costing Model. Rail costs were derived from Rail Form A data. Barge costs were approximated from barge rates. Resulting unit costs were adjusted to represent mid-to-late fall, 1980.

<u>Farm Trucks</u>. Single unit two- and three-axle trucks owned and operated by growers are generally used to transport grain to GPWs. Vehicle payloads ranged from 350 to 500 bushels. An average unit cost of $0.748 per mile was derived based on the following parameters:

- Average operating speed, 45 mph.
- Estimated fuel consumption, 8 mpg.

Exhibit 39. Sample Commodity Flow Data.

GPU	GPW	Wheat (Thousands bu)	Amt. Transported by Mode and Destination (see below) 8012	8022	8011	8014	8021
53	C	63.6	34.0	29.6			
53	D	186.9	38.3	114.1	1.3	28.7	4.5
53	E	92.4	90.4		2.0		
53	F	152.5			53.4	2.1	97.0
54	G	158.8	69.2	53.5		28.5	7.6
54	J	83.9	27.6	39.8	1.7	7.7	7.1
55	G	158.7	69.1	53.5		28.5	7.6
55	A	245.5	200.2		14.6		30.7
55	B	281.7	66.2		11.1	11.7	192.7
56	H	127.9	96.6				31.3
56	I	250.4	201.6				48.8
56	A	245.5	200.2		14.6		30.7
57	C	64.0	34.2	29.8			
57	D	186.6	38.3	114.0	1.2	28.6	4.5
57	E	92.7	90.7		2.0		
57	B	281.7	66.2		11.1	11.7	192.7
		2672.8	1322.8	434.3	113.0	147.5	655.2

	Mode	Destination	Market
8012	Rail	Pacific North Coast	Export
8022	Rail	Interior of Oregon or Washington	Domestic
8011	Truck	Pacific North Coast	Export
8014	Truck/Barge	Pacific North Coast via Lewiston, ID.	Export
8021	Truck/Barge	Pacific North Coast via Columbia or Snake River Ports.	Export

* Fictitious names have been used to maintain confidentiality of GPU and GPW-level data. Actual data are from two counties located in central Montana.

- Average vehicle cost (new), $30,000.
- Average driver salary, $5.00/hour.
- Insurance cost, $900/year.
- Maintenance cost, $700/year.
- Tire cost, $300/year.
- Fuel Price, $1.176/gallon.
- Annual mileage, 10,000.
- Useful service life, 10 years.
- Operating Expense (cents/mile):
  - Driver 11.1
  - Capital 30.0
  - Fuel 14.7
  - Insurance 9.0
  - Maintenance 7.0
  - Tires 3.0

This cost was subsequently applied on a round-trip basis to farm truck movements from GPUs to GPWs (and later on to GSTs), using 425 bushels as the average payload.

Exhibit 40. Sample Distance Matrix.

GPU	GPW	Distance (miles) GPU-GPW	GPW-8012	GPW-8022	GPW-8011	GPW-8014	GPW-8021
53	C	3.7	1330.9	960.9			
53	D	3.7	1330.9	960.9	893.5	526.6	641.5
53	E	3.7	1330.9		893.5		
53	F	22.2			888.2	521.3	636.2
54	G	16.6	1197.6	827.6		454.8	569.7
54	J	44.2	1129.9	759.9	787.4	420.5	535.4
55	G	4.3	1197.6	827.6		454.8	569.7
55	A	61.8	1132.8		791.1		539.1
55	B	62.3	1132.2		790.1	423.2	538.1
56	H	3.1	1210.9				558.3
56	I	3.8	1216.3				551.5
56	A	77.7	1132.8		791.1		
57	C	17.1	1330.9	960.9			
57	D	17.1	1330.9	960.9	888.5	521.6	636.5
57	E	17.1	1330.9		888.5		
57	B	80.2	1332.2		790.1	423.2	538.1

Grain Trucks (Linehaul). Two types of tractor/semitrailer rigs were typically used to transport grain from GPWs to river terminals or west coast markets. The first type was specially constructed semi-trailers having double hopper bottoms and capable of carrying 1,100 to 1,200 bushels. The second consisted of varied box-type semitrailers temporarily outfitted to haul 800 to 1,000 bushels as a backhaul movement. Average unit costs of $1.427, $1.27, and $1.15 per loaded mile were derived for loaded mileage/total mileage ratios of 70, 80, and 90 percent, respectively, based on the following parameters:*

- Equipment ownership, driver owned/operated.
- Depreciation method, straight line.
- Miles operated per year, 99,700.
- Fuel price, $1.12/gallon.
- Estimated fuel consumption: empty - 6.273 mpg
  grain - 3.162 mpg
  plywood- 3.802 mpg (backhaul)

* References: (1) "Owner-Operator Truck Cost Guide," USDA Office of Transportation, April 1980; and (2) Jansen, D.R., "An Analysis of the Costs of Truckload Freight Operations," Economics and Finance Department, Association of American Railroads, August 1979.

- Operating Expense (cents/mile)
  - Driver 22.1
  - Driver Expense 3.5
  - Capital 22.0
  - Maintenance 10.5
  - Tire 1.5
  - Licenses/permits 1.2
  - Federal tax 0.2
  - State/local tax 0.5
  - Insurance 5.0
  - Overhead 3.5

This unit cost was subsequently applied on a one-way trip basis for grain movements from GPWs to river terminals or west coast markets. Average payload was 1,017 bushels.

Rail Costs (Single Car Service). Standard Rail Form A costing procedures were used to cost out single car rail service. It involved computing the following three components.*

- Terminal Cost -- Terminal switching.
- Way Train Costs -- Costs of hauling from a GPW to a local yard on the origin end and from a local yard to the flour mill, malt house, or terminal elevator on the destination end.
- Through Train Costs -- Linehaul and inter- and intra-train switching costs.

Variable inputs included:

- Weight.
- Distance in shortline miles.

Constant inputs included:

- Average car weight -- 64 tons/box car, 96 tons/covered hopper.
- Average way trin mileage -- 102 miles.
- Circuity factor -- 1.17 for box cars, 1.18 for hopper cars (takes indirect routings into consideration).
- Temporal growth factor -- 1.396 (to grow 1977 Rail Form A costs to 1980).
- Car mix factor -- 1.116 (to account for a mixture of box and hopper cars instead of straight hopper cars).
- Various cost factors (see Exh. 41).

The cost of moving a single carload was first computed. Then, the total commodity flow was divided by the weight per car to obtain the unit cost. A small computer program was written to calculate variable and fully allocated costs for single car movements from selected stations in Montana and North Dakota to Portland on the Burlington Northern. The results of these calculations were reviewed with persons knowledgeable about rail costs and rates to establish their reasonableness.

* References: (1) Statement No. 1C1-77, "Railroad Carload Cost Scales-1977, November 1979, Page 126"; and Notice 3006-02 "Rail Update Ratios", both published by the Interstate Commerce Commission, Bureau of Accounts.

Exhibit 41. Component Cost Factors.

Item		Unequipped Box	Covered Hopper	
Variable Cost				
Terminal:	**per carload**	17735.406	17735.406	
	per cwt	0.124	0.124	
	total per cwt	13.980	9.361	(1)
Way Train:	**per car-mile**	69.94698	58.41394	
	per cwt-mile	0.02973	0.02973	
	total per cwt-mile	0.08438	0.06015	(2)
Through Train:				
	per car-mile	53.15459	45.79025	
	per cwt-mile	0.01938	0.01938	
	total per cwt-mile	0.06091	0.04323	(3)
Mileage:	**Total**	variable	variable	
	Way Train	102	102	(4)
	Through Train	D-102	D-102	(5)
Constant Expense				
Terminal Cost per cwt		3.749	3.749	(6)
(Line-Haul Cost per cwt)		0.01785	0.01785	(7)
Fully Allocated Cost				
Way Train per cwt-mile		[(2) + (7)] X 1.17		(8)
Through Train per cwt-mile		[(3) + (7)] X 1.17		
Total Terminal Cost per cwt		(1) + (6)		
Total Way Train Cost per cwt		(8) X (4)		
Total Through Train Cost per cwt		(9) X (5)		

Note: to eliminate interchange costs, subtract 3.53678 (box cars) and 3.60896 (hopper cars) from way and through train per car-mile variable costs and 0.00052 from line haul cost per cwt.

From this, the following equation was derived for computing rail costs, assuming covered hoppers with an average load of 94 tons:

$$c = 0.00056\, d + 0.12459$$

where: c = unit cost per bushel and d = one-way distance in miles.

Barge. The barge costing models developed to date do not include the Columbia-Snake system. Given (1) the lack of public sector information on barge costs and (2) the intra- and inter-modal competition taking place, the decision was made to set costs equal to rates for this type of service, recognizing that a small profit is undoubtedly being made by the barge companies.

Sample Cost Calculations. Exhibit 42 illustrates how the cost computations were actually performed.

Unit Terminal Costs

GPWs. Even though GPWs or country elevators are regulated by the Montana Department of Agriculture, reliable cost information on elevator operations was not available. Hence, it was necessary to modify/update an earlier USDA study to provide approximate unit costs. (USDA, "Cost of Storing and Handling Grain and Controlling Dust in Commercial Elevators, 1971-1972 -- Projections for 1973-1974.")

The data contained in the USDA study were adapted to Montana by applying regional adjustment and inflation factors. The USDA study (see table footnote) found that country elevator costs in the far west were higher than the national average primarily in the area of receiving and shipping costs. Consequently, a factor of 1.10 was applied. A series of inflation factors were developed and applied to the various cost components, outlined as follows:

Cost Component	Index	Factor*
Depreciation	Commercial & Factory Building	1.79
Insurance	Commercial Multi-peril Insurance	2.39
Taxes	Federal, State, and Local Tax Collections	1.91
Licenses & Bonds	Consumer Price	1.66
Direct Labor Adm. & OVH	Average Annual Wages for Wholesale & Retail Trade	1.66
Elec. & Heat	Fuel and Other Utilities	1.87
Truck Expenses	Motor Vehicles & Equipment	1.61
Building Repairs Equip. Repairs	Maintenance & Repairs	1.68
Grain Insurance Taxes on Grain	Producer Price Index-Grains	1.01
Fumigation Other	Producer Price Index-All Commodities	1.78

* USDA, "Cost of Storing and Handling Grain and Controlling Dust in Commercial Elevators 1971-1972 -- Projections for 1973-1974," p.368.

Exhibit 42. Sample GPW-Oriented Cost Calculations.

1. Farm Trucks
   From GPU 53 to GPW D:
   186,900 ÷ 425 = 439.8 or 440 veh
   440 X 3.7 X 2 X $0.748 = $2,435
2. Grain Trucks (Linehaul)
   From GPW D to Pacific North Coast (8011):
   2,500 ÷ 1017 = 2.5 or 3 veh
   3 X 893.5 X $1.15 = $3,083
   From GPW D to Lewiston, ID (8014):
   57,300 ÷ 1017 = 56.3 or 57 veh
   57 X 526.6 X $1.427 = $42,833
   From GPW D to Interior OR/WA (8021):
   9,000 ÷ 1017 = 8.8 or 9 veh
   9 X 641.5 X $1.27 = $7,332
3. Rail (Single Car Service)
   From GPW D to Pacific North Coast (8012):
   76,600 X [0.00056 (1330.9) + 0.12459] = $66,634
   From GPW D to Interior OR/WA (8022):
   228,100 X [0.00056 (960.9) + 0.12459] = $151,161
4. Barge
   From Lewiston, ID to Pacific North Coast (8014):
   57,300 X (0.1437 + $0.0523) = $11,231
   From Interior OR/WA to Pacific North Coast (8021):
   9,000 X (0.1437 + $0.0523) = $1,764
5. GPWs
   For GPW D, a country elevator having a throughput of 747,000 bu and a storage capacity of 162,000 bu (turnover ratio = 4.61):
   $$373{,}500 \text{ X } \left[\frac{0.1717}{4.61} + 0.00019\left(\frac{365}{1.67(4.61)} - 15\right) + 0.07575\right] = \$44{,}510$$
6. Cost Summary
   The above cost computations were performed for each GPU-GPW-mode/destination combination. From this, total and unit cost summaries were prepared for each GPU, GPW, and county. The following shows the type of summaries produced:

GPU	BUs (Thousands)	Total Costs ($ Thousands)					
		Farm Truck	Grain Truck	Rail	Barge	GPWs	Total
53	495.4	16.43	160.35	247.65	25.92	58.42	508.77
54	242.7	22.54	34.38	141.63	9.97	30.21	238.73
55	685.9	117.92	203.64	303.44	53.14	114.42	792.56
56	623.8	72.06	89.14	407.57	21.71	104.90	695.38
57	625.0	100.44	174.05	300.14	46.54	77.95	699.12
TOTAL COUNTY	2672.8	329.39	661.56	1400.43	157.28	385.90	2,934.56

Exhibit 43 shows estimated 1980 country elevator component costs per bushel of capacity for both truck and rail oriented facilities. These cost components were used to derive the following cost equation:

$$c = \frac{0.1717}{\text{Turnover ratio}} + 0.00019\,X \left[\frac{365}{\text{Turnover ratio}} - \text{free days}\right]$$

$$\text{Turnover} = \frac{\text{Annual elevator throughput}}{\text{Working storage capacity}}$$

Exhibit 43. 1980 Country Elevator Component Cost per Bushel of Capacity.

Cost Component	Handling Costs		Storage Costs
	Truck/Rail	Truck/Truck	
Fixed Cost			
Depreciation	1.05	0.92	4.18
Insurance	0.16	0.14	1.71
Taxes	0.18	0.18	2.34
Licenses/Bonds	-	-	0.26
Interest on Investments	0.77	0.68	6.64
Subtotal	2.16	1.92	15.13
Variable Costs			
Direct Labor	3.05	2.57	2.42
Adm. OVH	1.91	1.95	1.82
Elec. & Heat	0.44	0.43	0.14
Truck Expenses	0.43	0.59	-
Bldg. Repairs	0.02	0.02	0.97
Equip. Repairs	0.57	0.52	0.15
Grain Insurance	-	-	0.51
Taxes on Grain	-	-	0.14
Fumigation	-	-	0.27
Other	1.10	1.10	0.35
Int.on Working Capital	0.23	0.22	0.20
Subtotal	7.75	7.40	6.97
TOTAL COSTS	9.91	9.32	22.10

The first term calculates the fixed or capital unit cost component. The second term computes the variable unit cost for storage. The last term is the variable unit cost for handling. Working capacity was assumed to be 60 percent of storage capacity.

Unit Charges/Rates

In developing unit revenues or charges, published or otherwise established rates in effect on or about December 1, 1980, were used to the maximum extent possible. These rates covered basic transport and elevation services, applicable fuel surcharges, and short-term storage. They did not include charges for preparing or storing (long-term) grain or for rerouting or other in-transit privileges.

Rail. Tariff summaries containing published single and multi-car rates for export wheat were obtained. These rates were from stations (originating points) throughout Montana for grain moving to Pacific North Coast ports. Rates to different ports (except Astoria) have been standardized. Single car rates were also obtained for domestic wheat and barley.

No allowance was made for additional income stemming from rerouting, demurrage, or other accessorial charges.

Grain Trucks (Linehaul). Unlike rail rates, truck rates on agricultural commodities are not regulated or published. In Montana, they were generally set a few cents a bushel less than rail rates. Truck rates are further affected by: (1) a willingness of truckers to accept rather low remuneration if the movement is a backhaul when the truck would otherwise return empty, (2) the ability of the major grain companies to somewhat arbitrarily establish the rates they are willing to pay from a given locality to a market or river terminal, (3) variations in equipment size and type that lead to variations in unit costs, and hence rates, and (4) the premiums sometimes paid in order to take advantage of a market opportunity or simply meet a contractual commitment without penalty. Much of the fronthaul trucking was being provided by independent owner/operators; backhaul movements were being provided by anyone heading west who had an empty vehicle.

Short of auditing or sampling GPW records, there was no easy way of firmly establishing what GPWs were paying for truck transportation. Even if this were done, great care would have to be exercised to (1) make sure the rates were current and (2) carefully distinguish between fronthauls, backhauls, and movements for which premiums were paid. Consequently, it was decided to approximate grain truck revenues (charges to the grower) by using single car rail rates in existence prior to December 1, 1980, and then subject (1) the cost of barge transport and river elevator throughput charges (0.196 $/bu) and (2) an additional $0.06 per bushel, which was basically an "inducement" factor to use trucks. Furthermore, truck rates to interior Oregon and Washington points were increased by $0.027 per bushel to reflect the slightly higher rail rates for domestic movements.

Farm Trucks. Hauling grain in farm trucks is a cost to the grower. While typically thought of as part of the cost of producing grain, it can also be treated as a transport charge even though the service is performed by the grower. In this case, unit charges would be set equal to unit costs.

Barge and River Terminals. Although not published, nor subject to ICC regulation, barge rates were obtained from barge companies. An average charge of $0.1437 per bushel was used for barge transport from Lewiston, ID, to Portland, OR. An additional charge of $0.0523 per bushel was used to represent handling and storage at river terminal facilities. Barge rates for Almota and Central Ferry were slightly less ($0.1422 per bushel), although this is offset by slightly higher trucking charges.

GPWs. The following type of equation was used to estimate unit rates per bushel:

$$r = \left[\frac{365}{\text{Turnover ratio}} - \text{Free days}\right] \text{Storage cost/day} + \text{Handling}$$

$$\text{Turnover ratio} = \frac{\text{Annual elevator throughput}}{\text{Working storage capacity}}$$

This equation utilized (1) the maximum charges permitted under state regulation for storing and handling grain (0.1 cents per bushel per day and 10.5 cents per bushel, respectively in Montana), (2) a free storage period of 15 days, and (3) a working storage of 60 percent of capacity. It assumed that the storage capacity of the elevator remained full throughout the year. Actual handling charges could be somewhat less, depending on whether strong competition existed among GPW operators in a particular locality. The equation did not include revenue derived from ancillary services, such as cleaning or drying.

Sample Revenue Calculations. Exhibit 44 shows how the revenue computations were actually performed. (Revenues to the transporter are charges to the user.)

Network Data

Both the highway and rail networks were coded into machine-readable form for commodity and vehicle flow accounting purposes. Conventional coding practices were used: trackage or highway segments being represented by links and connections between segments and to GPWs by nodes.

Rail Network. The rail network was restricted to Montana segments used for the transport of grain. It also included network extensions westward to Seattle and Portland. A total of 710 rail links were identified, for which the following information was collected for each:

- Railroad subdivision.
- Length (miles).
- Load limit.
- Authorized maximum operating speed.
- Estimated scheduled running time.
- Trains per week.
- 1979 traffic density (millions of gross tons per mile per year).

Routings were determined by professional judgment rather than by using a minimum path algorithm. The sparsity of the rail network

Exhibit 44. Sample GPW-Oriented Revenue Calculations.

1. Farm Trucks
   Unit charges set equal to unit costs.
2. Grain Trucks (Linehaul)
   From GPW D to Pacific North Coast (8011):
   Rail Rate of $1.002 - $0.06 = $0.942 X 2,500 = $2,355
   From GPW D to Lewiston, ID (8014):
   $1.002 - $0.06 - $0.196 = $0.746 X 57,300 = $42,746
   From GPW D to Interior OR/WA (8021):
   $0.746 X 9000 = $6,714
3. Rail (Single Car Service)
   Published rates effective December 1, 1979:

Published Export and Domestic Rates - Wheat (¢/bu)

GPW	Single Car	26 Car 2-4 Origins	26 Car 1 Origin	52 Car 1 Origin
A, B, J	81.6	72.6	69.6	66.6
C, D, E	91.8	82.8	79.8	76.8
G	88.8	79.8	76.8	73.8
H, I	90.0	81.0	78.0	75.0

4. Barge
   Unit charges set equal to unit costs.
5. GPWs
   For GPW D:

$$373{,}500 \times \left[\left(\frac{365}{1.67\ (4.61)} - 15\right) \times 0.001 + 0.105\right] = \$51{,}354$$

6. Revenue Summary
   The above revenue computations were performed for each GPU-GPW- Mode/destination combination. From this, total and unit cost summaries were prepared for each GPU, GPW, and county. The following shows the type of summaries produced:

GPU	BUs (Thousands)	Total Revenues ($ Thousands) Farm Truck	Grain Truck	Rail	Barge	GPWs	Total
53	495.4	16.43	152.09	281.26	25.92	67.71	543.41
54	242.7	22.54	36.95	163.95	9.97	34.82	268.23
55	685.9	117.92	199.72	326.24	53.14	128.09	825.11
56	623.8	72.06	91.91	431.74	21.71	117.46	734.88
57	625.0	100.44	169.30	335.83	46.54	89.59	741.70
TOTAL COUNTY	2672.8	329.39	649.97	1539.02	157.28	437.67	3,113.33

coupled with the fact that train movements do not always follow the shortest route dictated this approach.

Highway Network. The highway network included state and county highway segments used for the transport of grain from GPWs to west coast markets, plus connecting segments that would potentially be used, depending on the location of subterminals. Also included were generalized network extensions westward to Lewiston, ID, via US 12 (Lolo pass) and to Portland, OR, and Seattle, WA, via interstate routes. A total of 1080 highway links were identified for which the following information was collected for each:

- Route number.
- Length (miles).
- Functional classification.
- Jurisdiction.
- Free flow speed.
- Existing daily truck volume.

In assigning traffic to the network, use was made of routings developed through professional judgment, rather than those developed using a minimum path algorithm . At the statewide level, routes used for grain movements are fairly obvious, although in several areas truck movements were apportioned among parallel routings in accordance with observations and data on segment use.

Base Case Inputs

The specific base case inputs were summarized into the five arrays and one data file listed below for input into the freight demand forecasting model:

- GPW Information File (array)

  Identification No.
  County Identification No.
  Distances to markets via individual modes or mode combinations
  Linehaul rates via rail, truck, and barge corresponding to the above distances
  X, Y coordinates (optional)
  GPW name
  GPW location
  GPW capacity
  GPW storage and handling charges (initial or maximum values)
  Alternative GPWs

- GPU Distance File (array)

  Shortest practical distance from the GPU centroid to each GPW.

- GPU Information File

  Identification No.
  County Identification No.
  Total grain production subdivided by that having GST potential or not
  X, Y coordinates (optional)

- County File (array)

  County Identification No.
  County Name

- Grain Flow Data (data file containing one record for each unique GPU/GPW/market/mode combination)

  GPU Identification No.
  GPW Identification No.
  Market Identification
  Total volume per specified period moving by identified modes having GST potential
  Total volume of other grains not having GST potential

Preparing Inputs for the Alternatives Being Considered

Future Grain Production and Markets

The case example involved determining (1) the economic feasibility of grain subterminals and unit train service; (2) resulting benefits or disbenefits to growers, elevator operators, and transport companies, if implemented; and (3) estimating impacts on the highway system. GSTs and unit train service together represented a hypothesized change to the transport services and rate structures then existing, the intent of which was to reduce transport costs. No estimates of future world or domestic demand for wheat and barley were prepared or used in this example. Consequently no "future" production or market demand forecasts were prepared for Montana wheat and barley, because the application did not require changes occurring in commodity flows over time.

On the other hand, the case example did require determining which grains and markets have subterminal and unit train potential, and establishing appropriate control totals. In the Montana study, grain having GST potential included all varieties of wheat being shipped to Pacific North Coast ports and other transshipment points located in the interior of Oregon or Washington. Although a number of terminals handle export wheat, all were located in proximity to one another and use the same rail lines. Of the 119.8 million bushels of Montana wheat marketed in 1979, 109.9 million moved west and thus were deemed to have GST potential.

Although the assumption was made that market demand does not change, this may not necessarily hold true if the markets being serviced by unit trains/GSTs are able to offer a better price for the product than the smaller markets. Not only is it possible to have market shifts, but the production of different grains may also change over the long term to cash in on the better price.

Function of GSTs. In this study, GSTs were viewed as the hinterland component of a grain assembly and delivery system consisting of GSTs, rail lines/unit train service, and improved port facilities. Under this concept, it was visualized that a number of port terminal elevator functions (e.g., storage, blending, inspection, certification) would be transferred back to GSTs located at strategic inland points.

Not only would the GST act as a regional assembly point and "pump house" for loading wheat into unit trains, but it also would perform most of the traditional GPW service functions, except for long-term storage. Subterminal loadout operations, unit train movements, and vessel loading would then become highly integrated and coordinated.

Alternatives. Potential alternatives included:

- Complete replacement of GPWs by GSTs (considered to be unlikely).
- GPWs and GSTs coexist whereby the former markets through the latter.
- Partial replacement of GPWs by GSTs, where
  - GPWs continue to function in areas where the transport costs via GST are greater than via local GPWs.
  - Portions of the grain traffic continue to move via single car rail for volume or service reasons.
  - GPWs on branchlines are phased out where railroads are successful in eliminating light density line rail operations.
- Upgrading of selected GPWs to handle multiple carloads (e.g., 26 cars) rather than full unit trains.

All of the foregoing alternatives could have been examined using the freight demand forecasting technique. In the Montana case example, alternatives were limited to (1) adding GSTs by simultaneously phasing out many of the existing GPWs, and (2) adding GSTs but keeping GPWs as local collection and marketing points. Retaining single car rail service exclusively was not considered to be a viable alternative with the introduction of volume rates, although it was useful as a base against which the other two alternatives could be compared. (The alternative of upgrading GPWs was not examined to the same degree as the other two alternatives for reasons unrelated to the case example.)

Under the first alternative, GPWs would continue to function in the same fashion as at present, except that westbound wheat would be shipped by truck to the GST instead of being loaded into covered hopper cars at the GPW. GPWs would retain their traditional marketing function, except that cooperative decision-making (with other GST users) would be necessary to assemble and market unit train loads of wheat.

Under the second alternative, the role of GPWs would change drastically in that the GSTs would largely supplant GPWs in assembling and marketing westbound wheat. As structured, this alternative required GSTs to provide a collector service (using motor carriers) to move grain from the more distant farms to the GST, or offer allowances in lieu thereof, to offset the longer farm-to-market hauls that many growers would face with the phase-out of the GPW system. Remaining GPWs would concentrate on marketing barley and wheat destined to other markets and low volume shipments either by truck or by single car rail.

Alternative Futures, Scenarios, and Conditions

Determining the Number and Location of GSTs. In determining the efficiency of subterminals, it was necessary to identify the number and location of GSTs. The two basic approaches for accomplishing this are:

- Location allocation theory, which addresses the problem of allocating one set of facilities (GSTs) to serve a second set of producers (GPUs). It seeks to minimize total transport costs (or maximize net income) in situations having up to three unknowns: the number, size (capacity or throughput), and location of facilities. A systematic search-and-evaluate process readily adaptable to computer application is used to develop optimal solutions.
- An empirical approach based on (1) subdividing a state into a series of grain producing regions, based on known production, (2) examining potential GST sites to determine which ones have the best potential, and (3) linking GPUs to GSTs on the basis of historical commerce/trade patterns and transport cost minimization. In this process, the analyst uses his knowledge of the grain industry in a state to make decisions on tributary areas and GPU-GST relationships, with the computer being used simply to make the computations and perform the accounting.

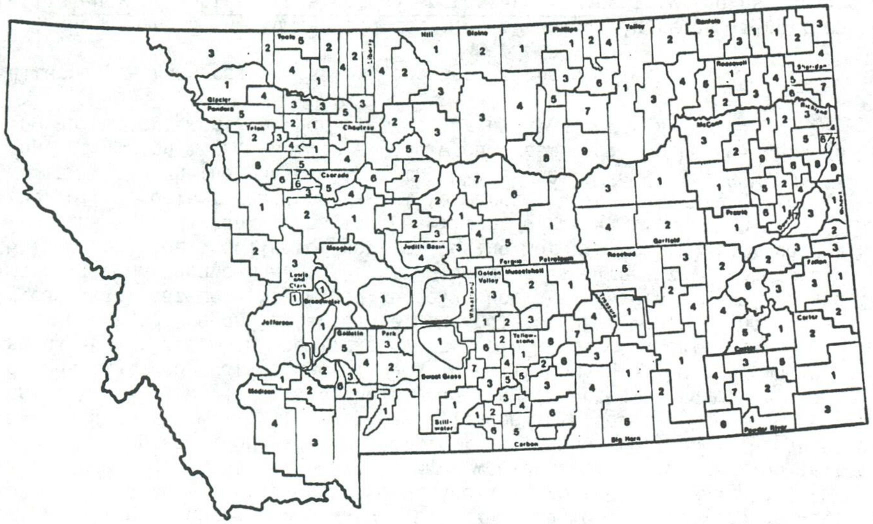
Irrespective of whether a mechanical or empirical process is employed, typical criteria used include:

- Maximizing profits (private enterprise).
- Coverage of the state (i.e., more or less equal opportunity for grower access to GSTs).
- Minimizing distance between GPUs and the nearest GST.
- Capitalizing on published rail rate structures -- especially where sizable differentials occur.
- Each GST or system of GSTs must be profitable.
- Minimizing the total number of GSTs to keep total infrastructure and operating costs as low as possible.
- Locations restricted to places having mainline rail service not requiring corporate capital investment to upgrade the track.
- Site characteristics. Specific site factors include (1) size and terrain, (2) ownership, (3) highway access, (4) availability of utilities, and (5) availability of land on either side of the proposed GST to allow for construction of side tracks that are uninterrupted by highway grade crossings.

Some of the foregoing criteria obviously conflict; not all of them can be fully satisfied. Philosophically, the two methods are somewhat different. Location allocation theory, if applied correctly, will produce a solution that minimizes total transportation costs. It requires that no *a priori* judgments be made, although prescreening of sites to make sure they have acceptable characteristics is wise. Location allocation theory will not ensure coverage of the state, nor will it minimize the distance between GPUs and the nearest GST. On the other hand, an empirical approach cannot ensure that the number and location of GSTs selected are optimal. Neither method can ensure GST profitability, nor can it handle the desire for retaining competition in the larger grain producing areas through multiple (overlapping) GSTs.

The method to be chosen depends on the intended application and the available resources. In the Montana study, an empirical process was employed to select ten locations for GSTs. Once selected, each GPU was then assigned to a GST based on highway distances and long-standing patterns of local or regional commerce. Exhibit 45 shows the

Exhibit 45. Grain Subterminal Tributary Areas.



resulting GST tributary areas, which were based on the following hypothesized GST locations:

Site No.	Location	Throughput
01	Pompeys Pillar	4.72
09	Benz	3.46
20	Mission	2.64
24	Moccasin	4.18
26	Kershaw	14.41
28	Havre	14.04
32	Saco	5.15
37	Macon	12.56
40	Homestead	6.37
52	Conrad	21.16

Also shown is the potential annual throughput for each GST (wheat in millions of bushels), which varies appreciably by location. Throughputs by themselves do not establish facility feasibility. Consequently, further detailing of the characteristics, operations, and cost of GSTs was necessary to establish an appropriate regime under which the feasibility of GSTs might be ascertained, individually and collectively.

Changes to Commodity Flows

The introduction of GSTs and unit trains potentially results in a sizable reduction in transport costs for virtually every movement. If cost were to be the sole basis for determining use of a particular alternative, the projected outcome would be near total diversion from the present to the proposed transport service.

Such drastic shifts are unlikely. In Montana, the commodity flows developed for the base case were reduced to account for a residual of low volume, special destination, or high priority shipments not appropriate to GSTs and unit trains. Of the estimated 109.9 million bushels of westbound wheat, 88.7 million bushels were found to be reasonably available to GSTs after subtracting 15 percent of present truck movements and 50 percent of rail movements to destinations in interior Oregon and Washington. Exhibit 46 presents the results from dividing the commodity flow matrix between GST potential and GPW residual traffic.

Changes to Unit Costs

In addition to the unit costs developed previously, such costs had to be estimated for unit train service, for trucks used in collector service, and for GSTs.

Rail Costs (Unit Train Service). The ICC algorithm for estimating single car costs was modified for estimating unit train costs by:

- Eliminating way train costs.
- Eliminating inter- or intra-train switching costs.
- Reducing clerical costs by 25 percent per carload and 75 percent per shipment.

Grain Trucks (GST-Supplied Collector Service). Tractor/semi-trailer rigs specially designed for hauling grain would be used on a contractual basis to transport grain from GPWs or GPUs to GSTs. Payload was assumed to be 1017 bushels. Assuming an empty backhaul, the average cost would amount to $1.933 per loaded mile (using the parameters presented earlier, adjusted to reflect this type of service), which was well above established rates for such service. Consequently, costs were set equal to rates for this type of service.

GSTs. The following cost equation was used:

$$c = \frac{a}{\text{Turnover ratio}} + 0.00016 \left[\frac{365}{1.25 \text{ X Turnover ratio}} \right] + 0.0516$$

where:

a = 0.8863 for a 500,000 bu capacity GST

= 0.5636 for a 1,000,000 bu capacity GST.

Exhibit 46. GST and Residual Traffic.

GPU	Wheat (Thousands bu)	Base Case Mode and Destination					Alternatives	
		8012	8022	8011	8014	8021	GST Potential	GPW Residual
53	495.4	162.7	145.7	54.7	30.8	101.5	395.1	100.3
54	242.7	96.8	93.3	1.7	36.2	14.7	188.2	54.5
55	685.9	335.5	53.5	25.7	40.2	231.0	614.6	71.3
56	623.8	498.4	0	14.6	0	110.8	605.0	18.8
57	625.0	229.4	143.8	14.3	40.3	197.2	515.4	109.6
TOTAL COUNTY	2672.8	1322.8	436.3	111.0	147.5	655.2	2318.3	354.5

Mode		Destination
8012	Rail	Pacific North Coast
8022	Rail	Interior of Oregon or Washington
8011	Truck	Pacific North Coast
8014	Truck/Barge	Pacific North Coast via Lewiston, ID
8021	Truck/Barge	Pacific North Coast via Columbia or Snake River Ports

The first term calculates the fixed or capital unit cost component. The second term computes the variable unit cost for storage. The last term computes the variable unit cost for handling. Working capacity was assumed to be 80 percent of storage capacity.

Sample Cost Calculations. Exhibit 47 shows how the additional cost computations were performed.

Changes to Unit Revenues/Charges

The modal alternatives examined required that additional unit rates be obtained or estimated for trucks used in collector service and for GSTs.

Exhibit 47. Sample GST-Oriented Cost Calculations.

1. Farm Trucks
   From GPU 53 to GST 24:
   395,100 ÷ 425 = 929.6 or 930 veh
   930 X 16.1 X 2 X $0.748 = $22,400
2. Grain Trucks (GST-Supplied Collector Service)
   From GPU 55 to GST (42 mi):
   614,600 ÷ 1017 = 604.3 or 605 veh
   605 X 1017 X [0.09171 + (0.0009329 * 42) + (0.0000013 * 42^2)] = $82,000
   From GPU 57 to GST (64 mi):
   515,000 ÷ 1017 = 506.4 or 507 veh
   507 X 1017 X [0.15171 - (0.0004338 * 64) + (0.0000093 * 64^2) - (0.0000000132 * 64^3)] = $81,700
3. Rail (Unit Train Service)
   From GST 24 to Pacific North Coast:
   4,181,100 X [0.000515 (1054.3) + 0.07623] = $2,588,900
4. GSTs
   In the Montana study, it was assumed that GSTs would be new facilities constructed primarily for the rapid loading of grain rather than for grain storage purposes. GST land acquisition, site preparation, side track construction and elevator construction, and equipping were estimated to cost $3.31 million for a 500,000-bushel facility.

   Component costs included (in thousands):

Sitework	$ 385
General elevator and structures	1,600
500,000-bu storage annex (optional)	900
General elevator machinery	1,100
Special equipment	85
Electrical	140
	$ 3,310 (500,000 bu) or $ 4,210 (1,000,000 bu)

The annual cost of such a facility would amount to $443,150 assuming financing at a 12 percent interest rate over 20 years, or $0.8863 per bushel of capacity.

For GST 24, a medium-sized facility having a potential annual throughput of 4,181,100 bu and a storage capacity of 500,000 bu (turnover ratio = 8.3622):

$$4{,}181{,}100 \times \left[\frac{0.8863}{8.3622} + 0.00016\left(\frac{365}{1.25 \times 8.3627}\right) + 0.0516\right] = \$682{,}356$$

Exhibit 47. Sample GST-Oriented Cost Calculations. (Continued)

5. Cost Summary

The above cost computations were performed for each GPU-GPW-GST combination. From this, total and unit cost summaries were prepared for each GPU, county, and GST. The following shows the type of summaries produced:

GPU	BUs (Thousands)	Total Costs/GSTs					
		Farm Truck	Grain Truck	Rail	Barge	GSTs	Total
53	395.1	22.4	0	244.6	0	64.5	331.5
54	188.2	0	23.8	116.5	0	30.7	171.0
55	614.6	0	82.0	380.5	0	100.3	562.8
56	605.0	50.3	0	374.6	0	98.7	523.6
57	515.4	0	81.7	319.1	0	84.1	484.9
TOTAL COUNTY	2318.3	72.7	187.5	1435.3	0	378.3	2073.8

GPU	BUs (Thousands)	Total Costs/Remaining GPWs					
		Farm Truck	Grain Truck	Rail	Barge	GPWs	Total
53	100.3	2.8	24.1	52.9	3.9	13.8	97.5
54	54.5	5.4	5.2	31.4	1.5	7.6	51.1
55	71.3	9.1	30.6	18.5	8.0	11.5	77.7
56	18.8	2.0	0	13.4	3.3	3.5	22.2
57	109.6	15.4	30.4	52.9	8.1	16.6	123.4
TOTAL COUNTY	354.5	34.7	90.3	169.1	24.8	53.0	371.9

Grain Trucks (GST-Supplied Collector Service). Established truck rates did exist for collector type grain movements to Billings and Great Falls. By using this information, collector service rates were established on a one-way mileage basis, as follows:

One-Way Mileage	Rate \$/bu	One-Way Mileage	Rate \$/bu
50	0.150	250	0.414
100	0.192	300	0.510
150	0.252	350	0.570
200	0.330		

These rates were converted to the following two equations, which were then used in computing intermediate rates:

$$c = 0.09171 + (0.0009329 * D) + (0.0000013 * D^2) \text{ where } D \leq 50$$

$$c = 0.15171 - (0.0004338 * D) + (0.0000093 * D^2) - (0.0000000132 * D^3) \text{ where } D > 50$$

where:

c = cost per bushel: and
D = distance (one-way).

GSTs

GST rates were computed using the following equation:

$$r = \left[\frac{365}{\text{Turnover}}\right] \text{Storage cost/day + Handling charge}$$

$$\text{Turnover} = \frac{\text{Annual elevator throughput}}{\text{Working storage capacity}}$$

In some of the applications, charges greater than those currently permitted by the Montana Department of Agriculture were necessary to ensure profitability of the GST. A working storage of 80 percent of rated capacity has been used.

Sample Revenue Calculations. Exhibit 48 shows how the additional revenue computations were performed.

Subterminal (Alternative) Inputs

In addition to the base case inputs described previously, additional inputs for the different alternatives being considered were summarized into the following two arrays:

- GST Information File (array)

  Identification No.
  County Identification No.

Exhibit 48. Sample GST-Oriented Revenue Calculations.

1. Grain Trucks (GST-Supplied Collector Service)
From GPU 55 to GST 24:
$$614{,}600 \times [0.09171 + 0.009329\,(42.3) + 0.0000013\,(42.3)^2] = \$82{,}048$$
From GPU 57 to GST 24:
$$515{,}000 \times [0.15171 - 0.0004338\,(64.1) + 0.0000093\,(64.1)^2 - 0.0000000132\,(64.1)^3] = \$81{,}699$$

2. GSTs
For GST 24, based on present GPW charges, which consist of a storage charge of 001 cent/bu/day and a handling charge of 10.5 cents/bu:
$$4{,}181{,}100 \times \left[0.001 \left(\frac{365}{1.25}\,(8.3622)\right) + 0.105\right] = \$585{,}016$$
Thus, $585,016 in gross revenues less $682,356 in expenses would produce a net loss of $97,340.

For GST 24, based on increasing the handling charge to 14.5 cents/bu to return a 10 percent profit:
$$4{,}181{,}100 \times \left[0.001 \left(\frac{365}{1.25}\,(8.3622)\right) + 0.145\right] = \$752{,}260$$
Thus $752,260 in gross revenues less $682,356 in expenses would produce a net profit of $69,904. This handling charge was used in subsequent calculations.

3. Revenue Summary
The above revenue computations were performed for each GPU-GPW-GST combination. From this, total and unit cost summaries were prepared for each GPU, county, and GST. The following shows the type of summaries produced:

GPU	BUs (Thousands)	Total Revenues/GSTs					
		Farm Truck	Grain Truck	Rail	Barge	GSTs	Total
53	395.1	22.4	0	296.3	0	71.1	389.8
54	188.2	0	23.8	141.2	0	33.9	198.9
55	614.6	0	82.0	461.0	0	110.6	653.6
56	605.0	50.3	0	453.8	0	108.9	613.0
57	515.4	0	81.7	386.6	0	92.7	561.0
TOTAL COUNTY	2318.3	72.7	187.5	1738.9	0	417.2	2416.3

Exhibit 48. Sample GST-Oriented Revenue Calculations. (Continued)

GPU	BUs (Thousands)	Total Revenues/Remaining GPWs					
		Farm Truck	Grain Truck	Rail	Barge	GPWs	Total
53	100.3	2.8	22.8	66.0	3.9	13.8	109.3
54	54.5	5.4	5.5	40.0	1.5	7.5	59.9
55	71.3	9.1	30.0	23.8	8.0	8.8	79.7
56	18.8	2.0	13.8	0	3.3	2.6	21.7
57	109.6	15.4	29.6	66.0	8.1	15.1	134.2
TOTAL COUNTY	354.5	34.7	101.7	195.8	24.8	47.8	404.8

Distance to markets via rail
Volume rates
GST name
GST location
GST capacity
GST storage and handling charges

- GPU Distance File (array)

  Shortest practical distance from the GPU centroid to each GST.

Computing System Costs and Revenues

Formulate Cost and Revenue Estimating Equations

In Montana, resulting cost and revenue relationships or estimating equations developed for use in the model had the following format:

R_1 = (volume)(distance)(unit revenue/charge)

R_2 = (volume)(unit revenue/charge)

C_1 = (volume)(distance)(unit cost)

C_2 = (volume)(unit cost)

where:

R = total revenue or charge;
C = total cost,

subscript 1 = a physical movement through space (e.g., transport company); and
subscript 2 = terminal, transfer, or warehousing services (e.g., grain elevator).

Variations to these basic relationships come primarily in the form of different unit revenues and costs for the various modal or terminal components. Resulting equations are as follows:

$$R_b = V_b\,[r_1+r_3+r_4+r_6+r_7]$$

$$C_b = V_b\,[c_1+c_3+c_4+c_6+c_7]$$

$$R_a = V_r\,[r_1+r_3+r_4+r_6+r_7] + V_s[r_2+r_5+r_6+r_8]$$

$$C_a = V_r\,[c_1+c_3+c_4+c_6+c_7] + V_s[c_2+c_5+c_6+c_8]$$

$$V_b = V_r + V_s$$

where:

R_b = base case revenues;

C_b = base case costs;

V_b = base case commodity flow;

R_a = alternative revenues;

C_a = alternative costs;

V_s = commodity flows through subterminals;

V_r = residual commodity flows;

r = unit rates, as defined below;

c = unit costs, as defined below; and

d = unit distances, as defined below.

		Revenues/ Charges	Costs	Distance
Line-Haul Modes	Single Car Rail	r_1	c_1	d_1
	Unit Train	r_2	c_2	d_2
	Grain Truck	r_3	c_3	d_3
	Barge	r_4	c_4	d_4
Feeder Service	Collector Truck	r_5	c_5	d_5
	Farm Truck	r_6	c_6	d_6
Terminal Services	GPW	r_7	c_7	-
	GST	r_8	c_8	-

Exhibit 49 shows how revenues and costs were computed using the developed cost and revenue estimating equations for two different commodity movements.

Exhibit 49. Sample Application of Cost and Revenue Estimating Equations.

1. For a commodity flow of 38,300 bu moving from GPU 53 to GPW D to the Pacific North Coast by rail:

$$R_b = 38.3\ [(.918) + (0) + (0) + (.130) + (.137)] = \$45,386$$

$$C_b = 38.3\ [(.870) + (0) + (0) + (.130) + (.119)] = \$42,858$$

$$R_a = 0\ [(.918) + (0) + (0) + (.130) + (.137)] + 38.3\ [(.750) + (0) + (.057) + (.180)] = \$37,802$$

$$C_a = 0\ [(.870) + (0) + (0) + (.130) + (.137)] + 38.3\ [(.619) + (0) + (.057) + (.163)] = \$32,134$$

$$V_b = V_r + V_s = 0 + 38.3 = 38.3$$

2. For a commodity flow of 28,700 bu moving from GPU 53 to GPW D to the Pacific North Coast via truck/barge through Lewiston, ID:

$$R_b = 28.7\ [(0) + (.746) + (.196) + (.130) + (.137)] = \$34,698$$

$$C_b = 28.7\ [(0) + (.748) + (.196) + (.130) + (.119)] = \$34,239$$

$$R_a = 4.3\ [(0) + (.746) + (.196) + (.130) + (.137)] + 24.4\ [(.750) + (0) + (.057) + (.180)] = \$29,282$$

$$C_a = 4.3\ [(0) + (.748) + (.196) + (.130) + (.119)] + 24.4\ [(.619) + (0) + (.057) + (.163)] = \$25,602$$

$$V_b = V_r + V_s = 4.3 + 24.4 = 28.7$$

Exhibit 49. Sample Application of Cost and Revenue Estimating Equations. (Continued)

	Unit Revenues/ Charges		Unit Costs		Distances
Single Car Rail	r_1	.918	c_1	.870	1330.9
Unit Train	r_2	.750	c_2	.619	1054.3
Grain Truck	r_3	.746	c_3	.748	526.6
Barge	r_4	.196	c_4	.196	
Collector Truck	r_5	.057	c_5	.057	16.1
Farm Truck	r_6	.130	c_6	.130	3.7
GPW	r_7	.137	c_7	.119	-
GST	r_8	.180	c_8	.163	-

Determine the Mode Split Process

In grain transport, mode choice decisions reflect partly economics and partly service, with the former lending itself to quantitative solutions and the latter not. Introducing a new mode or mode combination or a new service is really a routing alternative. If it costs less than the existing mode for comparable quality service, substitution will take place. In Montana, the mode split process used this "least cost mode" principle.

Often, the user may wish to impose several constraints on such a quantitative process. The first involves setting a minimum threshhold level governing the point that modal diversion will occur (e.g., users rarely divert for, say, half a cent per bushel savings). The second would be to establish a zone of indifference within which proportional diversion takes place. The third is to set a limit on maximum market share, as previously discussed. The latter was the only constraint applied in the Montana study.

Select User Options

A large number of potential options could have been built into the computational process, although in Montana only a few were actually employed. Potential options included:

- Choosing between having the computer determine and thus select the least cost GST routing, or using previously determined tributary areas tying to GPWs or GPUs to GSTs.
- Adjusting the total amounts of grain, or that considered having GST potential, to reflect expected changes in the amount and varieties produced and market demands. This can be done by applying one or more factors, or by using a normalizing process to meet a predetermined projection.
- Adjusting the unit costs and rates incorporated into the cost and rate equations or location-based rate arrays to more-oe-less bring such information up-to-date without having to reconstruct the cost and rate input data.
- Investigating the benefits of cost-sharing arrangements for trucking grain between GPUs and GSTs so as to lessen locational discrimination created in the siting of GSTs.
- Choosing between letting GPW and GST handling and storage charges vary with throughput or using the maximum rates that may be allowable. Use of the latter does not guarantee that each GPW or GST will be independently profitable, however.
- Adjusting the computations to the scenario being considered. Scenarios can include:
    - Complete replacement of GPWs by GSTs.
    - Partial replacement.
    - GPWs and GSTs coexist whereby the former markets through the latter.
    - A system of upgraded GPWs handling multiple carloads in lieu of GSTs.
    - A three-tier system comprised of conventional GPWs, upgraded GPWs, and full GSTs.
    - Testing GST proposals developed by others.
- Choosing the mode choice assumption to be used. This can invole (1) setting a minimum threshhold level governing the point that modal diversion will occur, (2) establishing a zone of indifference within which proportional diversion takes place, or (3) setting a limit on maximum market share.
- Adjusting assumptions concerning farm and grain truck size and use.
- Rerouting grain traffic not diverted to GSTs through a consolidated system of GPWs.

Compute Base Case and Alternative Transportation Costs and Revenues. Each grain flow record was sequentially read, revenues and costs were computed via the GPW and GST alternatives, and a choice was made between routing all, or part, or none of the grain via each proposed GST as compared with the present routing via a GPW. Grain flow, revenue, cost, distance, and vehicle volume information was then entered onto one or more output records for the base case and each GST alternative.

Prepare Output Records

Once computations had been completed for a particular grain flow record, one or more output records were prepared consisting of the following information:

- Control Information — GPU Ident. No.; GPW Ident. No.; GST Ident. No.

Category	Group	Fields	Repeated for
		County Ident. No. Market Ident.	
• Grain Flow Information (bu X 1,000)		Total grain flow Total grain flow having GST potential Other grains GST potential grain via GSTs GST potential grain via GPWs	
• Revenues/ Charges	Linehaul	(1) Single Car Rail (2) Unit Train (3) Grain Truck (4) Barge	Repeated for: Base Case (via GPWs) GST alone Residual only (via GPWs) GST+Residual Difference from Base Case
	Collector	(5) Collector Truck (6) Farm Truck	
	Terminal	(7) GPW (8) GST	
	Components	Linehaul (1+2+3+4) Collector (5+6) Terminal (7+8) Grain Co. (all except 6) Growers (6) Total (all)	
• Transport Costs	Linehaul	(1) Single Car Rail (2) Unit Train (3) Grain Truck (4) Barge	Repeated for: Base Case (via GPWs) GST alone Residual only (via GPWs) GST+Residual Difference from Base Case
	Collector	(5) Collector Truck (6) Farm Truck	
		(7) GPW (8) GST	
	Components	Linehaul (1+2+3+4) Collector (5+6) Terminal (7+8) Grain Co. (all except 6) Growers (6) Total (all)	
• Distance		GPU to GPW GPW to Market GPU to GST GST to Market GPW to GST	
• Vehicles		Rail Cars Grain Trucks Collector Trucks Farm Trucks	Repeated for the same five cases identified above

Exhibit 50 shows a sample output record for a commodity flow of 28,700 initially moving by truck/barge, but anticipated to shift over in part to GST/unit trains.

<u>Summarizing and Evaluating Results (Computed Costs and Revenues)</u>

All reports can be produced by sorting the file into GPU, GPW, GST, county, or market sequence, and simply adding the data from the appropriate fields. Summary tables can be produced either as an aggregate

Exhibit 50. Sample Output Record.

GPU Ident. No.	53
GPW Ident. No.	D
GST Ident. No.	24
County Ident.	
Market Ident.	
Total Grain	28.7
Total Grain w/GST pot.	28.7
Other Grains	
GST pot. grain GSTs	24.4
GST pot. grain GPWs	4.3

Distance		
	GPU to GPW	3.7
	GPW to Market	1330.9
	GPU to GST	16.1
	GST to Market	1054.3
	GPW to GST	12.4

Vehicles	1	2	3	4	5
Rail Cars	0	8.0	0	8.0	+ 8.0
Grain Trucks	28.2	0	4.2	4.2	- 24.0
Collector Trucks	0	0	0	0	0
Farm Trucks	67.5	57.4	10.1	67.5	0

	Revenues/Charges					Transport Costs				
	1	2	3	4	5	1	2	3	4	5
Single Car Rail	0	0	0	0	0	0	0	0	0	0
Unit Train	0	18.30	0	18.30	+ 18.30	0	15.10	0	15.10	+ 15.10
Grain Truck	21.41	0	3.21	3.21	- 18.20	21.47	0	3.22	3.22	- 18.25
Barge	5.63	0	0.84	0.84	- 4.79	5.63	0	0.84	0.84	- 4.79
Collector Truck	0	0	0	0	0	0	0	0	0	0
Farm Truck	0.37	1.39	0.06	1.45	+ 1.08	0.37	1.39	0.06	1.45	+ 1.08
GPW	3.93	0	0.59	0.59	- 3.34	3.42	0	0.51	0.51	- 2.91
GST	0	4.39	0	4.39	+ 4.39	0	3.98	0	3.98	+ 3.98
Linehaul	27.04	18.30	4.05	22.35	- 4.69	27.00	15.10	4.06	19.16	- 7.84
Collector	0.37	1.39	0.06	1.45	+ 1.08	0.37	1.39	0.06	1.45	+ 1.08
Terminal	3.93	4.39	0.59	4.98	+ 1.05	3.42	3.98	0.51	4.49	+ 1.07
Grain Co.	30.97	22.69	4.64	27.33	- 3.64	30.42	19.08	4.57	23.65	- 6.77
Growers	0.37	1.39	0.06	1.45	+ 1.08	0.37	1.39	0.06	1.45	+ 1.08
TOTAL	31.14	24.08	4.70	28.78	- 2.36	30.79	20.47	4.63	25.10	- 5.69

<u>Key</u>

1 - Base Case (via GPWs)
2 - GST alone
3 - Residual (via GPWs)
4 - GST + Residual
5 - Difference from Base Case

amount (say, $ x 1,000) or on a unit basis ($x.xxx/bu obtained by dividing by the appropriate grain flow total). In addition to output records, input data required consist of GPU county name and sub-designation, name of elevator or GPW, location of GST, and name of county. Suggested formats for final reports are given as follows:

GPU, GPW, County or Market Summaries (2 sheet printout).

Ident. No.	Name/ Location	1/	Line Haul Rev	Line Haul Cost	Line Haul Net	Collection Rev	Collection Cost	Collection Net	Terminal Rev	Terminal Cost	Terminal Net
		Base									
		GST									
		Residual									
		Sum									
		Diff.									
	(repeated hereafter)										

Ident. No.	Name/ Location	1/	Grain Co. Rev	Grain Co. Cost	Grain Co. Net	Grower Rev	Grower Cost	Grower Net	Total Rev	Total Cost	Total Net
		Base									
		GST									
		Residual									
		Sum									
		Diff.									
	(repeated hereafter)										

County, GST, or Market Detailed Revenue and Cost Summaries (2 sheet printout)

County, GST, or Market Name

		Single Car Rail	Unit Train	Grain Truck	Barge	Collector Truck	Farm Truck	GPW	GST	Line Haul	Collection	Terminal	Grain Co.	Grower	Total
Revenues/ Charges	Base														
	GST														
	Residual														
	Sum														
	Diff.														
	% Change														
Transport Costs	Base														
	GST														
	Residual														
	Sum														
	Diff.														
	% Change														
Net	Base														
	GST														
	Residual														
	Sum														
	Diff.														
	% Change														
Total Grain															
Grain with GST Potential															
Other Grain															
Grain via GPWs Before															
Grain via GPWs After															
Grain via GSTs															
Percent Change															
(repeated hereafter)															

1/ (1) Base traffic: potential GST grain plus other grains
(2) GST traffic: grain diverted to GST
(3) Residual traffic: grain not diverted to GSTs plus other grains
(4) Sum: (2) + (3)
(5) Difference: (1) - (4)

County, GST, or Market Vehicle Miles and Ton-Miles-Summaries
(2 sheet printout)

County, GST, or Market Name

	Base	GST	Residual	Sum	Diff.	% Change
Rail-Unit Train						
Grain Truck						
Barge						
Collector Truck						
Farm Truck						
GPUs to GPWs						
GPUs to GSTs						
Subtotal Line Haul						
Subtotal Collection						
Subtotal Grain Co.						
Subtotal Grower						
Total						

(repeated hereafter)

The summary programs developed to prepare the foregoing outputs should also be designed to automatically produce state totals for each of the fields identified. Depending on the type of computer being used, the user may be able to prepare these reports, using RPG or similar languages, rather than to write special purpose programs. Other summary programs obviously could be developed to meet the special needs of prospective users. Reports prepared for GPUs and GPWs should be treated confidentially. Exhibits 51, 52, and 53 show sample summary tables.

Exhibit 51. Example of a Summary Revenue and Cost Table.

County		Linehaul			Collector			Terminal		
		Rev.	Cost	Net	Rev.	Cost	Net	Rev.	Cost	Net
Franklin	Base	2946.3	2219.3	727.0	329.4	329.4	0	437.7	385.9	51.8
	GST	1926.4	1622.8	303.6	72.7	72.7	0	417.2	378.3	38.9
	Residual	322.3	284.2	38.1	34.7	34.7	0	47.8	53.0	- 5.2
	Sum	2248.7	1907.0	341.7	107.4	107.4	0	465.0	431.3	33.7
	Diff.	-697.6	-312.3	-385.3	-222.0	-222.0	0	27.3	45.4	- 18.1

County		Grain Co.			Grower			Total		
		Rev.	Cost	Net	Rev.	Cost	Net	Rev.	Cost	Net
Franklin (Cont'd)	Base	3384.0	2605.2	778.8	329.4	329.4	0	3713.4	2934.6	778.8
	GST	2343.6	2001.1	342.5	72.7	72.7	0	2416.3	2073.8	342.5
	Residual	370.1	337.2	43.3	34.7	34.7	0	404.8	371.9	43.3
	Sum	2713.7	2338.3	375.4	107.4	107.4	0	2821.1	2445.7	375.4
	Diff.	-670.3	-266.9	-403.4	-222.0	-222.0	0	-892.3	-488.9	- 403.4

Exhibit 52. Example of a Detailed Revenue and Cost Table.

		Single Car Rail	Unit Train	Grain Truck	Barge	Farm Truck	GPW	GST	Total
Revenues/ Charges	Base	1539.0	0	650.0	157.3	329.4	437.7	0	3113.3
	GST	0	1738.9	187.5	0	72.7	0	417.2	2416.3
	Residual	195.8	0	101.7	24.8	34.7	47.8	0	404.8
	Sum	195.8	1738.9	289.2	24.8	107.4	47.8	417.2	2821.1
	Diff	-1343.2	+1738.9	- 360.8	- 132.5	- 222.0	- 389.9	+ 417.2	- 292.2
	% Change	- 87	-	- 56	- 84	- 67	- 89	-	- 9
Transport Costs	Base	1400.4	0	661.6	157.3	329.4	385.9	0	2934.6
	GST	0	1435.3	187.5	0	72.7	0	378.3	2073.8
	Residual	169.1	0	90.3	24.8	34.7	53.0	0	371.9
	Sum	169.1	1435.3	277.8	24.8	107.4	53.0	378.3	2445.7
	Diff	-1231.3	+1435.3	- 383.8	- 132.5	- 222.0	- 332.9	+ 378.3	- 488.9
	% Change	- 88	-	- 58	- 84	- 67	- 86	-	- 17
Net	Base	- 138.6	0	+ 11.6	0	0	- 51.8	0	- 178.7
	GST	0	- 303.6	0	0	0	0	- 38.9	- 342.5
	Residual	- 26.7	0	- 11.4	0	0	+ 5.2	0	- 32.9
	Sum	- 26.7	- 303.6	- 11.4	0	0	+ 5.2	- 38.9	- 375.4
	Diff	+ 111.9	- 303.6	- 23.0	0	0	+ 57.0	- 38.9	- 196.7

Total Wheat	2,672.8
Wheat with GST Potential	2,672.8
Other Grain	1,628.2
Wheat via GPWs Before	2,672.8
Wheat via GPWs After	354.5
Wheat via GSTs	2,318.3

Exhibit 53. Example of a VMT Summary Table.

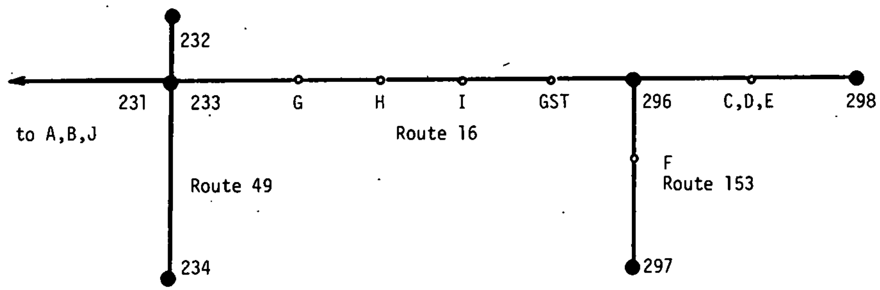
	Vehicle-Miles of Travel (000)					
	Base	GST	Residual	Sum	Diff.	% Change
Rail	648.7	733.3	64.3	797.7	+ 148.6	+23
Grain Truck	521.2		78.2	78.2	- 443.0	-85
Barge						
Collector Truck	0	68.3	0	68.3	+ 68.3	-
Farm Truck	220.5	48.6	21.0	69.6	- 150.9	-68
Subtotal Linehaul	1169.9	733.3	142.5	875.8	- 294.1	-25
Subtotal Collector	220.5	116.9	21.0	137.9	- 82.6	-37
Subtotal Grain Co.	1169.9	801.6	142.5	944.1	- 225.8	-19
Subtotal Grower	220.5	48.6	21.0	69.6	- 150.9	-68
TOTAL	1390.4	850.2	163.5	1013.7	- 376.7	-27

Impacts on the State Highway System

Traffic Assignment

Exhibit 54 shows a schematic of the state highway network for the example county along with resulting grain and farm truck volumes both for the base case and the alternative. The estimated traffic volumes were developed by converting commodity flows (in bushels) to vehicle equivalents (425 bushels per farm truck and 1,017 bushels per grain truck), and then assigning the vehicle equivalents to a coded highway network. The figures used for vehicle equivalents, which are rather crucial in estimating traffic volumes, were derived from grain movement system data and discussions with elevator operators. They imply that both grain and farm trucks are often overloaded (i.e., higher axle loadings than permitted by law). Also indicated is the relative impact of grain traffic relative to measured heavy truck volumes and the relative change in total heavy truck volumes were a grain subterminal implemented.

Exhibit 54. Example Estimated Grain and Farm Truck Volumes.



Schematic of the State Highway Network in Franklin County

Route No.	Dir.	Origin Node	Dest. Node	Dist. (mi)	Ave. Daily Hvy. Trk. Volume	Assigned Grain & Farm Trucks 1/ Base Case	% of ADHTV	Alter-native	% of ADHTV	Percent Change
16	W	298	C,D,E	14.3	197	1691	7	2675	11	+ 4
16	W	C,D,E	296	2.5	197	1759	7	3936	16	+ 9
153	N	297	F	22.2	99	0	0	432	3	+ 3
153	N	F	296	17.0	141	150	1	582	3	+ 2
16	W	296	GST	9.9	294	1909	5	4518	12	+ 7
16	E	I	GST	0	294	0	0	1459	14	+ 4
16	W	GST	I	0	294	1909	5	287	1	- 4
16	E	H	I	6.8	294	0	0	887	2	+ 2
16	W	I	H	6.8	294	1957	5	294	1	- 5
16	E	G	H	11.4	317	0	0	597	2	+ 2
16	W	H	G	11.4	317	1988	5	299	1	- 4
16	W	G	233	36.7	218	2059	8	309	1	- 6
49	S	232	233	3.6	11	421	31	422	31	0
49	N	234	233	71.5	32	0	0	0	0	0
16	W	233	231	12.8	298	2480	7	730	2	- 5

1/ Figures shown are estimated annual (1) grain truck linehaul movements from GPWs to river terminals or markets, and (2) farm and grain truck movements from GPUs to GSTs. Excludes farm truck movements to/from GPWs, which primarily use local roads. Percent of average daily heavy truck volume computed by:

$$\% = \frac{1}{ADHTV} \times \frac{2 \text{ X Assigned Grain \& Farm Trucks}}{250}$$

Vehicle-Miles of Travel

Potential changes in traffic volumes are meaningful on a link basis, but not on a system basis. Thus, it often becomes necessary to compute and compare estimates of vehicle-miles of travel (VMT). Exhibit 55 shows how this can be done for, say, a system of GSTs in the state.

VMT computations are conceptually easy to perform, since they

Exhibit 55. Anticipated Changes in System Heavy Truck VMT.

A. Anticipated Changes in System Heavy Truck VMT

	Annual Heavy Truck Vehicle-Miles of Travel (Thousands) Within Montana	Out-of-State	Total VMT
Base Case			
Farm Trucks to GPWs	4,854.9	-	4,854.9
Grain Trucks in Linehaul Service to Markets, River Terminals.	12,748.6	9,509.3	22,257.9
Subtotal	17,603.5	9,509.3	27,112.8
Alternative 3(with a GST-Supplied Collector Service)			
Farm Trucks to GSTs	607.5	-	607.5
Grain Trucks in Collector Service to GSTs	3,134.1	-	3,134.1
Farm Trucks to GPWs (Residual)	1,079.3	-	1,079.3
Grain Trucks in Linehaul Services to Markets, River Terminals (Residual)	1,913.8	1,427.3	3,341.1
Subtotal	6,734.7	1,427.3	8,162.0
Alternative 3 (without a GST-Supplied Collector Service)			
Farm Trucks to GSTs	8,107.1	-	8,107.1
Farm Trucks to GPWs (Residual)	1,079.3	-	1,079.3
Grain Trucks in Linehaul Services to Markets, River Terminals (Residual)	1,913.8	1,427.3	3,341.1
Subtotal	11,100.2	1,427.3	12,527.5

Exhibit 55. Anticipated Changes in System Heavy Truck VMT. (Continued)

B. Changes in Annual Truck Vehicle-Miles of Travel

	Truck Vehicle-Miles of Travel (Thousands)		
	Within Montana	Out-of-State	Total VMT
Change in Truck Vehicle Miles of Travel			
With GST-Supplied Collector Service	- 10,868.8	- 8,082.0	- 18,950.8
Percent Change	- 62%	- 85%	- 70%
Without GST-Supplied Collector Service	- 6,503.3	- 8,082.0	- 14,585.3
Percent Change	- 37%	- 85%	- 54%

involve multiplying truck volumes by link or over-the-road distances. The user, however, must consider whether one-way or round-trip movements should be measured and whether computations should encompass the entire highway system or only that portion under agency jurisdiction. This can lead to a fairly extensive set of components, as indicated in the following for this example:

	Truck Type	O/D	System
Base Case	Farm Truck	GPU to GPW	Combination state and local highway system (mainly local, however)
	Grain Truck	GPW to Market or River Terminal	State highway system
Alternative	Farm Truck	GPU to GST	Combination state and local highway system (mainly state in this instance)
		GPU to GPW	Residual; same as before
	Grain Truck (collector)	GPU to GST	Combination state and local highway system (mainly state, however)
	Grain Truck (linehaul)	GPW to Market or River Terminal	Residual; same as before

It can be further complicated by backhauling (fronthauling) commodities in the other direction and by triangular travel.

Pavement Performance and Life

Determining the impact of changed volumes and vehicle types on pavement performance and life typically requires (1) an extensive amount of pavement testing (for deflection under prescribed loadings), (2) measurement or calculations of pavement structure, and (3) extensive data on the amount, axle and tire configurations, and loadings of heavy vehicle traffic over the highway system. The three possible assessments that can reasonably be made on a link or an area basis are:

1. Summarize vehicles on a link basis and determine the differential between that occurring under the scenarios with the base case. The problem with this approach is equating farm trucks with grain trucks, which have different impacts on pavement structure. Consequently, a simple change in the number of vehicles with grain subterminals is relatively meaningless.
2. Determining the change in equivalent annual load applications (EALA). This extension to the preceding neutralizes the differences between different vehicle types, although it requires other assumptions or data on the proportion of different wheel/axle configurations, tare weights, and loadings. The problem with this approach is that differential EALA does not directly relate to pavement life. For example, a 10 percent increase in EALA does not mean a 10 percent decrease in the remaining pavement life, since the effects of (a) pavement age, (b) design strength, and (c) other traffic have not been included.
3. Estimating the change in service life. This extension to the preceding can utilize either very detailed pavement condition and structure information contained in a state's highway information system files and traffic volume and classification information or various assumptions and default data developed by FHWA for Highway Needs Studies. The problem with the former is that the data required will not be available uniformly across a state and involves a level of detail that goes far beyond the level of planning and analysis presented in this report. Determination of service life is dependent on the following factors:

In Montana, the following process was developed to identify the significance of changes in equivalent annual load applications for approximating the impact on pavement performance and life. It was based on the following computational process:

1. First, farm and grain truck volumes were summarized on a link basis for each of the alternatives as well as the base case. From this, the change in farm and grain truck volumes caused by the implementation of GSTs was computed.
2. Next, farm and grain truck volume changes were translated into EALA equivalents, which neutralized the difference in vehicle types.
3. Using Montana Department of Highways (MDH) data (estimates of annual daily traffic by link, classification counts giving the percentage of vehicles that are trucks, and EALA factors computed from truck weight study data) base year traffic was translated into EALA equivalents on a link basis.
4. The EALA equivalents computed in steps 2 and 3 were compared by dividing the prospective change (step 2) by the base traffic (step 3) to determine the relative impact of GSTs.

The actual EALA computations are performed using several different equations depending on the type of traffic to be analyzed and the form of the available data. All of the equations, however, follow the general form shown below:

$$\text{EALA} = \begin{pmatrix}\text{CRITICAL}\\ \text{LANE}\\ \text{FACTOR}\end{pmatrix} \times \begin{pmatrix}\text{NUMBER OF}\\ \text{TRUCKS PER}\\ \text{YEAR}\end{pmatrix} \times \begin{pmatrix}\text{18-KIP SINGLE-AXLE}\\ \text{EQUIVALENT CONSTANT}\\ \text{FOR THE SPECIFIC}\\ \text{TRUCK TYPE}\end{pmatrix} \text{ or;}$$

$$\text{EALA} = \text{CLF} \times \text{VOLUME} \times \text{E}$$

where:

CLF = CRITICAL LANE FACTOR; a factor describing the portion of the road width used by the truck; 0.4 for Interstate highways, 0.5 for all other highways.

E = 18-kip single-axle equivalent constant; a factor describing the equivalent number of 18,000-pound axle loads for the truck type and load.

The equations actually used are given below:

- EALA for present situation, i.e., all heavy truck traffic:

$$\text{EALA}_p = \text{CLF} \times \text{ADHT} \times 365 \times \text{E}$$

where: ADHT = average daily heavy truck volume (supplied by MDH);

CLF = critical lane factor as shown above; and

E = 18-kip single-axle equivalent constant = 1.2 for Interstate, 1.0 for Primary, and 0.8 for Secondary highways. Derived from the W-4 tables for the 1978 truck weight study (for FHWA).

- Change in grain-traffic-generated EALA:

$$\text{EALA}_{S\text{-}B} = \text{CLF} \quad ((FT_S - FT_B) \times E_{FT}) + ((GT_S - GT_B) \times E_{GT})$$

where: FT_B = farm truck count for base case;

FT_S = farm truck count for alternative;

GT_B = grain truck count for base case;

GT_S = grain truck count for alternative;

E_{FT} = farm truck equivalent constant (developed below); and

E_{GT} = grain truck equivalent constant (developed below).

- EALA for alternative, i.e., all heavy truck traffic:

$$\text{EALA}_F = \text{EALA}_p + \text{EALA}_{S\text{-}B}$$

The EALA computations are complicated to some extent by the wide range of truck loadings that are actually occurring. (Information received from elevator operators implies that farm trucks are severely overloaded. This is understandable in that farm trucks largely use state secondary and county roads with little enforcement of load limits being practiced, nor are grain growers aware of the axle loadings involved. Grain trucks also appear to be overloaded. Although Montana does have permanent weigh stations, they can be bypassed by waiting until the stations are closed or by using alternative routings. MDH records imply load limit compliance, but such data are probably not representative of grain truck movements. Thus, given the uncertainty associated with truck axle configurations and average loaded weights, computations were done assuming both legally and overloaded conditions and the answers were arrayed as a "range." The equivalent constant (E) values must reflect these varying loads and must also account for the proportion of loaded backhaul miles. The E values that were used, along with the appropriate modifications are shown as follows:

		18-kip single-axle equivalent constants 1/	
		Primary	Secondary
farm truck 2/ -	empty	0.0528	0.0387
	loaded (legal)	0.9072	0.7946
	overloaded	1.3770	1.3084
grain truck 3/ -	empty	0.1416	0.1066
	loaded (legal)	2.4850	2.3595
	overloaded		

1/ Source: Montana Department of Highways. Subsequently modified.

2/ Assumes that 50 percent of farm trucks are 2-axle, dual rear tired vehicles carrying 8 tons (267 bu) legally loaded or 10 1/2 tons (350 bu) overloaded and 50 percent are 3-axle, dual rear tired vehicles carrying 13 tons (433 bu) legally loaded or 15 tons (500 bu) overloaded.

3/ Assumes that 18-wheel, 5-axle rigs are used. Montana Department of Agriculture calculations indicate that such vehicles can haul 25 tons (830 bu) legally loaded and 30.5 tons (1,017 bu) overloaded.

Ideally, EALA should be computed directionally. This was not possible, given the nature of the base data. Consequently, the constants finally used were derived as follows from those given previously:

- Farm truck utilization: loaded to warehouse, empty on return.

  E_{FT} = E(Loaded) + E(Empty)

- Grain truck utilization (linehaul): loaded for outbound grain, loaded 60 percent of backhauls.

  E_{GT} = 1.6 X E(Loaded) + 0.4 X E(Empty)

- Grain truck utilization (collector): loaded to warehouse, empty on return.

  E_{GT} = E(Loaded) + E(Empty)

	Primary Roads	Secondary Roads
Farm Truck	0.7149	0.6736
Grain Truck (Linehaul)	2.8394	2.5729
Grain Truck (Collector)	2.1364	1.8971

These E values, along with the number of vehicles were used to compute the EALA estimates for each highway link. Exhibits 56 and 57 show the computations and the results obtained for the example area.

Exhibit 56. Sample EALA Computations.

Input Data

Highway Type - primary
CLF - 0.5
ADHTV - 36.7

	Base Case	Alternative	Change
Farm Trucks	60	25	- 35
Grain/Line Haul	310	70	-240
Trucks/Collector	0	110	+110
EALA (base) - 6700			

Exhibit 56. Sample EALA Computations. (Continued)

$EALA_{a-b}$ (assuming all trucks overloaded)

= 0.5 (-35 X 0.7149)+(110 X 2.1364)+(-240 X 2.8394) = -471.5

$EALA_{a-b}$ (assuming all trucks legally loaded)

= 0.5 (-35 X 0.48)+(110 X 1.3133)+(-240 X 2.0163) = -356.2

$EALA_F$ (assuming all trucks overloaded)

= 6700 - 471.5 = 6228.5 or a 7% decrease in EALA

$EALA_F$ (assuming all trucks legally loaded)

= 6700 - 356.2 = 6343.8 or a 5.3% decrease in EALA

Thus, for this particular link, the traffic associated with the alternative causes a decrease in equivalent annual load applications ranging from 5.3% to 7.0%.

Exhibit 57. Anticipated Changes in Link VMT and EALA.

Origin Node	Dest. Node	VMT/1000 Base	VMT/1000 Alt.	Percent Change	EALA/1000 Base	EALA/1000 Alt.	Percent Change
298	C,D,E	2.8	2.9	+4	36.0	37.0	+ 3
C,D,E	296	0.5	0.5	+9	36.0	37.8	+ 5
297	F	2.2	2.3	+4	18.1	19.0	+ 5
F	296	2.4	2.5	+2	25.7	26.6	+ 3
296	GST	2.9	3.1	+7	53.7	56.3	+ 5
I	GST	0.0	0.0	0	53.7	54.7	+ 2
H	I	2.0	2.0	-2	53.7	54.3	+ 1
G	H	3.6	3.5	-3	57.9	58.3	+ 1
G	233	8.0	7.5	-6	39.8	34.8	-12
232	233	0.1	0.1	0	2.0	1.8	-12
234	233	2.3	2.3	0	5.9	5.9	0
233	231	3.8	3.6	-5	54.4	49.2	-10

CASE EXAMPLE C -- ROADRAILER SERVICE IN THE BUFFALO TO NEW YORK CITY CORRIDOR

Purpose and Intent of the Case Example

The primary purpose underlying this case example was to have a state transportation agency test the freight demand forecasting technique developed under this NCHRP project. A companion purpose was to provide that agency with information of value to them -- in this case estimates of the market potential for RoadRailer service in a specified corridor. The case example was undertaken by the New York State Department of Transportation (NYSDOT) staff using techniques presented in the User's Manual.

Specific phases initially thought to be necessary for testing the freight demand forecasting technique and achieving the desired answers included:

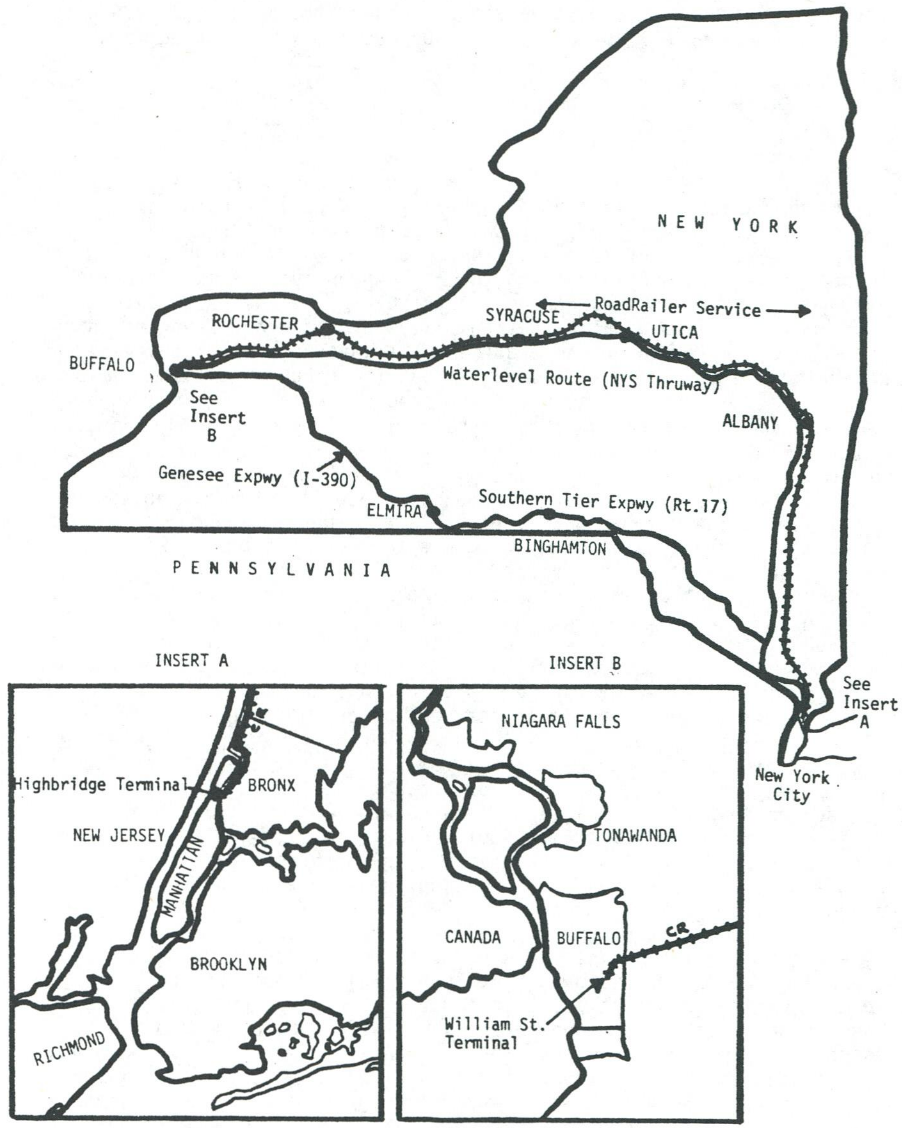
1. Developing a commodity or traffic flow data base for costing purposes from available secondary data, or in lieu thereof, selecting a representative set of movements.
2. Determining unit (i.e., motor carrier and RoadRailer) modal costs under a variety of traffic and operating conditions using the Truck Costing Model included as part of the User's Manual and operations data available to NYSDOT. Costs include both line-haul and drayage (i.e., local pickup and delivery).
3. Determining unit modal traffic and revenues under different tariff/rate structures. This involves developing a simple modal diversion relationship.
4. Combining the results from 1, 2, and 3 to estimate RoadRailer revenues and costs under different traffic, rate, and cost conditions.

Background on RoadRailer Service

The NYSDOT has long been committed to improving intermodal freight transportation into the New York City area and elsewhere in New York State. To accomplish this objective, its Rail Division has for some time been implementing a "Full Freight Access Program" in the New York City area and a rail terminal improvement program across New York State. The former involves increasing overhead clearances along the lower portion of the Hudson Line, thus permitting trailer-on-flat-car (TOFC) service directly into New York City for the first time. The latter includes new trackage in New York City, yard consolidation and rehabilitation, and the provision of team tracks, where needed, for the use of shippers located on abandoned branchlines. The need for intermodal freight improvement has previously been identified in the NYSDOT report Intermodal Study, dated June 1978. The study included market research and analysis of freight movements between New York City and Buffalo, as well as between other city pairs.

In November 1982, the Road-Rail Transportation Company, Inc. (RRTC) initiated RoadRailer service between New York City and Buffalo, and later extended this service to include an intermediate stop at Rochester (not incorporated into this case example). RoadRailer service competes primarily with for-hire and private motor carriers using the New York State Thruway or the Southern Tier and Genesee Expressways for line-haul movement, and to a lesser extent with conventional rail carload and TOFC service. Exhibit 58 illustrates the rail and highway routes being used. While the service is being provided entirely by

Exhibit 58. Map Showing Competing Routes



private enterprise (i.e., RRTC and Conrail), NYSDOT has invested over a million dollars in physical improvements to the three rail yards or terminals used in providing this service. RoadRailer is a dual-mode semitrailer unit having flanged wheels which can be assembled into trains for line-haul movement over the rail system. See Exhibit 59. It is similar in concept to TOFC, except that it eliminates the need for the flat car. Its main competition is motor carrier transport, especially contract carriers and firms using private or exempt trucking. The Buffalo-New York City market was chosen by the BiModal Corporation (parent company) to demonstrate the feasibility of intermodal services between markets 200 to 800 miles apart. The long-term market potential within this distance range is large; one estimate is that it contains upwards of 73 percent of the national market for the intermodal transport of containerizable commodities. Its importance to states lies in (1) the innovativeness of the service and its application across the US and (2) its long-term potential for diverting medium-distance over-the-road heavy truck movements back to rail, thus potentially halting or reversing recent trends of ever increasing truck volumes on state highways. NYSDOT, which had planned to initiate a similar service as a demonstration project, welcomed the opportunity to have this service be provided by a private firm without having to become directly involved in a demonstration project. Obviously, NYSDOT retains a strong interest in its success and has been monitoring the use of the service since its inception.

Exhibit 59. RoadRailer Trailer

The case example chosen involves examining volume, rate, and cost structures of the Buffalo/Rochester/New York City RoadRailer service to estimate the point at which this service becomes truly competitive with trucking, and thus can survive on a self-sustaining basis. This question has become increasingly important because of (1) the need to assess the cost and revenue estimates furnished to the State by the provider of the service and (2) the traffic generated by RoadRailer during the first year of service did not achieve initial expectations, although traffic volumes have been steadily increasing.

The following provides a brief description on the RoadRailer operation between New York City and Buffalo. Freight is loaded into a RoadRailer unit at its origin and then drayed to the RoadRailer terminal in New York City or Buffalo. The New York City terminal is located at the Highbridge Yard, on Depot Place near 170th Street, adjacent to the Major Deegan Expressway; the Buffalo terminal is the William Street Yard, located on William Street near Memorial Drive and Filmore Avenue. At the terminal, the loaded RoadRailer units are assembled into trains to be hauled to other terminal. The westbound train closes out at 6:45 p.m. and departs the Highbridge Yard for Buffalo at 7:45 p.m., with scheduled arrival at the William Street Yard being 6:00 a.m. The eastbound train closes out at 6:25 p.m. and departs the William Street Yard for the New York City at 7:15 p.m., with scheduled arrival at the Highbridge Yard being 5:30 a.m. The target running time is 9 1/2 hours over a distance of 426.3 miles, or an average speed of 45 mph. This is comparable to the average speeds achieved by motor carriers. At both terminals, RoadRailer units are available for pick-up approximately one hour after arrival. Independent truckers provide supporting drayage services under contract with the BiModal Corporation. Conrail provides a three-man train crew and the locomotive (traction) for the line-haul portion of the RoadRailer trip, while the terminal operations are handled by the RRTC. Crew changes take place at Selkirk and Syracuse. The maximum train length allowed by Conrail is presently 60 RoadRailer units, although until recently operations have been limited to a lesser number of units by yard capacity. Obviously the number of trains in each direction, as well as the size and number of tracks available for storing and assembling RoadRailer units into trains, can be increased as the demand for this service grows. Shippers indicate that RoadRailer is a reliable, dependable overnight service between Buffalo and New York City, with virtually no instances of equipment malfunctions or train delays having been reported.

Defining the Problem

Objective of the Study

Examine volume, rate, and cost structures of the Buffalo-New York City RoadRailer service to provide estimates of its potential in this and similar markets.

General Parameters

1. Physical and Cultural Aspects -- Geographic limits are the Buffalo and New York City metropolitan areas, or more specifically, the boundary formed by the location of firms situated within convenient pick-up and delivery distances of the RoadRailer terminals in the above

two cities. (The notion of a service area boundary, which can never really be delineated, is at best an imprecise measure of market potential.) Affected transport infrastructure (routes) includes Conrail's Hudson and Albany-Buffalo mainlines and the Interstate highways (or equivalent expressways) connecting Buffalo and New York City. Affected shippers are those presently utilizing motor carriers or private trucking to ship merchandise in truckload quantities between Buffalo and New York City who could find it more economical to utilize RoadRailer service instead of motor carriers.

2. General Orientation -- Primarily modal with the emphasis being on comparing services.

3. Modes, Transport Facilities, and Services Utilized -- RoadRailer service and truckload motor carrier service between Buffalo and New York City over previously identified routes. Trucking includes common, contract, and private carriers operating both single and tandem trailers. Much of the freight is thought to be moving under contract rates.

4. Commodities being Transported -- Merchandise and some bulk commodities moving in truckload units. Market is limited to commodities originating and terminating in the identified service areas.

5. Alternative Futures, Scenarios, or Conditions to be Examined Application is primarily focused on the present or base year, although it includes the removal of tolls from the New York State Thruway. Alternative futures or scenarios involving the projection of traffic for future years are not a part of this case example.

6. Regulatory Environment -- Unrestrained competition between existing trucking and the recently introduced RoadRailer service.

Major Tasks to be Accomplished (See Figure 1 of the User's Manual)

1. Present Economic Activities
2. Freight Traffic Generation
3. Freight Traffic Distribution
4. Present Service, Cost & Price Characteristics
5. Modal Division

Analytical Choices

1. Measure Performance in Economic, Physical, or Impact Terms -- Economic, since the application involves examining the costs of competing transport services to appraise the potential of RoadRailer service.

2. Estimate Modal Shares on a Unit Price or Cost Basis -- Primarily on a cost basis, although rates must be considered in determining traffic volumes.

3. Apply a Physical Distribution or Transport Economics Orientation -- Transport economics, since storage and distribution costs incurred by individual firms would be approximately the same among competing modes.

4. Price/Cost Movements on a One-Way or Round-Trip Basis -- In this application, transport costs have been computed as one-way movements. Normally, such costs would be computed on a round-trip basis taking into account backhaul utilization. This requires reliable information on backhaul utilization, which does not exist in this case example. In this case, an analysis of round-trips would be more dependent upon the backhaul assumptions made rather than on the unit costs employed.

5. Optimizing Locations or Flows -- Not required.

Required Products

1. Record for all or selected movements containing the following information:

- Identification

  a. Assigned origin.
  b. Assigned destination.
  c. Commodity type.

- Contents

  a. Commodity flow volume (in tons annually).
  b. Designation as an existing or potential movement.
  c. Unit revenues/charges via RoadRailer and various motor carrier services (for-hire, private, exempt, etc.).
  d. Unit transport costs via RoadRailer and various motor carrier services. RoadRailer costs to be based on those expected once anticipated traffic volumes have been achieved.

2. Report summarizing the anticipated economics of RoadRailer service compared with existing truck transport.

Simplifying Premises and Assumptions

1. RoadRailer service and costs are based on an average of 40 units per train. Thus, the case example assumes normal operations rather than start-up conditions.

2. Aggregate demand within the Buffalo-New York City corridor is price and service inelastic.

3. Modal division solely dependent on logistics costs.

4. Use of the higher truck weights allowed by the Surface Transportation Reform Act of 1982.

5. Reducing the scope of the case example by disregarding the Rochester traffic.

Data Requirements and Availability

1. Aggregate commodity movements by RoadRailer and truck between Buffalo and New York City.

2. Unit costs for RoadRailer and truck service.

Preparing Base Case Inputs

Commodity Flows

Acquisition of or development of a suitable commodity flow matrix is the single most important input for this application. Since a matrix containing data-giving commodity identification, volume or weight of the movement, motor carrier type, and unit or total carrier charges disaggregated to the county level was not available, nor could one be developed from available secondary data, NYSDOT instead identified a set of representative movements to be used as a proxy for the desired commodity flow matrix in examining the feasibility of RoadRailer service. While this substitution was not ideal from the standpoint of illustrating the use of the freight demand forecasting technique, it does illustrate how a partial set of data can be assembled and used to carry out the intended study in situations where a state has neither the staff time nor fiscal resources to collect alternative primary data. In this case, primary data would have been preferred, and is considered essential if the market potential of RoadRailer service is to be fully established. In making this substitution, the resulting product will not be as statistically reliable as that which would have been achieved had more complete commodity flow data been available.

The starting point was the following two Transearch tabulations showing originating and terminating freight by geographic area (see Exhibits 60 and 61):

1. A tabulation of freight to/from the New York City (NYC) Business Economic Area (BEA) from/to the Buffalo BEA (a standard Transearch product), which reports traffic generated in tons and 40-foot freight container equivalents. Traffic is also further divided by the following modes or submodes: rail carload, intermodal, for-hire truckloads, shipments carried by private or exempt truckers, airborne, and water-8orne. Volumes reported are an estimate of all traffic between the NYC BEA and the Buffalo BEA classified by Standard Transportation Commodity Code (STCC) at the 5-digit level of detail.

2. A tabulation of freight to/from the Mid-West Region to that portion of the NYC BEA east of the Hudson River (a special tabulation purchased by NYSDOT), which reports traffic by mode or submode in tons for rail, TOFC, and truck. Traffic reported was an estimate of surface traffic between a NYSDOT Rail Division defined Mid-West Region and the New York State part of the NYC BEA classified by STCC at the 3-digit level of detail.

The foregoing data sets had these limitations:

1. Since the data were not true commodity flow data, origin and destination linkages could not be ascertained directly, and thus had to be approximated through using other information.

2. Since the data were highly aggregated, the tabulations reported traffic from a far larger geographic area than for which shippers would normally consider using RoadRailer service. The tabulations also included movements which did not represent potential RoadRailer traffic.

3. Direct identification of the firms generating or receiving the traffic from the data was not possible. Thus pick-up and delivery movements from the RoadRailer terminal had to be approximated.

Thus, NYSDOT had to devise a process to enhance and extend these data to produce a set of representative movements. This, then, would allow preparation of modal cost estimates and extension to all surface traffic between Buffalo and New York City. The key lay in selecting representative movements. Since this could not be done statistically, guidelines were developed to develop likely commodity flows and minimize possible distortions. Commodities selected by NYSDOT were:

- Known, relatively large-scale movements between New York City and Buffalo.
- Representative of the principal types of commodities likely to move between these two cities.
- Typically, (1) inputs to manufacturing activities located in these cities, (2) outputs of manufacturing processes located in these cities, or (3) widely used consumer products.
- Capable of being shipped (economically) by rail, truck, or RoadRailer.

Steps used by the NYSDOT staff in developing representative movements are outlined below:

1. First, identify the principal commodity groups generating traffic from which to select representative movements. In this case, NYSDOT used the Transearch tabulations to identify the following commodity groups:

- Food or kindred products (STCC Code 20).
- Pulp, paper, or allied products (STCC Code 26).
- Chemicals or allied products (STCC Code 28).
- Petroleum and coal products (STCC Code 29).
- Clay, concrete, glass, or stone (STCC Code 32).
- Metal products (STCC Codes 33 and 34).
- Manufacturers (STCC Codes 35, 36, 37, 38 and 39).
- Freight, all kinds (STCC Code 46).

Although appreciable tonnages of petroleum products move between New York and Buffalo, most of this traffic moves by water. Because diversion of this traffic to RoadRailer was unlikely, NYSDOT chose to exclude this commodity group.

2. Using the foregoing tabulations and other supplementary information, NYSDOT staff then selected representative commodities. The following documents a portion of the reasoning used by the NYSDOT staff for accomplishing this.

- The choices from the food and kindred products group were relatively easy: flour in the eastbound direction and sugar in the westbound. Because Buffalo is a major milling center, and because flour is a major commodity flowing from Buffalo to New York City, flour (in bags) was included. Although New York City is not a sugar refining center in the sense that Buffalo is a flour milling center, sugar beets and sugar cane are received and refined in the New York City BEA. For this reason, sugar (in bags) was included.
- The pulp, paper and allied products and printed paper groups are important, because New York City is a major printing center. On the other hand, the Buffalo BEA is neither a major printing nor a major paper manufacturing area. The largest eastbound flow was printing paper. Inasmuch as the tabulation indicated that this traffic moved entirely by rail, it was excluded from further consideration. Paper (other than printing paper) was a better candidate because a majority of this traffic moves by truckload (TL), less-than-truckload (LTL), private/ exempt truck, and RoadRailer. A similar situation occurred in the westbound direction. Containers or boxes and paper move by private/exempt truck, LTL, and to a lesser extent, by TL. Converted paper or paperboard products move almost entirely by TL. While the foregoing commodities

Exhibit 60.

TRANSEARCH

TRAFFIC FLOW DATA NORMALIZED TO 1981 - IN TONS

ORIGIN : BEA 10 BUFFALO NY
DESTINATION : BEA 12 NEW YORK NY

TWO-DIGIT STCC SUMMARY

STCC	COMMODITY	TOTAL TONS	TOTAL FCE	RAIL CARLOAD	RAIL INTERMODAL	HIGHWAY FOR HIRE TL	HIGHWAY FOR HIRE LTL	HIGHWAY PRIV/EX	AIR	WATER
01	FARM PRODUCTS	50879	2432	6000	0	5335	0	39544	0	0
14	NONMETALLIC MINERALS	810	36	0	0	36	0	568	0	206
20	FOOD OR KINDRED PRODUCTS	415845	19870	247200	0	136573	9128	17879	0	5065
22	TEXTILE MILL PRODUCTS	212	10	0	0	0	0	212	0	0
23	APPAREL OR RELATED PRODUCTS	70	9	0	0	56	0	12	0	2
24	LUMBER OR WOOD PRODUCTS	1711	77	0	0	60	0	1651	0	0
25	FURNITURE OR FIXTURES	3543	606	1100	0	613	1194	636	0	0
26	PULP, PAPER OR ALLIED PRODUCTS	64174	3002	28300	0	31011	1207	3384	0	272
27	PRINTED MATTER	47	2	0	0	47	0	0	0	0
28	CHEMICALS OR ALLIED PRODUCTS	436072	19822	80200	0	330296	8500	16901	164	11
29	PETROLEUM OR COAL PRODUCTS	245072	11140	0	0	85611	3209	6205	0	150047
30	RUBBER OR MISC PLASTICS	9872	482	0	0	3806	6066	0	0	0
31	LEATHER OR LEATHER PRODUCTS	1935	129	0	0	1228	315	392	0	0
32	CLAY, CONCRETE, GLASS OR STONE	60153	2868	7800	0	21978	1870	28505	0	0
33	PRIMARY METAL PRODUCTS	62506	2842	7700	0	30533	3991	20179	103	0
34	FABRICATED METAL PRODUCTS	12036	562	0	0	9433	1342	767	494	0
35	MACHINERY	12502	652	0	0	7374	4542	556	29	1
36	ELECTRICAL EQUIPMENT	22602	1110	0	0	20244	1699	652	7	0
37	TRANSPORTATION EQUIPMENT	53531	4425	42300	0	703	1298	9219	11	0
38	INSTRUM, PHOTO EQ, OPTICAL EQ	372	19	0	0	372	0	0	0	0
39	MISC MANUFACTURING PRODUCTS	2080	208	0	0	1159	921	0	0	0
40	WASTE OR SCRAP MATERIALS	11	1	0	0	0	0	11	0	0
46	MISC MIXED SHIPMENTS	10200	680	0	10200	0	0	0	0	0
	TOTAL	1466235	70984	420600	10200	686468	45282	147273	808	155604
	PERCENT OF TOTAL	100.0		28.7	0.7	46.8	3.1	10.0	0.1	10.6

ADDITIONAL STCC DETAIL

STCC	COMMODITY	TOTAL TONS	TOTAL FCE	RAIL CARLOAD	RAIL INTERMODAL	HIGHWAY FOR HIRE TL	HIGHWAY FOR HIRE LTL	HIGHWAY PRIV/EX	AIR	WATER
01137	WHEAT	6000	273	6000	0	0	0	0	0	0
01195	POTATOES, OTHER THAN SWEET	2576	117	0	0	0	0	2576	0	0
01210	CITRUS FRUITS	784	36	0	0	784	0	0	0	0
01221	APPLES	14179	645	0	0	0	0	14179	0	0
01227	PEARS	829	38	0	0	0	0	829	0	0
01290	MISC FRESH FRUITS OR TREE NUTS	531	24	0	0	531	0	0	0	0
01318	ONIONS, DRY	9265	463	0	0	0	0	9265	0	0
01333	CABBAGE	4395	220	0	0	0	0	4395	0	0
01334	CELERY	925	46	0	0	0	0	925	0	0
01335	LETTUCE	1664	83	0	0	0	0	1664	0	0
01337	CAULIFLOWER	881	44	0	0	0	0	881	0	0

LEGEND : FCE - 40 FOOT FREIGHT CONTAINER EQUIVALENT

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TRANSEARCH

TRAFFIC FLOW DATA NORMALIZED TO 1981 - IN TONS

ORIGIN : BEA 12 NEW YORK NY
DESTINATION : BEA 10 BUFFALO NY

TWO-DIGIT STCC SUMMARY

STCC	COMMODITY	TOTAL TONS	TOTAL FCE	RAIL CARLOAD	RAIL INTERMODAL	HIGHWAY FOR HIRE TL	HIGHWAY FOR HIRE LTL	HIGHWAY PRIV/EX	AIR	WATER
01	FARM PRODUCTS	17491	825	0	0	3401	0	14090	0	0
08	FOREST PRODUCTS	2847	129	0	0	2847	0	0	0	0
14	NONMETALLIC MINERALS	1889	86	0	0	158	0	0	0	1731
20	FOOD OR KINDRED PRODUCTS	73075	3336	17100	0	35843	11012	9120	0	0
22	TEXTILE MILL PRODUCTS	5786	354	0	0	961	3666	1159	0	0
23	APPAREL OR RELATED PRODUCTS	3350	185	0	0	1275	1910	0	71	94
24	LUMBER OR WOOD PRODUCTS	53	5	0	0	41	0	12	0	0
25	FURNITURE OR FIXTURES	3237	611	0	0	338	2850	49	0	0
26	PULP, PAPER OR ALLIED PRODUCTS	28142	1405	2600	0	10466	7067	7824	0	185
27	PRINTED MATTER	6498	329	0	0	4029	2397	0	0	72
28	CHEMICALS OR ALLIED PRODUCTS	86160	3947	9400	0	35149	23764	17219	59	569
29	PETROLEUM OR COAL PRODUCTS	198285	9013	6600	0	5237	966	314	0	185168
30	RUBBER OR MISC PLASTICS	21176	1284	0	0	5926	2919	12095	236	0
31	LEATHER OR LEATHER PRODUCTS	2785	201	0	0	2455	211	119	0	0
32	CLAY, CONCRETE, GLASS OR STONE	15196	728	0	0	13189	1361	646	0	0
33	PRIMARY METAL PRODUCTS	67409	3066	7500	0	45364	1570	12051	162	762
34	FABRICATED METAL PRODUCTS	3098	148	0	0	718	1069	1136	0	175
35	MACHINERY	6870	333	0	0	3829	1802	1188	51	0
36	ELECTRICAL EQUIPMENT	7080	721	0	0	3391	3067	622	0	0
37	TRANSPORTATION EQUIPMENT	37801	3843	0	0	31253	6369	179	0	0
38	INSTRUM, PHOTO EQ, OPTICAL EQ	1697	87	0	0	988	517	192	0	0
39	MISC MANUFACTURING PRODUCTS	3475	348	0	0	1326	2082	0	0	67
40	WASTE OR SCRAP MATERIALS	2700	135	2700	0	0	0	0	0	0
46	MISC MIXED SHIPMENTS	2200	147	0	2200	0	0	0	0	0
	UNCLASSIFIED	60	3	0	0	0	60	0	0	0
	TOTAL	598360	31269	45900	2200	208184	74659	78015	579	188823
	PERCENT OF TOTAL	100.0		7.7	0.4	34.8	12.5	13.0	0.1	31.6

ADDITIONAL STCC DETAIL

STCC	COMMODITY	TOTAL TONS	TOTAL FCE	RAIL CARLOAD	RAIL INTERMODAL	HIGHWAY FOR HIRE TL	HIGHWAY FOR HIRE LTL	HIGHWAY PRIV/EX	AIR	WATER
01195	POTATOES, OTHER THAN SWEET	6003	273	0	0	0	0	6003	0	0
01221	APPLES	1737	79	0	0	0	0	1737	0	0
01230	TROPICAL FRUITS	3401	155	0	0	3401	0	0	0	0
01318	ONIONS, DRY	1104	55	0	0	0	0	1104	0	0
01333	CABBAGE	1731	87	0	0	0	0	1731	0	0
01335	LETTUCE	858	43	0	0	0	0	858	0	0
01337	CAULIFLOWER	1030	52	0	0	0	0	1030	0	0
01393	SWEET CORN	246	12	0	0	0	0	246	0	0
01394	TOMATOES	414	21	0	0	0	0	414	0	0

LEGEND : FCE - 40 FOOT FREIGHT CONTAINER EQUIVALENT

Exhibit 61.

* TRANSEARCH *
HARLEM RIVER YARD MARKET ANALYSIS
CONTAINERIZABLE COMMODITIES

ORIGIN REGION : MIDWEST REGION
DESTINATION REGION : NEW YORK CITY

STCC	COMMODITY	TOTAL RAIL	TOTAL TOFC	TOTAL TRUCK	TOTAL ALL MODES
		(TONS)			
11	FIELD CROPS	0	0	3223	3223
12	FRESH FRUITS OR TREE NUTS	0	0	20522	20522
13	FRESH VEGETABLES	0	0	65897	65897
200	FOOD OR KINDRED PRODUCTS	0	0	59214	59214
201	MEAT OR POULTRY, FRESH OR CHIL	0	0	15564	15564
202	DAIRY PRODUCTS	0	0	35647	35647
203	CANNED OR PRESERVED FOOD	4678	0	190634	195312
204	GRAIN MILL PRODUCTS	216150	0	171843	387993
205	BAKERY PRODUCTS	0	0	2030	2030
206	SUGAR, BEET OR CANE	0	0	397	397
207	CONFECTIONERY OR REL PROD	0	0	2860	2860
208	BEVERAGES OR FLAVOR EXTRACTS	18900	0	239115	258015
209	MISC FOOD PREPARATIONS	36327	0	47310	83637
210	TOBACCO PRODUCTS	0	0	121	121
211	CIGARETTES	0	0	942	942
220	TEXTILE MILL PRODUCTS	0	0	561	561
228	THREAD OR YARN	0	0	1082	1082
229	MISC TEXTILE GOODS	0	0	2018	2018
230	APPAREL OR RELATED PRODUCTS	0	0	621	621
231	MENS OR BOYS CLOTHING	0	0	360	360
233	WOMENS OR CHILDRENS CLOTHING	0	0	114	114
238	MISC APPAREL OR ACCESSORIES	0	0	406	406
239	MISC FINISHED TEXTILE GOODS	0	0	3863	3863
240	LUMBER OR WOOD PRODUCTS	0	0	62325	62325
242	SAWMILL OR PLANING MILL PROD	0	0	92	92
243	MILLWORK OR PREFAB WOOD PROD	0	0	6486	6486
244	WOODEN CONTAINERS	0	0	2334	2334
249	MISCELLANEOUS WOOD PRODUCTS	0	0	8105	8105
250	FURNITURE OR FIXTURES	0	0	542	542
251	HOUSEHOLD OR OFFICE FURNITURE	2922	0	20410	23332

Note: Other origin/destination regions were "West" and "Central"

REEBIE ASSOCIATES
FEBRUARY 1983

Exhibit 61. (Continued.)

* TRANSEARCH *
HARLEM RIVER YARD MARKET ANALYSIS
CONTAINERIZABLE COMMODITIES

ORIGIN REGION	DESTINATION REGION	TOTAL RAIL	TOTAL TOFC	TOTAL TRUCK	TOTAL ALL MODES
		(TONS)			
BUFFALO	NEW YORK CITY	205720	0	1308371	1514091
CINCINNATI	NEW YORK CITY	136284	0	589717	726001
TOLEDO	NEW YORK CITY	117835	2149	613565	733549
DETROIT	NEW YORK CITY	263915	0	388223	652138
CHICAGO	NEW YORK CITY	134907	0	633005	767912
ST. LOUIS	NEW YORK CITY	39365	0	159150	198515
TWIN CITIES	NEW YORK CITY	109707	0	394811	504518
KANSAS CITY	NEW YORK CITY	99535	0	242135	341670
DALLAS	NEW YORK CITY	72779	0	83243	156022
HOUSTON	NEW YORK CITY	53157	0	104141	157298
DENVER	NEW YORK CITY	36245	2042	132538	170825
SEATTLE	NEW YORK CITY	258147	0	39498	297645
SAN FRANCISCO	NEW YORK CITY	232683	3223	167229	403135
LOS ANGELES	NEW YORK CITY	211820	0	302001	513821
TOTAL OUTBOUND		1972099	7414	5157627	7137140
NEW YORK CITY	BUFFALO	10380	0	779533	789913
NEW YORK CITY	CINCINNATI	20547	0	388329	408876
NEW YORK CITY	TOLEDO	1906	0	285180	287086
NEW YORK CITY	DETROIT	16082	0	365420	381502
NEW YORK CITY	CHICAGO	10030	17622	447824	475476
NEW YORK CITY	ST. LOUIS	0	0	284316	284316
NEW YORK CITY	TWIN CITIES	491	0	196396	196887
NEW YORK CITY	KANSAS CITY	2808	0	131655	134463
NEW YORK CITY	DALLAS	11474	0	201765	213239
NEW YORK CITY	HOUSTON	8235	0	261905	270140
NEW YORK CITY	DENVER	0	0	172427	172427
NEW YORK CITY	SEATTLE	6687	0	64529	71216
NEW YORK CITY	SAN FRANCISCO	7530	0	113755	121285
NEW YORK CITY	LOS ANGELES	25880	1182	261838	288900
TOTAL INBOUND		122050	18804	3954872	4095726

Note: Other origin/destination regions were "West" and "Central"

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were similar, the latter was included because of the larger size of the movement and its RoadRailer potential.

- Selection of appropriate commodities from the chemicals and allied products group was more challenging. Much of this industry is located in New Jersey, with a large portion of this traffic moving by rail for cost and safety reasons. Thus the potential for diversion to RoadRailer was not considered high. Industrial chemicals (eastbound) and agricultural chemicals and soap (westbound) were included, after considering the factors specifically affecting chemicals and the selection of commodities in general.

In the end, the following commodities were selected:

Eastbound Commodities	Commodity Group	Westbound Commodities
Flour	20	Sugar
Paper	26	Converted Paper
Industrial Chemicals	28	Agricultural Chemicals
-	28	Soap
Misc. Plastic Products	30	-
Glass Containers	32	-
Steel Mill Products	33	-
Ventilating Equipment	35	-
Carbon Products	36	Wiring Equipment and Electric Fixtures
FAK (freight all kinds)	46	FAK

3. Using supplemental information on the location of industries in the NYC and Buffalo BEAs which produce or consume previously identified commodities, the NYSDOT staff then assigned an origin and destination to each movement. Qualitative tests applied in developing synthesized movements included whether (1) the resulting movement was a reasonable representation of the total universe of commodity movements for which RoadRailer service appeared competitive with trucking and (2) the movements selected provided reasonable geographic coverage of both the NYC and Buffalo BEAs.

The assignment of origins and destinations depended on staff knowledge of the specific movement. Where a particular commodity was already moving via RoadRailer service, or was known to NYSDOT staff from other work, actual origins and destinations were used. For commodities whose movement patterns were unknown, origins and destinations were projected by comparing the commodity flows to firms listed in the publication County Business Patterns (issued annually by the U. S. Bureau of the Census). This publication reports the number and employment size of establishments by detailed industry for each county. This allowed a comparison to be made between firms located in the counties comprising the two BEAs with the commodities moving between these BEAs.

Exhibit 62 shows the county origins and destinations assigned to each movement previously identified by NYSDOT. Allocating origins and destinations to the most likely counties gave the movement pattern shown in Exhibit 63. This was further modified by NYSDOT to improve the resulting geographic distribution. In the end, 12 movements were selected having the characteristics described in Exhibit 64. Exhibit 65 describes the reasoning used to assign a specific origin and desti-

Exhibit 62. Counties of Origin and Destination by Commodity

Commodity	Counties Shipping	Counties Receiving
	EASTBOUND	
Flour	Erie	Kings Bronx
Ventilating Equipment	Erie	New York
Steel Mill Products	Erie	Queens Suffolk
Industrial Chemicals	Niagara	New York Kings Nassau
Carbon Products for Electrical Uses	Niagara	Suffolk Kings Nassau Queens
Paper other than Printing	Niagara	Westchester
Glass Containers	Erie Chautauqua	(no clear choice)
	WESTBOUND	
Sugar	Kings	Erie
Converted Paper Products	Kings Nassau New York Bronx	Erie
Wiring Products	Kings Queens	Erie
Soap	Richmond Kings	(no clear choice)
Agricultural Chemicals	New York Suffolk	Niagara

nation to each of the selected movements and the routing that would be used for travel between the origin or destination and the RoadRailer terminal.

Unit Transport Costs

In this case example, unit cost estimates were developed for both RoadRailer service and trucking alternatives.

Exhibit 63. Allocating Origins and Destinations to the Most Likely County

Commodity	Shipping County	Receiving County
Flour	Erie	Kings
Sugar	Kings	Erie
Converted Paper	Kings	Erie
Wiring Equipment	Kings	Erie
Steel Mill Products	Erie	Queens
Ventilation Equipment	Erie	New York
Industrial Chemicals	Niagara	New York
Agricultural Chemicals	New York	Niagara
Carbon Products	Niagara	Suffolk
Glass Containers	Chautauqua	New York
COMMODITIES NOT READILY ASSIGNABLE TO SPECIFIC COUNTIES		
Misc. Plastic Products		
Paper		
Soap		
FAK (Freight, all kinds)		

Exhibit 64. Final Allocation of Origins and Destinations

Commodity	Originating County	Destination County
Flour	Erie	Bronx
Sugar	Kings	Erie
Paper	Niagara	Westchester
Converted Paper	Kings	Erie
Industrial Chemicals	Niagara	New York
Soap	Richmond	Erie
Glass Containers	Chautauqua	Nassau
Steel Mill Products	Erie	Queens
Ventilation Equipment	Erie	New York
Carbon Products	Niagara	Suffolk
Lighting and Wiring	Queens	Erie
FAK	Bronx	Erie
FAK	Erie	Bronx

RoadRailer Unit Costs

RoadRailer costs are unusual in the sense that several different transport companies share in the costs incurred. Thus, RRTC expenditures in providing RoadRailer service is in part a reimbursement for the costs actually incurred by others in providing a portion of those services and presumably includes an allowance for a "profit." Whether a profit does indeed incur depends on the volume of traffic and terms of the contract. In this case, RRTC is the common carrier marketing the transport service. The firm also provides the terminal operation using facilities owned by Conrail and improved by New York State. Conrail provides line-haul transport between the RoadRailer terminals. Independent truckers provide drayage services between the terminal and the shipper or consignee. Unit transport costs then are a combination of:

Exhibit 65. Selected Movements

Commodity	Specific Origin	Pick-up Routing	Specific Destination	Delivery Routing
1. Flour	Flour mills located in Buffalo's harbor district.	I-190	3 large bakeries in the Bronx-proxy destination: Major Deegan Expwy at 230th St.	I-87
2. Sugar	Plant located near Gowanus Canal in Brooklyn.	I-278 I-87	2 food processing plants north and east of downtown Buffalo.	I-190
3. Paper	Mill in southeast Niagara Falls	I-190 I-290	Plant on Hudson R. 16 miles north of NYS Thruway	I-87 NY-9
4. Converted Paper	Plant south of former Brooklyn Navy Yard.	I-278 I-87	Large printer on Walden Ave. on Buffalo's east side.	I-190, Walden Ave.
5. Industrial Chemicals	Chemical plants on south side of Niagara Falls.	I-190	Plants in Greenpoint section of Brooklyn.	I-87 I-278
6. Soap	Proctor-Gamble plant at Port Ivory, Staten Island.	I-278 I-87	Large Food products wholesaler in Southtown on Buffalo waterfront.	I-190
7. Glass Containers	Plant at Falconer	NY-60, I-90 I-190	Cosmetic mfgs in Northwest Corner or Nassau County	I-95 I-295 NY-495
8. Steel Mill Products	Foundaries at Lackawanna	Ridge Road	Fabricators in Long Island City and Maspeth.	I-87 I-278
9. Ventilation Equipment	Large plant in Black Rock Section of Buffalo	NY-196	Heating contractors in Manhattan (west side @ 20th St.)	I-87 Local Sts
10. Carbon Products	Large Plant in western Niagara Falls	I-190 I-290	Concentration of Electric/electronic mfgs in southwest Suffolk Co.	I-95 I-295 NY-495 NY-110
11. Lighting & Wiring	Mfgs in Long Island City	I-278 I-87	Electrical wholesalers in Buffalo east of downtown	I-190 Local Sts
12. FAK	RoadRailer Terminal	-	RoadRailer Terminal	-

- RRTC's corporate overhead plus a portion of the parent company's (BiModal Corporation) overhead costs (i.e., officer salaries and fringes, headquarter's expenses, etc.).
- RRTC's terminal operating costs in New York City and Buffalo. This includes such items as employee salaries and fringes, marketing and promotion, other local office expenses, insurance, terminal lease, utilities, equipment leases, and loss and damage claims.
- Local drayage provided by independent owner-operators under contract to RRTC. Reimbursement is on a formula basis taking into account distance and time of the local movement and the net weight of the trailer.
- Line-haul transport provided by Conrail under contract with the RRTC. Conrail is being reimbursed under negotiated train and trailer mile rates plus direct reimbursement for crew and fuel expenses.

In order to establish true costs, those being incurred by Conrail and independent owner-operators could be estimated, rather than using the amounts provided in contractual agreements. The Uniform Rail Costing System (URCS) and the NCHRP Truck Costing Model would typically be used to estimate those cost components. Differences between costs incurred and reimbursement by RRTC represents a "profit" and not a true cost.

The following paragraphs describe how the foregoing components were estimated. Also given is a synopsis of different alternatives for estimating unit costs and factors that had to be taken into account in preparing these estimates.

Corporate Overhead. In a large trucking company, corporate overhead is typically between 2 and 5 percent of total operating expenses. In this case, it will be appreciably higher given the "start-up" character of the operation and the lack of RoadRailer services elsewhere to contribute to corporate overhead. Because of the uniqueness of the RoadRailer operation, a dollar value or percentage for corporate overhead can be established only through reviewing RRTC's financial records. NYSDOT has not made such an review, although it may do so in the future. While it is unlikely that the RRTC is currently contributing to BiModal Corporation's overhead, the expectation is that the service being offered will eventually become profitable, and thus will provide a return on the investment of venture capital made by the parent company in starting RoadRailer service in New York State. The BiModal Corporation anticipates establishing similar services elsewhere in the country, which would have an impact on corporate overhead. Determination of the unit cost component appropriately assiged to corporate overhead is usually left to accountants, and thus has not been included in this case example.

Terminal Operations. The high cost of terminal operations has traditionally hindered the growth of TOFC services, and this situation is applicable to RoadRailer service under present traffic levels. The following illustrates why terminal operations are costly. At both the New York City and Buffalo terminals, the incoming train is disassembled and loaded trailers are assigned to truckers for delivery between 6:00 and 8:00 a.m. Activity subsides until later in the day when loaded trailers arrive at the terminal. Activity peaks between 4:00 and 6:00 p.m. as the outgoing train is assembled. Since the level of staffing must be sufficient to handle the twice-a-day peaks, yard activity is necessarily spread over more than one shift. The cost of terminal operations can be further divided into two components: costs that are largely fixed and those that are largely variable (i.e., varying with the level of traffic). Terminal operating and administration expenses are examples of the former; loss and damage claims (L&D) and car ownership costs are examples of the latter. In this case example, terminal operations and administration have been treated as fixed costs and car ownership and L&D as variable costs. Although this simplification was made necessary by the use of secondary data, it is appropriate to macro-level studies. Had financial data been available (through a review audit of the RRTC's financial records), a more realistic division between fixed and variable costs might have been possible.

Had this study been done only to meet NYSDOT's internal needs, the Department would have directly sought information on terminal costs from RRTC's financial records. Such information, however, would be considered confidential, and thus could not be used in a case example. Thus, using more generalized cost information previously furnished to NYSDOT by the BiModal Corporation, operating costs for each terminal were estimated to be \$2,320/day, administration \$1,955/day, and L&D at \$13 per loaded trailer. (Although the RoadRailer unit is designed to greatly reduce cargo damage, such still occurs.) Car ownership costs were estimated using the following reasoning. The cost of a new RoadRailer trailer was estimated to be \$35,000. (This estimate was based on a 1982 cost of \$32,500 plus an allowance for inflation.) Assume that financing was secured for the equipment at 12.5 percent per year for 8 years, and that it costs \$4,000/year to maintain each trailer beyond the routine servicing and inspection performed by terminal operating personnel.
Ownership costs thus amount to approximately \$11,000 per trailer per year. Since RoadRailer service operates five days a week and the east and westbound trains operate concurrently, the maximum utilization that can be made for a trailer is one, one-way trip per day (say 250 trips per year). Since traffic is not uniform over time, allowance must also be made for spare trailers, which in this case example was assumed to be 25 percent. If the traffic was balanced in both directions (i.e., all 250 trips were loaded), trailer ownership costs would amount to (\$11,000 x 1.25)/250 = \$55 per loaded trailer. If the traffic was one directionsl (i.e., only 125 trips were loaded), trailer ownership costs would amount to (\$11,000 x 1.25)/125 = \$110 per loaded trailer. Hence the range of values shown in Exhibit 66 for terminal costs.

Exhibit 66. RoadRailer Terminal Costs

No. of RoadRailer Units in Train	Cost Per Trailer Handled for				Total Terminal Cost
	Terminal Operations	Admin-istration	Loss & Damage	Ownership Cost	
10	232	196	13	55-110	496-551
20	116	98	13	55-110	282-337
30	77	65	13	55-110	210-265
40	58	49	13	55-110	175-230
50	46	39	13	55-110	153-208
60	39	33	13	55-110	140-195
70	33	28	13	55-110	129-184
80	29	24	13	55-110	121-176

Source: Adapted from a August 13, 1982 letter from Robert S. Reebie to William C. Hennessy, Commissioner, NYSDOT.

<u>Local Drayage</u>. Local drayage can be estimated using a combination of (1) the remuneration provisions of the contracts that independent owner-operators have with the RRTC, (2) average distance driven and time as reported on driver's logs, and (3) the number of loaded and empty trailers hauled on an average day. To obtain these data would require examining RRTC's financial records. Since this would involve using confidential information, such an approach could not be used in this case example. The alternative applied was to use the value which approximates the drayage charges that would be billed to the shipper or consignee, which in this case averages \$65/trailer for pickup or delivery of domestic freight within the local service area and driver use for one hour. Higher charges would apply to import/export freight (an additional \$55), use of driver and tractor beyond one hour to effect pickup or delivery (\$15 per additional half-hour), and pickup or delivery within the extended service area (an additional \$30 in Buffalo and \$55 in New York City). While this represents costs to the RRTC, it does include a "profit" for owner-operators as well as administrative charges.

<u>Line-Haul Transport</u>. As mentioned previously, line-haul transport is provided by Conrail under contract with the RRTC. Exhibit 67 approximates the costs incurred by the RRTC for provision of this service. The agreement includes rates for each train start (excluding crew and fuel), and each unit of RoadRailer equipment hauled between NYC and Buffalo, NYC and Rochester, and Rochester and Buffalo, whether empty or loaded. Actual crew and fuel charges (times a multiplier) are then added to train start and unit charges. Two sets of rates are shown: one for the first year (or a traffic level of less than 50 loaded trailers in each direction), and the other for the second and succeeding years (or a traffic level greater than 50 loaded units in each direction). Provisions are made for other charges, such as cost escalation, predeparture annulment, enroute annulment, additional trains, ad-

Exhibit 67. RoadRailer Line Haul Costs

1st Year[1/]

Train Cost = MILES [8.56 + 0.105(UNITS)]

2nd and Following Years[1/]

Train Cost = MILES [10.61 + 0.18 (UNITS)]

No of RoadRailer Units in Train	First Year			Succeeding Years		
	Train Cost $	Cost per Trailer	Cost per Mile	Train Cost $	Cost per Trailer	Cost per Mile
10	4,132	413	0.95	5,336	534	1.24
20	4,584	229	0.53	6,110	306	0.71
30	5,035	168	0.39	6,884	229	0.53
40	5,487	137	0.32	7,658	191	0.44
50	5,937	119	0.27	8,432	169	0.39
60	6,390	106	0.25	9,206	153	0.36
70	6,838	97	0.23	9,979	142	0.33
80	7,293	91	0.21	10,753	134	0.31

1/ Equations derived from the agreement between Road-Rail Transportation Company, Inc. and Consolidated Rail Corporation. Distance between Buffalo and New York City is approximately 430 miles via rail.

ditional locomotives, and changes in service frequency (i.e., 12 trains per week rather than the current 10).

The costs shown in Exhibit 67 make no distinction as to whether the trailer is loaded or not. Obviously only loaded trailer movement generate revenue, yet empty trailer movements incur costs. Since the flow of trailers over time must be the same in both directions to maintain equipment availability at both Buffalo and New York City, the costs shown must be adjusted upward to account for the cost of hauling empty trailers. Exhibit 68 shows net costs for different degrees of backhaul utilization. At the present time, eastbound trains generally contain only loaded trailers, whereas on westbound trains, the backhaul utilization rate has been running around 25 percent (although major marketing efforts are being made to attract additional westbound movements to reduce the present traffic imbalance).

The cost computations can be extended further to estimate Conrail's cost in providing the line-haul service. This can be done using the Uniform Rail Cost System (URCS) subtechnique. Although NYSDOT has obtained the necessary software from the ICC to undertake rail costing,

Exhibit 68. RoadRailer Linehaul Costs Versus Backhaul Utilization (First Year)

No. of RoadRailer Units in Train	Cost Per Loaded Trailer at Percent Backhaul Utilization				
	0%	25%	50%	75%	100%
10	826	723	620	516	413
20	458	401	344	286	229
30	336	294	252	210	168
40	274	240	206	171	137
50	238	208	179	148	119
60	212	186	159	133	106
70	194	170	146	121	97
80	182	159	137	114	91

the Department has not yet been able to make necessary adjustments to the program to make it operational on the Department's Burroughs B7800 computer. (URCS was originally programmed for DEC equipment, although it has subsequently been reprogrammed for IBM computers.) Given the present unavailability of URCS to NYSDOT, its use has not been illustrated in this case example.

The preceding component costs must be summed to develop total RoadRailer unit costs. This has been done in Exhibit 69.

Motor Carrier Costs

Motor carrier costs can be estimated by first determining the routes and distances between sample movement origins and destinations and then applying the NCHRP Truck Costing Model described in the User's Manual.

Route Structure. There are two principal routes between New York City and Buffalo: the water level route and the Southern Tier route. Both routes have rail and truck service, but only the water level route has RoadRailer service. In all, 9 mode-route combinations are possible over these two routes. See Exhibit 70.

Mode-route combinations considered include: (1) RoadRailer via the "water-level" route (Conrail's east-west mainline across upstate New York), (2) truckload movements via the New York State Thruway with and without tolls, and (3) truckload movements via Route 17 (Southern Tier

Exhibit 69. RoadRailer Unit Costs

No. of RoadRailer Units in Train	Cost per Trailer							
	Cost Component			Percent Backhaul Utilization				
	Terminal	Local Drayage	Line Haul	0%	25%	50%	75%	100%
10	496-551	130	413-826	1507	1390	1273	1156	1039
20	282-337	130	229-458	925	854	783	712	641
30	210-265	130	168-336	731	675	620	564	508
40	175-230	130	137-274	634	586	538	490	442
50	153-208	130	119-238	576	533	489	446	402
60	140-195	130	106-212	537	497	457	416	376
70	129-184	130	97-194	508	470	432	394	356
80	121-176	130	91-182	488	452	415	379	342

Exhibit 70. Mode-Route Combinations Between New York City and Buffalo

Route	Mode	Service
Water level	Truck, toll road	TL/LTL
	Truck, no tolls	TL/LTL
	RoadRailer	
	TOFC/COFC*	
	Rail Carload*	
	Waterborne	
Southern Tier	Truck, no tolls	TL/LTL
	TOFC/COFC*	
	Rail Carload	

*Not included in this analysis

Expressway) and I-390 (Genesee Expressway). For the Southern Tier route, appropriate "nonexpressway" connecting routes between I-390 and the particular plant, mill, warehouse, or distribution facility in Erie and Niagara Counties were identified. (The one partial exception to this was the use of Route 17 across the state as the route used for moving glass containers from Chautauqua County to New York City.)

Each of the four mode-route combinations consists of three segments: local pickup, line-haul movement, and local delivery. For freight moved by RoadRailer, the three segments are separate and distinct. For freight moved by truck in full trailerloads, the three segments are less distinct because the freight involved moves directly from origin to destination without consolidation or distribution. This point-to-point movement resembles a line-haul movement, but in fact includes both line-8aul and pickup and delivery segments. The latter were considered to be those portions of the line-haul movements within the built-up areas of New York City, Buffalo, and Niagara Falls.

Line-Haul Segment Distances. The length of the line-haul segments of the trip were taken from NYSDOT's photolog file. The photolog was also used to identify the speed limits allowed on different sections of each route. Travel time was calculated by multiplying the prevailing speed limit by the distance that the speed limit was in force. Although this involved some error stemming from the fact that trucks at times travel below the speed limit, this error was offset by the occurrence of travel at speeds above the speed limit.

A delay of one minute was added for each traffic light encountered on route. While the red phase of a traffic light is seldom 60 seconds long, the use of one minute delay also allows time for the acceleration and deceleration that occurs at a signalized intersection.

PUD Segment Distances. The length of these sections was measured by NYSDOT staff using 1:250,000 scale maps. Travel times on these segments were estimated by the NYSDOT staff familiar with the New York City and Buffalo areas. Because this procedure is error prone, considerable care was taken in developing these estimates to ensure reasonableness.

As a check on travel time on the PUD segments, speeds on these segments were calculated by dividing trip distance by the estimated travel time.

Trip distances and travel times are shown for each route, for each commodity, in Exhibits 71 and 72. Distance and travel time are also shown by line-haul and PUD segments, and by total trip. These numbers were used as input to the NCHRP Truck Costing Model to calculate the trip costs shown in Exhibit 73.

To determine the costs for the trips with tolls, the costs were recalculated, using actual Thruway tolls as an additional fixed cost. These tolls are shown below.

TOLLS, WATER LEVEL, AND SOUTHERN TIER

	Eastbound	Westbound	Tri-Boro Bridge
WL	$41.35	$35.35	$6.25
ST	$ 9.85	$ 3.85	$6.25

Exhibit 71. Trip Distances

COMMODITY	ROUTE	WEST PUD (Miles)	LINE HAUL	EAST PUD	TOTAL TRIP
1. Flour	WL	11	431	3	445
	ST	7	378	3	388
2. Sugar	WL	10	431	25	466
	ST	11	378	25	414
3. Paper	WL	27	431	7*	465
	ST	23	375	7*	405
4. Converted	WL	8	431	24	463
	ST	4	378	24	406
5. Industrial Chemicals	WL	21	431	20	472
	ST	4	375	20	414
6. Soap	WL	12	431	22*	465
	ST	8	378	22*	408
7. Glass Containers	WL	-	-	-	-
	ST	-	382	27	409
8. Steel Mill Products	WL	13	431	19	463
	ST	11	378	19	408
9. Ventilation Equipment	WL	14	431	14	459
	ST	18	374	14	406
10. Carbon Products	WL	23	431	42	496
	ST	22	375	42	439
11. Electric Products	WL	9	431	19	459
	ST	6	378	19	403
12. FAK	WL	7	431	5	443
	ST	3	378	5	386

The tolls are for a 5-axle tractor trailer, hauling one trailer. The difference between eastbound and westbound tolls stems from the fact that the Tappan Zee Bridge toll is collected in the Eastbound direction only. Tolls on the water level and Southern Tier routes for commodities not crossing the Yonkers toll barrier are $39.95 and $8.45, respectively. Tolls on the water level and Southern Tier routes for commodities not crossing the Tappen Zee Bridge or passing through the Harriman or Spring Valley toll barriers are $31.50 and $0.00, respectively.

The trip distances, travel times, and tolls used to calculate the costs of the trips with tolls are shown in Exhibit 74. Resulting trip costs calculated using the truck costing model are shown in Exhibit 75.

Unit Rates

RoadRailer Rates

The Road-Rail Transportation Company offers three plans analogous to TOFC plans:

Exhibit 72. Travel Times

COMMODITY	ROUTE	WEST PUD (Hours: Minutes)	LINE HAUL	EAST PUD	TOTAL TRIP
1. Flour	WL	:25	7:50	:15	8:30
	ST	:20	7:55	:15	8:30
2. Sugar	WL	:20	7:50	1:15	9:25
	ST	:15	7:55	1:15	9:25
3. Paper	WL	:30	7:50	:15*	8:35
	ST	:40	7:51	:15*	8:46
4. Converted Paper	WL	:20	7:50	1:00	9:10
	ST	:15	7:55	1:00	9:10
5. Industrial Chemicals	WL	:30	7:50	:45	9:05
	ST	:35	7:51	:45	9:11
6. Soap	WL	:15	7:50	1:30*	9:35
	ST	:10	7:55	1:30*	9:35
7. Glass Containers	WL	-	-	-	-
	ST	-	7:34	1:00	8:34
8. Steel Mill Products	WL	:25	7:50	:45	9:00
	ST	:20	7:55	:45	9:00
9. Ventilation Equipment	WL	:40	7:50	1:00	9:30
	ST	:35	8:05	1:00	9:40
10. Carbon Products	WL	:35	7:50	1:30	9:55
	ST	:40	7:51	1:30	10:01
11. Electric Products	WL	:20	7:50	:45	8:55
	ST	:15	7:51	:45	8:51
12. FAK	WL	:20	7:50	:10	8:20
	ST	:10	7:55	:10	8:15

* Net reduction in line haul.

Plan A. The customer provides his own RoadRailer trailers on a full service lease of $750 per month. The customer then elects to bring this trailer loaded with merchandise to the origin terminal for line-haul movement to the destination terminal via a dedicated train. Customer then arranges to pick up the trailer upon notification from the destination terminal.

Plan B. The customer provides his own RoadRailer trailer on a full service daily rental basis of $35 for all or part of any calendar day (excluding weekends and holidays), calculated from the day when the trailer is taken from the origin terminal until it is returned to the destination terminal empty and in good condition after one or more trips. Customer then arranges for his own movement of the trailer at the origin and destination terminal.

Plan C. Transportation of domestic freight, including local service area pickup and driver use for one hour, line-haul movement, and local service delivery and driver assistance for one hour.

Exhibit 73. Trip Costs Excluding Tolls

COMMODITY	ROUTE	PER LOAD
1. Flour	WL ST	$419.97 $399.98
2. Sugar	WL ST	$460.98 $426.79
3. Paper	WL ST	$459.99 $417.51
4. Converted Paper	WL ST	$477.30 $418.54
5. Industrial Chemicals	WL ST	$466.92 $426.79
6. Soap	WL ST	$459.99 $420.60
7. Glass Containers	WL ST	- $421.63
8. Steel Mill Products	WL ST	$458.02 $403.61
9. Ventilation Equipment	WL ST	$454.06
10. Carbon Products	WL ST	$490.66 $434.27
11. Electrical Products	WL ST	$454.06 $398.66
12. FAK	WL ST	$438.23 $381.85

So far, most shipments have been made under Plan C at a rate of $460 per shipment between Buffalo and New York City and $400 between New York City and Buffalo. Shippers using RoadRailer so far tend to be (1) intermittent users, (2) firms which do not have private trucking on contractual arrangements with a particular carrier, or (3) firms trying out RoadRailer service. Hence the appeal of Plan C, which avoids equipment leasing or separate drayage arrangements. An additional $30 or $55 is charged for pickup or delivery in the extended Buffalo and New York City service areas, respectively, Other charges may also be levied for the use of the driver, tractor, and RoadRailer unit for longer time periods, for multiple stops for pickups or deliveries, or for shipments moving under U.S. customs bond.

Exhibit 74. Input for Trip Costs with Tolls

COMMODITY	ROUTE	DISTANCE (miles)	TRAVEL TIME (hours:minutes)	TOLLS (dollars, cents)
1. Flour	WL ST	445 388	8:30 8:30	$41.35 $ 9.85
2. Sugar	WL ST	466 414	9:25 9:25	$41.60 $10.10
3. Paper	WL ST	465 405	8:36 8:46	$39.95 $ 8.45
4. Converted Paper	WL ST	463 406	9:10 9:10	$41.60 $10.10
5. Industrial Chemicals	WL ST	472 414	9:05 9:11	$47.60 $16.10
6. Soap	WL ST	465 408	9:35 9:35	$31.50 $ 0.00
7. Glass Containers	WL ST	- 409	- 8:34	- $15.60
8. Steel Mill Products	WL ST	463 408	9:00 9:00	$47.60 $16.10
9. Ventilation Equipment	WL ST	459 406	9:30 9:40	$41.35 $ 9.85
10. Carbon Products	WL ST	496 439	9:55 10:01	$47.60 $16.10
11. Electric Products	WL ST	459 403	8:55 8:51	$41.60 $10.10
12. FAK	WL ST	443 386	8:20 8:15	$41.35/$35.35 $9.85/$3.85

Motor Carrier Rates

In marketing the RoadRailer service, RRTC sales personnel have in the course of these efforts collected appreciable information on the rates charged to different shippers by competing motor carrier services. Unfortunately, this information has not been made available to NYSDOT. Nor has NYSDOT specific information on the conditions surrounding known movements (i.e., whether the routing used by the motor carrier is the water level or Southern Tier route; whether single or tandem trailers (twin 40- or 45-foot trailers are allowed on the New York State Thruway) are being used; whether the service is provided by common, contract, or private carriers, and the degree to which the equipment is being utilized in the backhaul direction). As indicated in Exhibit 75, the cost incurred in using Southern Tier route is considerably less than that using the water level route (NYS Thruway) due largely to the shorter distance and the freedom from tolls. (Tandem 40- or 45-foot trailers are not allowed on the Southern Tier Expressway. Tandem 28-foot trailers, allowed under the Surface Transportation Assistance Act of 1982, are not yet commonly used in New York State.)

Exhibit 75. Trip Costs Including Tolls

COMMODITY	ROUTE	PER LOAD
1. Flour	WL ST	$500.10 $409.83
2. Sugar	WL ST	$521.99 $436.89
3. Paper	WL ST	$498.96 $409.09
4. Converted Paper	WL ST	$499.62 $411.73
5. Industrial Chemicals	WL ST	$514.52 $442.89
6. Soap	WL ST	$491.49 $403.61
7. Glass Containers	WL ST	- $437.23
8. Steel Mill Products	WL ST	$505.62 $419.71
9. Ventilation Equipment	WL ST	$495.41 $411.48
10. Carbon Products	WL ST	$558.92 $450.37
11. Electric Equipment	WL ST	$495.66 $408.76
12. FAK Eastbound	WL ST	$497.58 $391.70
FAK Westbound	WL ST	$492.03 $385.70

While no specific information was available on backhaul utilization, the predominate flows are eastbound. Since considerable excess capacity exists in the westbound direction, allowance had to be made for empty movements in this direction.

In performing a study of this type, states would normally obtain information on the rates being charged by different trucking firms either directly from the companies or through shippers using the service. Since this was not done in this case, approximate rates were derived by increasing the lower of the trip costs shown in Exhibit 75 by 30 percent for eastbound movements and 20 percent for westbound movements based on an assumed eastbound trailer utilization of 100 percent and westbound of 60 percent, which reflects corridor commodity flows. This approximation was derived in the following manner. If (1) trucking costs were $1/mile in both directions, (2) the eastbound rate was $1.30 and (3) the westbound rate was $1.20/mile, (lower to attract business) then a trucking firm would effectively earn (1.0)($1.30) and (0.6)($1.20)/2 = (1.30 + 0.72/2 or $1.01/mile which just covers costs. Westbound rates are known to be especially competitive, given the excess capacity in the westbound direction. As an independent check on this, rates on flour moving to New York City were obtained from a wholesale bakery. RoadRailer rates are $1.12/cwt and motor carrier rates average $1.05/cwt. (The latter are contract rates and involve the use of tandem trailers.) These rates agree closely with those shown in Exhibit 75 after allowing for capacity differences between the two types of equipment. A standard highway trailer can haul 25.5 tons of cargo, whereas a RoadRailer unit is limited to a load of 20.5 tons. (This limit stems in part from the use of a smaller diameter flanged wheel and a Conrail established axle load limit of 60,000 lb. Conrail applies this limit to each trailer regardless of whether adjacent units are loaded or empty. Thus, interspacing empty trailers to share the load of heavily laden trailers is not allowed.)

Exhibit 76 shows the estimated rates for RoadRailer and motor carrier movements by commodity type. On a trailerload basis, the exhibit implies that RoadRailer rates are less than those charged by motor carriers.

While trailerload rates look favorable for RoadRailer service, they become less attractive when the trailer "weighs out" rather than "cubes out." Exhibit 77 shows the effective rates on a per hundredweight basis. This exhibit takes into account the density of the commodity in addition to the payload limits established by maximum axle loadings on the highway and rail systems. Exhibit 77 indicates that RoadRailer and motor carrier rates are close and that neither mode appears to have a significant pricing advantage over the other. This fact partially explains why the growth in RoadRailer traffic has been substantially less than that originally forecasted. A substantial price advantage simply does not exist. In addition, shippers often have contractual arrangements in place which they are unwilling to forego unless a substantial reduction in transport costs can be guaranteed over a period of time.

Modal Division

When this case example was originally conceived, the intention was to demonstrate the use of a simple modal distribution model to estimate modal division under varying rate structures. This would then allow NYSDOT to independently estimate the traffic levels and rate structure which would maximize the profitability of the new service.

When NYSDOT reached the point of undertaking modal division, Department staff concluded that the modal division task was not that essential in providing the information being sought. This decision reflected, in part, the difficulties encountered in assembling a commodity flow matrix from available secondary data and the limitations created by substituting therefore, a set of movements considered to be representative. The latter, while adequate for providing approximate cost

Exhibit 76. Estimated Rates per Trailer

Commodity	Direction	Estimated Rates Per Trailer		Lower Cost Mode
		RoadRailer	Motor Carrier	
1. Flour	eastbound	460	533	RR
2. Sugar	westbound	400	524	RR
3. Paper	eastbound	545	532	MC
4. Converted Paper	westbound	400	494	RR
5. Industrial Chemicals	eastbound	430	576	RR
6. Soap	westbound	455	484	RR
7. Glass Containers	eastbound	545	568	RR
8. Steel Mill Products	eastbound	460	546	RR
9. Ventilation Equipment	eastbound	460	535	RR
10. Carbon Products	eastbound	545	585	RR
11. Electric Products	westbound	400	491	RR
12. FAK	westbound	400	470	RR
13. FAK	eastbound	460	501	RR

Note: Based on the use of single 40- or 45-foot trailers.

and rate comparisons, precluded undertaking the modal division task. While a further illustration of modal division would have been desirable, it would essentially duplicate the modal division model presented in Case Example B, and thus was not felt to be all that essential.

To perform modal division, NYSDOT would first assemble primary data through shipper interviews. While this would take time and staff effort, and require the cooperation and participation of the RRTC, the work itself is straightforward. Present and past users of RoadRailer service would be contacted to determine the characteristics and cost (rates) of the trucking service previously or currently being used for the movement. Any institutional or contractual arrangements which would constrain or effectively preclude modal shifts, even when the cost via RoadRailer was less, would be identified. At the same time, similar contacts would be made with shippers having suitable traffic, but who have not chosen to utilize RoadRailer service. Information obtained would be used to build a commodity flow matrix. While such a matrix would not be statistically drawn from the universe of shipments between Buffalo and New York City, it still would be most useful in determining market penetration under different rate structures. Such a matrix would normally be assembled and continuing assessments made as part of on-going marketing efforts by the RRTC or its parent organization.

Assuming that NYSDOT had proceeded ahead with this phase, present and perspective shippers would be contacted for information on shipments being made between the two market areas. Each resulting interview record would include data on (1) the local origin and destination of the movement in the Buffalo and New York City and the route used between these two areas, (2) annual volume or weight of the movement, (3) commodity type and density, (4) cost or rates charged for trucking services presently or formerly used, (5) general type, such as common carrier, contract carrier, owner-operator, private trucking, (6) identification of any institutional or contractual arrangements that inhibit the use of an alternative mode, such as RoadRailer, and the permanence thereof, (7) any annual minimums, backhaul, or equipment use commitments presently in place affecting mode choice, and (8) any other service criteria, attitudinal, or policy constraints affecting mode choice.

Once this matrix has been assembled, the following procedure should be used to estimate modal diversion and resulting costs and revenues:

1. First, if private trucking is used or the rates are unknown, an approximate cost must be estimated and added to the record. This would require setting up a distance-estimating procedure based on the origin and destination of the movement and the route chosen between New York City and Buffalo, and then applying the truck costing model and other pertinent information on the characteristics and utilization of the trucking service used to approximate the charges or costs to the user.
2. Second, vehicle (trailerload) equivalents would have to be determined for both the motor carrier and RoadRailer modes using commodity density and information on trailer capacity (i.e., cubic footage and maximum payload). From this, unit charges or rates would be computed for both modes.
3. Each record would then be screened to identify those for which RoadRailer service offers a lower unit cost, and thus would be expected to use this service for economic reasons.
4. Those movements passing the screening in step 3 would be subjected to further screening to identify the degree of institutional or contractual constraints inhibiting modal diversion.
5. Finally, commodity flow matrix records would be summarized to estimate actual and potential traffic volumes and revenues under the present rate structure and reflecting different assumptions regarding ultimate diversion.
6. To test the sensitivity to alternative rate structures, steps 2 through 5 would be repeated to estimate the short- and long-range traffic potential of RoadRailer service under different rate scenarios.
7. The analysis could be further extended to estimate the costs of providing RoadRailer service and resulting net profit or loss under different rate scenarios.

Exhibit 77. Estimated Rates per CWT

Commodity	Assigned STCC	Density lbs/cu.ft.1/	RoadRailer: Wt. or Vol. Constrained 2/	RoadRailer: Eff. Rate per CWT	Motor Carrier: Wt. or Vol. Constrained	Motor Carrier: Eff. Rate per CWT	Lower Cost Mode
1. Flour	20411	42	weight	1.12	weight	1.04	MC
2. Sugar	20621	43	weight	0.98	weight	1.03	RR
3. Paper	26213	37	weight	1.33	weight	1.04	MC
4. Converted Paper	26451	19	weight	0.98	volume	1.08	RR
5. Industrial Chemicals	28211	38	weight	1.05	weight	1.13	RR
6. Soap	28419	24	weight	1.11	weight	0.95	MC
7. Glass Containers	32212	14	volume	1.62	volume	1.69	RR
8. Steel Mill Products	33125	44	weight	1.12	weight	1.07	MC
9. Ventilation Equipment	35641	15	volume	1.28	volume	1.49	RR
10. Carbon Products	36241	22	weight	1.33	weight	1.14	MC
11. Electric Products	36791	12	volume	1.39	volume	1.70	RR
12. FAK	45111	20	weight	0.98	volume	0.98	Same
13. FAK	45111	20	weight	1.12	volume	1.04	MC

1/ Source: Appendix B of Users Manual.

2/ RoadRailer trailer has a volume of 3,022 cu.ft., of which 80% (2400 cu.ft.) is considered usable. Maximum payload is 20.5 tons.

3/ Based on a 25.5 ton load in a similar sized trailer.

APPENDIX A — TRUCK COSTING PROGRAM

INTRODUCTION

The Truck Costing Program is written in UCSD-Pascal for use on an Apple II microcomputer equipped with 64K (65536) bytes of random access memory (RAM), one disk drive, a printer (optional), and the p-System operating system. UCSD-Pascal and the p-System were chosen to ensure reasonably simple transfer of the finished program between various models of microcomputer.

All input to the program is accomplished by means of a series of input subroutines that are external to the Truck Costing Program. The subroutines are called by the Truck Costing Program from the System Library. The input subroutines are designed to ensure that the user cannot enter any data types or values that would cause program or system errors (e.g., typing a nonnumeric character when the input variable is a numeric type would ordinarily cause a fatal system error that would force the user to reinitialize the machine). The input subroutines also fix the number of characters that may be entered for each input and check to see that the entered value falls within an acceptable range.

The operation of the program is depicted by the functional block diagram shown in Figure A-1. This diagram outlines the operation of each of the four major modules available to the user. Detailed descriptions of trip cost and file revision procedures along with figures showing actual terminal displays are shown in the section on programs operation.

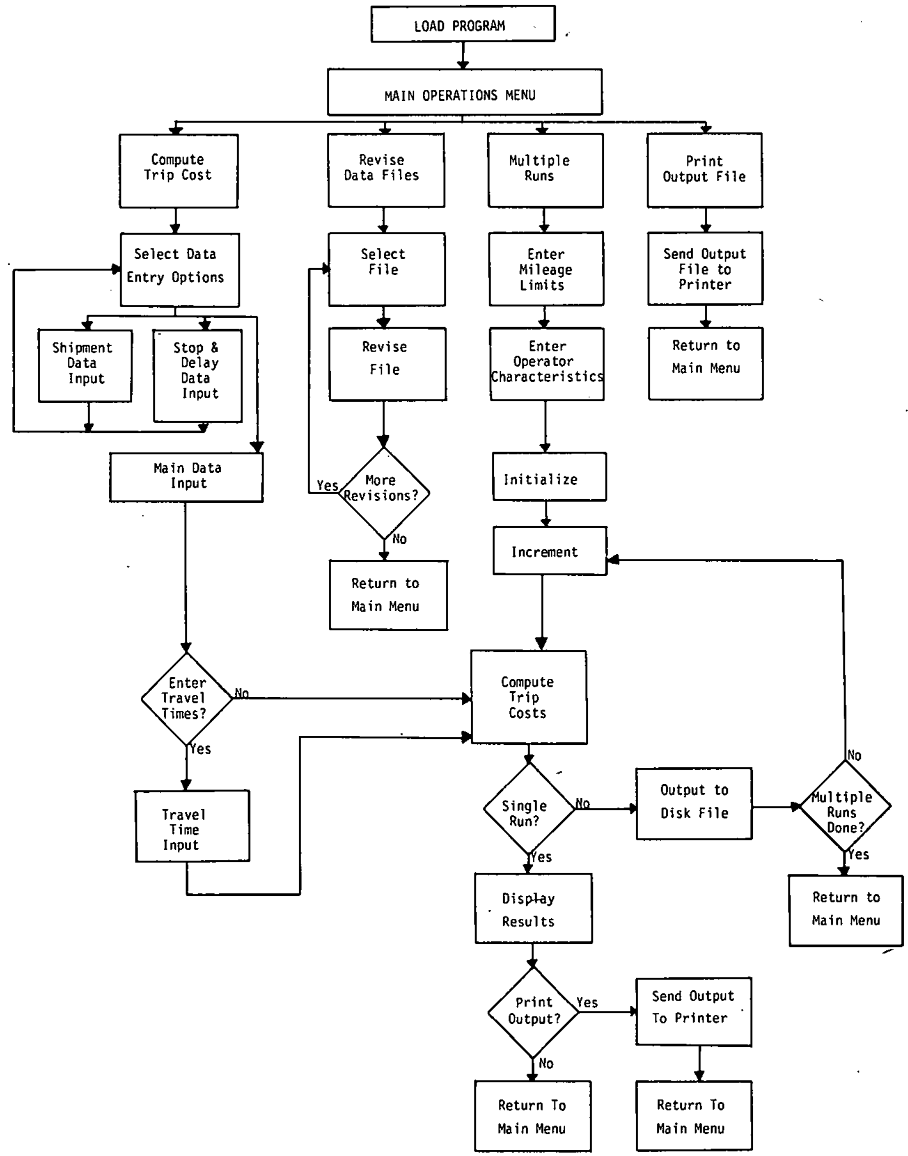
Certain precautions were taken in designing the program logic to protect the user from accidental loss of input and output files. Some of these steps result in what may seem to be an excessive number of disk operations that tend to slow down the program operation. It was felt that since microcomputers frequently operate under conditions that are not conducive to high reliability (e.g., conditions such as unstable power source, high temperature, excessive dust and dirt, etc.) it was necessary to trade off some operating speed for a more secure data storage arrangement. For example, in the multiple-run mode, a power line problem that may force the operator to reinitialize the machine or may even cause damage to the hardware will result in the loss of a maximum of one data point.

PROGRAM OPERATION

Introduction

The Truck Costing Technique has been programmed in UCSD-Pascal to run on an Apple II-microcomputer. This section will introduce the user to the program and step through a calculation showing the major menus and input screens that are used by the program.

Figure A.1. Functional Block Diagram of the Truck Costing Program.



Startup

The Truck Costing Program is stored on one 5 1/4-in. diskette. This diskette also contains all system files needed by the computer. The program will start and run automatically when the computer is turned on, and it will restart automatically every time the machine is re-initialized providing that the diskette remains in the disk drive.

Main Operations Menu

The Main Operations Menu, shown in Exhibit A-1, is the primary menu for the user. Upon any user-selected escape ("< ESC > ") from an input screen, the program halts its operation and returns to this primary menu. The primary menu also reappears at the completion of any computation or group of computations. The program will recycle like this indefinitely with no need to reload the program or reinitialize the computer.

EXHIBIT A-1

```
TRUCK COSTING MODEL

++ OPERATIONS MENU ++

1. COMPUTE TRIP COST

2. REVISE DATA FILES

3. MULTIPLE RUNS

4. PRINT OUTPUT FILE


ENTER NUMBER OF DESIRED OPERATION:
```

The user is asked to select a mode of operation from the four choices listed on the menu. The major operation is No.1 in Exhibit A-1, COMPUTE TRIP COST. Selection of this operation will allow the user to enter data and select options as described in the following paragraphs.

COMPUTE TRIP COST

Data Entry Options

After selection of operation 1 from the primary menu, the user is offered the data entry options as shown in Exhibit A-2.

EXHIBIT A-2

```
** DATA ENTRY OPTIONS **

1. ENTER SHIPMENT DATA

2. ENTER STOP AND DELAY DATA


ENTER NUMBER OF DESIRED OPTION:

<ESC>=RESTART  <RETURN> TO CONTINUE
```

Note that the user may elect to restart the program by using the <ESC> key. This user option will be available throughout the program. Its effect is to return the user to the primary menu and to undo all data entries up to that point.

This screen may be bypassed entirely by using the <RETURN> key because shipment data and stop and delay data are not required for the operation of the program. The sequence of screens for both options will be described at this point.

Shipment Data

When the user selects data entry option 1 (Exh. A-2, ENTER SHIPMENT DATA, the Shipment Data screen appears (Exh. A-3).

EXHIBIT A-3

```
                ** SHIPMENT DATA **

LEGAL MAXIMUM G.V.W. (LBS).....:
TRACTOR TARE WEIGHT (LBS)......:
TRAILER TARE WEIGHT (LBS)......:
TRAILER CUBIC CAPACITY (CU-FT).:
PRODUCT DENSITY (LBS/CU-FT)....:
SHIPMENT SIZE..................:
   UNITS: P(OUNDS, T(ONS, K(G..:




WANT TO ENTER SHIPMENT DATA?
<ESC>=RESTART  <RETURN> FOR DEFAULT
```

The user is then required to confirm the intent to enter the shipment data. Once the users, intent is verified the data may be entered. Notice that hitting the <RETURN> key will supply a default value (if one is available) for each entry. Should this option be selected, the program uses the data entered by the user to determine whether the product will fill the trailer cubic capacity before the gross vehicle weight reaches the legal maximum (also termed "cube-out"). Based on this determination, the program computes the number of truckloads for the entire shipment and computes an average payload weight. This information will be used later for ton-mile and per ton cost computations.

If the user enters "0" for no stops, the program returns to the data entry option screen. Should the user select another number, "4" for example (see Exh. A-6), the screen will display a blank table (Exh. A-4) and the user then enters the data to fill out this table.

EXHIBIT A-4

```
                ** STOPS AND DELAYS **


STOP#    HOURS    MINUTES    REASON
  1
  2
  3
  4




SELECT REASON FROM THE LIST BELOW:
L(OAD, U(NLOAD, W(AITING, O(THER
```

This option can be used to modify the calculations to account for trip-specific terminal costs. The program sums the stop and delay times, multiplies by the hourly cost of stop-time as entered through the following screen (Exh. A-5), and adds the result to the trip cost.

EXHIBIT A-5

```
              ** STOPS AND DELAYS **

ENTER DRIVER WAGE FOR STOP TIME ($/HR)

                   $
```

Stop and Delay Data

On selection of data entry option No.2 in Exhibit A-2, ENTER STOP AND DELAY DATA, the user is asked to confirm this choice by entering the number of stops and delays to be considered (Exh. A-6).

EXHIBIT A-6

```
** STOPS AND DELAYS **

HOW MANY STOPS ON THIS TRIP?
(0 TO 9)
```

After this entry, the program returns to the data entry option screen where either option may be selected for entry or reentry of data. The user may also by using the <RETURN> key go right to the next input screen.

Enter Input Values

This input screen allows the user to enter the operator characteristics and some optional information that will allow identification of specific trip characteristics (Exh. A-7).

EXHIBIT A-7

```
+++ ENTER INPUT VALUES +++

ORIGIN.....................:
DESTINATION................:
COMMODITY..................:
DATE...MONTH:  ..DAY:  ..YEAR:
MILES/HEADHAUL.............:
MILES/ROUNDTRIP............:
MILES/YEAR.................:
TONS OF PAYLOAD............:
TERMINAL CHARGES ($).......:
FUEL PRICE (CENTS/GAL).....:
TRACTOR M.P.G..............:
TRACTOR OWNER..............:
  (C=COMPANY  D=DRIVER)

EQUIPMENT TYPE.............:
  0=NO TRLR      5=GRAIN
  1=DRY VAN      6=DUMP
  2=REEFER       7=LIVESTK
  3=FLATBED      8=AUTORAC
  4=TANK         9=DBL VAN
```

Default values (entered by using the <RETURN> key) are available for most of the required inputs. The program guards against improper input values by checking each entry against an allowed range for the particular variable and then requiring the user to reenter out-of-range values. Additionally, if the user has selected other options, such as "ENTER SHIPMENT DATA," the program will enter previously computed values on the screen rather than let the user enter a new value.

Time Functions

After the appearance of the general input screen, the user may enter travel times (Exh. A-8).

EXHIBIT A-8

```
** TIME  FUNCTIONS **

WANT TO ENTER TRAVEL TIMES (Y,N)?
```

These travel times are used to compute average speed for the trip and may be used to estimate power requirements to maintain such an average speed for the trip. As shown in Exhibit A-9, distances are segregated into loaded and empty categories, and the user then enters the duration of the particular portion of the trip. The program computes and displays the average speed. The program also checks for unreasonable speeds and requires reentry of any times that result in unreasonable speeds.

EXHIBIT A-9

** TIME FUNCTIONS **

	MILES	HOURS	MINUTES	SPEED
LOADED:	1000	19	40	50.8
EMPTY:	1000			

Default Value Modification

The Truck Costing Program uses a large number of input variables in computing trip costs. The most sensitive of these variables and the most carrier-specific variables are entered as user input to the program, although default values are available for most of the inputs. Other input data are maintained in several data files that are read from disk, as necessary, by the program. The default values may be altered by use of the data file revision routines. A sample of the revision procedure, as it applies to the trailer data file, is shown below. The pattern of operations shown in the example applies to all of the data files.

Examination of Trailer Data File

When the user selects the Trailer Data File for revision, the contents of the file is read from the disk and displayed on the user's terminal, as shown in Exhibit A-10, and the user is asked to verify the intent to modify the file.

EXHIBIT A-10

** TRAILER DATA FILE **

#	TRAILER TYPE	PRICE ($)	-ECONOMIC- SLVG	LIFE	---TAX--- SLVG	LIFE
0	NO TRLR	$ 0	$ 0	0YRS	0%	0YRS
1	DRY VAN	$14000	$ 5250	8YRS	10%	8YRS
2	REEFER	$30588	$ 8900	8YRS	10%	8YRS
3	FLATBED	$10400	$ 5130	8YRS	10%	8YRS
4	TANK	$25200	$13000	8YRS	10%	8YRS
5	GRAIN	$14236	$ 7075	8YRS	10%	8YRS
6	DUMP	$22080	$12027	8YRS	10%	8YRS
7	LIVESTK	$16967	$ 4068	8YRS	10%	8YRS
8	AUTORAC	$24986	$ 8843	8YRS	10%	8YRS
9	DBL VAN	$32540	$15918	8YRS	10%	8YRS

STILL WANT TO MODIFY?

If the user affirms the intent to revise the file, the program requests the number of the line to be modified (Exh. A-11).

EXHIBIT A-11

```
        ** TRAILER DATA FILE **

# TRAILER    PRICE  -ECONOMIC-   ---TAX---
   TYPE       ($)   SLVG  LIFE   SLVG LIFE

0 NO TRLR  $     0 $     0  0YRS  0%  0YRS
1 DRY VAN  $14000 $ 5250  8YRS 10%  8YRS
2 REEFER   $30588 $ 8900  8YRS 10%  8YRS
3 FLATBED  $10400 $ 5130  8YRS 10%  8YRS
4 TANK     $25200 $13000  8YRS 10%  8YRS
5 GRAIN    $14236 $ 7075  8YRS 10%  8YRS
6 DUMP     $22080 $12027  8YRS 10%  8YRS
7 LIVESTK  $16967 $ 4068  8YRS 10%  8YRS
8 AUTORAC  $24986 $ 8843  8YRS 10%  8YRS
9 DBL VAN  $32540 $15918  8YRS 10%  8YRS


MODIFY WHICH LINE?
```

In this example the user wishes to modify line 4. When the user enters the line number, the values on corresponding line of the display are removed and the user can enter new values (Exh. A-12).

EXHIBIT A-12

```
        ** TRAILER DATA FILE **

# TRAILER    PRICE  -ECONOMIC-   ---TAX---
   TYPE       ($)   SLVG  LIFE   SLVG LIFE

0 NO TRLR  $     0 $     0  0YRS  0%  0YRS
1 DRY VAN  $14000 $ 5250  8YRS 10%  8YRS
2 REEFER   $30588 $ 8900  8YRS 10%  8YRS
3 FLATBED  $10400 $ 5130  8YRS 10%  8YRS
4          $       $         YRS   %   YRS
5 GRAIN    $14236 $ 7075  8YRS 10%  8YRS
6 DUMP     $22080 $12027  8YRS 10%  8YRS
7 LIVESTK  $16967 $ 4068  8YRS 10%  8YRS
8 AUTORAC  $24986 $ 8843  8YRS 10%  8YRS
9 DBL VAN  $32540 $15918  8YRS 10%  8YRS


MODIFY WHICH LINE? 4
```

After the entire line is entered, the program asks the user to verify the new values (Exh. A-13).

EXHIBIT A-13

```
        ** TRAILER DATA FILE **

# TRAILER    PRICE  -ECONOMIC-   ---TAX---
   TYPE       ($)   SLVG  LIFE   SLVG LIFE

0 NO TRLR  $     0 $     0  0YRS  0%  0YRS
1 DRY VAN  $14000 $ 5250  8YRS 10%  8YRS
2 REEFER   $30588 $ 8900  8YRS 10%  8YRS
3 FLATBED  $10400 $ 5130  8YRS 10%  8YRS
4 TANK     $25200 $13000  8YRS 10%  8YRS
5 GRAIN    $14236 $ 7075  8YRS 10%  8YRS
6 DUMP     $22080 $12027  8YRS 10%  8YRS
7 LIVESTK  $16967 $ 4068  8YRS 10%  8YRS
8 AUTORAC  $24986 $ 8843  8YRS 10%  8YRS
9 DBL VAN  $32540 $15918  8YRS 10%  8YRS


IS LINE #4 CORRECT? (Y,N)
```

At this point the data file has not actually been modified and all original values are intact. If the user verifies that the line is correct, the new data file is written back to the disk and the modification is completed. Should the user find that the new line is incorrect for any reason, the modification procedure can be aborted by typing "N" in answer to the verification request. In either case, the user is now offered a chance to make further modifications (Exh. A-14).

EXHIBIT A-14

** TRAILER DATA FILE **

#	TRAILER TYPE	PRICE ($)	-ECONOMIC- SLVG	LIFE	---TAX--- SLVG	LIFE
0	NO TRLR	$ 0	$ 0	0YRS	0%	0YRS
1	DRY VAN	$14000	$ 5250	8YRS	10%	8YRS
2	REEFER	$30588	$ 8900	8YRS	10%	8YRS
3	FLATBED	$10400	$ 5130	8YRS	10%	8YRS
4	TANK	$25200	$13000	8YRS	10%	8YRS
5	GRAIN	$14236	$ 7075	8YRS	10%	8YRS
6	DUMP	$22080	$12027	8YRS	10%	8YRS
7	LIVESTK	$16967	$ 4068	8YRS	10%	8YRS
8	AUTORAC	$24986	$ 8843	8YRS	10%	8YRS
9	DBL VAN	$32540	$15918	8YRS	10%	8YRS

MORE MODIFICATIONS?

If the user answers "yes", the modification process repeats for the same file. A "no" answer allows the modification routine to terminate.

OUTPUT

After all of the desired inputs are completed, the program computes the cost of the specified trip. The program computes values for seven different cost measures and the resulting values are displayed on the console, as shown in Exhibit A-15.

EXHIBIT A-15

```
*** TRIP COSTS ***

COST PER MILE...........$ 0.9957
COST PER HEADHAUL MILE..$ 1.9913
COST PER ROUND TRIP.....$ 1991.31
COST OF HEADHAUL........$ 995.66
COST PER TON-MILE.......$ 39.8262
COST PER CWT............$ 1991.31
COST PER TON............$ 39826.2
GALLONS OF FUEL CONSUMED: 416.67

WANT PRINTED OUTPUT?? (Y,N)
```

This output screen also offers the user an optional printed output of the results of the computations. The printed output form includes information on certain input values and internal variable values that may be of interest to the user.

The output screen is the last display in this sequence. When the user is finished with this screen the program will again display the Main Operations Menu (Exh. A-1) and wait there for the user's next selection.

Table A-1 shows a sample hardcopy output of the NCHRP Project 20-17A truck costing subtechnique.

TABLE A-1

TRUCK COSTING SUB-TECHNIQUE
FOR NCHRP 20-17A

11/18/82 10182:329/5423

** TRIP DATA **

ORIGIN	DESTINATION	COMMODITY	WEIGHT (POUNDS)	<---DISTANCE TRAVELLED IN MILES---> HEADHAUL	ROUNDTRIP	DEADHEAD	<---SPEED IN MPH---> HEADHAUL	DEADHEAD	NUMBER OF STOPS
PHL	CHI	20 371 30	48825.0	982.00	2088.00	1106.00	49.93	56.72	3

** TIME FUNCTIONS **

TRANSIT TIMES IN HOURS HEADHAUL	DEADHEAD	<-----STOP AND DELAY TIMES IN HOURS------> LOAD	UNLOAD	WAIT	OTHER
19.67	19.50	2.75	2.00	1.42	0.00

** SHIPMENT DATA **

SIZE OF SHIPMENT	DENSITY LB/CU-FT	AVG LOAD (POUNDS)	NUMBER OF TRUCKLOADS
97.65 TONS	20.000	48825.0 LIMITED BY WEIGHT	4

** COMPONENT COSTS PER TRUCKLOAD **
(CENTS PER MILE &)
(PERCENT OF TOTAL)

<----------------FIXED COSTS---------------->

INSUR ANCE	OVER- HEAD	LIC & PERMIT	FED HUT	TRAC COST	TRLR COST
5.00	3.50	1.20	0.21	22.81	7.66
4.53%	3.17%	1.09%	0.19%	20.68%	6.95%

<----------------------------VARIABLE COSTS------------------------------->

DRIVER WAGE	DRIVER EXP	FUEL COST	3RD ST TAX	TRAC TIRE	TRAC MAINT	TRLR TIRE	TRLR MAINT	STOP COST	TERM COST
22.00	3.50	23.96	0.50	1.45	9.00	0.80	1.50	2.64	4.55
19.95%	3.17%	21.72%	0.45%	1.31%	8.16%	0.73%	1.36%	2.40%	4.13%

** TOTAL COSTS **
(PER TRUCKLOAD)

PER MILE	ROUNDTRIP	HEADHAUL	DEADHEAD	TON-MILE	CWT	TON
$ 1.1028	$ 2302.69	$ 1082.97	$ 1219.72	$ 0.0961	$ 4.72	$ 94.32

APPENDIX B — COMMODITY ATTRIBUTES

INTRODUCTION

In applying the freight demand forecasting technique, users often require commodity-specific information, such as product value, density, shelf life, etc. This is particularly true when mode choice depends on logistics costs (e.g., storage, damageability, etc.) in addition to price and service.

Users can obtain accurate information on particular products from government publications, trade associations, or shippers. Often, information is required on a broad range of commodities. In such cases, the default information contained in this appendix may suffice.

The commodity attribute file contains information on approximately 1,200 commodities at the 5-digit STCC code level. Information is included on value, density, special handling requirements, and shelf life. The data were originally compiled by the MIT Center for Transportation Studies (Kuttmer, W.S.,"A Disaggregate File of Commodity Attributes." MIT Center for Transportation Studies, Report Number 79-12, August 1979). Much of the value and density data are based on an unpublished analysis by Marty Costello, research analyst of the U.S. Department of Transportation. Shelf lives and density for fruits and vegetables were compiled from U. S. Department of Agriculture publications. Finally, MIT research staff estimates provided the remainder of the information.

At least three types of problems had to be dealt with in the assembly of this type of commodity information. The first of these is that for many commodities, data were not readily available in any form. Thus, estimates had to be used for some commodity attributes. Secondly, where data were available, it was not in comparable form. In addition to the problem of unit conversions, there are many types of measurements that can be made of any given attribute. For example: Is "density" the unpacked density, the package density, or the density as the packages are stacked in a transport vehicle? Are prices wholesale, or retail? An attempt has been made to standardize measuring systems as much as possible. Finally, commodity attributes can vary greatly within a commodity classification. This is true not only because a single commodity classification may actually include several types of commodities, but also because commodity attributes vary by producer and they even vary over time for a single producer of a single commodity. Thus, it was necessary to seek something approaching the "average" commodity attributes for each classification. These three problems pose severe limitations on the accuracy of the data, and users should therefore think of the file as "order-or-magnitude" estimates rather than as precise figures. However, the estimates should be adequate for most transportation analysis purposes.

DESCRIPTION

A sample listing from the Commodity Attribute File is as follows:

1	2	3	4	5	6	7	8
11221	58.	0.020	24		*	0	LIGNITE
13111	54.	0.050	23		*	0	PETROLEUM CRUDE
13121	36.	0.100	23		G	0	GAS NATURAL
13211	49.	0.060	23	FL	*	0	GASOLINE NATURAL
14111	78.	0.030	00		*	0	DIMENSION STONE QUARRY
14211	100.	0.020	24		*	0	AGRICULTURAL LIMESTONE

The following information is shown for each commodity at the 5-digit STCC code level:

1. STCC Code
2. Density (lbs/cu ft)
3. Product Value ($/lb)
4. Plausible Packing Type
5. Hazardous Material Code
6. Special Handling Code
7. Shelf Life (days)
8. Description

Each of these characteristics is further described in the following paragraphs. A printout of the Commodity Attribute File is shown in Exhibit B-1.

STCC Code (1)

The Standard Transportation Commodity Code numbers as used by the railroad tariffs, the Interstate Commerce Commission, and the Census of Transportation are used. To reduce the size of the file to manageable proportions, 5-digit aggregated commodity groups were selected instead of the complete 7-digit code. That is, each 5-digit STCC number in this file represents a group of all the 7-digit STCC commodity classifications which have numbers beginning with those five digits.

Density (2)

Figures quoted are for density as loaded in a transport vehicle in pounds per cubic foot. Thus, the density is the weight of a shipment of a given commodity, divided by the volume of the transport vehicle consumed by the shipment.

Value (3)

Product value information was obtained from 1972 MIT research and inflated to 1977 using Supplier Price indices. The value indicated is intended to be an estimate of the price the consignee must pay the shipper for ownership of the commodity without any transportation costs. For commodities shipped intra-corporation, this value corresponds to values that would be used by the firm for in-house accounting.

Plausible Packing Types (4)

Plausible packing types are types for which there is evidence of their use in moving a given commodity. This information was obtained from National Motor Freight Conference (NMFC) tariffs (which list required packagings for most commodities) and from the equipment code listed in the ICC/FRA 1% Waybill Sample tape.

The universe of feasible packaging was reduced to five categories coded by single numbers. There are two numbers for each commodity. The first number is the probable packing type for LTL/LCL shipments, and the second number denotes a packing type for truckload and carload shipments. The five categories are:

0 -- Loose. These commodities are shipped basically "as is," but it is not practical to pour, dump, or pump it when loading or unloading (i.e., watermelons, livestock, automobiles, machinery, etc.).

1 -- In Containers in Packages. These commodities are intended for retail sale, such as boxes of canned foods, electronic equipment packed in inner containers for added protection, items designed to facilitate pallet loading or an above average commodity value if the inner container represents value added.

2 -- In Packages. This describes items for transport that have been prepared so that they can be stocked or piled in a vehicle (i.e., barrels, boxes, crates, coils, rolls, pails, bags, bundles, etc.).

3 -- Liquid Bulk. These commodities are usually liquids or liquified gases. Although tank trucks are divided into bulkheads and it is possible to take delivery on less than a truckload in liquid bulk, the entire truck is usually filled at one location and bulkheads are emptied at different stops. Such traffic is therefore not LTL in the usual sense.

4 -- Dry Bulk. This indicates truckloads or carloads of solid commodities where pouring and dumping are practical for loading and unloading. Grain, coal, particular chemical products, ore, gravel, and sand generally are moved this way.

Hazardous Materials Code (5)

The hazardous material symbol is a two-letter code that describes the type of hazard, if any, that a material poses in transport. The codes stand for:

XA Class A explosive
XB Class B explosive
XC Class C explosive
NG Nonflammable compressed gas
FG Flammable compressed gas
CG Compressed gas
FL Flammable liquid
CL Combustible liquid
FS Flammable solid
OM Oxidizing material
OP Organic peroxide
PA Poison Class A
PB Poison Class B
IR Irritating material
EA Etiologic agent
RM Radioactive material
CM Corrosive material

Special Handling Code (6)

The special handling code is given as:

* No special handling
G Compressed or liquified
F Freezing temperatures required
T Temperature control other than freezing
S Shock control required
O Other special handling

The special handling code is derived from MIT data and information in the NMFC tariffs. Specifying which commodities required shock protection was difficult because nearly every commodity is fragile to some degree. A rather narrow specification was selected which encompasses only china or glass products, and delicate machinery or equipment.

Shelf Life (7)

Shelf life is the estimated time in days between when a commodity is produced and the time it is so old that it cannot be sold at usual market prices. A "0" indicates a shelf life of greater than 180 days since the transportation time is a rather insignificant proportion of shelf life for a product that can last longer than 6 months.

Shelf life is determined only by physical deterioration of the product, not by fashion or technological obsolescence, since the latter are not usually predictable. However, an exception is made for newspapers and periodicals because these generally have very short and predictable shelf lives. Generally speaking, only agricultural products have shelf lives, as defined here, of less than 6 months. These data came primarily from U. S. Department of Agriculture publications (U.S. Department of Agriculture, The Commercial Storage of Fruits, Florist, and Nursery Stocks).

01121	20.	0.560	22	* 0	RAW COTTON IN BALES
01129	10.	0.500	22	* 0	RAW COTTON NEC
01131	42.	0.030	24	* 0	BARLEY
01132	42.	0.030	24	* 0	CORN EXC POPCORN
01133	42.	0.030	24	* 0	OATS
01134	36.	0.110	24	* 0	RICE, ROUGH
01135	43.	0.030	24	* 0	RYE
01136	46.	0.050	24	* 0	SORGHUM GRAINS
01137	41.	0.050	24	* 0	WHEAT EXC BUCKWHEAT
01139	41.	0.050	24	* 0	GRAIN NEC
01141	20.	0.090	22	* 0	COTTONSEEDS
01142	39.	0.080	24	* 0	FLAXSEEDS
01143	27.	0.230	22	* 0	PEANUTS (RAW)
01144	45.	0.130	24	* 0	SOYBEANS
01149	22.	0.120	24	* 0	OIL SEEDS/NUTS/KERNELS NEC
01151	21.	0.620	22	* 140	LAWN GRASS SEED
01152	10.	0.150	22	* 140	POPCORN NOT POPPED
01159	21.	0.420	22	* 140	FIELD SEEDS NEC
01191	10.	0.120	22	* 0	HAY/FODDER/ROUGHAGE
01192	25.	1.090	22	* 0	HOPS
01193	23.	1.270	22	* 140	LEAF TOBACCO
01194	12.	0.080	22	T 0	POTATOES, SWEET
01195	36.	0.080	22	T 0	POTATOES OTHER THAN SWEET
01196	17.	0.160	22	* 0	STRAW EXC CHOPPED
01197	44.	0.010	24	* 0	SUGAR BEETS
01198	27.	0.010	24	* 0	SUGAR CANE
01199	18.	0.120	24	* 0	FIELD CROPS NEC
01211	22.	0.050	22	T 35	GRAPEFRUIT
01212	24.	0.080	22	T 84	LEMONS
01214	26.	0.040	22	T 56	ORANGES
01215	24.	0.120	22	T 21	TANGERINES
01219	23.	0.140	22	T 35	CITRUS FRUITS NEC
01221	20.	0.080	22	T 140	APPLES
01222	25.	0.090	22	T 7	APRICOTS
01223	12.	0.170	22	T 7	CHERRIES
01224	25.	0.110	22	T 70	GRAPES
01225	16.	0.120	22	T 21	NECTARINES
01226	16.	0.090	22	T 21	PEACHES
01227	22.	0.090	22	T 112	PEARS
01228	16.	0.120	22	T 21	PLUMS/PRUNES
01229	16.	0.130	22	T 28	DECIDUOUS FRUITS NEC
01231	16.	0.280	22	T 21	AVOCADOS
01232	20.	0.070	22	T 21	BANANAS
01233	16.	0.260	22	T 21	PINEAPPLES
01239	24.	0.340	22	T 21	TROPICAL FRUITS NEC
01291	16.	0.410	22	T 7	CANE/BUSH BERRIES
01292	16.	0.170	22	T 84	CRANBERRIES
01293	8.	0.320	22	T 7	STRAWBERRIES
01294	37.	0.960	22	* 0	COCOA BEANS
01295	24.	1.880	22	* 0	COFFEE GREEN
01298	20.	0.410	22	* 0	NUTS EDIBLE IN SHELL
01299	10.	0.250	22	* 0	FRESH FRUITS/TREE-NUTS NEC
01311	20.	0.050	22	T 84	FRESH BEETS
01312	27.	0.070	22	T 112	FRESH CARROTS
01313	10.	0.130	22	T 0	FRESH GREEN ONIONS
01315	16.	0.130	22	T 56	FRESH RADISHES
01317	20.	0.120	22	T 112	FRESH TURNIPS
01318	21.	0.080	22	T 112	ONIONS DRY
01319	20.	0.130	22	T 140	BULBS/ROOTS/TUBERS NEC
01331	12.	0.140	22	T 14	BROCCOLI
01332	17.	0.160	22	T 28	BRUSSEL SPROUTS
01333	15.	0.050	22	T 42	CABBAGE
01334	21.	0.090	22	T 70	CELERY
01335	15.	0.080	22	T 14	LETTUCE/ROMAINE
01336	9.	0.050	22	T 14	SPINACH/KALE/CHARDS/COLLARDS
01337	10.	0.130	22	T 21	CAULIFLOWER
01339	24.	0.090	22	T 14	LEAFY FRESH VEG NEC
01341	46.	0.130	24	* 0	BEANS
01342	43.	0.070	24	* 0	PEAS/SPLIT PEAS
01343	20.	0.080	22	* 0	LENTILS/LUPINES/COWPEAS
01349	14.	0.090	22	* 0	DRY RIPE VEGETABLE SEEDS NEC
01391	14.	0.090	22	T 7	BEANS GREEN/STRING/LIMA/WAX
01392	20.	0.030	22	T 14	WATERMELONS
01393	20.	0.050	22	T 4	SWEET CORN
01394	20.	0.050	22	T 7	TOMATOES
01395	17.	0.080	22	T 14	CUCUMBERS
01396	10.	0.170	22	T 14	PEPPERS
01397	20.	0.090	22	T 56	PUMPKINS/SQUASH/CYMLINGS
01398	19.	0.090	22	T 14	CANTALCUPES/MUSKMELONS/MELONS
01399	19.	0.090	22	T 14	FRESH VEGETABLES NEC
01411	12.	0.660	00	O 0	CATTLE EXC CALVES
01412	12.	0.760	00	O 0	CALVES
01413	12.	0.420	00	O 0	SWINE
01414	12.	0.440	00	O 0	SHEEP
01415	12.	0.440	00	O 0	GOATS OR KIDS
01419	12.	0.740	00	O 0	LIVESTOCK NEC
01421	15.	0.090	22	T 7	DAIRY FARM PRODUCTS
01431	17.	0.600	22	* 0	WOOL EXC SCOURED
01432	17.	1.390	22	* 0	MOHAIR EXC SCOURED
01439	13.	1.330	22	* 0	ANIMAL FIBERS NEC EXC SILK
01511	7.	0.150	22	O 0	LIVE CHICKENS
01512	7.	0.370	20	O 0	LIVE TURKEYS
01513	7.	0.200	22	O 0	LIVE BABY CHICKS
01519	7.	0.320	22	O 0	LIVE POULTRY NEC
01521	8.	0.750	11	T 7	EGGS MARKET
01522	8.	0.890	22	S 7	HATCHING EGGS CHICKEN
01523	8.	0.970	22	S 7	HATCHING EGGS TURKEY
01529	8.	0.860	22	T 7	POULTRY EGGS NEC
01911	5.	1.540	00	T 4	CUT FLOWERS
01912	10.	1.620	22	* 112	NURSERY STOCK
01915	42.	0.430	24	* 0	HERBS
01916	8.	0.750	22	T 3	MUSHROOMS
01917	7.	0.970	22	O 7	VEGETABLE OR BERRY PLANTS
01918	8.	1.510	22	* 0	FLOWER OR VEGETABLE SEEDS
01919	12.	3.850	22	* 14	HORTICULTURAL SPECIALTIES NEC
01921	10.	7.700	00	O 0	HORSES/PONIES/MULES/ASSES ETC
01923	12.	0.960	22	T 28	HIDES/SKINS/PELTS NOT TANNED
01926	51.	0.050	24	* 0	ANIMAL/POULTRY MANURE
01929	12.	7.700	00	O 0	ANIMAL SPECIALTIES NEC
01991	14.	0.120	22	* 0	CHOPPED/GROUND STRAW/HAY ETC
01992	33.	0.060	24	* 0	CHOPPED/GROUND ALFALFA
01999	12.	0.260	22	* 0	FARM PRODUCTS NEC
08422	18.	1.200	22	* 0	BARKS/GUMS CRUDE
08423	46.	0.260	22	* 0	LATEX OR ALLIED GUMS
08611	15.	0.230	00	* 14	CHRISTMAS TREES
08612	5.	1.850	22	* 14	DECORATIVE EVERGREENS/MISTLETOE
08613	6.	2.310	22	* 14	FERNS
08619	12.	0.920	22	* 14	FOREST PROD NEC
09121	11.	0.110	22	T 0	FINFISH
09122	11.	0.590	22	T 0	SHELLFISH
09123	4.	0.420	22	* 0	WHALE PRODUCTS
09131	59.	0.300	24	* 0	SHELLS OYSTER/CRAB/CLAM ETC
09132	8.	4.160	22	* 0	MARINE ANIMAL SKINS UNTANNED
09139	12.	0.340	22	* 0	MISC MARINE PROD NEC
09691	20.	0.700	22	O 0	TROPICAL FISH HATCHERIES/FARMS
10111	133.	0.020	24	* 0	IRON DIRECT SHIPPING ORES CRUDE

10112	71.	0.020	24	*	0	IRON BENEFICIATING ORES CRUDE
10113	63.	0.020	24	*	0	IRON CONCETR/AGGLOMERATES
10211	120.	0.010	24	*	0	COPPER ORES CRUDE
10212	132.	0.260	24	*	0	COPPER CONCENTR/PRECIPITATES
10311	67.	0.020	24	*	0	LEAD ORES CRUDE
10312	95.	0.200	24	*	0	LEAD CONCENTRATES
10321	56.	0.020	24	*	0	ZINC ORES CRUDE
10322	89.	0.200	24	*	0	ZINC CONCENTRATES
10331	62.	0.020	24	*	0	LEAD/ZINC ORES CRUDE
10332	93.	0.200	24	*	0	LEAD/ZINC CONCENTRATES
10411	60.	0.020	24	*	0	GOLD ORE/TAILINGS CRUDE
10412	90.	100.000	22	*	0	GOLD CONCENTRATES/BULLION
10421	60.	0.020	24	*	0	SILVER ORE/TAILINGS
10422	90.	32.000	22	*	0	SILVER CONCENTRATES/BULLION
10511	73.	0.020	24	*	0	BAUXITE ORES CRUDE
10513	63.	0.020	24	*	0	BAUXITE ORES CALCINATED
10514	35.	0.020	24	*	0	ALUMINUM ORES EXC BAUXITE
10611	60.	0.020	24	*	0	MANGANESE DIRECT SHIPPING
10612	56.	0.020	24	*	0	MANGANESE BENEFICIATING
10613	52.	0.020	24	*	0	MANGANESE CONCEN/AGGLOMERATES
10711	60.	0.020	24	*	0	TUNGSTEN ORES CRUDE
10712	22.	1.000	22	*	0	TUNGSTEN CONCENTRATES
10811	61.	0.020	24	*	0	CHROMIUM ORES CRUDE
10812	90.	1.000	24	*	0	CHROMIUM CONCENTRATES
10923	66.	0.020	24	*	0	RADIOACTIVE ORES
10929	70.	0.020	24	*	0	METAL ORES NEC
11111	60.	0.020	24	*	0	RAW ANTHRACITE
11112	60.	0.020	24	*	0	CLEANED/PREPARED ANTHRACITE
11119	80.	0.0	24	*	0	ANTHRACITE COAL WASTES
11211	56.	0.020	24	*	0	RAW BITUMINOUS COAL
11212	56.	0.020	24	*	0	CLEANED/PREPARED BITUMIN COAL
11219	80.	0.0	24	*	0	BITUMINOUS COAL WASTES
11221	58.	0.020	24	*	0	LIGNITE
13111	54.	0.050	23	*	0	PETROLEUM, CRUDE
13121	36.	0.100	23	G	0	GAS NATURAL
13211	49.	0.060	23	FL*	0	GASOLINE NATURAL
14111	78.	0.030	00	*	0	DIMENSION STONE QUARRY
14211	100.	0.020	24	*	0	AGRICULTURAL LIMESTONE
14212	61.	0.020	24	*	0	FLUXING STONE
14213	80.	0.020	24	*	0	DOLOMITE RAW/BROKEN/CRUSHED
14215	74.	0.020	24	*	0	FURNACE LIMESTONE
14219	74.	0.020	24	*	0	CRUSHED/BROKEN STONE NEC
14411	99.	0.020	24	*	0	SAND EXC ABRASIVE
14412	101.	0.020	24	*	0	GRAVEL
14413	85.	0.020	24	*	0	INDUSTRIAL SAND/GRAVEL
14511	58.	0.020	24	*	0	BENTONITE CRUDE
14512	88.	0.020	24	*	0	FIRE CLAY CRUDE
14513	24.	0.050	22	*	0	FULLERS EARTH CRUDE
14514	24.	0.050	22	*	0	KAOLIN/BALL CLAY CRUDE
14515	66.	0.020	24	*	0	FELDSPAR CRUDE
14516	24.	0.050	22	*	0	MAGNESITE/BRUCITE CRUDE
14519	57.	0.020	24	*	0	CLAY CERAMIC/REFRACTORY MIN NEC
14711	69.	0.020	24	*	0	BARITE CRUDE
14712	73.	0.050	24	*	0	FLUOSPAR CRUDE
14713	66.	0.030	24	*	0	POTASH/SODA/BORATE CRUDE
14714	110.	0.020	24	*	0	APATITE/PHOSPHATE ROCK/CLAY
14715	57.	0.020	24	*	0	ROCK SALT
14716	120.	0.020	23	*	0	SULPHUR CRUDE
14719	83.	0.020	24	*	0	CHEM/FERTILIZER MINERALS NEC
14911	100.	0.020	24	*	0	GYPSUM/ANHYDRITE CRUDE
14912	24.	0.050	22	*	0	MICA CRUDE
14913	78.	0.020	24	*	0	NATIVE ASPHALT/BITUMENS
14914	55.	0.020	24	*	0	PUMICE/PUMICITE CRUDE
14915	34.	0.030	20	*	0	TALC/SOAPSTONE/PYROPHYLLITE
14916	78.	0.020	24	*	0	NATURAL ABRASIVES
14917	21.	0.050	22	*	0	PEAT NATURAL
14918	19.	0.050	22	*	0	DIATOMACEOUS/INFUSORIAL EARTHS
14919	64.	0.020	24	*	0	NONMETALLIC MINERALS NEC
14921	66.	0.020	23	*	0	WATER RAW
14922	66.	0.020	13	*	0	WATER DRINKING
19111	9.	25.000	00	*	0	GUNS/HOWITZERS/MORTARS >30 MM
19251	14.	500.000	00	XB*	0	GUIDED MISSILES ASSEMBLED
19291	31.	0.250	22	XA*	0	ARTILLERY AMMO ETC
19293	17.	0.500	22	*	0	MILITARY BOMBS/MINES/PARTS
19299	16.	0.500	22	XB*	0	AMMO/RELATED PARTS NEC
19311	39.	5.000	00	*	0	MILITARY TANKS/PARTS
19312	39.	5.000	00	*	0	MILITARY SELF PROPELLED WEAPONS
19313	35.	5.000	00	*	0	FULL TRACKED COMBAT VEH/PARTS
19411	6.	50.000	11	*	0	MIL SIGHTING/FIRE CONTROL EQ
19511	12.	25.000	22	*	0	MACHINE GUNS 30 MM OR LESS
19512	12.	25.000	22	*	0	SMALL ARMS 30 MM OR LESS
19611	30.	25.000	11	*	0	SMALL ARMS AMMO 30 MM OR LESS
19911	17.	25.000	22	*	0	MISC ORDNANCE/ACC/PARTS
20111	33.	0.590	00	T	14	CARCASSES FRESH OR CHILLED
20119	17.	0.710	22	T	14	MEAT NEC FRESH/CHILL EXC SAUSAG
20121	27.	0.620	00	F	0	CARCASSES FRESH FROZEN
20129	30.	0.740	22	F	0	MEAT NEC FRESH FROZEN
20131	50.	0.270	23	*	0	LARD
20132	12.	0.770	22	T	7	MEATS OR SAUSAGE COOKED, ETC
20133	9.	0.840	22	T	7	SAUSAGE FRESH
20134	28.	0.600	11	*	0	CANNED MEAT
20139	56.	0.690	23	*	0	MEAT PRODUCTS NEC
20141	25.	0.400	00	*	0	HIDES SKINS PELTS UNTANNED
20143	57.	0.170	23	*	0	GREASE OR INEDIBLE TALLOW
20144	32.	0.190	22	*	0	ANIMAL REFUSE
20149	49.	0.360	24	*	0	ANIMAL BY PRODUCTS INEDIBLE NEC
20151	10.	0.410	22	T	0	DRESSED POULTRY SML GAME FRSH
20156	8.	0.780	22	*	70	EGGS
20158	15.	0.390	22	F	0	POULTRY SMALL GAME BY PROD
20161	23.	0.410	22	F	0	DRESSED POULTRY SMALL GAME FROZ
20168	15.	0.390	22	F	0	POULTRY SMALL GAME BY-PROD
20171	19.	0.430	11	*	0	CANNED POULTRY SMALL GAME
20172	8.	0.780	22	*	70	EGGS
20211	25.	1.020	22	T	7	CREAMERY BUTTER
20231	25.	0.480	11	*	0	DRY MILK PROD
20233	29.	0.290	22	*	0	EVAP OR CONDENSED MILK PROD
20234	8.	0.350	22	*	0	ICE CREAM MIX OR ICE MILK MIX
20241	13.	0.350	22	F	21	ICE CREAM RELATED DESSERTS
20251	30.	0.960	22	T	35	CHEESE
20252	13.	0.580	11	T	7	COTTAGE CHEESE
20258	14.	0.380	22	T	21	CASEIN PRODUCTS
20259	22.	0.370	22	T	7	SPEC DAIRY PROD NEC
20261	8.	0.120	22	F	0	BULK FL MILK INCL SKIM CREAM
20262	15.	0.370	11	T	7	PKGD MILK INCL SKIM CREAM
20264	12.	0.380	11	T	7	BUTTERMILK CHOCO ETC FLAV MILK
20311	29.	0.870	11	*	0	CANNED FISH ETC INCL SOUPS
20314	26.	2.170	11	*	0	SMKD,SALTED,PICKLED DRIED SEA
20321	27.	0.440	11	*	0	CANNED BABY FOODS
20322	28.	0.380	11	*	0	CANNED SOUPS EXC 20381 311 361
20323	24.	0.340	11	*	0	CANNED BEAN SPECIALTIES
20329	18.	0.360	11	*	0	CANNED SPECIALTIES, NEC
20331	25.	0.340	11	*	0	CANNED FRUITS
20332	31.	0.330	11	*	0	CANNED VEGETABLES
20333	18.	0.330	11	*	0	CANNED HOMINY OR MUSHROOMS
20334	36.	0.310	11	*	0	CANNED FRUIT JUICE EXC 20996
20335	28.	0.330	11	*	0	CANNED VEGETABLE JUICES
20336	30.	0.380	11	*	0	CATSUP OR OTHER TOMATO SAUSES
20338	27.	0.300	11	*	0	JAMS JELLIES PRESERVES
20339	27.	0.310	11	*	0	CANNED FRUITS VEGETABLES NEC
20341	28.	0.400	11	*	0	DRIED OR DEHYDRATED FRUITS

20342	27.	0.530	11	*	0	DRIED VEG/SOUPS EXC 01341-349
20343	26.	0.130	11	*	0	DRIED POTATO EXC 20992
20352	27.	0.380	22	T	28	PICKLES OR RELATED
20354	27.	0.610	11	T	14	SALAD DRESS, MAYONNAISE SPREDS
20359	27.	0.610	11	T	14	SAUCE SEASON NEC EXC 20997 336
20361	20.	0.800	11	F	0	FROZEN PROCES FISH SEA FOODS
20362	6.	1.820	11	F	0	FRESH PROCES FISH SEA FOODS
20371	34.	0.380	11	F	0	FROZEN FRUITS
20372	35.	0.360	11	F	0	FROZEN JUICES OR ADES
20373	31.	0.360	11	F	0	FROZEN VEGETABLES
20374	20.	0.500	22	F	0	FROZ PREPARED FOODS SOUPS SEA
20379	26.	0.400	11	F	0	FROZ FRUIT JUICES VEG NEC
20381	20.	0.500	22	F	0	FROZ PREPARED FOODS SOUPS SEA
20389	26.	0.500	22	F	0	FROZ SPECIALTIES NEC
20391	38.	0.530	11	*	0	MIXED CANNED FRTS, VEG SEA FDS
20411	42.	0.090	24	*	0	WHEAT FLOUR EXC 20451-20452
20412	38.	0.080	24	*	0	WHEAT BRAN MIDDLINGS OR SHORTS
20413	21.	0.150	12	*	0	CORN MEAL FLOUR EXC 20421-23
20414	27.	0.150	22	*	0	RYE FLOUR OR MEAL
20415	27.	0.150	22	*	0	BUCKWHEAT FLOUR OR MEAL
20416	37.	0.080	24	*	0	OATMEAL FOR FLOUR
20418	41.	0.050	24	*	0	GRAIN MEAL BY PRODUCTS
20419	20.	0.150	22	*	0	FLOUR OR GRAIN MILL PROD NEC
20421	63.	0.090	24	*	0	PREPARED FEED
20423	26.	0.480	11	*	0	CANNED FEEDS ANIMAL FISH POULTR
20431	20.	0.390	11	*	0	COOKED CEREALS FLAKED SHRED
20432	20.	0.390	11	*	0	CEREALS UNCOOKED
20441	43.	0.150	24	*	0	RICE CLEANED
20442	29.	0.150	24	*	0	RICE FLOUR BRAN OR MEAL
20443	42.	0.150	24	*	0	BREWERS RICE
20449	28.	0.150	24	*	0	MILLED RICE OR BY PROD NEC
20451	33.	0.260	22	*	0	PREPARED FLOUR
20452	21.	0.420	11	*	0	PREPARED FLOUR MIXES
20461	86.	0.070	23	*	0	CORN SYRUP
20462	45.	0.090	14	*	0	CORNSTARCH
20463	23.	0.280	22	*	0	CORN SUGAR
20464	17.	0.290	22	*	0	DEXTRINE
20465	56.	0.310	23	*	0	CORN OIL
20466	21.	0.300	22	*	0	STARCH EXC CORN
20467	40.	0.110	24	*	0	WET PROCESS CORN BY PROD
20469	89.	0.110	23	*	0	WET PROC CORN MILL PROD NEC
20511	30.	0.350	24	*	1	BREAD OR SIMILAR BAKERY PROD
20521	13.	0.510	11	*	14	BISCUITS CRACKERS PRETZELS
20529	9.	0.680	11	*	14	DRY BAKERY PROD NEC
20611	32.	0.100	22	*	0	RAW CANE OR BEET SUGAR
20616	72.	0.030	23	*	0	SUGAR MOLASSES
20617	76.	0.040	23	*	0	BLACKSTRAP MOLASSES
20618	10.	0.140	24	*	0	BAGASSE
20619	43.	0.130	24	*	0	SUGAR MILL PRODUCTS
20621	43.	0.180	14	*	0	SUGAR GRAN OR POWDERED
20622	83.	0.130	23	*	0	SUGAR LIQUID OR SYRUP
20625	84.	0.130	23	*	0	SUGAR REFINING BY PROD
20626	16.	0.200	22	*	0	MOLASSES,BEET PULP
20629	46.	0.160	24	*	0	SUGAR REFINED CANE BEET NEC
20711	20.	0.640	22	T	28	CANDY OR CANDY BARS
20712	21.	0.930	11	*	28	ASSORTED BLANCHED NUTS
20713	21.	0.640	22	T	28	CHOCOLATE OR COCOA PRODUCTS
20714	32.	1.050	11	*	0	CHEWING GUM
20719	21.	0.640	22	*	28	CONFECTIONARY PROD NEC
20821	27.	0.170	11	*	0	BEER BOTTLES/CANS/BEER KEGS
20823	30.	0.050	24	FS*	0	MALT EXTRACT OR BREWERS SPENT
20831	35.	0.100	24	*	0	MALT
20832	15.	0.200	22	*	0	MALT FLOUR OR SPROUTS
20839	17.	0.200	11	*	0	MALT PROD OR BY PRODNEC
20841	26.	0.390	11	T	0	WINES BRANDY BRANDY SPIRITS
20851	31.	0.610	11	T	0	DISTIL RECTIFI BLENDED LIQUORS
20859	35.	0.030	24	*	0	BY PROD OF LIQUOR DISTILLING
20861	27.	0.140	11	*	0	SOFT DRINKS BOTT CANNED BULK
20871	26.	1.570	22	*	0	MISC FLAV EXTRACTS SYRUPS
20911	55.	0.290	23	*	0	COTTONSEED OIL EXC 20961
20914	17.	0.090	22	*	0	COTTONSEED CAKE MEAL BY PROD
20915	16.	0.080	22	*	0	COTTON LINTERS
20921	57.	0.240	23	*	0	SOYBEAN OIL EXC 20961
20923	42.	0.260	24	*	0	SOYBEAN CAKE, MEAL, FLOUR ETX
20931	55.	0.180	23	*	0	LINSEED OIL EXC 20961
20933	55.	0.310	23	*	0	NUT OR VEG OILS NEC
20939	57.	0.090	23	*	0	NUT OR VEG OIL SEED CAKE NEC
20941	16.	0.170	22	*	0	MARINE OIL MILL PROD
20942	50.	0.170	24	FS*	0	MARINE OIL MILL BY PROD
20951	17.	4.380	11	*	0	ROASTED COFFEE INCL INSTANT
20961	18.	0.460	22	T	0	SHORTENING ETC OILS EXC 20465
20962	24.	0.510	22	T	0	MARGARINE
20971	16.	0.020	00	F	0	ICE NATURAL OR MFG
20981	22.	0.430	11	*	0	MACARONI,ETC
20991	18.	0.990	11	*	0	DESSERTS READY TO MIX
20992	8.	0.360	11	*	0	CHIPS POTATO CORN ETC
20993	80.	0.170	23	*	0	SWEETENING SYRUPS OR MOLASSES
20994	16.	1.340	22	*	0	BAKING POWDER OR YEAST
20995	29.	0.580	11	*	0	GROCERIES
20996	16.	0.280	11	*	0	VINEGAR OR CIDER
20997	20.	1.060	11	*	0	SPICES
20998	12.	0.730	11	*	0	TEA
20999	25.	0.580	11	*	0	FOOD PREP OR BY PROD NEC
21111	11.	2.590	11	*	0	CIGARETTES
21211	18.	3.520	11	*	0	CIGARS
21311	12.	1.450	11	*	0	CHEWING TOBACCO
21312	12.	1.680	11	*	0	SMOKING TOBACCO
21313	14.	1.450	11	*	0	SNUFF
21411	22.	1.380	22	*	0	TOBACCO STEMMED OR REDRIED
21419	10.	1.550	22	*	0	TOBACCO BY PROD LEAF
22111	13.	1.750	22	*	0	COTTON DUCK OR ALLIED FABRICS
22112	13.	1.400	22	*	0	COTTON SHEETINGS UNFINISHED
22113	5.	2.040	22	*	0	COTTON OR CHIEFLY SO BLANKETS
22119	18.	1.340	22	*	0	COTTON FABRICS OR SPECIALTIES
22211	14.	1.920	22	*	0	MAN MADE FIBER INCL GLASS TYPE
22213	5.	2.240	22	*	0	MAN MADE FIBER BLANKETS
22221	10.	2.650	22	*	0	SILK WOVEN FABRICS
22311	12.	2.410	22	*	0	WOOL BROAD WOVEN FABRICS
22313	5.	2.370	22	*	0	WOOL OR CHIEFLYWOOL, BLANKETS
22411	12.	2.650	22	*	0	NARROW FABRICS
22511	10.	2.290	22	*	0	KNIT FABRICS
22711	16.	1.570	22	*	0	WOVEN CARPETS OR RUGS
22721	16.	1.410	22	*	0	TUFTED CARPETS OR RUGS
22799	16.	1.440	22	*	0	CARPETS MATS RUGS NEC
22811	17.	1.030	22	*	0	COTTON YARN
22813	10.	2.400	22	*	0	WOOL THREAD OR YARN
22819	12.	1.290	22	*	0	YARN, N.E.C.
22841	12.	1.000	11	*	0	THREAD EXC HEMP/JUTE/LINEN/RAMIE
22911	16.	0.530	22	*	0	FELT GOODS EXC WOVEN FELTS
22921	8.	3.120	22	*	0	LACE GOODS EXC EMBROIDERIES
22931	5.	0.390	22	*	0	PADDINGS OR UPHOLSTERY FILL
22941	6.	0.200	22	*	0	TEXTILE WASTE GARNETTED/PROCES-
22951	12.	1.200	22	*	0	ARTIFICIAL LEATHER AND OILCLOTH
22961	27.	1.220	22	*	0	TIRE CORD OR FABRICS
22971	15.	1.630	22	*	0	WOOL OR MOHAIR SCOUR/CARBONIZED
22972	6.	1.220	22	*	0	TOPS ALL FIBERS PROC
22973	10.	0.820	22	*	0	TEXTILE FIBERS FOR SPINNING
22974	12.	0.290	22	*	0	WOOL OR MOHAIR GREASE
22981	12.	1.150	22	*	0	CORDAGE OR TWINE
22991	12.	1.160	22	*	0	BONDED FIBER FABRICS

22995	12.	0.270	22	*	0	VEGETABLE FIBERS EXC COTTON
22999	5.	1.310	22	*	0	TEXTILE GOODS NEC
23111	7.	3.300	22	*	0	MALES CLOTHING
23311	8.	3.800	22	*	0	WOMENS CLOTHING
23511	3.	3.810	22	*	0	MILLENERY EXC 23711/23961
23521	4.	3.550	22	*	0	HATS CAPS OR HAT BODIES MENS
23711	8.	62.560	22	*	0	FUR GOODS EXC 23861
23811	8.	4.360	22	*	0	DRESS GLOVES MITTENS LININGS
23812	6.	3.720	22	*	0	WORK GLOVES MITTENS
23841	10.	3.050	22	*	0	ROBES/DRESSING GOWNS EXC CHILD
23851	10.	4.040	22	*	0	RAINCOATS ETC
23861	7.	7.070	22	*	0	LEATHER OR SHEEP LINED CLOTHING
23871	6.	6.480	22	*	0	APPAREL BELTS
23891	5.	3.980	22	*	0	APPAREL NEC
23911	7.	4.940	22	*	0	WINDOW CURTAINS EXC LACE
23912	10.	6.510	22	*	0	DRAPERIES OR TAPESTRIES
23921	6.	4.160	22	*	0	BEDSPREDS OR BED SETS
23922	11.	2.350	22	*	0	SHEETS OR PILLOW CASES
23923	18.	1.930	22	*	0	COTTON TOWELS OR WASH CLOTHS
23924	17.	4.000	22	*	0	TABLECLOTHS NAPKINS ETC
23925	3.	2.980	22	*	0	PILLOWS
23926	10.	1.570	22	*	0	MOPS OR DUSTERS
23927	17.	5.730	22	*	0	SLIP COVERS EXC EMBROIDERED
23928	6.	2.780	22	*	0	COMFORTERS OR QUILTS EXC EMBROD
23929	6.	3.150	11	*	0	TEXTILE HOUSEFURNISHINGS NEC
23931	10.	0.610	22	*	0	TEXTILE BAGS EXC 23929 23461
23941	10.	1.950	22	*	0	TENTS
23942	10.	1.820	22	*	0	AWNINGS OR SHADES
23943	10.	1.330	22	*	0	TARPAULINS
23944	10.	2.530	22	*	0	SAILS
23949	12.	1.670	22	*	0	CANVAS PRODUCTS NEC EXC BAGS
23951	5.	2.660	22	*	0	TEX. EMBROIDERIES OR STAMPED ART
23961	7.	1.330	22	*	0	TEXTILE APPAREL FINDINGS ETC
23991	17.	1.690	22	*	0	AUTOMOBILE SEAT COVERS
23993	8.	2.220	22	*	0	SLEEPING BAGS
23994	7.	10.960	22	*	0	PARACHUTES
23999	5.	2.200	22	*	0	FABRICATED TEXTILE PROD NEC
24111	29.	0.030	00	*	0	SAWLOGS
24112	41.	0.030	00	*	0	RAILROAD OR MINE TIES
24113	35.	0.050	00	*	0	SHORT LOGS OR WOOD BOLTS
24114	51.	0.030	00	*	0	PULPWOOD LOGS
24115	28.	0.030	24	*	0	PULPWOOD OR OTHER WOOD CHIPS
24116	25.	0.040	00	*	0	WOOD POSTS POLES OR PILING
24117	23.	0.010	00	*	0	FUELWOOD HOGFUEL CORDWOOD
24118	22.	0.030	00	*	0	WOOD MINE PROPS OR MINE TIMBERS
24119	49.	0.040	24	*	0	PRIMARY FOREST PROD NEC
24211	29.	0.070	00	*	0	LUMBER ROUGH/DRESSED
24212	56.	0.060	00	*	0	SAWED TIES RAIL/MINE
24214	41.	0.290	00	*	0	HARDWOOD DIMENSION STOCK
24215	25.	0.310	22	*	0	HARDBOARD FLOORING
24219	28.	0.090	22	*	0	LUMBER OR DIMENSION STOCK NEC
24291	17.	0.120	22	*	0	SHINGLES
24292	14.	0.120	22	*	0	COOPERAGE STOCK
24293	26.	0.030	24	*	0	SHAVINGS OR SAWDUST
24294	8.	0.040	22	*	0	EXCELSIOR BALED OR BULK
24299	29.	0.110	00	*	0	SAWMILL/PLANING MILL PROD NEC
24311	8.	0.770	22	*	0	WINDOW UNITS WOOD
24312	12.	0.860	22	*	0	WINDOW SASH WOODEN
24313	14.	0.620	22	*	0	WINDOW OR DOOR FRAMES OR JAMBS
24314	13.	0.570	22	*	0	DOORS/SHUTTERS WOOD
24316	21.	0.470	22	*	0	WOOD MOULDINGS
24332	12.	0.590	00	*	0	PREFAB BUILDINGS WOOD
24333	14.	0.470	22	*	0	READY CUT WOOD BUILDINGS
24341	8.	0.650	00	*	0	WOOD KITCHEN CABINETS
24391	41.	0.500	00	*	0	PREFAB STRUC MEMB OR LAMINATES
24411	12.	0.170	00	*	0	BOXES CASES CRATES CARRIERS
24412	10.	0.310	00	*	0	ANIMAL/POULTRY COOPS CRATES
24413	6.	0.190	00	*	0	FRUIT/VEG BASKETS ETC
24414	4.	0.470	22	*	0	BASKETS EXC 24413/39411/91/41
24415	13.	0.610	00	*	0	COOPERAGE
24416	18.	0.190	22	*	0	BOX SHOOKS
24419	18.	0.210	22	*	0	WOOD CONTAINERS NEC
24911	65.	0.070	00	*	0	OIL TREATED WOOD PILING
24912	33.	0.070	00	*	0	OIL TREATED WOOD RAIL TIES
24919	27.	0.070	00	*	0	WOOD PRODUCTS NEC
24921	8.	0.540	22	*	0	RATTAN/BAMBOO/WILLOW WARE
24931	8.	0.520	22	*	0	LASTS OR RELATED MATERIALS
24941	14.	1.190	22	*	0	CORK PRODUCTS
24951	18.	0.470	22	*	0	HAND TOOL HANDLES
24961	14.	0.270	00	*	0	SCAFFOLDING EQUIPMENT
24962	6.	0.300	00	*	0	LADDERS OR LADDER PARTS
24971	8.	0.690	22	*	0	WOODEN WARE
24972	10.	0.680	22	*	0	WOODEN NOVELTIES OR FLATWARE
24981	14.	0.180	22	*	0	POLES/RODS/STAKES/WOOD FINISHED
24982	12.	0.490	22	*	0	BILLBOARDS/SIGN FRAMES WOOD
24983	12.	0.460	22	*	0	BATH TUB/TOILET SEATS ETC
24985	12.	0.560	22	*	0	BTLE STPS/ICE CREAM STICKS ETC
24987	12.	0.650	22	*	0	QUILTING FRAMES ETC WOOD
24988	7.	0.390	22	*	0	IRONING BOARDS/TABLES WOOD
24992	15.	0.190	00	*	0	PALLETS/SKIDS/PLATFORMS WOOD
24993	29.	0.270	22	*	0	HARDBOARD
24994	12.	0.720	22	*	0	MASTS/SPARS/OARS ETC
24995	12.	0.900	00	*	0	PIPE CONDUIT OR FITTINGS WOOD
24996	38.	0.220	00	*	0	WOOD PARTICLE BOARD
24997	11.	0.460	00	*	0	WOOD FENCING/GATES
24998	5.	0.470	00	*	0	WOOD REELS OR SPOOLS EXC 35522
24999	18.	0.520	22	*	0	WOOD PROD NEC
25111	4.	1.130	22	*	0	CHAIRS EXC32719/819/699
25121	5.	1.190	22	*	0	TABLES/DESK HOUSEHOLD
25131	4.	1.780	00	*	0	SOFAS/COUCHES/SETTEES ETC
25141	7.	1.700	00	*	0	BUFFETS/SERVERS/CHINA/CLOSETS
25151	3.	1.040	00	*	0	MATTRESSES/BED SPRINGS ETC
25153	6.	1.780	22	*	0	STUDIO COUCHES/SOFA BEDS ETC
25161	8.	1.590	00	*	0	DRESSERS/VANITIES/DRAWERS ETC
25171	5.	1.330	22	*	0	RADIO/PHONO/TV CABINETW
25173	14.	1.280	22	*	0	FILING CABINETS OR CASES
25174	8.	0.900	22	*	0	KITCHEN CABINETS EXC WOOD
25179	8.	1.620	22	*	0	CABINETS/CASES NEC
25181	10.	1.080	22	*	0	INFANTS/CHILDRENS FURNITURE
25199	4.	1.650	22	*	0	HOUSEHOLD/OFFICE FURNITURE NEC
25311	22.	1.360	22	*	0	SCHOOL FURN EXC32819/719/699
25312	4.	1.530	22	*	0	SEATS FOR PUBLIC CONVEYANCES
25314	14.	1.420	00	*	0	THTRE/AUDITOR/BLEACHER SEATS
25319	10.	2.010	00	*	0	PUBLIC BLDG FURNITURE NEC
25411	13.	1.220	00	*	0	WOOD PARTITIONS/SHELVING ETC
25421	8.	1.070	22	*	0	METAL PARTITIONS/SHELVING ETC
25911	18.	1.130	22	*	0	VENETIAN BLINDS INCLCURTAINRODS
25991	10.	2.060	00	*	0	HOSPITAL BEDS
25999	6.	1.390	00	*	0	FURNITURE/FIXTURES NEC
26111	36.	0.120	22	*	0	PULP
26112	76.	0.120	23	*	0	PULPMILL BY PRODUCTS
26211	31.	0.130	22	*	0	NEWSPRINT

26212	27.	0.510	22	*	0	GROUNDWOOD PAPER,UNCOATED
26213	37.	0.630	22	*	0	PRINTING PAPER ASSORTED VARIET
26214	36.	0.120	22	*	0	WRAPPING PAPER
26217	23.	0.150	22	*	0	SPECIAL INDUSTRIAL PAPER
26218	17.	0.330	22	*	0	SANITARY TISSUE STOCK
26219	24.	0.280	22	*	0	PAPER NEC
26311	30.	0.320	00	*	0	PAPERBOARD/PULPBOARD/FIBERBOARD
26421	16.	0.990	22	*	0	ENVELOPES EXC 26491
26431	21.	0.400	22	*	0	PAPER BAGS
26441	17.	2.470	22	*	0	WALLPAPER
26451	19.	1.020	11	*	0	OFFICE SUPPLIES
26452	19.	0.330	22	*	0	COATED PAPERBOARD
26453	7.	0.840	22	*	0	CLOSURES FOR BOTTLES/JARS ETC
26459	19.	0.870	11	*	0	DIECUT PAPER NEC
26461	14.	0.810	00	*	0	BITUMINOUS FIBER PIPE
26462	8.	0.740	22	*	0	EGG CARTONS/CASES ETC
26469	12.	0.760	22	*	0	PRESSED/MOLDED PULP GOODS NEC
26471	16.	0.560	11	*	0	SANITARY TISSUES OR HEALTH PROD
26472	8.	0.640	11	*	0	SAINTARYNAPKINS/TAMPONS
26491	16.	1.080	22	*	0	STATIONERY/TABLETS/ENVELOPES
26492	16.	1.150	22	*	0	WRAPPING PRODUCTS
26495	15.	1.020	22	*	0	BUSINESS MACHINE SUPPLIES
26497	9.	0.200	22	*	0	PACKING CUSHIONS ETC
26499	24.	0.220	22	*	0	CONVERTED PAPER PROD NEC
26511	14.	0.400	22	*	0	PAPERBOARD/FIBERBOARD BOXES
26514	10.	0.440	22	*	0	BASKETS/HAMPERSP PAPERBOARD
26515	8.	0.470	00	*	0	PALLETS/SKIDS PAPERBOARD
26542	14.	0.500	22	*	0	PAPRBD CONTRS FOR BOTTLES ETC
26543	12.	0.440	11	*	0	PAPERBOARD CANS/PAILS/TUBS/ETC
26545	10.	0.400	11	*	0	PAPER PLATES/DISHES/SPOONS ETC
26549	11.	0.540	22	*	0	SANITARY FOOD CONTNRS NEC
26551	12.	0.470	00	*	0	FIBER SHIPPING CANS ETC
26611	24.	0.230	00	*	0	INSULATING BOARD
26612	20.	0.280	00	*	0	CONSTRUCTION PAPER
26613	27.	0.250	00	*	0	WALLBOARD EXC 26993
26614	12.	0.210	22	*	0	INSULATING MATERIALS EXC 26611
26615	8.	0.260	22	*	0	CONSTRUCTION PANELS/PARTITIONS
26619	28.	0.240	22	*	0	BUILDING PAPER/BOARD NEC
27111	29.	0.780	22	*	3	NEWSPAPERS
27211	29.	1.550	22	*	3	PERIODICALS
27311	21.	1.880	22	*	0	BOOKS
27411	18.	1.850	22	*	0	CATALOGS/DIRECTORIES
27415	20.	1.560	22	*	0	CARDS/TICKETS EXC27711
27417	22.	1.410	22	*	0	SEALS/LABELS/TAGS ETC
27419	17.	1.640	22	*	0	PRINTED MATTER NEC
27611	20.	0.930	22	*	0	MANIFOLD BUSINESS FORMS
27711	14.	2.360	11	*	0	GREETING CARDS/SEALS/LABELS/TAG
27811	17.	1.010	22	*	0	BLANKBOOKS/PADS/TABLETS
27812	17.	1.400	22	*	0	LOOSELEAF BINDERS
27911	12.	1.570	22	*	0	PRODUCTS OF PRINTING SERVICES
28121	26.	0.330	22	CL*	0	INORGANIC BLEACHING COMPOUNDS
28122	94.	0.130	23	*	0	SODIUM ALKALIES
28123	57.	0.180	24	*	0	SODIUM COMPOUNDS EXC28122
28124	88.	0.130	23	CL*	0	POTASSIUM ALKALIES
28125	66.	0.180	24	*	0	POTASSIUM COMPOUNDS EXC 28124
28126	29.	0.350	22	*	0	BA/CA/MG/SR CMPDS EXC 28121
28128	79.	0.460	23	CGG	0	CHLORINE
28129	29.	0.440	22	*	0	ALKALIES NEC
28132	60.	0.490	23	FGG	0	ACETYLENE
28133	62.	0.460	23	G	0	CARBON DIOXIDE
28134	54.	0.440	23	G	0	ELEMENTAL GASES
28139	58.	0.420	23	FGG	0	INDUSTRIAL GASES NEC
28141	54.	0.070	23	*	0	CRUDE PROD: COALTAR/PETR/GAS
28151	75.	0.130	23	*	0	CYCLIC INTERMEDIATES
28156	55.	1.310	23	*	0	ORGANIC DYES
28158	12.	2.430	22	*	0	ORGANIC PIGMENTS
28161	145.	1.330	23	*	0	TITANIUM PIGMENTS
28162	14.	0.530	22	*	0	LEAD PIGMENTS
28163	18.	0.660	22	*	0	ZINC PIGMENTS
28169	16.	0.770	22	*	0	INORGANIC PIGMENTS NEC
28181	63.	0.200	23	FL*	0	MISC ACYCLIC ORGANIC CHEM PROD
28182	50.	0.310	23	FL*	0	MISC ACYCLIC ORGANIC CHEM PROD
28183	56.	0.420	23	*	0	MISC CYCLIC CHEM PROD
28184	71.	0.200	13	FL*	0	ALCOHOLS
28185	61.	0.220	23	*	0	GLYCOLS OR GLYCERINE
28186	79.	0.160	23	*	0	ORGANIC ACIDS OR SALTS
28188	12.	1.920	22	PCO	0	CHEM WARFARE GASES
28189	61.	0.460	23	FL*	0	INDUSTRIAL ORGANIC CHEM NEC
28191	43.	0.070	24	UM*	0	AMMONIA OR AMMONIA COMPOUNDS
28192	89.	0.110	13	CL*	0	NITRIC ACID
28193	115.	0.290	13	*	0	SULPHURIC ACID
28194	105.	0.110	23	*	0	INORGANIC ACIDS EXC NITRIC/SULP
28195	21.	0.770	22	*	0	CO/CU/FE/NI/ZN COMPOUNDS
28196	80.	0.240	23	*	0	ALUMINUM COMPOUNDS
28197	22.	1.990	22	RM*	0	RADIOACTIVE OR NUCLEAR CHEMICAL
28198	74.	0.040	23	CGG	0	ANHYDROUS AMMONIA
28199	48.	0.070	24	*	0	INDUSTR INORGANIC CHEMICALS
28211	38.	0.660	24	*	0	PLASTICS MAT/PLASTICIZERS ETC
28212	36.	1.060	22	*	0	SYNTHETIC RUBBERS
28213	14.	0.860	22	*	0	SYNTH ORGANIC FIBERS EXC 32293
28311	22.	15.130	11	T	120	DRUGS FOR HUMAN USE
28312	22.	13.400	22	F	7	DRUGS FOR VETERINARY USE
28411	24.	0.420	22	*	0	SYNTH ORGANIC DETERGENTS
28419	24.	0.450	11	*	0	SOAP OR OTHER DETERGENTS
28422	14.	0.500	22	CL*	0	SPECIALTY CLEANING PREPARATIONS
28423	19.	0.340	22	FL*	0	WAXES OR POLISHING PREPARS
28431	63.	0.420	23	*	0	SURFACE ACTIVE AGENTS ETC
28441	24.	2.450	11	*	0	PERFUMES/COSMETICS ETC
28511	18.	0.710	22	*	0	PAINTS/VARINISHES/LACQUERS ETC
28512	62.	0.790	23	FL*	0	PAINT OIL/THINNER/SOLVENTS ETC
28513	14.	0.280	11	*	0	PUTTY
28519	16.	0.620	11	*	0	PAINTS/VARNISHES ETC NEC
28612	59.	0.300	23	*	0	GUM/WOOD CHEMICALS
28712	51.	0.040	24	*	0	SUPERPHOSPHATE
28713	74.	0.080	23	CG*	0	AMMONIATING/N FERTILIZER SOL
28714	63.	0.060	14	*	0	MISC FERTILIZER COMPOUNDS
28719	55.	0.080	24	*	0	FERTILIZERS NEC
28799	57.	1.540	23	*	0	AGRICULTURAL CHEMICALS NEC
28911	20.	0.480	11	*	0	ADHESIVES/CEMENTS/GLUES ETC
28921	25.	1.570	22	XBO	0	EXPLOSIVES EXC19291-19299/611
28931	16.	0.640	22	*	0	PRINTING INK
28991	30.	0.180	11	*	0	SALT COMMON
28993	12.	6.640	11	XCO	0	FIREWORKS/PYROTECHNICS
28994	56.	0.310	23	*	0	FATTY ACIDS
28995	12.	0.490	22	CL*	0	WATER TREATING COMPOUNDS
28996	22.	0.280	24	*	0	BLACKS
28998	72.	1.040	23	*	0	MISC CHEM COMPOUNDS EXC 28911
28999	23.	2.180	11	FL*	0	CHEM PROD NEC EXC 28911
29111	48.	0.080	23	*	0	GASOLINE/JET FUELS/ ETC
29112	54.	0.060	23	*	0	KEROSENE EXC 29111
29113	56.	0.060	23	*	0	DISTILLATE FUEL OIL
29114	49.	0.110	13	*	0	PETROLEUM LUBRICANTS
29115	13.	1.840	22	*	0	PETROLEUM LUB GREASES
29116	59.	0.030	23	*	0	ASPHALT/TAR/PITCHES
29117	54.	0.030	23	*	0	RESIDUAL FUEL OIL ETC
29119	49.	0.250	23	*	0	PETRO REFINING PRODS NEC
29121	35.	0.100	23	G	0	LIQUEFIED PETRO/COAL GASES
29511	24.	0.250	00	*	0	ASPHALT PAVING MIXTURES

29521	29.	0.170	22	*	0	ASPHALT SAT FELTS/BOARDS/ROOFIN
29522	56.	0.110	23	*	0	ASPHALT/TAR COATINGS/CEMENTS
29523	28.	0.310	22	*	0	ASPHALT SHINGLES/SIDING ETC
29529	18.	0.450	00	*	0	ASPHALT FELTS/COATINGS NEC
29911	20.	0.100	22	*	0	COKE/COAL BRIQUETTES
29912	84.	0.230	23	*	0	LUBRICANTS EXC 29114/5
29913	45.	0.050	24	*	0	PETRO COKE EXC 29911
29914	60.	0.100	24	*	0	COKE PROD FROM COAL EXC 29911
29919	50.	0.080	23	*	0	PETRO/COAL PROD NEC
30111	18.	1.090	00	*	0	PNEUMATIC TIRES
30114	14.	0.950	22	*	0	INNER TUBES
30115	20.	0.760	22	*	0	TREAD RUBBER RELATED MATERIALS
30119	10.	1.090	00	*	0	TIRES RELATED PROD NEC
30211	12.	1.990	22	*	0	RUBBER FOOTWEAR
30212	12.	3.120	22	*	0	PLASTIC FOOTWEAR
30311	12.	0.230	22	FS*	0	RECLAIMED RUBBER
30411	19.	1.020	22	*	0	RUBBER/PLASTIC BELTS
30412	14.	1.020	22	*	0	RUBBER/PLASTIC HOSE
30612	14.	1.020	22	*	0	RUBBER/PLASTIC HOSE
30613	3.	1.150	00	*	0	SPONGE OR FOAM RUBBER GOODS
30614	15.	0.600	22	*	0	RUBBER FLOOR OR WALL COVERING
30618	12.	0.820	22	*	0	FABRICATED RUBBER PROD NEC
30619	14.	0.820	22	*	0	FABRICATED RUBBER PROD NEC
30711	5.	2.380	22	*	0	PLASTIC DINNERWARE/HOUSEWARES
30712	8.	1.980	22	*	0	PLASTIC PIPES/TUB-NG/FITTINGS
30713	10.	2.160	22	*	0	INDUSTRIAL MOLDED PLASTIC PROD
30714	14.	0.670	22	*	0	UNSUPPORTED VINYL/POLYETH FILM
30715	27.	0.670	22	*	0	UNSUPPORTED PLASTIC FLOOR/WALL
30716	7.	0.620	22	*	0	EXPANDED OR FOAMED PLASTIC
30717	15.	0.350	22	*	0	PLASTIC LAMINATED SHEETS/ETC
30718	3.	1.800	22	*	0	PLASTIC PKGING/SHIPPING CONT
30719	6.	2.200	11	*	0	MISC FABRCTD PLSTC PROD NEC
30729	13.	2.200	22	*	0	MISC FABRCTD PLSTC PROD NEC
31111	13.	1.720	22	*	0	LEATHER TANNED/FINISHED
31211	13.	2.840	22	*	0	INDUSTRIAL LEATHER BELTING
31311	15.	1.370	22	*	0	BOOT/SHOE CUT STOCK
31411	12.	4.090	22	*	0	FOOTWEAR EXC PLASTIC/RUBBER
31421	12.	2.640	22	*	0	HOUSE SLIPPERS
31511	14.	6.420	22	*	0	DRESS/WORK GLOVES/MITTENS
31611	6.	3.230	22	*	0	LUGGAGE/HANDBAGS ETC
31999	14.	5.830	22	*	0	LEATHER GOODS NEC
32111	26.	0.260	22	S	0	WINDOW GLASS
32112	23.	0.220	22	S	0	PLATE GLASS
32113	24.	0.220	22	S	0	LAMINATED GLASS INC SAFETY
32119	28.	0.250	22	S	0	FLAT GLASS NEC
32211	10.	0.360	22	S	0	GLASS CONTAINERS EXC BOTTLES
32212	14.	0.350	22	S	0	GLASS BOTTLES
32219	14.	0.380	11	S	0	GLASS CONTAINERS NEC
32291	16.	0.540	11	S	0	TABLE/KITCHEN/ART/NOVELTY GLASS
32292	9.	0.640	22	S	0	LIGHTING GLASS EXC BULBS
32293	16.	0.720	00	*	0	GLASS FIBER EXC YARN
32294	6.	0.810	22	S	0	GLASS MIRRORS
32295	14.	0.370	22	S	0	GLASS BRICKS/BLOCKS ETC
32296	4.	0.690	22	S	0	ELECTRONIC PROD GLASS EXC TUBES
32299	17.	0.800	22	S	0	GLASS NEC
32411	80.	0.080	24	*	0	HYDRAULIC CEMENT
32412	16.	0.160	22	*	0	READY MIX DRY CEMENT
32511	35.	0.050	22	*	0	BRICK EXC GLASS/CERAM/REFRACTOR
32512	23.	0.210	22	*	0	GLAZED BRICK/BLOCK
32531	21.	0.230	22	*	0	CERAMIC WALL/FLOOR TILE
32551	29.	0.150	22	*	0	CLAY REFRACTORIES
32552	23.	0.290	22	*	0	NONCLAY REFRACTORIES
32591	14.	0.080	00	*	0	CLAY CULVERTS/CULVERTS/PIPE
32592	14.	0.060	22	*	0	CLAY DRAIN TILE
32593	14.	0.090	22	*	0	TERRA COTTA
32594	13.	0.060	22	*	0	CLAY ROOFING TILE
32595	22.	0.110	00	*	0	CLAY TILE BEAMS ETC
32599	16.	0.090	22	*	0	STRUCTURAL CLAY PROD NEC
32611	15.	0.690	22	*	0	VITREOUS CHINA PLUMBING ETC
32621	11.	1.250	22	S	0	TABLE OR KITCHEN CHINA
32641	20.	0.670	22	*	0	PORCELAIN ETC ELECTRICAL SUPP
32699	14.	1.250	22	*	0	POTTERY PROD NEC
32711	21.	0.050	00	*	0	CONCRETE BRICK OR BLOCK
32713	20.	0.090	00	*	0	CONCRETE POSTS
32714	16.	0.090	00	*	0	CONCRETE TILE CONDUIT ETC
32715	17.	0.140	00	*	0	CONCRETE STRUCT SHAPES
32719	18.	0.150	00	*	0	CONCRETE PROD NEC
32731	180.	0.030	33	0	1	READY MIXED CONCRETE WET
32741	48.	0.020	24	*	0	LIME OR LIME PLASTER
32751	12.	0.220	22	*	0	GYPSUM LATH
32752	20.	0.220	22	*	0	GYPSUM PLASTER
32753	24.	0.210	22	*	0	GYPSUM BUILDING MATERIALS
32754	23.	0.220	00	*	0	GYPSUM WALLBOARD
32759	20.	0.220	22	*	0	GYPSUM PROD EXC BUILDING MATER
32811	20.	0.020	00	*	0	CUT GRANITE OR GRANITE PROD
32812	20.	0.020	22	*	0	CUT LIMESTONE OR LIMESTONE PROD
32813	20.	0.100	22	*	0	CUT MARBLE OR MARBLE PROD
32814	20.	0.070	00	*	0	CUT SLATE/SOAPSTONE/TALC ETC
32819	20.	0.080	22	*	0	CUT STONE OR STONE PROD NEC
32911	18.	1.590	22	*	0	NONMETALLIC ARTIFICIAL ABRASIVE
32912	18.	1.270	22	*	0	NONMETAL BONDED/COATED ABRASIVE
32914	6.	2.540	11	*	0	METAL ABRASIVES
32919	23.	1.750	22	*	0	ABRASIVE PROD NEC
32921	12.	0.970	22	*	0	ASBESTOS FRICTION MATERIAL
32922	22.	0.620	22	*	0	ASBESTOS CEMENT PROD
32923	23.	0.260	22	*	0	ASPHALT/VINYL FLOOR TILE
32924	24.	0.870	22	*	0	ASBESTOS INSULATION
32929	25.	0.410	22	*	0	ASBESTOS PROD NEC
32931	17.	1.110	22	*	0	GASKETS ALL TYPES
32932	16.	0.730	22	*	0	ASBESTOS PACKING ALL TYPES
32951	8.	0.030	24	*	0	VERMICULATE EXFOLIATED/LOOSE
32952	55.	0.070	24	*	0	LIGHTWEIGHT AGGREGATES/CLAYS
32953	69.	0.080	24	*	0	MAGNESIA/MAGNESITE
32954	26.	0.200	22	*	0	TALC/SOAPSTONE/PYROPHYLLITE
32955	72.	0.030	24	*	0	FELDSPAR GROUND/TREATED
32956	42.	0.030	24	*	0	CRUSHED ETC UNCLACINED GYPSUM
32957	22.	0.330	22	*	0	MICA GROUND/TREATED
32958	20.	1.630	22	*	0	NATURAL GRAPHITE
32959	69.	0.200	24	*	0	OTHER NONMETALLIC MINER/EARTHS
32961	4.	0.350	22	*	0	MINERAL WOOL
32996	7.	0.370	22	*	0	NONMETAL MINRL INSUL MATER NEC
32999	10.	4.700	22	*	0	NONMETALLIC MINERAL PROD NEC
33111	83.	0.180	00	*	0	PIG IRON
33112	56.	0.0	24	*	0	FURNACE SLAG
33113	45.	0.050	24	*	0	COKE OR COKE SCREENINGS/BREEZE
33115	94.	0.170	24	*	0	METALLIZING PLANT PRODS.
33119	63.	0.070	24	*	0	COKE OVEN PROD NEC
33121	106.	0.220	00	*	0	STEEL INGOT
33122	98.	0.500	00	*	0	IRON OR STEEL PLATES
33123	131.	0.500	00	*	0	IRON SHEET OR STRIPL
33124	89.	0.270	00	*	0	IRON BARS
33125	44.	0.410	00	*	0	IRON STR,SHAPES,PILING, MILL PRD
33126	96.	0.410	00	*	0	IRON PIPE ETC
33127	33.	0.330	22	*	0	TIN MILL PROD
33128	92.	0.160	00	*	0	RAILWAY TRACK MATERIAL
33129	23.	0.190	00	*	0	PRIMARY IRON OR STEEL PROD NEC
33131	53.	0.270	24	*	0	FERROMANGANESE
33132	58.	0.460	00	*	0	FERROCHROME
33133	78.	0.510	24	*	0	FERROSILICON
33134	73.	1.120	24	*	0	ADDITIVE ALLOYS, EXC. COPPER

33135	24.	1.120	22	*	0	ELECTRO METLRGCL PROD, NEC
33139	24.	0.550	22	*	0	FERROALLOYS NEC
33151	24.	0.550	22	*	0	NONINSUL FERROUS WIRE
33152	23.	0.900	22	*	0	STEEL NAILS ETC
33155	26.	0.490	22	*	0	STEEL WIRE EXC MISC
33211	54.	0.370	00	*	0	IRON OR STEEL CAST PIPE/FITTING
33219	35.	0.420	22	*	0	IRON/STEEL CASTINGS NEC
33311	47.	0.850	00	*	0	PRIMARY COPPER,ALLOY,PIG/SLABS
33312	96.	0.500	24	*	0	COPPER MATTE/SPEISS/DUST/ETC
33321	30.	0.250	00	*	0	PRIMARY LEAD OR LEAD ALLOY
33322	83.	0.170	24	*	0	LEAD MATTE/SPEISS/DUST
33331	31.	0.460	00	*	0	PRIMARY ZINC OR ZINC ALLOY
33332	67.	0.200	24	*	0	ZINC DROSS/RESIDUES/ASHES
33341	67.	0.430	00	*	0	PRIMARY ALUMINUM OR ALLOY
33342	50.	0.300	24	*	0	ALUMINUM RESIDUES ETC
33391	38.	0.700	00	*	0	MAGNESIUM OR ALLOY INGOTS ETC
33392	26.	3.510	00	*	0	MANGANESE OR ALLOY SLAB ETC
33393	26.	6.070	00	*	0	MOLYBDENUM OR ALLOY SLAB ETC
33394	27.	3.160	00	*	0	NICKEL OR ALLOY SLAB ETC
33395	23.	2.960	00	*	0	TIN OR ALLOY SLAB
33396	91.	3.190	00	*	0	TITANIUM OR ALLOY SLAB ETC
33398	16.	2.070	24	*	0	MISC NONFERROUS RESIDUES
33399	84.	1.190	00	*	0	PRIMARY NONFERR. PIG/SLAB/INGOTS
33511	47.	1.650	00	*	0	COPPER/BRASS/BRONZE RODS/BARS
33512	32.	1.590	00	*	0	COPPER/BRASS/BRONZE PLATE
33513	25.	1.940	00	*	0	COPPER/BRASS/BRONZE PIPE
33519	12.	1.810	22	*	0	COPPER/BRASS/BRONZE SHAPES NEC
33521	29.	0.700	22	*	0	ALUMINUM OR ALLOY PLATE
33523	27.	0.770	22	*	0	ALUMINUM OR ALLOY RODS
33524	15.	0.870	00	*	0	ALUMINUM OR ALLOY PIPE
33529	24.	0.900	00	*	0	ALUMINUM OR ALLOY SHAPES NEC
33561	25.	0.620	22	*	0	MAGNESIUM OR ALLOY BASIC SHAPES
33562	25.	0.970	22	*	0	LEAD OR ALLOY BASIC SHAPES
33563	25.	3.640	00	*	0	NICKEL OR ALLOY BASIC SHAPES
33564	25.	0.550	22	*	0	ZINC OR ALLOY BASIC SHAPES
33565	25.	3.510	22	*	0	TITANIUM BASIC SHAPES
33566	20.	1.190	22	*	0	WELDING RODS ETC
33567	20.	1.370	22	*	0	SOLDER ETC
33569	70.	3.510	00	*	0	NONFERROUS METAL SHAPES NEC
33571	50.	0.820	22	*	0	ALUMINUM OR ALLOY WIRE
33572	20.	1.940	22	*	0	COPPER OR ALLOY WIRE
33573	20.	3.690	22	*	0	NONFERROUS METAL OR ALLOY WIRE
33574	16.	3.110	22	*	0	WIRE OR CABLE INSULATED
33612	18.	0.820	22	*	0	ALUMINUM OR ALLOY CASTINGS
33621	12.	0.950	22	*	0	BRASS/BRONZE/COPPER ETC CASTING
33691	12.	1.100	22	*	0	MAGNESIUM OR ALLOY CASTINGS
33692	16.	0.520	22	*	0	ZINC OR ALLOY CASTINGS
33693	20.	0.330	22	*	0	LEAD OR ALLOY CASTINGS
33699	18.	1.020	22	*	0	NONFERROUS METAL CASTINGS NEC
33911	31.	0.460	00	*	0	IRON OR STEEL FORGINGS
33921	20.	1.520	00	*	0	NONFERROUS METAL FORGINGS
33991	22.	1.990	22	*	0	METAL POWDER/FLAKES/PASTE
33992	20.	2.090	22	*	0	NONFERROUS METAL NAILS ETC
33999	146.	0.170	24	*	0	PRIMARY NONFERROUS METAL NEC
34111	5.	1.120	22	*	0	METAL CANS
34211	8.	5.410	22	*	0	TABLE/KITCHEN CUTLERY
34213	8.	9.580	22	*	0	SCISSORS ETC
34215	20.	16.370	22	*	0	RAZOR BLADES OR RAZORS NON ELEC
34219	11.	12.370	22	*	0	CUTLERY NEC NON ELECT
34231	18.	3.860	22	*	0	MECHANICS HAND TOOLS
34232	12.	22.370	22	*	0	EDGE TOOLS
34233	18.	5.400	22	*	0	FILES/RASPS/FILE ACCESSORIES
34234	10.	2.730	22	*	0	SHOVELS/SPADES/SCOOPS/SCRAPERS
34235	10.	1.370	00	*	0	HEAVY FORGED TOOLS
34236	10.	1.530	22	*	0	AGRICULTURAL HAND TOOLS
34239	15.	2.900	22	*	0	HAND TOOLS NEC
34251	12.	6.020	22	*	0	HAND SAWS
34261	12.	2.950	22	*	0	DOOR OR WINDOW HARDWARE
34282	14.	2.160	22	*	0	FIREPLACE EQUIP
34283	14.	2.310	22	*	0	HINGES/HASPS/BUTTS EXC CABINET
34284	12.	1.850	22	*	0	CABINET HARDWARE
34285	20.	1.510	22	*	0	HOOKS/CLAMPS/CLIPS ETC
34289	13.	1.400	22	*	0	BUILDERS HARDWARE NEC
34291	14.	3.240	02	*	0	TRANSPORTATION EQ HARDWARE
34292	14.	3.160	22	*	0	FURNITURE HARDWARE
34293	14.	3.080	22	*	0	VACUUM OR INSULATED BOTTLES
34294	12.	2.160	22	*	0	HOSE FITTINGS ETC
34298	14.	0.770	22	*	0	HARDWARE, N.E.C.
34299	12.	2.900	22	*	0	HARDWARE NEC
34311	20.	1.910	22	*	0	CAST IRON SANITARY WARE
34312	11.	1.690	22	*	0	METAL SANITARY WARE EXC CAST
34321	12.	1.950	22	*	0	PLUMBING FIXTURE FITTINGS
34331	10.	2.520	22	*	0	OIL BURNERS
34332	10.	1.540	00	*	0	WARM AIR FURNACES
34333	17.	1.120	00	*	0	CAST IRON HEATING BOILERS
34334	10.	1.120	22	*	0	DOMESTIC HEATING STOVES
34335	23.	0.980	00	*	0	STEEL HEATING BOILERS
34336	10.	1.190	00	*	0	PARTS FOR NON ELECT HEATING EQ
34339	7.	1.270	00	*	0	HEATING EQ NEC
34411	37.	0.440	00	*	0	FABRICATED STRUCT METAL PROD
34412	12.	0.880	00	*	0	FABR STRUCT METAL PROD NONFERRO
34421	14.	0.550	00	*	0	METAL DOORS OR FRAMES
34422	12.	0.620	00	*	0	METAL WINDOW SASH OR FRAMES
34423	17.	1.260	00	*	0	METAL MOLDING OR TRIM
34425	8.	3.320	00	*	0	METAL WINDOW OR DOOR SCREENS
34431	20.	1.960	00	*	0	HEAT EXCHANGERS
34432	15.	0.320	22	*	0	FABRICATED STEEL PLATE
34433	24.	0.390	00	*	0	STEEL POWER BOILERS PARTS
34434	8.	0.710	00	*	0	GAS CYLINDERS
34435	18.	0.700	00	*	0	METAL TANKS EXC PRESSURE
34439	46.	0.470	00	*	0	FABRICATE PLATE PROD NEC
34441	20.	0.510	00	*	0	SHEET METAL ROOFING ETC
34442	16.	0.540	00	*	0	SHEET METAL CULVERTS/FLUMES ETC
34443	6.	1.030	22	*	0	SHEET METAL CORNICES/SKYLITES
34444	5.	0.550	00	*	0	SHEET METAL STOVE DUCTS
34445	12.	0.950	22	*	0	SHEET METAL ROOF DRAINAGE
34446	16.	0.790	00	*	0	SHEET METAL BINS/VATS ETC
34447	8.	1.090	22	*	0	SHEET METAL AWNINGS/CANOPIES
34449	12.	0.600	22	*	0	SHEET METAL PROD NEC
34461	14.	1.110	00	*	0	ORNAMENTAL METAL WORK
34462	3.	0.620	00	*	0	SCAFFOLDING/LADDERS ETC
34464	22.	0.920	00	*	0	STAIRS CASES BALCONIES
34469	8.	0.740	00	*	0	ARCHITECTURAL METAL WORK NEC
34492	12.	1.040	00	*	0	PREFAB BUILDINGS OR PARTS
34499	42.	0.600	00	*	0	METAL CONSTRU MATERIALS NEC
34521	20.	1.110	22	*	0	BOLTS
34529	20.	2.050	22	*	0	INDUSTRIAL FASTENERS NEC
34611	5.	2.340	22	*	0	VITREOUS ENAMELED METAL PROD
34612	14.	1.600	22	*	0	STAMPED OR SPUN HOSPITAL PROD
34613	5.	1.390	22	*	0	AUTO STAMPINGS
34614	29.	1.230	22	*	0	METAL CLOSURES
34615	7.	1.060	22	*	0	METAL BOXES/BASKETS/BUCKETS ETC
34616	8.	1.280	22	*	0	DISPENSERS/HOLDERS/ETC
34619	16.	1.340	00	*	0	METAL SPAMPINGS NEC
34812	14.	0.740	22	*	0	WIRE SPRINGS
34813	15.	0.660	22	*	0	WIRE FENCING/POSTS/GATES
34814	18.	0.880	22	*	0	WIRE CLOTH
34815	18.	0.700	22	*	0	WIRE CHAIN
34816	20.	0.550	22	*	0	BARBED OR TWISTED WIRE
34817	40.	1.110	00	*	0	WELDED WIRE FABRIC OR MESH

34819	20.	0.810	22	*	0	FABRICATED WIRE PROD NEC
34912	6.	0.900	00	*	0	STEEL SHIPPING PAILS BARRELS ET
34913	8.	0.920	00	*	0	METAL REELS
34919	14.	0.930	00	*	0	METALBARRELS/DRUMS/KEGS NEC
34921	12.	1.260	22	*	0	METAL SAFES OR VAULTS
34931	17.	0.880	00	*	0	STEEL SPRINGS EXC WIRE
34941	12.	2.690	22	*	0	METAL VALVES FOR PIPING
34942	16.	1.390	22	*	0	METAL FITTINS FOR PIPING SYS
34943	23.	1.360	22	*	0	METAL PIPE COILS
34944	12.	1.600	22	*	0	FABRICATED METAL PIPE OR FITTIN
34991	12.	1.910	22	*	0	COLLAPSIBLE METAL TUBES
34992	18.	1.000	22	*	0	METAL LEAF OR FOIL
34993	12.	1.830	22	*	0	FURNITURE PARTS METAL
34994	18.	1.410	00	*	0	COATED METALS AND METAL PROD
34996	18.	1.410	22	*	0	FOIL SANITARY FOOD CONTAINERS
34997	4.	0.980	00	*	0	METAL SHIPPIN CONTAINERS
34998	19.	0.860	22	*	0	FABRICATED METAL PROD NEC
34999	17.	1.410	00	*	0	FABRICATED METAL PROD NEC
35112	62.	3.730	00	*	0	STEAM ENGINES/TURBINES
35195	16.	3.130	22	*	0	OUTBOARD MOTORS
35199	25.	2.960	00	*	0	INTERNAL COMBUSTION ENGINES NEC
35222	22.	2.090	00	*	0	WHEEL TRACTORS
35223	5.	1.630	00	*	0	PLANTING/SEEDING MACHINERY
35224	10.	1.360	00	*	0	PLOWS/LISTERS/HARROWS/ETC
35225	8.	1.960	00	*	0	HARVESTING/HAYING MACHINERY
35227	6.	2.010	22	*	0	MACHINES FOR PREPARING CROPS
35228	10.	1.520	22	*	0	BARN/BARNYARD/POULTRY EQUIPMENT
35229	10.	1.420	22	*	0	FARM MACHINERY NEC
35241	9.	1.470	22	*	0	GARDEN/LAWN EQ
35311	20.	2.060	00	*	0	CONTRACTORS TRACTORS
35312	50.	2.540	00	*	0	RAILWAY MAINT EQ
35313	50.	2.060	00	*	0	PARTS FOR CONTRACTORS TRACTORS
35314	20.	2.670	00	*	0	POWER CRANES/DRAGLINES/SHOVELS
35316	10.	2.770	00	*	0	MIXERS/PAVERS/ETC
35318	15.	2.920	00	*	0	SCRAPERS/GRADERS/ROLLERS/ETC
35319	24.	2.550	00	*	0	CONSTRUCTION MACHINERY NEC
35321	15.	3.150	00	*	0	UNDERGROUND MINING MACHINERY
35322	15.	3.440	00	*	0	CRUSHING/PULVERIZING PLANTS
35329	15.	3.050	00	*	0	MINING MACHINERY
35331	14.	3.460	00	*	0	OIL/GAS DRILLING MACHINERY
35339	14.	5.050	00	*	0	OIL/GAS MACHINERY NEC
35341	10.	2.930	00	*	0	ELEVATORS/MOVING STAIRWAYS
35351	10.	2.740	00	*	0	CONVEYORS
35361	10.	1.650	00	*	0	HOISTS
35362	12.	2.560	00	*	0	OVERHEAD TRAVELING CRANES
35371	17.	2.050	00	*	0	INDUSTRIAL TRUCKS/TRACTORS ETC
35373	13.	0.930	00	*	0	SKIDS/PALLETS METAL
35412	14.	4.950	22	*	0	MACHINE TOOLS METAL CUTTING
35421	28.	3.300	00	*	0	MACHINE TOOLS METAL FORMING
35441	19.	5.780	00	*	0	SPECIAL DIES/JUGS/PATTERNS
35451	10.	6.610	22	*	0	MACHINE TOOL ACCESSORIES
35481	56.	4.130	00	*	0	ROLLING MILL MACHINERY
35484	13.	2.620	22	*	0	AUTO MAINT EQ
35489	13.	4.550	22	*	0	METALWORKING MACHINERY
35511	10.	4.790	22	*	0	DAIRY PLANT MACHINERY
35512	10.	5.550	00	*	0	BAKERY MACHINERY
35513	10.	4.010	22	*	0	MEAT/POULTRY PACKING MACHINERY
35514	5.	5.090	22	*	0	FRUIT/VEG CANNING/PACKING MACHI
35515	10.	4.700	22	*	0	BOTTLING MACHINERY
35516	10.	3.240	00	*	0	FLOUR MILL/GRAIN MACHINERY
35519	10.	4.620	22	*	0	FOOD PROD MACHINERY NEC
35522	12.	5.410	22	*	0	TEXTILE MACHINERY
35531	12.	3.080	00	*	0	WOODWORKING MACHINERY
35541	10.	3.840	00	*	0	PAPER INDUS MACHINERY
35552	12.	6.010	20	*	0	PRINTING TRADE MACHINERY

35591	14.	6.090	00	*	0	CHEM MFG MACHINERY
35592	14.	2.470	22	*	0	FOUNDRY MACHINERY
35594	12.	4.330	22	*	0	RUBBER/PLASTICS WORKING MACHIN
35595	26.	4.900	00	*	0	PETROLEUM REFINERY MACHINERY
35596	12.	2.770	00	*	0	COTTON GINNING MACHINERY
35597	12.	2.160	00	*	0	CLAY WORKING MACHINERY
35599	12.	4.830	22	*	0	SPECIAL INDUSTRY MACHINERY NEC
35611	10.	3.630	22	*	0	INDUSTRIAL PUMPS
35614	14.	3.130	00	*	0	AIR/GAS COMPRESSORS
35619	10.	3.260	00	*	0	INDUSTRIAL PUMPS NEC
35621	16.	5.060	22	*	0	BALL/ROLLER BEARINGS
35641	15.	2.820	00	*	0	INDUSTRIAL FANS/BLOWERS
35642	5.	2.560	22	*	0	DUST COLLECTION EQUIPMENT
35661	16.	4.620	22	*	0	PLAIN BEARINGS
35669	15.	1.830	00	*	0	MECH POWER TRANS EQ NEC
35671	14.	3.050	00	*	0	INDUSTRIAL PROCESS FURNACES
35691	10.	3.430	22	*	0	MISC INDUSTRIAL MACHINERY NEC
35721	14.	7.440	22	S	0	TYPEWRITERS
35731	10.	28.340	22	S	0	ELEC DATA PROC EQ
35741	10.	13.890	22	S	0	CALCULATING/ACCOUNTING MACHINES
35761	12.	6.760	22	S	0	SCALES/BALANCES EXC LABORATORY
35791	13.	9.050	22	S	0	ADDRESSING/DUPL/DICTATING MACH
35799	7.	17.530	22	S	0	OFFICE MACHINES NEC
35811	10.	4.950	22	*	0	AUTO MERCHANDISING MACHY
35821	10.	4.720	22	*	0	COMMERCIAL LAUNDRY EQ
35822	10.	4.570	22	*	0	DRY CLEANING EQUIPMENT
35851	10.	2.310	22	*	0	HEAT TRANSFER EQ
35853	6.	2.820	22	*	0	COMMERCIAL REFREGERATION EQ
35854	16.	2.490	22	*	0	COMPRESSORS
35855	13.	2.010	00	*	0	CONDENSING UNITS
35856	13.	2.670	00	*	0	ICE MAKING MACHINERY
35857	18.	2.970	00	*	0	AIR CONDITIONING EQ
35859	6.	2.620	22	*	0	REFRIGERATORS NEC
35891	10.	2.470	22	*	0	COMMERCIAL COOKING EQ
35892	10.	3.080	22	*	0	COMMERCIAL VACUUM CLEANERS
35899	11.	4.620	22	*	0	SERVICE INDUSTRIES MACHINES NEC
35921	10.	3.460	22	*	0	CARBURETORS/PISTONS/PISTON RING
35922	10.	3.210	22	*	0	VALVES FOR INTERNAL COMBUS ENG
35991	10.	3.460	22	*	0	CARBURETORS/PISTONS/PISTON RING
35993	14.	3.130	22	*	0	FLEXIBLE METAL HOSE NON ELEC
35994	6.	3.610	00	*	0	AMUSEMENT/CARNIVAL MACHINES
35999	23.	3.960	00	*	0	MACHINERY NEC
36111	12.	12.180	22	S	0	ELECTR INTEGRATING METERS
36112	10.	17.290	22	S	0	RADIO TEST EQUIPMENT
36113	10.	21.800	22	S	0	INDICATNG MEASURG/RECORDG INSTR
36121	15.	1.670	22	*	0	TRANSFORMERS
36123	15.	2.510	22	*	0	POWER REGULATORS/BOOSTERS
36129	20.	2.090	00	*	0	SPECIALTY TRANSFORMERS NEC
36131	13.	4.330	22	*	0	SWITCHBOARD APPARATUS
36132	12.	4.960	22	*	0	CIRCUIT BREAKERS/FUSES
36211	18.	3.910	00	*	0	MOTORS
36212	18.	5.440	00	*	0	GENERATORS
36213	18.	4.050	00	*	0	LAND TRANS GENERATORS
36214	18.	4.750	00	*	0	PRIME MOVER GENERATORS
36215	18.	4.330	00	*	0	MOTOR GENERATOR ELECTRIC
36216	18.	3.910	22	*	0	PARTS FOR MOTORS/GENERATORS
36219	12.	4.050	00	*	0	MOTORS/GENERATORS NEC
36221	20.	5.370	22	*	0	INDUSTRIAL CONTROLS
36231	16.	2.080	00	*	0	ARC WELDING MACHINES
36232	12.	1.690	22	*	0	ARC WELDING ELECTRODES
36241	22.	2.470	22	*	0	CARBON/GRAPHITE PROD ELECTRICAL
36291	15.	4.300	22	*	0	CAPACITORS NON ELECTRONIC
36292	12.	3.750	22	*	0	RECTIFYING APPARATUS
36299	15.	2.930	00	*	0	ELECTRICAL INDUS APPARATUS NEC
36311	7.	1.580	22	*	0	HOUSEHOLD RANGES

36314	8.	1.230	22	*	0	SMALL HOUSEHOLD HEATING APPLI
36321	7.	1.650	22	*	0	HOUSEHOLD REFRIGERATORS
36331	9.	1.710	22	*	0	HOUSEHOLD WASHING MACHINES
36332	12.	1.650	22	*	0	OTHER HOUSEHOLD LAUNDRY EQ
36341	11.	1.340	22	*	0	ELECTRIC FANS EXC ATTIC
36343	8.	1.230	22	*	0	SMALL HOUSEHOLD HEATING APPLI
36346	13.	1.420	22	*	0	SMALL HOUSEHOLD ELECTR APPLIANC
36347	10.	2.970	22	*	0	PERSONAL ELECTRIC APPLIANCES
36349	11.	1.700	22	*	0	ELECTRIC HOUSEWARES NEC
36351	14.	1.770	22	*	0	HOUSEHOLD VACUUM CLEANERS
36361	12.	3.640	22	*	0	SEWING MACHINES
36392	11.	2.020	22	*	0	HOUSEHOLD WATER HEATERS
36393	13.	3.240	22	*	0	HOUSEHOLD DISHWASHING MACHINES
36399	12.	2.430	22	S	0	HOUSEHOLD APPLIANCES NEC
36411	6.	3.070	22	*	0	ELECTRIC LAMPS
36421	7.	2.300	22	*	0	RESIDENTIAL ELECTRIC FIXTURES
36424	12.	1.740	22	*	0	VEHICULAR LIGHTING EQUIPMENT
36425	8.	1.240	22	*	0	OUTDOOR LIGHTING EQUIPMENT
36429	8.	2.650	22	*	0	LIGHTING FIXTURES NEC
36432	15.	1.810	11	*	0	POWER OUTLETS
36433	12.	1.880	11	*	0	SWITCHES
36434	12.	1.280	22	*	0	LIGHTNING RODS
36435	12.	1.540	00	*	0	OVERHEAD TROLLEY LINE
36439	10.	1.670	22	*	0	CURRENT CARRYING WIRE NEC
36441	34.	1.350	00	*	0	POLE LINE/TRANSMISSION HARDWARE
36442	12.	1.200	22	*	0	ELECT CONDUIT
36449	12.	1.140	22	*	0	NONCURRENT WIRING DEVICES NEC
36511	10.	3.030	22	S	0	HOUSEHOLD/AUTO RADIOS
36512	10.	3.220	22	S	0	HOUSEHOLD TEVEVISION
36521	12.	1.510	22	*	0	PHONOGRAPH RECORDS
36611	12.	11.170	00	*	0	TELEPHONE SWITCHING EQUIPMENT
36612	10.	9.070	22	S	0	NONSWITCHING TELEPHONE EQ
36621	12.	16.660	00	*	0	RADIO/TV TRANSMITTING EQUIPMENT
36711	10.	5.510	22	S	0	ELECTRONIC TUBES EXC X RAY
36741	10.	6.240	22	*	0	SEMICONDUCTOR DEVICES
36791	12.	3.030	22	*	0	MISC ELECTRONIC COMPONENTS
36911	30.	0.990	22	*	0	STORAGE BATTERIES
36921	23.	1.690	22	*	0	PRIMARY BATTERIES
36931	6.	11.570	22	*	0	X RAY EQUIPMENT
36941	17.	2.950	22	*	0	ELECTR EQ FOR INTERNAL COMB ENG
36999	10.	2.080	22	*	0	ELECTR MACHINERY NEC
37111	6.	1.400	00	*	0	MOTOR PASSENGER CARS
37112	5.	1.210	00	*	0	MOTOR TRUCKS
37113	3.	2.890	00	*	0	MOTOR COACHES/FIRETRUCKS
37114	8.	2.250	00	*	0	MOTOR COMBAT VEHICLES
37115	5.	1.460	00	*	0	AUTO CHASSIS
37116	3.	1.280	00	*	0	MOTOR BUSSES/TRUCKS CHASSIS
37119	7.	1.480	00	*	0	MOTOR VEHICLES NEC
37121	7.	1.110	00	*	0	PASSENGER MOTOR CAR BODIES
37131	5.	1.040	00	*	0	MOTOR TRUCK BODIES
37132	3.	0.650	00	*	0	MOTOR BUS BODIES
37142	7.	2.090	22	*	0	MOTOR VEHICLE ACCESSORIES
37143	10.	0.650	00	*	0	MOTOR VEHICLE GEAR FRAMES
37144	23.	1.100	00	*	0	MOTOR VEH INT COBUSTION ENGINES
37145	31.	0.970	22	*	0	MOTOR VEHICLE BRAKES
37146	23.	1.250	00	*	0	MOTOR VEHICLE STEERING GEARS
37147	8.	1.110	00	*	0	MOTOR VEHICLE BODY PARTS
37148	11.	0.550	22	*	0	MOTOR VEHICLE WHEELS
37149	17.	1.580	22	*	0	MOTOR VEHICLE PARTS NEC
37151	4.	0.970	00	*	0	TRUCK TRAILERS
37211	5.	511.650	00	*	0	COMPLETE MILITARY AIRCRAFT
37213	5.	48.850	00	*	0	COMPLETE COMMERCIAL AIRCRAFT
37221	5.	23.640	22	*	0	AIRCRAFT ENGINES
37222	4.	56.500	00	XB*	0	MISSILE/SPACE VEHICLE ENGINES
37231	6.	21.790	22	*	0	AIRCRAFT PROPELLERS
37299	4.	19.560	22	*	0	AIRCRAFT PARTS NEC
37321	2.	1.420	00	*	0	INBOARD MOTOR BOATS
37322	2.	1.390	22	*	0	OUTBOARD MOTOR BOATS
37323	10.	0.860	00	*	0	NONPROPELLED SHIPS
37324	10.	0.810	00	*	0	CAR FLOATS/PONTOON/PORT BRIDGES
37329	12.	1.430	22	*	0	SHIPS/BOATS NEC
37411	36.	1.450	00	*	0	LOCOMOTIVES/TENDERS
37413	23.	2.720	00	*	0	PARTS FOR LOCOMOTIVES
37421	10.	3.080	00	*	0	PASSENGER TRAIN CARS
37422	10.	0.670	00	*	0	FREIGHT TRAIN CARS
37423	10.	2.000	00	*	0	STREET CARS
37424	15.	1.450	00	*	0	MAINTENANCE CARS
37426	25.	0.450	00	*	0	RAILROAD CAR WHEELS
37428	22.	2.540	00	*	0	RAILROAD PARTS EXC WHEELS
37429	31.	0.0	00	*	0	RAILROAD PARTS EXC WHEELS
37511	5.	3.050	22	*	0	MOTORCYCLES ETC
37512	6.	1.420	22	*	0	BICYCLES
37513	10.	2.350	22	*	0	PARTS FOR MOTORCYCLES ETC
37691	16.	13.960	00	*	0	GUIDED MISSILE PARTS ETC
37911	4.	1.280	00	*	0	TRAILER COACHES HOUSING TYPE
37912	4.	1.390	00	*	0	TRAVEL TRAILERS/CAMPERS
37992	10.	1.160	00	*	0	HORSEDRAWN VEHICLES
37993	10.	1.170	00	*	0	HAND CARTS/WAGONS
37994	14.	1.270	22	*	0	HORSEDRAWN VEHICLE PARTS
37995	4.	1.190	22	*	0	SLEIGHS/SLEDS HORSEDRAWN
37999	10.	2.300	22	*	0	TRANSPORTATION EQ NEC
38111	4.	60.000	22	S	0	FLIGHT NAVIGATIONAL INSTRUMENTS
38112	5.	20.000	22	*	0	SURVEYING/DRAFTING INSTRUMENTS
38113	8.	60.000	22	S	0	LAB/SCIENTIFIC INSTRUMENTS
38119	5.	60.000	22	S	0	ENGINEERING/LAB INSTRU NEC
38212	12.	4.000	22	S	0	GAS/WATER METERS
38213	4.	30.000	22	S	0	WEATHER MEASURING INSTRUMENTS
38219	6.	30.000	22	S	0	MECH MEASURING INSTRU NEC
38221	10.	30.000	22	S	0	AUTO TEMPERATURE CONTROLS
38311	4.	17.600	22	S	0	OPTICAL INSTRU
38411	6.	22.460	22	*	0	SURGICAL/MEDICAL INSTRU
38412	6.	4.500	22	*	0	HOSPITAL FURNITURE
38421	8.	16.080	22	*	0	ORTHOPEDIC/PROSTHETIC SUPPLIES
38431	10.	14.620	22	*	0	DENTAL INSTRU
38511	5.	21.130	22	*	0	SPECTACLES ETC
38612	6.	12.570	22	*	0	PHOTOGRAPHIC DEVELOPING EQ
38613	9.	14.170	22	S	0	STILL/MOTION PICTURE EQ
38615	16.	5.900	22	S	140	PHOTO FILM
38618	12.	0.770	22	*	0	PREPARED PHOTOGRAPHIC CHEMICALS
38619	12.	10.110	22	S	0	PHOTO EQUIPMENT NEC
38711	6.	9.290	22	S	0	WATCHES/CLOCKS ETC
39111	13.	42.460	22	0	0	JEWELRY
39141	13.	13.500	22	*	0	SILVERWARE
39311	6.	5.730	22	S	0	PIANOS
39312	6.	6.120	22	S	0	ORGANS
39313	5.	7.030	22	*	0	PIANO OR ORGAN PARTS
39319	4.	6.060	22	S	0	MUSICAL INSTRU EXC PIANO/ORGAN
39411	15.	2.560	11	*	0	GAMES/TOYS
39421	3.	2.740	22	*	0	DOLLS/STUFFED TOYS
39431	6.	1.340	22	*	0	BABY OR DOLL CARRIAGES
39439	10.	1.020	22	*	0	CHILDRENS VEHICLES
39491	5.	4.750	22	*	0	FISHING TACKLE
39492	8.	1.170	22	*	0	BILLIARD/POOL TABLES
39493	13.	0.960	22	*	0	BOWLING ALLEYS AND BALLS
39494	8.	5.400	22	*	0	GOLF CLUBS/BALLS ETC
39496	4.	4.100	22	*	0	TENNIS/BASEBALL/CRICKET/ETC EQ
39497	8.	1.600	22	*	0	PLAYGROUND/GYM EQUIPMENT
39499	7.	2.030	22	*	0	SPORTING GOODS NEC
39511	5.	9.760	22	*	0	PENS
39521	14.	4.200	22	*	0	PENCILS OR CRAYONS

39522	10.	0.630	22	*	0	ARTISTS' MATERIALS
39531	10.	4.490	22	*	0	MARKING DEVICES
39551	14.	1.170	22	*	0	CARBON/STENCIL PPR, INK RIBBNS
39611	12.	5.120	22	*	0	COSTUME JEWELRY
39621	5.	7.510	22	*	0	FEATHERS ETC
39631	12.	2.650	22	*	0	BUTTONS
39641	12.	4.540	22	*	0	ZIPPERS/FASTENERS
39642	6.	2.630	22	*	0	NEEDLES/PINS/FASTENERS
39911	10.	3.110	22	*	0	BROOMS/BRUSHES
39921	10.	0.750	22	*	0	FLOOR CVRS (HARD), LINOLEUM,ETC
39931	6.	2.070	22	*	0	LUMINOUS TUBING SIGNS
39932	4.	1.130	22	*	0	NONELECTRIC ADVERTISING SIGNS
39934	10.	0.950	22	*	0	NONELECTRIC ROAD SIGNS
39941	12.	4.090	22	*	0	MORTICIANS GOODS
39961	24.	0.800	11	*	0	MATCHES
39971	10.	52.180	22	*	0	FURS DRESSED OR DYED
39991	14.	2.840	22	*	0	CHEM FIRE EXTINGUISH EQ
39992	5.	4.570	22	*	0	COIN OP AMUSEMENT MACHINES
39993	10.	4.020	22	*	0	BEAUTY/BARBER SHOP FURN/EQ
39994	4.	12.900	22	*	0	HAIRWORK/TOUPEES/WIGS
39995	8.	3.170	22	*	0	TOBACCO PIPES/HOLDERS ETC
39996	5.	1.350	11	*	0	CHRISTMAS TREE DECORATIONS
39998	10.	3.610	00	*	0	MISC MFG GOODS NEC
39999	14.	1.630	11	*	0	MISC MFG GOODS NEC
40112	52.	0.0	24	*	0	ASHES
40211	65.	0.090	04	*	0	IRON/STEEL SCRAP/WASTE
40212	29.	0.170	00	*	0	BRASS,BRONZ,COPPER SCRAP
40213	28.	0.170	00	*	0	LEAD,ZINC, ALLOW SCRAP
40214	30.	0.170	00	*	0	ALUMINIUM/ALLOY SCRAP
40219	72.	0.170	04	*	0	NONFERR./ALLOY SCRAP (N.E.C.)
40221	18.	0.010	22	*	0	TEXTILE WASTE
40231	34.	0.010	22	*	0	WOOD SCRAP/WASTE
40241	50.	0.010	22	*	0	PAPER WASTE/SCRAP
40251	54.	0.020	04	*	0	CHEM/PETRO WASTE/SCRAP
40261	22.	0.010	00	*	0	RUBBER/PLSCT WASTE/SCRAP
40271	50.	0.010	24	*	0	STONE,CLAY,GLASS WASTE/SCRAP
40281	24.	0.010	22	*	0	LEATHER WASTE/SCRAP
40291	50.	1.000	24	*	0	WASTE/SCRAP N.E.C.
41111	26.	1.650	00	*	0	MISC. FRGHT SHPMENTS
41112	14.	0.170	22	*	0	MISC. FRGHT SHPMENTS
41114	10.	0.080	00	*	0	MISC. FRGHT SHPMENTS
41115	9.	0.170	00	*	0	MISC. FRGHT SHPMENTS
41116	5.	0.500	22	*	0	MISC. FRGHT SHPMENTS
41117	10.	0.500	00	*	0	MISC. FRGHT SHPMENTS
41119	32.	0.080	00	*	0	MISC. FRGHT SHPMENTS
41211	5.	0.330	00	*	0	MISC. FRGHT SHPMENTS
42111	9.	1.690	00	*	0	SHPNG CONTAINERS RETURNED EMPTY
42112	15.	0.170	00	*	0	SHPNG CONTAINERS RETURNED EMPTY
42211	2.	0.690	00	*	0	TRAILERS, SEMI'S RETURNED EMPTY
43111	10.	165.400	22	*	0	MAIL, EXPRESS,OTHR CONTRACT
43115	10.	33.100	00	*	0	MAIL, EXPRESS,OTHR CONTRACT
43211	10.	0.830	00	*	0	MAIL, EXPRESS,OTHR CONTRACT
44111	20.	1.650	00	*	0	FREIGHT FORWARDER TRAFFIC
45111	20.	1.650	00	*	0	SHIPPER ASSN TRAFFIC
46111	20.	1.650	00	*	0	T.O.F.C SHIPMENTS
46211	9.	2.070	22	*	0	MIXED MAJOR GROUPS,CANT SEPARATE
47111	10.	1.650	22	*	0	SMALL PKGD SHPMNTS (LCL/LTL)
49057	60.	0.490	23	FGG	0	FLAMMABLE COMPRESS GAS
49160	50.	0.170	24	FS*	0	FLAMMABLE SOLID
49880	22.	1.990	22	RM*	0	RADIOACTIVE OR NUCLEAR CHEMICAL

APPENDIX C — TRUCK COSTING PROGRAM LISTING

```
TRUCK COSTING MODEL TEXT FILES

TCMTEXT:                              16-NOV-82

FILE NAME            DATE     START LNGTH TYPE
--------------- --------- ----- ----- ----
TCM3.TEXT        18-NOV-82     6    14  TEXT
TIMESHIP.TEXT    16-NOV-82    20    14  TEXT
COSTCOMP3.TEXT   16-NOV-82    34    26  TEXT
REVISE.TEXT       6-JAN-83    60    20  TEXT
ROUTINES.TEXT    14-JAN-83    80    26  TEXT
TCMIO.TEXT        3-JAN-83   106    18  TEXT
COMPUTE.TEXT      3-JAN-83   124    14  TEXT
SYSTEM.COMPILER  19-SEP-80   138    75  CODE
TCM.CODE          6-JAN-83   213    46  CODE
<UNUSED>                     259    21

 9 FILES


(*$S++,N+*)
PROGRAM TCM;
USES TRANSCEND,APPLESTUFF,ROUTINES;

(**************************************)
(* TRUCK COST PROGRAM  VERSION 3.0    *)
(* FINISHED VERSION OF THIS PROGRAM   *)
(* COMPLETED 11/18/82.                *)
(* WRITTEN BY DANIEL R. GEALT FOR     *)
(* NCHRP 20-17A PROJECT.              *)
(* PROJECT MANAGER: F.W. MEMMOTT      *)
(**************************************)


VAR ESCAPE,RETURN,DONE,NEWFILE      :BOOLEAN;
    TIMECHEK,SHIPCHEK,AUTOCOMP      :BOOLEAN;
    COUNT,DAY,MONTH,YEAR,NSTOPS     :INTEGER;
    NUMEQUIP,NTRUCKS,SERIAL         :INTEGER;
    V1,V6,V21,V23,V24,V29,V31,V32   :INTEGER;
    MPDAY,NIGHTRATE                 :REAL;
    MPMEAL,MEALRATE                 :REAL;
    QUANTITY,DENSITY,AVGLOAD        :REAL;
    SHIPLOAD,WCAP,VCAP,MAXLOAD      :REAL;
    STOPWAGE,LTIME,UTIME,WTIME      :REAL;
    OTIME,LCOST,UCOST,WCOST,OCOST   :REAL;
    HHTIME,DHTIME,RTMILES,HHMILES   :REAL;
    DHMILES,VHH,VRT,VDH,TERMCHARGE:REAL;
    MAXWT,TRACWT,TRLRWT,TRLRCUBE    :REAL;
    V2,V3,V4,V5,V7,V8,V9,V10        :REAL;
    V11,V12,V13,V14,V15,V16,V17     :REAL;
    V18,V19,V20,V22,V25,V26,V27     :REAL;
    V28,V30,CORPDISCOUNT,GALLONS    :REAL;
    V33,V34,V35,FUEL,MR,ML,TX3      :REAL;
    MPYSTART,MPYSTEP,MPYSTOP        :REAL;
    MHHSTART,MHHSTEP,MHHSTOP        :REAL;
    PCTLDMIL,RUNS,COMPS             :REAL;
    ORIGIN,DEST,CARGO,EQUIP         :STRING;
    TRACTOR,OWNER,LDLIMIT           :STRING;
    N1,N2,N3,N4,N5,N6,N7,N8,N9,N10:STRING[15];
    N11,N12,N13,N14,N15,N16,N17     :STRING[15];
    N18,N19,N20,N21,N22,N23,N24     :STRING[15];
    N25,N26,N27,N28,N29,N30,N31     :STRING[15];
    N32,N33,N34,N35                 :STRING[15];
    ITCBRKS              :FILE OF RECORD
                              BREAKS:INTEGER;
                              PERCENT:REAL
                             END;
```

```
    OUTFILE                 :FILE OF RECORD
                                  RECNUM:INTEGER;
                                  CPMILE,CPTON,CPTNMILE,
                                  MPY,MHH,PCTLD:REAL;
                                  EQUIPTYP,EQUIPOWN:INTEGER
                                END;
    F                       :FILE OF RECORD
                                  S:STRING[136]
                                END;
    COUNTFILE               :FILE OF RECORD
                                  SERIALNUM:INTEGER;
                                  RUNNUM,COMPNUM:REAL
                                END;
    P                       :TEXT;


    EQUIPFILE               :FILE OF RECORD
                                  NAME:STRING[8];
                                  PRICE,ESALVG:REAL;
                                  ELIFE,TSALVG,TLIFE:INTEGER
                                END;

    DFLTFILE                :FILE OF RECORD
                                  NAME:STRING[25];
                                  VALUE:REAL
                                END;

PROCEDURE MAINMENU; FORWARD;
SEGMENT PROCEDURE SHIPMENT; FORWARD;
SEGMENT PROCEDURE STOPS; FORWARD;
SEGMENT PROCEDURE SCREEN; FORWARD;
SEGMENT PROCEDURE COSTCOMP; FORWARD;
SEGMENT PROCEDURE READDATA; FORWARD;

(*$ITCMTEXT:COMPUTE.TEXT*)
(*$ITCMTEXT:TIMESHIP.TEXT*)
(*$ITCMTEXT:COSTCOMP3.TEXT*)
(*$ITCMTEXT:REVISE.TEXT*)
(*$ITCMTEXT:TCMIO.TEXT*)


(*************************)
(* MAIN DATA ENTRY SCREEN *)
(*************************)

SEGMENT PROCEDURE SCREEN;

VAR N,LINE                         :INTEGER;

BEGIN

WRITELN (CHR(12));
UNITCLEAR (1);
WRITELN ('       +++ ENTER INPUT VALUES +++');
WRITELN;
WRITELN ('ORIGIN......................:');
WRITELN ('DESTINATION.................:');
WRITELN ('COMMODITY...................:');
WRITELN ('DATE...MONTH:  ..DAY:  ..YEAR:');
WRITELN ('MILES/HEADHAUL..............:');
WRITELN ('MILES/ROUNDTRIP.............:');
WRITELN ('MILES/YEAR..................:');
WRITELN ('TONS OF PAYLOAD.............:');
WRITELN ('TERMINAL CHARGES ($)........:');
WRITELN ('FUEL PRICE (CENTS/GAL)......:');
WRITELN ('TRACTOR M.P.G...............:');
WRITELN ('TRACTOR OWNER...............:');
WRITELN ('   (C=COMPANY  D=DRIVER)');
WRITELN;
WRITELN ('EQUIPMENT TYPE..............:');
(*$I-*)
```

```
RESET (EQUIPFILE,'*TRAILER.DATA');
(*$I+*)
IF IORESULT<>0 THEN BEGIN
     GOTOXY (0,22);
     WRITE ('FILE NOT FOUND ON BOOT DISKETTE!!');
     PAUSE (3);
     EXIT (COMPUTE);
    END;
N:=-1;
REPEAT
     N:=N+1;
     SEEK (EQUIPFILE,N);
     GET (EQUIPFILE);
     IF EOF (EQUIPFILE) THEN N:=9
          ELSE BEGIN
          NUMEQUIP:=N;
          EQUIP:=EQUIPFILE^.NAME;
          IF N<=4 THEN BEGIN
               LINE:=N+18;
               GOTOXY (2,LINE);
               WRITE (N,'=',EQUIP)
              END
               ELSE BEGIN
               LINE:=N+13;
               GOTOXY (17,LINE);
               WRITE (N,'=',EQUIP)
              END
         END;
   UNTIL N=9;
CLOSE (EQUIPFILE,LOCK);
END;


(*[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[*)
(* PROCEDURE TO SHOW MAIN MENU FOR THE*)
(* TRUCK COSTING MODEL  DRG 4-22-82   *)
(*]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]*)

PROCEDURE MAINMENU;


VAR REPLY                           :CHAR;


BEGIN
AUTOCOMP:=FALSE;
WRITELN (CHR(12));
UNITCLEAR (1);
WRITELN;
WRITELN ('          TRUCK COSTING MODEL');
WRITELN;
WRITELN;
WRITELN ('         ++  OPERATIONS MENU  ++');
WRITELN;
WRITELN;
WRITELN ('         1.  COMPUTE TRIP COST');
WRITELN;
WRITELN ('         2.  REVISE DATA FILES');
WRITELN;
WRITELN ('         3.  MULTIPLE RUNS    ');
WRITELN;
WRITELN ('         4.  PRINT OUTPUT FILE');
WRITELN;
WRITELN;
WRITELN;
WRITELN ('ENTER NUMBER OF DESIRED OPERATION: ');
REPLY:='*';
WHILE NOT (REPLY IN ['1'..'4']) DO BEGIN
     GOTOXY (36,18);
     WRITE (' ');
     SPOT (36,18,REPLY,ESCAPE,RETURN);
     IF ESCAPE THEN EXIT (MAINMENU);
     IF ORD(REPLY)=17 THEN EXIT (TCM);
     ERASE (0,21,39);
    END;
```

```
WRITE (CHR(12));
GOTOXY (0,22);
CASE REPLY OF
     '1':COMPUTE;
     '2':REVISE;
     '3':BEGIN
          AUTOCOMP:=TRUE;
          AUTOINPUT;
          COSTCOMP;
         END;
     '4':PRINTFILE;
    END;
END;


(* BEGIN MAIN PROGRAM *)

BEGIN
YEAR:=0;
REPEAT
MAINMENU;
UNTIL FALSE;
END.

(*************************************)
(*PROCEDURE TO INPUT STOP DATA FOR TCM*)
(*************************************)

SEGMENT PROCEDURE STOPS;
VAR N,LINE,LF                          :INTEGER;
    H,M,R                              :REAL;
    A                                  :CHAR;
    STR                                :STRING;

BEGIN
WRITE (CHR(12));
UNITCLEAR (1);
GOTOXY (10,6);
WRITE ('** STOPS AND DELAYS **');
GOTOXY (7,9);
WRITE ('HOW MANY STOPS ON THIS TRIP? ');
GOTOXY (0,10);
WRITE ('                    (0 TO 9)');
GETINPUT (1,36,9,1,0,9,R,ESCAPE,RETURN,0);
NSTOPS:=TRUNC (R);
IF NSTOPS>0 THEN BEGIN
     GOTOXY (0,22);
     WRITE ('SELECT REASON FROM THE LIST BELOW:');
     GOTOXY (0,23);
     WRITE ('L(OAD, U(NLOAD, W(AITING, O(THER');
     GOTOXY (0,9);
     WRITE ('                                        ');
     GOTOXY (0,10);
     WRITE ('                                        ');
     GOTOXY (0,11);
     WRITE ('STOP#    HOURS    MINUTES    REASON');
     N:=0; REPEAT N:=N+1;
          GOTOXY (2,N+11);
          WRITE (N);
         UNTIL N=NSTOPS;
     N:=0; REPEAT N:=N+1;
          LINE:=N+11;
          GETINPUT (1,11,LINE,2,0,11,H,ESCAPE,RETURN,0);
          IF ESCAPE THEN EXIT (COMPUTE);
          GETINPUT (1,20,LINE,2,0,59,M,ESCAPE,RETURN,0);
          IF ESCAPE THEN EXIT (COMPUTE);
          H:=H+(M/60);
          REPEAT
               READIN (1,31,LINE,1,STR,ESCAPE,RETURN);
               IF ESCAPE THEN EXIT (COMPUTE);
               IF(STR<>'L')AND(STR<>'U')AND(STR<>'W')AND(STR<>'O')THEN BEGIN
                    NOTE (30,20);
                    GOTOXY (31,LINE);
                    WRITE (' ')
                   END;
```

```
            UNTIL (STR='U')OR(STR='L')OR(STR='W')OR(STR='O');
            CASE STR[1] OF
                 'L': LTIME:=LTIME+H;
                 'U': UTIME:=UTIME+H;
                 'W': WTIME:=WTIME+H;
                 'O': OTIME:=OTIME+H
                END;
        UNTIL N=NSTOPS;
     WRITE (CHR(12));
     UNITCLEAR (1);
     GOTOXY (10,6);
     WRITE ('** STOPS AND DELAYS **');
     GOTOXY (0,9);
     WRITE ('ENTER DRIVER WAGE FOR STOP TIME ($/HR)');
     GOTOXY (17,11);
     WRITE ('$');
     GETINPUT (1,18,11,5,0,50,STOPWAGE,ESCAPE,RETURN,0);
     IF ESCAPE THEN EXIT (COMPUTE);
     LCOST:=LTIME*STOPWAGE;
     UCOST:=UTIME*STOPWAGE;
     WCOST:=WTIME*STOPWAGE;
     OCOST:=OTIME*STOPWAGE;
    END;
RETURN:=FALSE;
END;


(*************************************)
(* PROCEDURE TO INPUT SHIPMENT DATA *)
(*************************************)

SEGMENT PROCEDURE SHIPMENT;
VAR R                              :REAL;
    A                              :CHAR;
    S                              :STRING;

PROCEDURE DEFAULT (VBL:REAL; X,Y,SIZE,DECIMALS:INTEGER); FORWARD;
(**************************************)
(* PROCEDURE TO WRITE DEFAULT VALUES *)
(**************************************)

PROCEDURE DEFAULT;
BEGIN
GOTOXY (X,Y);
WRITE (VBL:SIZE:DECIMALS);
END;


PROCEDURE SHIPINPUT;
BEGIN
GETINPUT (1,32,9,6,30000,150000.0,MAXWT,ESCAPE,RETURN,1);
IF RETURN THEN DEFAULT (MAXWT,32,9,6,1);
IF ESCAPE THEN EXIT (COMPUTE);
GETINPUT (1,33,10,5,10000,40000.0,TRACWT,ESCAPE,RETURN,1);
IF RETURN THEN DEFAULT (TRACWT,32,10,6,1);
IF ESCAPE THEN EXIT (COMPUTE);
GETINPUT (1,33,11,5,5000,35000.0,TRLRWT,ESCAPE,RETURN,1);
IF RETURN THEN DEFAULT (TRLRWT,32,11,6,1);
IF ESCAPE THEN EXIT (COMPUTE);
GETINPUT (1,33,12,5,1500,10000,TRLRCUBE,ESCAPE,RETURN,1);
IF RETURN THEN DEFAULT (TRLRCUBE,32,12,6,1);
IF ESCAPE THEN EXIT (COMPUTE);
GETINPUT (1,34,13,4,0.1,1000,DENSITY,ESCAPE,RETURN,1);
IF RETURN THEN DEFAULT (DENSITY,32,13,6,1);
IF ESCAPE THEN EXIT (COMPUTE);
GETINPUT (1,32,14,6,1,1.0E6,QUANTITY,ESCAPE,RETURN,0);
IF ESCAPE THEN EXIT (COMPUTE);
REPEAT
     SPOT (32,15,A,ESCAPE,RETURN);
     IF ESCAPE THEN EXIT (COMPUTE);
     IF (A<>'P') AND (A<>'T') AND (A<>'K') THEN ERASE (32,15,1);
UNTIL (A='P') OR (A='T') OR (A='K');
GOTOXY (32,15);
```

```
CASE A OF
      'P': WRITE ('POUNDS');
      'T': BEGIN
            WRITE ('TONS');
            QUANTITY:=QUANTITY*2000;
           END;
      'K': BEGIN
            WRITE ('KG');
            QUANTITY:=QUANTITY*2.2;
           END
     END;
PAUSE (2.5);
END;

BEGIN
SHIPCHEK:=FALSE;
R:=32767;
QUANTITY:=0;
REPEAT
      WRITE (CHR(12));
      GOTOXY (9,6);
      WRITE ('** SHIPMENT DATA **');
      GOTOXY (0,9);
      WRITE ('LEGAL MAXIMUM G.V.W. (LBS).....:');
      GOTOXY (0,10);
      WRITE ('TRACTOR TARE WEIGHT (LBS)......:');
      GOTOXY (0,11);
      WRITE ('TRAILER TARE WEIGHT (LBS)......:');
      GOTOXY (0,12);
      WRITE ('TRAILER CUBIC CAPACITY (CU-FT).:');
      GOTOXY (0,13);
      WRITE ('PRODUCT DENSITY (LBS/CU-FT)....:');
      GOTOXY (0,14);
      WRITE ('SHIPMENT SIZE..................:');
      GOTOXY (3,15);
      WRITE ('UNITS: P(OUNDS, T(ONS, K(G..:');
      GOTOXY (0,23);
      WRITE ('<ESC>=RESTART  <RETURN> FOR DEFAULT');
      GOTOXY (0,22);
      WRITE ('WANT TO ENTER SHIPMENT DATA?');
      A:=YESNO (1,29,22,ESCAPE);
      IF ESCAPE THEN EXIT (COMPUTE);
      IF A='Y' THEN BEGIN
            SHIPCHEK:=TRUE;
            SHIPINPUT;
            WCAP:=MAXWT-(TRACWT+TRLRWT);
            VCAP:=TRLRCUBE*DENSITY;
            IF WCAP<=VCAP THEN MAXLOAD:=WCAP
                  ELSE MAXLOAD:=VCAP;
            R:=QUANTITY/MAXLOAD;
            IF R<=32766 THEN BEGIN
                  NTRUCKS:=TRUNC (QUANTITY/MAXLOAD);
                  IF (QUANTITY/MAXLOAD)>(TRUNC(QUANTITY/MAXLOAD)) THEN NTRUCKS:=NTRUCKS+1;
                  AVGLOAD:=QUANTITY/NTRUCKS;
                  IF WCAP<=VCAP THEN LDLIMIT:='LIMITED BY WEIGHT'
                        ELSE LDLIMIT:='LIMITED BY VOLUME'
                 END
                  ELSE BEGIN
                  ERASE (0,22,30);
                  GOTOXY (0,22);
                  WRITE ('SHIPMENT SIZE IS TOO LARGE!!');
                  PAUSE (3)
                 END
          END
           ELSE R:=0;
     UNTIL R<=32766;
RETURN:=FALSE;
IF QUANTITY>0 THEN QUANTITY:=QUANTITY/2000;
END;
```

```
SEGMENT PROCEDURE COSTCOMP;
(************************************)
(* THIS PROCEDURE CALCULATES THE      *)
(* VALUES OF THE 14 COMPONENT COST    *)
(* FACTORS USED IN THE RCAI TRUCK-COST*)
(* MODEL.            4-5-82  DRG      *)
(************************************)
VAR J,N,NN,NNN,NNNN,ITCBPTS        :INTEGER;
    HEAP                           :^INTEGER;
    SUM,I,D,S1,S2,S,S3,S4,S5,CRT   :REAL;
    CHH,CTM,CHW,CDH,CTN,CPMHH      :REAL;
    ITCMAX,B1,B2,B3,B4,B5          :REAL;
    C,PCT                          :ARRAY[1..16] OF REAL;
(************************************)
(* DESCRIPTION OF VARIABLES:          *)
(*     N=LOOP COUNTER                 *)
(*     NNN,NNNN=SPARE INTEGERS        *)
(*     I=INTEREST RATE                *)
(*     D=COMPUTED INV.TAX CREDIT RATE *)
(*     S1,S2,S3,S4,S5=INTERMEDIATE    *)
(*       RESULTS OF CAPITAL COST EQNS. *)
(*     S=SUMMING VARIABLE FOR DEPREC. *)
(*       TAX SHIELD CALCULATIONS      *)
(*     V=GROUP OF INPUT VALUES        *)
(*     C=ARRAY OF COMPUTED COST CONTRI-*)
(*       BUTIONS                      *)
(*     PCT=ARRAY OF COST COMPONENTS   *)
(*       OVER COST PER MILE           *)
(*     B=GROUP OF TRACTOR OR TRAILER  *)
(*       INPUT DATA (TEMPORARY)       *)
(************************************)

PROCEDURE PRINTOUT; FORWARD;
PROCEDURE ITCCOMP (VAR TXLIFE,ITCRATE:REAL); FORWARD;

PROCEDURE ITCCOMP;
VAR N,NN,LLIMIT,ULIMIT             :INTEGER;
BEGIN
N:=0;
CLOSE (ITCBRKS,LOCK);
(*$I-*)
RESET (ITCBRKS,'*ITC.DATA');
(*$I+*)
N:=IORESULT;
IF N<>0 THEN BEGIN
     WRITE (CHR(12));
     GOTOXY (0,23);
     WRITE ('ITC FILE NOT OPENED.  IO ERROR #',N);
     PAUSE (8);
     CLOSE (ITCBRKS,LOCK);
     EXIT (COSTCOMP)
    END;
SEEK (ITCBRKS,0);
GET (ITCBRKS);
N:=ITCBRKS^.BREAKS;
ITCBPTS:=N;
SEEK (ITCBRKS,N);
GET (ITCBRKS);
ITCMAX:=ITCBRKS^.PERCENT;
LLIMIT:=0;
NN:=0;
REPEAT NN:=NN+1;
     SEEK (ITCBRKS,NN);
     GET (ITCBRKS);
     ULIMIT:=ITCBRKS^.BREAKS;
     IF (TXLIFE>=LLIMIT) AND (TXLIFE<ULIMIT) THEN BEGIN
          ITCRATE:=ITCBRKS^.PERCENT;
          CLOSE (ITCBRKS,LOCK);
          EXIT (ITCCOMP);
         END;
     LLIMIT:=ULIMIT;
    UNTIL NN=N;
CLOSE (ITCBRKS,LOCK);
END;
```

```
(**************************************)
(* COST COMPONENT SUBROUTINE BEGINS   *)
(**************************************)
PROCEDURE CAPITAL;
BEGIN
(*SELECT INTEREST RATE*)
IF V1=1 THEN I:=V9/100
     ELSE I:=V12/100;
(*INITIALIZE TRACTOR AND TRAILER CAPITAL COST*)
C[13]:=0;C[14]:=0;
(*REPEAT CAPITAL COST COMPUTATION TWICE*)
(*TRACTOR FIRST THEN TRAILER*)
FOR NN:=1 TO 2 DO BEGIN
     CASE NN OF
          1:BEGIN
               (*COPY TRACTOR DATA TO "B" VARIABLES*)
               B1:=V28; B2:=V29; B3:=V30; B4:=V31; B5:=V32
              END;
          2:BEGIN
               (*COPY TRAILER DATA TO "B" VARIABLES*)
               B1:=V20; B2:=V21; B3:=V22; B4:=V23; B5:=V24
              END
         END;
     IF B1>0 THEN BEGIN
          (*INV.TAX CREDIT RATE*)
          ITCCOMP (B4,D);
          (*COMPUTE INV. TAX CREDIT*)
          S1:=B1 *(D/100);
          (*COMPUTE NPV SALVAGE*)
          S2:=((B3 -((B5/100) *B1 ))*((V11/100)/2))/(EXP(B2 *LN(1+I)));
          (*INIT. SUM VARIABLE AND CONVERT B4 TO INTEGER*)
          S:=0; J:=ROUND (B4 );
          (*COMPUTE NPV OF DEPRC.TAX SHIELD*)
          N:=0; REPEAT N:=N+1;
               S:=S+((((B1-((B5/100) *B1))/B4)*(V11/100))/(EXP(N*LN(1+I))));
               UNTIL N=J; S3:=S;
          (*COMPUTE NPV OF CAPITAL COST*)
          S4:=(B1-(S1+S2+S3))/(1-(V11/100));
          (*COMPUTE ANNUAL CAPITAL OUTLAY*)
          S5:=(S4*I)/(1-(1/(EXP(B2*LN(1+I)))));
          CASE NN OF
               1:C[13]:=(S5/V2)*100;
               2:C[14]:=(S5/V2)*100
              END
         END
          ELSE CASE NN OF
               1:C[13]:=0;
               2:C[14]:=0
              END
    END
END;


PROCEDURE COMPONENT12;
BEGIN
(* COMPUTE INSURANCE COST *)
C[1]:=(V13/V2)*100;
(* COMPUTE DRIVER WAGE *)
C[2]:=(V14/V2)*100;
(* COMPUTE DRIVER EXPENSES *)
C[3]:=(V15/V2)*100;
(* INCREMENTAL EXPENSE EQN ===>MPMEAL:=MPDAY/3;
C[3]:=(TRUNC(V3/MPDAY)*NIGHTRATE)+(TRUNC(V3/MPMEAL)*MEALRATE);
C[3]:=(C[3]*100)/V3;<=== ******)
(* COMPUTE FUEL COST *)
C[4]:=V7/V8;
(* COMPUTE OVERHEAD COST *)
C[5]:=(V16/V2)*100;
(* COMPUTE LICENSE AND PERMIT COST *)
C[6]:=(V17/V2)*100;
(* COMPUTE 3RD STRUCTURE TAX *)
C[7]:=V18;
(* COMPUTE FEDERAL HIGHWAY USER TAX *)
```

```
C[8]:=(V19/V2)*100;
(* COMPUTE TRACTOR MAINTENANCE COST *)
(* TEST INPUT VALUE FOR $MI. OR CENTSMI. *)
IF V35<=50 THEN C[9]:=V35
     ELSE C[9]:=(V35/V2)*100;
MR:=C[9]*V2/100;
(* COMPUTE TRACTOR TIRE COST *)
C[10]:=(V33/V34)*100;
(* COMPUTE TRAILER MAINTENANCE COST *)
(* TEST INPUT VALUE FOR $MI. OR CENTSMI. *)
IF V27<=10 THEN C[11]:=V27
     ELSE C[11]:=(V27/V2)*100;
ML:=C[11]*V2/100;
(* COMPUTE TRAILER TIRE COST *)
C[12]:=(V25/V26)*100;
C[15]:=((LCOST+UCOST+WCOST+OCOST)/V3)*100;
C[16]:=(TERMCHARGE/V3)*100;
END;

PROCEDURE TOTALS;

BEGIN
SUM:=0;
FOR N:=1 TO 16 DO SUM:=SUM+C[N];
FOR N:=1 TO 16 DO PCT[N]:=(C[N]/SUM)*100;
SUM:=SUM/100;
CPMHH:=SUM*(V3/V4);
CRT:=SUM*V3;
CHH:=SUM*V4;
CTM:=CRT/(V4*V5);
CHW:=CRT/(V5*20);
CDH:=CRT-CHH;
CTN:=CRT/V5;
GALLONS:=V3/V8;
END;


PROCEDURE STARTRUN;
BEGIN
V2:=MPYSTART-MPYSTEP;
V4:=MHHSTART-MHHSTEP;
END;


PROCEDURE INCREMENT;
BEGIN
V4:=V4+MHHSTEP;
IF V4=MHHSTART THEN V2:=V2+MPYSTEP;
V3:=V4/(PCTLDMIL/100);
END;

PROCEDURE CHECKVAL;
BEGIN
DONE:=FALSE;
IF (V2>=MPYSTOP) AND (V4>=MHHSTOP) THEN DONE:=TRUE
     ELSE IF V4>=MHHSTOP THEN V4:=MHHSTART-MHHSTEP;
END;


PROCEDURE FILEOUT;
VAR N,LASTREC                  :INTEGER;
BEGIN
(*$I-*)
IF NEWFILE THEN BEGIN
     REWRITE (OUTFILE,'*TCM.OUT');
     NEWFILE:=FALSE
    END
     ELSE RESET (OUTFILE,'*TCM.OUT');
IF (IORESULT=10) AND (NOT NEWFILE) THEN REWRITE (OUTFILE,'*TCM.OUT');
(*$I+*)
```

```
SEEK (OUTFILE,0);
GET (OUTFILE);
IF EOF (OUTFILE) THEN N:=0
     ELSE N:=OUTFILE^.RECNUM;
LASTREC:=N+1;;
SEEK (OUTFILE,LASTREC);
OUTFILE^.RECNUM:=LASTREC;
OUTFILE^.CPMILE:=CPMHH;
OUTFILE^.CPTON:=CTN;
OUTFILE^.CPTNMILE:=CTM;
OUTFILE^.MPY:=V2;
OUTFILE^.MHH:=V4;
OUTFILE^.PCTLD:=PCTLDMIL;
OUTFILE^.EQUIPTYP:=V6;
OUTFILE^.EQUIPOWN:=V1;
PUT (OUTFILE);
SEEK (OUTFILE,0);
OUTFILE^.RECNUM:=LASTREC;
OUTFILE^.CPMILE:=0.0;
OUTFILE^.CPTON:=0.0;
OUTFILE^.CPTNMILE:=0.0;
OUTFILE^.MPY:=0.0;
OUTFILE^.MHH:=0.0;
OUTFILE^.PCTLD:=0.0;
OUTFILE^.EQUIPTYP:=0;
OUTFILE^.EQUIPOWN:=0;
PUT (OUTFILE);
CLOSE (OUTFILE,LOCK);
PAGE (OUTPUT);
GOTOXY (0,10);
WRITE ('TRUCK COST MODEL RUNNING...');
GOTOXY (0,21);
WRITE ('RUN #',LASTREC,' IS COMPLETE');
GOTOXY (0,23);
WRITE ('HIT ANY KEY TO INTERRUPT THE PROGRAM!');
GOTOXY (79,23);
END;



PROCEDURE DISPLAY;

VAR A:CHAR;

BEGIN
UNITCLEAR (1);
WRITELN (CHR(12));WRITELN;WRITELN;
WRITELN ('        ***  TRIP COSTS  ***');
WRITELN;
WRITELN ('COST PER MILE...........$',SUM:7:4);
WRITELN ('COST PER HEADHAUL MILE..$',CPMHH:7:4);
WRITELN ('COST PER ROUND TRIP.....$',CRT:7:2);
WRITELN ('COST OF HEADHAUL........$',CHH:7:2);
WRITELN ('COST PER TON-MILE.......$',CTM:7:4);
WRITELN ('COST PER CWT............$',CHW:7:4);
WRITELN ('COST PER TON............$',CTN:7:2);
WRITELN ('GALLONS OF FUEL CONSUMED:',GALLONS:7:2);
A:='*';
GOTOXY (0,14);
WRITE ('WANT PRINTED OUTPUT?? (Y,N)  ');
A:=YESNO (1,29,14,ESCAPE);
IF ESCAPE THEN EXIT (COSTCOMP);
WRITELN;WRITELN;
IF A='Y' THEN BEGIN
      WRITELN ('OUTPUT TO PRINTER...');
      PRINTOUT;
     END;
END;
```

```
PROCEDURE PRINTOUT;
CONST B='...........';
      BL=' ';
      D='$';
      E='CENTS';

VAR LINE                              :STRING[136];
    I,N                               :INTEGER;
    WT                                :REAL;
    PL                                :ARRAY[1..20] OF STRING;
    TONS,A                            :STRING;


PROCEDURE GRAB (HOWMANY:INTEGER);
VAR N                                 :INTEGER;
BEGIN
FOR N:=1 TO HOWMANY DO BEGIN
     GET (F);
     LINE:=F^.S;
     WRITELN (P,LINE);
    END;
END;


PROCEDURE SPACE (HOWMANY:INTEGER);
VAR N                                 :INTEGER;
BEGIN
FOR N:=1 TO HOWMANY DO WRITELN (P);
END;



PROCEDURE PRINT1;
VAR S1,S2                        :STRING;
BEGIN
SPACE (2);
GRAB (2);
TRUNCSTRING (RUNS,S1);
TRUNCSTRING (COMPS,S2);
WRITELN(P,MONTH:2,'/',DAY:2,'/',YEAR,BL:8,SERIAL,':',S1,'/',S2);
SPACE (1);
GRAB (1);
SPACE (1);
GRAB (3);
WT:=V5*2000;
WRITELN (P,ORIGIN:12,DEST:16,CARGO:16,BL:6,WT:8:2,BL:4,HHMILES:9:2,BL:4,
     RTMILES:9:2,BL:4,DHMILES:9:2,BL:5,VHH:8:2,BL:4,VDH:8:2,BL:5,
     NSTOPS:5);
SPACE (3);
GRAB (1);
SPACE (1);
GRAB (3);
WRITELN (P,HHTIME:8:2,BL:6,DHTIME:8:2,BL:8,LTIME:6:2,BL:6,UTIME:6:2,BL:6,
     WTIME:6:2,BL:6,OTIME:6:2,BL:12,QUANTITY:8:2,BL:6,DENSITY:8:3,BL:6,
     SHIPLOAD:8:2,BL:6,NTRUCKS:6);
TONS:='    ';
IF SHIPCHEK THEN TONS:='TONS';
WRITELN (P,TONS:90,LDLIMIT:40);
SPACE (2);
GRAB (3);
SPACE (1);
GRAB (4);
END;


PROCEDURE PRINT2;
BEGIN
WRITELN (P,C[1]:5:2,BL:2,C[5]:6:2,BL:2,C[6]:6:2,BL:2,C[8]:6:2,BL:2,
     C[13]:6:2,BL:2,C[14]:6:2,BL:13,
     C[2]:6:2,BL:2,C[3]:6:2,BL:2,C[4]:6:2,BL:2,C[7]:6:2,BL:2,
     C[10]:6:2,BL:2,C[9]:6:2,BL:2,C[12]:6:2,BL:2,C[11]:6:2,BL:2,
     C[15]:6:2,BL:2,C[16]:6:2);
END;
```

```
PROCEDURE PRINT3;
BEGIN
A:=PL[2];
WRITELN (P,PCT[1]:5:2,A,PCT[5]:6:2,A,PCT[6]:6:2,A,
      PCT[8]:6:2,A,PCT[13]:6:2,A,
      PCT[14]:6:2,PL[13],PCT[2]:5:2,A,PCT[3]:6:2,A,PCT[4]:6:2,A,
      PCT[7]:6:2,A,PCT[10]:6:2,A,PCT[9]:6:2,A,
      PCT[12]:6:2,A,PCT[11]:6:2,A,PCT[15]:6:2,A,PCT[16]:5:2,PL[1]);
SPACE (3);
GRAB (2);
SPACE (1);
GRAB (2);
WRITELN (P,D:10,SUM:8:4,D:10,CRT:8:2,D:10,CHH:8:2,D:10,CDH:8:2,D:10,
      CTM:8:4,D:10,CHW:8:2,D:10,CTN:8:2);
(*NAMES;*)
(*PARAM;*)
PAGE (P);
END;


BEGIN
A:='%';
PL[1]:=A;
FOR N:=2 TO 20 DO BEGIN
      A:=CONCAT (A,' ');
      PL[N]:=A;
     END;
RESET (F,'*PRINTFORM.DATA');
REWRITE (P,'*PRINTER:');
SEEK (F,0);
PRINT1;
PRINT2;
PRINT3;
CLOSE (F,LOCK);
CLOSE (P,NORMAL);
END;


PROCEDURE COUNTUP (WHATTODO:INTEGER);
(*************************************)
(* WHATTODO=0 --> READ NUMBERS ONLY *)
(*    "     =1 --> INCREMENT RUNS    *)
(*    "     =2 --> INCREMENT COMPS   *)
(*    "     =3 --> INCREMENT BOTH    *)
(*    "     =4 --> WRITE NUMBERS ONLY*)
(*************************************)
BEGIN
RESET (COUNTFILE,'*COUNTERS.DATA');
IF WHATTODO<4 THEN BEGIN
      SEEK (COUNTFILE,0);
      GET (COUNTFILE);
      IF EOF(COUNTFILE) THEN BEGIN
            COUNTFILE^.SERIALNUM:=0;
            COUNTFILE^.RUNNUM:=0;
            COUNTFILE^.COMPNUM:=0
           END;
      SERIAL:=COUNTFILE^.SERIALNUM;
      RUNS:=COUNTFILE^.RUNNUM;
      COMPS:=COUNTFILE^.COMPNUM;
      CASE WHATTODO OF
            0:;
            1:RUNS:=RUNS+1;
            2:COMPS:=COMPS+1;
            3:BEGIN
                  RUNS:=RUNS+1;
                  COMPS:=COMPS+1;
                 END
           END
     END;
```

```
SEEK (COUNTFILE,0);
COUNTFILE^.SERIALNUM:=SERIAL;
COUNTFILE^.RUNNUM:=RUNS;
COUNTFILE^.COMPNUM:=COMPS;
PUT (COUNTFILE);
CLOSE (COUNTFILE,LOCK);
END;



BEGIN
IF AUTOCOMP THEN BEGIN
     STARTRUN;
     COUNTUP (1);
     REPEAT
           INCREMENT;
           COMPS:=COMPS+1;
           COMPONENT12;
           CAPITAL;
           TOTALS;
           FILEOUT;
           CHECKVAL;
          UNTIL (DONE) OR (KEYPRESS);
     COUNTUP (4)
    END
     ELSE BEGIN
     COUNTUP (3);
     COMPONENT12;
     CAPITAL;
     TOTALS;
     DISPLAY
    END;
IF KEYPRESS THEN UNITCLEAR (1);
END;

SEGMENT PROCEDURE REVISE;

VAR N               :INTEGER;
    R               :REAL;
    ESCAPE,RETURN   :BOOLEAN;

PROCEDURE TRAC;

VAR N,LINE,LINES,I,I1,I2,I3:INTEGER; R,R1,R2:REAL; ST,S1,S2:STRING; A:CHAR;
    ESCAPE,RETURN:BOOLEAN;
    F:FILE OF RECORD
          NAME:STRING[8];
          PRICE,ESALVG:REAL;
          ELIFE,TSALVG,TLIFE:INTEGER
         END;

PROCEDURE LISTFILE; FORWARD;
PROCEDURE LINEIN; FORWARD;


PROCEDURE LINEIN;
BEGIN
(*$I-*)
RESET (F,'*TRACTOR.DATA');
(*$I+*)
I:=IORESULT;
IF I<>0 THEN BEGIN
     ERASE (0,23,40);
     GOTOXY (0,23);
     WRITE ('FILE NOT FOUND ON BOOT DISKETTE !!');
     PAUSE (3);
     EXIT (REVISE)
    END;
```

```
GOTOXY (1,11);
WRITE ('          $        $          YRS     %    YRS');
READIN (1,2,11,8,ST,ESCAPE,RETURN);
F^.NAME:=ST;
GETINPUT (1,12,11,5,0,1.0E5,R,ESCAPE,RETURN,0);
F^.PRICE:=R;
GETINPUT (1,19,11,5,0,7.0E4,R,ESCAPE,RETURN,0);
F^.ESALVG:=R;
GETINPUT (1,25,11,2,0,30,R,ESCAPE,RETURN,0);
F^.ELIFE:=TRUNC (R);
GETINPUT (1,31,11,2,0,75,R,ESCAPE,RETURN,0);
F^.TSALVG:=TRUNC (R);
GETINPUT (1,35,11,2,0,30,R,ESCAPE,RETURN,0);
F^.TLIFE:=TRUNC (R);
GOTOXY (0,23);
WRITE ('IS INPUT LINE CORRECT? (Y,N)');
A:=YESNO (1,29,23,ESCAPE);
IF A='N' THEN ERASE (1,11,40)
     ELSE BEGIN
     SEEK (F,N);
     PUT (F)
    END;
CLOSE (F,LOCK);
END;


PROCEDURE LISTFILE;
BEGIN
(*$I-*)
RESET (F,'*TRACTOR.DATA');
(*$I+*)
IF IORESULT<>0 THEN BEGIN
     ERASE (0,23,40);
     GOTOXY (0,23);
     WRITE ('FILE NOT FOUND ON BOOT DISKETTE !!');
     PAUSE (3);
     EXIT (REVISE)
    END;
SEEK (F,N);
GET (F);
IF EOF(F) THEN BEGIN
     GOTOXY (11,14);
     WRITE ('****************');
     GOTOXY (11,15);
     WRITE ('*FILE IS EMPTY!*');
     GOTOXY (11,16);
     WRITE ('****************');
     LINES:=0;
     CLOSE (F,LOCK);
     EXIT (LISTFILE)
    END
     ELSE BEGIN
     LINES:=1;
     ST:=F^.NAME;
     R1:=F^.PRICE;
     R2:=F^.ESALVG;
     TRUNCSTRING (R1,S1);
     TRUNCSTRING (R2,S2);
     I1:=F^.ELIFE;
     I2:=F^.TSALVG;
     I3:=F^.TLIFE;
     GOTOXY (2,11);
     WRITE (ST:8,' $',S1:5,' $',S2:5,I1:3,'YRS',I2:3,'% ',I3:2,'YRS')
    END;
CLOSE (F,LOCK);
END;
```

```
BEGIN
PAGE (OUTPUT);
N:=0;
GOTOXY (8,6);
WRITE ('** TRACTOR DATA FILE **');
GOTOXY (0,8);
WRITE ('  TRACTOR   PRICE  -ECONOMIC-  ---TAX---');
GOTOXY (0,9);
WRITE ('   TYPE       ($)    SLVG  LIFE  SLVG LIFE');
LISTFILE;
GOTOXY (0,23);
WRITE ('STILL WANT TO MODIFY?');
A:=YESNO (1,22,23,ESCAPE);
IF A='Y' THEN BEGIN
     IF LINES=0 THEN BEGIN
          ERASE (11,14,20);
          ERASE (11,15,20);
          ERASE (11,16,20)
         END;
     ERASE (0,23,40);
     LINEIN;
     ERASE (0,23,40);
    END;

END;

PROCEDURE TRLR;

VAR N,LINE,LINES,I,I1,I2,I3:INTEGER; R,R1,R2:REAL; ST,S1,S2:STRING; A:CHAR;
    ESCAPE,RETURN:BOOLEAN;
    F:FILE OF RECORD
         NAME:STRING[8];
         PRICE,ESALVG:REAL;
         ELIFE,TSALVG,TLIFE:INTEGER
        END;

PROCEDURE LISTFILE; FORWARD;
PROCEDURE LINEIN (RECNUM:INTEGER); FORWARD;


PROCEDURE LINEIN;
BEGIN
(*$I-*)
RESET (F,'*TRAILER.DATA');
(*$I+*)
IF IORESULT<>0 THEN BEGIN
     ERASE (0,23,40);
     GOTOXY (0,23);
     WRITE ('FILE NOT FOUND ON BOOT DISKETTE !!');
     PAUSE (3);
     EXIT (REVISE)
    END;
N:=RECNUM;
LINE:=N+11;
GOTOXY (1,LINE);
WRITE ('             $        $           YRS    %    YRS');
READIN (1,2,LINE,8,ST,ESCAPE,RETURN);
F^.NAME:=ST;
GETINPUT (1,12,LINE,5,0,1.0E5,R,ESCAPE,RETURN,0);
F^.PRICE:=R;
GETINPUT (1,19,LINE,5,0,50000.0,R,ESCAPE,RETURN,0);
F^.ESALVG:=R;
GETINPUT (1,25,LINE,2,0,30,R,ESCAPE,RETURN,0);
F^.ELIFE:=TRUNC (R);
GETINPUT (1,31,LINE,2,0,75,R,ESCAPE,RETURN,0);
F^.TSALVG:=TRUNC (R);
GETINPUT (1,35,LINE,2,0,30,R,ESCAPE,RETURN,0);
F^.TLIFE:=TRUNC (R);
GOTOXY (0,23);
WRITE ('IS LINE #',N,' CORRECT? (Y,N)');
A:=YESNO (1,26,23,ESCAPE);
IF A='N' THEN ERASE (1,LINE,40)
```

```
     ELSE BEGIN
     LINES:=LINES+1;
     SEEK (F,N);
     PUT (F)
    END;
CLOSE (F,LOCK);
END;


PROCEDURE LISTFILE;
BEGIN
(*$I-*)
RESET (F,'*TRAILER.DATA');
(*$I+*)
IF IORESULT<>0 THEN BEGIN
     ERASE (0,23,40);
     GOTOXY (0,23);
     WRITE ('FILE NOT FOUND ON BOOT DISKETTE !!');
     PAUSE (3);
     EXIT (REVISE)
    END;
N:=-1;
REPEAT N:=N+1;
     LINE:=N+11;
     LINES:=N;
     SEEK (F,N);
     GET (F);
     IF EOF(F) THEN N:=9
          ELSE BEGIN
          ST:=F^.NAME;
          R1:=F^.PRICE;
          R2:=F^.ESALVG;
          TRUNCSTRING (R1,S1);
          TRUNCSTRING (R2,S2);
          I1:=F^.ELIFE;
          I2:=F^.TSALVG;
          I3:=F^.TLIFE;
          GOTOXY (2,LINE);
          WRITE (ST:8,' $',S1:5,' $',S2:5,I1:3,'YRS',I2:3,'% ',I3:2,'YRS')
         END;
    UNTIL  (N=9);
IF LINES=0 THEN BEGIN
     GOTOXY (11,14);
     WRITE ('****************');
     GOTOXY (11,15);
     WRITE ('*FILE IS EMPTY!*');
     GOTOXY (11,16);
     WRITE ('****************')
    END;
CLOSE (F,LOCK);
END;


BEGIN
PAGE (OUTPUT);
GOTOXY (8,6);
WRITE ('** TRAILER DATA FILE **');
GOTOXY (0,8);
WRITE ('# TRAILER   PRICE  -ECONOMIC-  ---TAX---');
GOTOXY (0,9);
WRITE ('   TYPE      ($)   SLVG  LIFE  SLVG LIFE');
FOR N:=0 TO 9 DO BEGIN
     GOTOXY (0,N+11);
     WRITE (N);
    END;
LISTFILE;
ERASE (0,23,40);
GOTOXY (0,23);
WRITE ('STILL WANT TO MODIFY?');
A:=YESNO (1,22,23,ESCAPE);
IF A='Y' THEN BEGIN
```

```
      IF LINES=0 THEN BEGIN
           ERASE (11,14,20);
           ERASE (11,15,20);
           ERASE (11,16,20)
          END;
      REPEAT
           ERASE (0,23,40);
           GOTOXY (0,23);
           WRITE ('MODIFY WHICH LINE?');
           I:=LINES+1;
           GETINPUT (1,19,23,1,0,I,R,ESCAPE,RETURN,0);
           N:=TRUNC(R);
           LINEIN (N);
           ERASE (0,23,40);
           GOTOXY (0,23);
           WRITE ('MORE MODIFICATIONS?');
           A:=YESNO (1,20,23,ESCAPE);
          UNTIL A='N';
     END;

END;

PROCEDURE DEFAULTS;
VAR N                                       :INTEGER;
     NUM                                    :REAL;
     ESCAPE,RETURN                          :BOOLEAN;
     S                                      :STRING;
     DEFAULTFILE                            :FILE OF RECORD
                                                   NAME:STRING[25];
                                                   VALUE:REAL
                                                  END;

BEGIN
WRITE (CHR(12));
GOTOXY (7,4);
WRITE ('** INPUT DEFAULT VALUES **');
GOTOXY (0,7);
WRITE (' # DESCRIPTION                              VALUE');
(*$I-*)
RESET (DEFAULTFILE,'*DEFAULT.DATA');
(*$I+*)
IF IORESULT<>0 THEN BEGIN
      GOTOXY (0,23);
      WRITE ('DEFAULT FILE NOT FOUND!!');
      PAUSE (3);
      EXIT (DEFAULTS)
     END;
FOR N:=0 TO 11 DO BEGIN
      SEEK (DEFAULTFILE,N);
      GET (DEFAULTFILE);
      S:=DEFAULTFILE^.NAME;
      NUM:=DEFAULTFILE^.VALUE;
      GOTOXY (0,(N+9));
      WRITE (N:2,' ',S,'  ',NUM:8:2);
     END;
GOTOXY (0,23);
WRITE ('<ESC>=RESTART  <RETURN> TO CONTINUE');
REPEAT
      GOTOXY (0,22);
      WRITE ('NUMBER OF RECORD TO BE REVISED:  ');
      GETINPUT (1,31,22,2,0,11,NUM,ESCAPE,RETURN,1);
      IF ESCAPE THEN EXIT (DEFAULTS);
      IF NOT RETURN THEN BEGIN
```

```
          N:=TRUNC(NUM);
          SEEK (DEFAULTFILE,N);
          GET (DEFAULTFILE);
          ERASE (30,(N+9),10);
          GETINPUT (1,31,(N+9),8,0,1.0E6,NUM,ESCAPE,RETURN,0);
          IF ESCAPE THEN EXIT (DEFAULTS);
          SEEK (DEFAULTFILE,N);
          DEFAULTFILE^.VALUE:=NUM;
          PUT \(DEFAULTFILE)
         END;
    UNTIL RETURN;
CLOSE (DEFAULTFILE,LOCK);
END;

PROCEDURE MISCDFLT;
VAR N                               :INTEGER;
    NUM                             :REAL;
    ESCAPE,RETURN                   :BOOLEAN;
    S                               :STRING;
    DEFAULTFILE                     :FILE OF RECORD
                                          NAME:STRING[25];
                                          VALUE:REAL
                                         END;

BEGIN
WRITE (CHR(12));
GOTOXY (7,1);
WRITE ('** MISC. DEFAULT VALUES **');
GOTOXY (0,3);
WRITE (' # DESCRIPTION                        VALUE');
(*$I-*)
RESET (DEFAULTFILE,'*MISC.DATA');
(*$I+*)
IF IORESULT<>0 THEN BEGIN
     GOTOXY (0,23);
     WRITE ('MISC. DEFAULT FILE NOT FOUND!!');
     PAUSE (3);
     EXIT (MISCDFLT)
    END;
FOR N:=0 TO 15 DO BEGIN
     SEEK (DEFAULTFILE,N);
     GET (DEFAULTFILE);
     S:=DEFAULTFILE^.NAME;
     NUM:=DEFAULTFILE^.VALUE;
     GOTOXY (0,(N+5));
     WRITE (N:2,' ',S,'  ',NUM:8:2);
    END;
GOTOXY (0,23);
WRITE ('<ESC>=RESTART  <RETURN> TO CONTINUE');
REPEAT
     GOTOXY (0,22);
     WRITE ('NUMBER OF RECORD TO BE REVISED:  ');
     GETINPUT (1,31,22,2,0,15,NUM,ESCAPE,RETURN,1);
     IF ESCAPE THEN EXIT (MISCDFLT);
     IF NOT RETURN THEN BEGIN
          N:=TRUNC(NUM);
          SEEK (DEFAULTFILE,N);
          GET (DEFAULTFILE);
          ERASE (30,(N+5),10);
          GETINPUT (1,31,(N+5),8,0,1.0E6,NUM,ESCAPE,RETURN,0);
          IF ESCAPE THEN EXIT (MISCDFLT);
          SEEK (DEFAULTFILE,N);
          DEFAULTFILE^.VALUE:=NUM;
          PUT (DEFAULTFILE)
         END;
    UNTIL RETURN;
CLOSE (DEFAULTFILE,LOCK);
END;
```

```
BEGIN
REPEAT
     WRITE (CHR(12));
     GOTOXY (6,3);
     WRITE ('** FILE REVISION UNIT **');
     GOTOXY (6,6);
     WRITE ('1.     TRACTOR DATA');
     GOTOXY (6,8);
     WRITE ('2.     TRAILER DATA');
     GOTOXY (6,10);
     WRITE ('3.     INPUT DEFAULTS');
     GOTOXY (6,12);
     WRITE ('4.     MISC. DEFAULTS');
     GOTOXY (0,22);
     WRITE ('ENTER NUMBER OF FILE TO MODIFY ');
     GOTOXY (0,23);
     WRITE ('<ESC>=RESTART  <RETURN>=CONTINUE');
     GETINPUT (1,31,22,1,1,4,R,ESCAPE,RETURN,1);
     IF ESCAPE THEN EXIT (REVISE);
     IF NOT RETURN THEN BEGIN
          N:=TRUNC (R);
          CASE N OF
               1:TRAC;
               2:TRLR;
               3:DEFAULTS;
               4:MISCDFLT
              END
         END;
    UNTIL RETURN;
END;


(*$S+*)
UNIT ROUTINES;
INTRINSIC CODE 23 DATA 24;
INTERFACE

     USES APPLESTUFF;
     VAR PRINTER:TEXT;


     PROCEDURE CURSORMOVE (XMIN,XMAX,YMIN,YMAX,XSTEP,YSTEP:INTEGER; VAR X,
                           Y:INTEGER; VAR ESCAPE:BOOLEAN);
     PROCEDURE DISPLAYPAGE (PAGENUM:INTEGER);
     PROCEDURE BLANKPAGE (PAGENUM:INTEGER);
     PROCEDURE PAUSE (SECONDS:REAL);
     PROCEDURE SPOT (X,Y:INTEGER; VAR A:CHAR; VAR ESCAPE,RETURN:BOOLEAN);
     PROCEDURE GETCHAR (X,Y:INTEGER; VAR A:CHAR; VAR ESCAPE,RETURN:BOOLEAN);
     PROCEDURE ERASE (X,Y,SIZE:INTEGER);
     PROCEDURE TRUNCSTRING (REALNUM:REAL; VAR NUMSTRG:STRING);
     PROCEDURE READIN (BLINKON,X,Y,SIZE:INTEGER; VAR ST:STRING; VAR ESCAPE,
                       RETURN:BOOLEAN);
     PROCEDURE GETINPUT (BLINKON,X,Y,SIZE:INTEGER; LLIMIT,ULIMIT:REAL;
                         VAR RLOUT:REAL; VAR ESCAPE,RETURN:BOOLEAN;
                         RETURNON:INTEGER);
     PROCEDURE SCREENDUMP;
     FUNCTION NUMBERSZ (CHARSTRING:STRING; VAR LF:INTEGER):REAL;
     FUNCTION NUMBER (CHARSTRING:STRING):REAL;
     FUNCTION REALTRUNC (REALNUM:REAL):REAL;
     FUNCTION YESNO (BLINKON,X,Y:INTEGER; VAR ESCAPE:BOOLEAN):CHAR;

IMPLEMENTATION


     PROCEDURE CURSORMOVE;
     VAR N:INTEGER;
         A:STRING[1];
         KEY:CHAR;
         PAGE1:BOOLEAN;
```

```
BEGIN
ESCAPE:=FALSE;
X:=XMIN;
Y:=YMIN;
N:=40;
GOTOXY (0,21);
WRITE (' I');
GOTOXY (0,22);
WRITE ('J K=MOVE  <ESC>=QUIT  <RETURN>=ENTER');
GOTOXY (0,23);
WRITE (' M');
IF XMAX>39 THEN BEGIN
     N:=80;
     GOTOXY (40,21);
     WRITE (' I');
     GOTOXY (40,22);
     WRITE ('J K=MOVE  <ESC>=QUIT  <RETURN>=ENTER');
     GOTOXY (40,23);
     WRITE (' M')
    END;
GOTOXY (X,Y);
REPEAT
     A[1]:=' ';
     GOTOXY (X,Y);
     UNITREAD (2,A[1],1);
     IF ORD(A[1])=27 THEN BEGIN
          ESCAPE:=TRUE;
          ERASE (0,21,N);
          ERASE (0,22,N);
          ERASE (0,23,N);
          DISPLAYPAGE (1);
          EXIT (CURSORMOVE)
         END;
     KEY:=A[1];
     IF X<=39 THEN PAGE1:=TRUE
          ELSE PAGE1:=FALSE;
     CASE KEY OF
          'J':BEGIN
               IF X>XMIN THEN X:=X-XSTEP
                    ELSE BEGIN
                    IF (X=XMIN) AND (Y>YMIN) THEN BEGIN
                         X:=XMAX;
                         Y:=Y-YSTEP
                        END
                   END;
              END;
          'I':BEGIN
               IF Y>YMIN THEN Y:=Y-YSTEP
                    ELSE BEGIN
                    IF (Y=YMIN) AND (X>XMIN) THEN BEGIN
                         Y:=YMAX;
                         X:=X-XSTEP
                        END
                   END;
              END;
          'M':BEGIN
               IF Y<YMAX THEN Y:=Y+YSTEP
                    ELSE BEGIN
                    IF (Y=YMAX) AND (X<XMAX) THEN BEGIN
                         Y:=YMIN;
                         X:=X+XSTEP
                        END
                   END;
              END;
          'K':BEGIN
               IF X<XMAX THEN X:=X+XSTEP
                    ELSE BEGIN
                    IF (X=XMAX) AND (Y<YMAX) THEN BEGIN
                         X:=XMIN;
                         Y:=Y+YSTEP
                        END
                   END;
              END;
         END;
```

```
     IF (PAGE1) AND (X>39) THEN DISPLAYPAGE (2);
     IF (NOT PAGE1) AND (X<=39) THEN DISPLAYPAGE (1);
    UNTIL KEY=CHR(13);
DISPLAYPAGE (1);
ERASE (0,21,N);
ERASE (0,22,N);
ERASE (0,23,N);
END;


PROCEDURE DISPLAYPAGE;
TYPE PA=PACKED ARRAY [0..1] OF 0..255;
     TWOFACE=RECORD CASE BOOLEAN OF
          TRUE:(INT:INTEGER);
          FALSE:(PTR:^PA)
         END;
VAR CHEAT:TWOFACE;
BEGIN
CASE PAGENUM OF
     1:CHEAT.INT:=-16300;
     2:CHEAT.INT:=-16299;
    END;
UNITCLEAR (1);
IF (PAGENUM=1) OR (PAGENUM=2) THEN CHEAT.PTR^[0]:=0;
END;


PROCEDURE BLANKPAGE;
CONST BLANKLINE='
VAR X,Y:INTEGER;
BEGIN
IF (PAGENUM IN [1..2]) THEN BEGIN
     IF PAGENUM=1 THEN X:=0
          ELSE X:=40;
     FOR Y:=0 TO 23 DO BEGIN
          GOTOXY (X,Y);
          WRITE (BLANKLINE);
         END
    END;
END;


PROCEDURE PAUSE;
VAR N,LIMIT:INTEGER;
BEGIN
LIMIT:=TRUNC(SECONDS*1000);
N:=0;
REPEAT
     N:=N+1;
    UNTIL N=LIMIT;
END;


PROCEDURE SPOT;
VAR I:INTEGER;
BEGIN
GOTOXY (X,Y);
IF X>39 THEN I:=0
     ELSE I:=79;
PAUSE (0.1);
REPEAT
     WHILE NOT KEYPRESS DO BEGIN
          GOTOXY (I,Y);
          PAUSE (0.1);
          GOTOXY (X,Y);
          PAUSE (0.1);
         END;
```

```
      READ (A);
      IF ORD (A)=4 THEN SCREENDUMP;
     UNTIL ORD (A)<>4;
ESCAPE:=(ORD(A)=27);
RETURN:=(EOLN);
IF EOLN THEN GOTOXY (X,Y);
END;



PROCEDURE GETCHAR;
BEGIN
REPEAT
      GOTOXY (X,Y);
      READ (A);
      IF ORD (A)=4 THEN SCREENDUMP;
     UNTIL ORD (A)<>4;
ESCAPE:=(ORD(A)=27);
RETURN:=(EOLN);
END;

PROCEDURE SCREENDUMP;
TYPE PA= PACKED ARRAY[1..40] OF 0..255;
VAR ADDR      :ARRAY[1..3] OF INTEGER;
    DATA      :RECORD
                   CASE BOOLEAN OF
                        TRUE  :(INT:INTEGER);
                        FALSE :(PTR:^PA)
                       END;
     I,J,K,L,M:INTEGER;
BEGIN
ADDR[1]:=1024; ADDR[2]:=1064; ADDR[3]:=1104;
REWRITE (PRINTER,'PRINTER:');
PAGE (PRINTER);
FOR I:=1 TO 3 DO
     FOR J:=0 TO 7 DO
          BEGIN
          FOR K:=0 TO 1 DO
               BEGIN
               DATA.INT:=ADDR[I]+(J*128)+(K*1024);
               FOR L:=1 TO 40 DO
                    BEGIN
                    M:=DATA.PTR^[L];
                    IF NOT (M IN [32..95]) THEN
                         BEGIN
                         IF M IN [0..31] THEN M:=M+64;
                         IF M IN [96..159] THEN M:=M-64;
                         IF M IN [160..223] THEN M:=M-128;
                         IF M IN [224..255] THEN M:=M-160
                        END;
                    WRITE (PRINTER,CHR(M));
                   END
              END;
          WRITELN (PRINTER)
         END;
CLOSE (PRINTER,NORMAL)
END;


PROCEDURE ERASE;
VAR N:INTEGER;
    STR:STRING;
BEGIN
STR:='';
FOR N:=1 TO SIZE DO STR:=CONCAT(STR,' ');
GOTOXY (X,Y);
WRITE (STR);
END;
```

```
FUNCTION REALTRUNC;
(*************************************)
(* FUNCTION TO TRUNCATE ANY SIZE REAL *)
(* NUMBER WITHOUT 'TRUNC' FUNCTION.   *)
(* THE PROCEDURE RETURNS A REAL VALUE.*)
(* DRG. 5/17/82                       *)
(*************************************)

VAR TNUM,NUM,REM:REAL;
    M,N,PTR,SIGN:INTEGER;
    DIGIT: ARRAY[0..40] OF INTEGER;


BEGIN
SIGN:=1;
IF REALNUM<0 THEN BEGIN
      SIGN:=-1;
      REALNUM:=REALNUM*SIGN
     END;
N:=-1;
REPEAT N:=N+1;
      PTR:=N;
      NUM:=REALNUM/PWROFTEN(N);
     UNTIL (NUM<10) AND (NUM>=0);
REM:=REALNUM;
FOR N:=PTR DOWNTO 0 DO BEGIN
      NUM:=REM/PWROFTEN(N);
      DIGIT[N]:=TRUNC (NUM);
      REM:=(NUM-DIGIT[N])*PWROFTEN(N);
     END;
TNUM:=0;
FOR N:=0 TO PTR DO BEGIN
      TNUM:=TNUM+(DIGIT[N]*PWROFTEN(N));
     END;
WHILE (REALNUM-TNUM>=1) DO BEGIN
      TNUM:=TNUM+1;
      DIGIT[0]:=DIGIT[0]+1;
      N:=-1;
      REPEAT N:=N+1;
            IF DIGIT[N]>9 THEN BEGIN
                  DIGIT[N]:=0;
                  DIGIT[N+1]:=DIGIT[N+1]+1
                 END;
           UNTIL N=PTR;
     END;
REALTRUNC:=TNUM*SIGN;
END;


PROCEDURE TRUNCSTRING;
(*************************************)
(* PROCEDURE TO TRUNCATE ANY SIZE REAL*)
(* NUMBER AND RETURN A "STRING" OF    *)
(* DIGITS.                            *)
(* DRG. 6/7/82                        *)
(*************************************)

VAR TNUM,NUM,REM:REAL;
    L,M,N,PTR,SIGN:INTEGER;
    DIGIT: ARRAY[0..40] OF INTEGER;


BEGIN
SIGN:=1;
IF REALNUM<0 THEN BEGIN
      SIGN:=-1;
      REALNUM:=REALNUM*SIGN
     END;
N:=-1;
REPEAT N:=N+1;
```

```
      PTR:=N;
      NUM:=REALNUM/PWROFTEN(N);
     UNTIL (NUM<10) AND (NUM>=0);
REM:=REALNUM;
FOR N:=PTR DOWNTO 0 DO BEGIN
      NUM:=REM/PWROFTEN(N);
      DIGIT[N]:=TRUNC (NUM);
      REM:=(NUM-DIGIT[N])*PWROFTEN(N);
     END;
TNUM:=0;
FOR N:=0 TO PTR DO BEGIN
      TNUM:=TNUM+(DIGIT[N]*PWROFTEN(N));
     END;
WHILE (REALNUM-TNUM>=1) DO BEGIN
      TNUM:=TNUM+1;
      DIGIT[0]:=DIGIT[0]+1;
      N:=-1;
      REPEAT N:=N+1;
            IF DIGIT[N]>9 THEN BEGIN
                 DIGIT[N]:=0;
                 DIGIT[N+1]:=DIGIT[N+1]+1
                END;
           UNTIL N=PTR;
     END;
NUMSTRG:='';
IF SIGN=-1 THEN BEGIN
      L:=PTR+1;
      FOR N:=0 TO L DO BEGIN
            NUMSTRG:=CONCAT (NUMSTRG,' ');
           END;
      NUMSTRG[1]:='-';
      L:=1
     END
      ELSE BEGIN
      L:=PTR;
      FOR N:=0 TO L DO BEGIN
            NUMSTRG:=CONCAT (NUMSTRG,' ');
           END;
      L:=0
     END;
FOR N:=PTR DOWNTO 0 DO BEGIN
      L:=L+1;
      NUMSTRG[L]:=CHR (DIGIT[N]+48);
     END;
END;


FUNCTION NUMBERSZ;
(* CONVERTS A STRING TO A REAL NUMBER *)

VAR FRACTION,WHOLE:STRING;
     FACTOR,SUM:REAL;
     I:INTEGER;

BEGIN
FRACTION:='';
WHOLE:='';
SUM:=0;
I:=0;

REPEAT
      I:=I+1;
      IF CHARSTRING[I] IN ['0'..'9'] THEN BEGIN
            WHOLE:=CONCAT(WHOLE,' ');
            WHOLE[LENGTH(WHOLE)]:=CHARSTRING[I];
           END;
```

```
     UNTIL (CHARSTRING[I]='.') OR (I=LENGTH(CHARSTRING));
IF I<LENGTH(CHARSTRING) THEN REPEAT
      I:=I+1;
      IF CHARSTRING[I] IN ['0'..'9'] THEN BEGIN
           FRACTION:=CONCAT(FRACTION,' ');
           FRACTION[LENGTH(FRACTION)]:=CHARSTRING[I]
          END
     UNTIL I=LENGTH(CHARSTRING);
IF LENGTH(WHOLE)>0 THEN BEGIN
      FACTOR:=PWROFTEN(LENGTH(WHOLE)-1);
      FOR I:=1 TO LENGTH(WHOLE) DO BEGIN
           SUM:=SUM+FACTOR*(ORD(WHOLE[I])-ORD('0'));
           FACTOR:=FACTOR/10
          END
     END
      ELSE FACTOR:=0.1;
LF:=LENGTH(FRACTION);
IF LENGTH(FRACTION)>0 THEN
      FOR I:=1 TO LENGTH(FRACTION) DO BEGIN
           SUM:=SUM+FACTOR*(ORD(FRACTION[I])-ORD('0'));
           FACTOR:=FACTOR/10
          END;
IF CHARSTRING[1]='-' THEN NUMBERSZ:=(-1)*SUM
      ELSE NUMBERSZ:=SUM
     END;


FUNCTION NUMBER;
(* CONVERTS A STRING TO A REAL NUMBER *)

VAR FRACTION,WHOLE:STRING;
     FACTOR,SUM:REAL;
     I:INTEGER;

BEGIN
FRACTION:='';
WHOLE:='';
SUM:=0;
I:=0;

REPEAT
      I:=I+1;
      IF CHARSTRING[I] IN ['0'..'9'] THEN BEGIN
           WHOLE:=CONCAT(WHOLE,' ');
           WHOLE[LENGTH(WHOLE)]:=CHARSTRING[I];
          END;
     UNTIL (CHARSTRING[I]='.') OR (I=LENGTH(CHARSTRING));
IF I<LENGTH(CHARSTRING) THEN REPEAT
      I:=I+1;
      IF CHARSTRING[I] IN ['0'..'9'] THEN BEGIN
           FRACTION:=CONCAT(FRACTION,' ');
           FRACTION[LENGTH(FRACTION)]:=CHARSTRING[I]
          END
     UNTIL I=LENGTH(CHARSTRING);
IF LENGTH(WHOLE)>0 THEN BEGIN
      FACTOR:=PWROFTEN(LENGTH(WHOLE)-1);
      FOR I:=1 TO LENGTH(WHOLE) DO BEGIN
           SUM:=SUM+FACTOR*(ORD(WHOLE[I])-ORD('0'));
           FACTOR:=FACTOR/10
          END
     END
      ELSE FACTOR:=0.1;
IF LENGTH(FRACTION)>0 THEN
      FOR I:=1 TO LENGTH(FRACTION) DO BEGIN
           SUM:=SUM+FACTOR*(ORD(FRACTION[I])-ORD('0'));
           FACTOR:=FACTOR/10
          END;
IF CHARSTRING[1]='-' THEN NUMBER:=(-1)*SUM
      ELSE NUMBER:=SUM
     END;
```

```
FUNCTION YESNO;
VAR A:CHAR; RETURN:BOOLEAN;
BEGIN
REPEAT
      IF BLINKON=0 THEN GETCHAR (X,Y,A,ESCAPE,RETURN)
           ELSE SPOT (X,Y,A,ESCAPE,RETURN);
      IF (A<>'Y') AND (A<>'N') AND (NOT ESCAPE) THEN BEGIN
           GOTOXY (X,Y);
           WRITE (' ')
          END;
     UNTIL (A='Y') OR (A='N') OR (ESCAPE);
YESNO:=A;
END;



PROCEDURE READIN;
(* READS FROM TERMINAL AS SPECIFIED *)

CONST BL=' ';
VAR BLANK:STRING; L,N,P,BS,PTR:INTEGER;
     A:CHAR;
BEGIN
N:=0;
ST:='';
REPEAT N:=N+1;
      ST:=CONCAT (ST,BL);
     UNTIL N=SIZE;
A:=' ';
PTR:=X;
L:=0;
N:=1;
WHILE L<>SIZE DO BEGIN
      IF L=0 THEN BEGIN
                X:=PTR;
                L:=1;
                REPEAT
                      IF BLINKON=0 THEN GETCHAR (X,Y,A,ESCAPE,RETURN)
                           ELSE SPOT (X,Y,A,ESCAPE,RETURN);
                       IF (ESCAPE) OR (RETURN) THEN EXIT (READIN);
               UNTIL (A<>' ') AND (ORD(A)<>8) ;
           ST[1]:=A
         END;
      IF (L<>SIZE) AND (NOT RETURN) THEN BEGIN
          REPEAT
                X:=X+1;
                N:=N+1;
                L:=L+1;
                IF X=PTR THEN BEGIN
                     REPEAT
                          IF BLINKON=0 THEN GETCHAR (X,Y,A,ESCAPE,RETURN)
                               ELSE SPOT (X,Y,A,ESCAPE,RETURN);
                           IF (ESCAPE) OR (RETURN) THEN EXIT (READIN);
                         UNTIL ORD(A)<>20
                    END
                    ELSE BEGIN
                     IF BLINKON=0 THEN GETCHAR (X,Y,A,ESCAPE,RETURN)
                          ELSE SPOT (X,Y,A,ESCAPE,RETURN);
                      IF (ESCAPE) OR (RETURN) THEN EXIT (READIN);
                    END;
                IF ORD(A)=8 THEN BEGIN
                     REPEAT
                          X:=X-1;
                          L:=L-1;
                          N:=N-1;
                          IF L<>0 THEN BEGIN
                                GOTOXY (X,Y);
                                WRITE (' ');
                                IF BLINKON=0 THEN GETCHAR (X,Y,A,ESCAPE,RETURN)
                                      ELSE SPOT (X,Y,A,ESCAPE,RETURN);
```

```
                                IF (ESCAPE) OR (RETURN) THEN EXIT (READIN)
                               END;
                          UNTIL (ORD(A)<>8) OR (L=0);
                      IF L<>0 THEN ST[N]:=A
                           ELSE N:=1
                          END
                      ELSE ST[N]:=A


                UNTIL (L=SIZE) OR (L=0) OR (RETURN)
           END;
      END;
  N:=0;
  L:=0;
  REPEAT N:=N+1;
       IF ST[N]<>' ' THEN L:=1;
      UNTIL N=SIZE;
  END;


  PROCEDURE GETINPUT;
  VAR  PTR,NONUM,L,LF:INTEGER; RL,NUM:REAL; S:STRING; GOODNUM:BOOLEAN;
  BEGIN

  REPEAT
       IF BLINKON=0 THEN READIN (0,X,Y,SIZE,S,ESCAPE,RETURN)
            ELSE READIN (1,X,Y,SIZE,S,ESCAPE,RETURN);
       IF ESCAPE THEN EXIT (GETINPUT);
       NONUM:=0;
       L:=0;
       REPEAT L:=L+1;
            IF S[L] IN ['0'..'9'] THEN NONUM:=1;
           UNTIL (L=SIZE) OR (NONUM=1);
       RL:=NUMBERSZ (S,LF);
       GOODNUM:=FALSE;
       IF (RL>=LLIMIT)AND(RL<=ULIMIT)AND(NONUM=1) THEN GOODNUM:=TRUE;
       IF RETURNON=0 THEN RETURN:=FALSE;
       IF GOODNUM THEN RETURN:=FALSE;
       IF GOODNUM=FALSE THEN BEGIN
            IF RETURN THEN EXIT (GETINPUT);
            PTR:=X-1;
            NOTE (15,15);
            REPEAT
                 PTR:=PTR+1;
                 GOTOXY (PTR,Y);
                 WRITE (' ');
                UNTIL PTR-X+1=SIZE
           END;
      UNTIL GOODNUM;
  RLOUT:=RL;
  PTR:=X-1;
  REPEAT
       PTR:=PTR+1;
       GOTOXY (PTR,Y);
       WRITE (' ');
      UNTIL PTR-X+1=SIZE;
  GOTOXY (X,Y);
  IF LF=0 THEN BEGIN
       TRUNCSTRING (RLOUT,S);
       WRITE (S:SIZE)
      END
      ELSE WRITE (RLOUT:SIZE:LF);
  END;


BEGIN
END.
```

```
SEGMENT PROCEDURE AUTOINPUT;
VAR S1:STRING;
BEGIN
PAGE (OUTPUT);
UNITCLEAR (1);
GOTOXY (7,6);
WRITE ('** MULTIPLE RUN INPUTS **');
GOTOXY (0,9);
WRITE ('MILES/YEAR  TO START......:');
GOTOXY (0,10);
WRITE ('MILES/YEAR  INCREMENT.....:');
GOTOXY (0,11);
WRITE ('MILES/YEAR  MAXIMUM.......:');
GOTOXY (0,12);
WRITE ('MILES/HEADHAUL  TO START..:');
GOTOXY (0,13);
WRITE ('MILES/HEADHAUL  INCREMENT.:');
GOTOXY (0,14);
WRITE ('MILES/HEADHAUL  MAXIMUM...:');
GOTOXY (0,15);
WRITE ('LOADED MILES AS % OF TOTAL:');
(*$I-*)
RESET (OUTFILE,'*TCM.OUT');
(*$I+*)
NEWFILE:=TRUE;
IF IORESULT=0 THEN BEGIN
     GOTOXY (0,17);
     WRITE ('REMOVE EXISTING OUTPUT FILE??');
     IF YESNO (1,30,17,ESCAPE)='N' THEN BEGIN
          NEWFILE:=FALSE;
          ERASE (0,17,40);
          GOTOXY (0,17);
          WRITE ('OUTPUT WILL BE ADDED TO EXISTING FILE!');
          PAUSE (3)
         END
    END;
CLOSE (OUTFILE,LOCK);
GOTOXY (0,23);
WRITE ('<ESC>=RESTART  ');
GETINPUT (1,27,9,6,5.0E4,5.0E5,MPYSTART,ESCAPE,RETURN,0);
IF ESCAPE THEN EXIT (MAINMENU);
GETINPUT (1,28,10,5,0,25000,MPYSTEP,ESCAPE,RETURN,0);
IF ESCAPE THEN EXIT (MAINMENU);
IF MPYSTEP=0 THEN BEGIN
     MPYSTOP:=MPYSTART;
     TRUNCSTRING (MPYSTOP,S1);
     GOTOXY (27,11);
     WRITE (S1:6)
    END
     ELSE GETINPUT (1,27,11,6,5.0E4,5.0E5,MPYSTOP,ESCAPE,RETURN,0);
IF ESCAPE THEN EXIT (MAINMENU);
GETINPUT (1,29,12,4,50,5000,MHHSTART,ESCAPE,RETURN,0);
IF ESCAPE THEN EXIT (MAINMENU);
GETINPUT (1,30,13,3,50,500,MHHSTEP,ESCAPE,RETURN,0);
IF ESCAPE THEN EXIT (MAINMENU);
GETINPUT (1,29,14,4,100,5000,MHHSTOP,ESCAPE,RETURN,0);
IF ESCAPE THEN EXIT (MAINMENU);
GETINPUT (1,30,15,3,20,100,PCTLDMIL,ESCAPE,RETURN,0);
IF ESCAPE THEN EXIT (MAINMENU);
END;


SEGMENT PROCEDURE PRINTFILE;
CONST BL=' ';
VAR N,LASTREC,TRLRTYP,TRKOWNER,REC :INTEGER;
    PERMILE,PERTON,PERTNMIL,MPYR   :REAL;
    MPHEADHL,LOADDPCT,MILECHEK     :REAL;
    S1,S2                          :STRING;
    P                              :TEXT;
```

```
PROCEDURE COUNTCHEK;
BEGIN
RESET (COUNTFILE,'*COUNTERS.DATA');
SEEK (COUNTFILE,0);
GET (COUNTFILE);
SERIAL:=COUNTFILE^.SERIALNUM;
RUNS:=COUNTFILE^.RUNNUM;
COMPS:=COUNTFILE^.COMPNUM;
CLOSE (COUNTFILE,LOCK);
TRUNCSTRING (RUNS,S1);
TRUNCSTRING (COMPS,S2);
END;

PROCEDURE PRINTHEAD;
BEGIN
IF YEAR=0 THEN WRITELN (P,'TRUCK COST MODEL',BL:12,SERIAL,':',S1,'/',S2)
     ELSE WRITELN (P,'TRUCK COST MODEL  ',MONTH:2,'/',DAY:2,'/',YEAR,
                    BL:2,SERIAL,':',S1,'/',S2);
END;


BEGIN
(*$I-*)
RESET (OUTFILE,'*TCM.OUT');
(*$I+*)
IF IORESULT <>0 THEN BEGIN
     PAGE (OUTPUT);
     CLOSE (OUTFILE,LOCK);
     GOTOXY (0,22);
     WRITE ('NO TCM OUTPUT FILE AVAILABLE!!');
     PAUSE (4);
     EXIT (MAINMENU)
    END
     ELSE BEGIN
     PAGE (OUTPUT);
     GOTOXY (6,15);
     WRITE ('** TRUCK COSTING MODEL **');
     GOTOXY (6,17);
     WRITE ('OUTPUT FILE TO PRINTER...');
     REWRITE (P,'*PRINTER:');
     COUNTCHEK;
     PRINTHEAD;
     SEEK (OUTFILE,0);
     GET (OUTFILE);
     LASTREC:=OUTFILE^.RECNUM;
     MILECHEK:=0;
     FOR N:=1 TO LASTREC DO BEGIN
          SEEK (OUTFILE,N);
          GET (OUTFILE);
          REC:=OUTFILE^.RECNUM;
          PERMILE:=OUTFILE^.CPMILE;
          PERTON:=OUTFILE^.CPTON;
          PERTNMIL:=OUTFILE^.CPTNMILE;
          MPYR:=OUTFILE^.MPY;
          MPHEADHL:=OUTFILE^.MHH;
          LOADPCT:=OUTFILE^.PCTLD;
          TRLRTYP:=OUTFILE^.EQUIPTYP;
          TRKOWNER:=OUTFILE^.EQUIPOWN;
          IF MILECHEK<>MPYR THEN BEGIN
               MILECHEK:=MPYR;
               WRITELN (P);
               WRITELN (P);
               WRITELN (P);
               WRITELN (P,'ANNUAL MILEAGE:',MPYR:10:1,
                     '     TRAILER TYPE: ',TRLRTYP,'     OWNER: ',TRKOWNER,
                     '     LOADED PCT:',LOADPCT:6:1);
               WRITELN (P);
               WRITELN (P,'RUN#      $/MILE      $/TON      $/TONMILE      ',
                     'HH MILES');
               WRITELN (P,'----      ------      -----      ---------      ',
                     '--------');
```

```
                WRITELN (P);
                WRITELN (P,REC:4,PERMILE:11:4,PERTON:10:2,
                     '     ',PERTNMIL:10:4,'   ',MPHEADHL:10:2)
               END
                ELSE WRITELN (P,REC:4,PERMILE:11:4,PERTON:10:2,
                          '     ',PERTNMIL:10:4,'   ',MPHEADHL:10:2);
          END
     END;
CLOSE (OUTFILE,LOCK);
CLOSE (P,NORMAL);
END;



(*****************************************)
(* PROCEDURE TO READ DATA FROM 'SCREEN' *)
(*****************************************)

SEGMENT PROCEDURE READDATA;

VAR DZ,R                                  :REAL;
    S                                     :STRING;
    PROCEDURE DEFAULT (VBL:REAL; X,Y,SIZE,DECIMALS:INTEGER); FORWARD;
(*************************************)
(* PROCEDURE TO WRITE DEFAULT VALUES *)
(*************************************)

PROCEDURE DEFAULT;
BEGIN
GOTOXY (X,Y);
WRITE (VBL:SIZE:DECIMALS);
END;

BEGIN
READIN (1,30,3,10,ORIGIN,ESCAPE,RETURN);
IF ESCAPE THEN EXIT(COMPUTE);
READIN (1,30,4,10,DEST,ESCAPE,RETURN);
IF ESCAPE THEN EXIT(COMPUTE);
READIN (1,30,5,10,CARGO,ESCAPE,RETURN);
IF ESCAPE THEN EXIT(COMPUTE);
IF YEAR=0 THEN GETINPUT (1,13,6,2,1,12,R,ESCAPE,RETURN,0)
     ELSE GETINPUT (1,13,6,2,1,12,R,ESCAPE,RETURN,1);
IF ESCAPE THEN EXIT(COMPUTE);
IF (YEAR<>0) AND (RETURN) THEN BEGIN
     GOTOXY (13,6);
     WRITE (MONTH:2,'..DAY:',DAY:2,'..YEAR:19',YEAR:2)
    END
     ELSE BEGIN
     MONTH:=TRUNC(R);
     IF MONTH=2 THEN DZ:=29
          ELSE BEGIN
          IF (MONTH=4)OR(MONTH=6)OR(MONTH=9)OR(MONTH=11) THEN DZ:=30
               ELSE DZ:=31
              END;
     GETINPUT (1,21,6,2,1,DZ,R,ESCAPE,RETURN,0);
     IF ESCAPE THEN EXIT(COMPUTE);
     DAY:=TRUNC(R);
     GOTOXY (30,6);
     WRITE ('19');
     GETINPUT (1,32,6,2,82,99,R,ESCAPE,RETURN,0);
     IF ESCAPE THEN EXIT(COMPUTE);
     YEAR:=TRUNC(R)
    END;
GETINPUT (1,31,7,5,150,10000,V4,ESCAPE,RETURN,1);
IF RETURN THEN DEFAULT (V4,30,7,6,1);
IF ESCAPE THEN EXIT(COMPUTE);
GETINPUT (1,31,8,5,V4,20000,V3,ESCAPE,RETURN,1);
IF RETURN THEN DEFAULT (V3,30,8,6,1);
IF ESCAPE THEN EXIT(COMPUTE);
GETINPUT (1,30,9,6,V3,3.0E5,V2,ESCAPE,RETURN,1);
IF RETURN THEN DEFAULT (V2,30,9,6,1);
IF ESCAPE THEN EXIT(COMPUTE);
IF NOT SHIPCHEK THEN BEGIN
```

```
      GETINPUT (1,32,10,4,1,75,V5,ESCAPE,RETURN,1);
      LDLIMIT:='                    ';
      SHIPLOAD:=0;
      NTRUCKS:=1;
      DENSITY:=0.0;
      IF RETURN THEN DEFAULT (V5,30,10,6,1);
      IF ESCAPE THEN EXIT(COMPUTE)
     END
     ELSE BEGIN
      V5:=AVGLOAD/2000;
      SHIPLOAD:=V5*2000;
      GOTOXY (0,10);
      WRITE ('AVERAGE PAYLOAD (TONS) ----->:',V5:4:1)
     END;
IF ESCAPE THEN EXIT(COMPUTE);
GETINPUT (1,30,11,6,0,2000,TERMCHARGE,ESCAPE,RETURN,1);
IF RETURN THEN DEFAULT (TERMCHARGE,30,11,6,1);
IF ESCAPE THEN EXIT(COMPUTE);
GETINPUT (1,33,12,3,30,500,V7,ESCAPE,RETURN,1);
IF RETURN THEN DEFAULT (V7,30,12,6,1);
IF ESCAPE THEN EXIT(COMPUTE);
FUEL:=V7/100.0;
GETINPUT (1,33,13,3,1,10,V8,ESCAPE,RETURN,1);
IF RETURN THEN DEFAULT (V8,30,13,6,1);
IF ESCAPE THEN EXIT(COMPUTE);
REPEAT
     READIN (1,30,14,1,S,ESCAPE,RETURN);
     IF ESCAPE THEN EXIT(COMPUTE);
     IF (S[1]<>'C') AND (S[1]<>'D') THEN BEGIN
          IF RETURN THEN BEGIN
               S[1]:='D';
               GOTOXY (30,14);
               WRITE (S[1])
              END
               ELSE BEGIN
               GOTOXY (30,14);
               WRITE (' ')
              END
         END;
    UNTIL S[1] IN ['C'..'D'];
V1:=1; OWNER:='COMPANY';
IF S[1]='D' THEN V1:=0;
IF S[1]='D' THEN OWNER:='DRIVER';
R:=NUMEQUIP;
V6:=2;
GETINPUT (1,30,17,1,0,R,R,ESCAPE,RETURN,1);
IF ESCAPE THEN EXIT(COMPUTE);
IF RETURN THEN BEGIN
      GOTOXY (30,17);
      WRITE (V6)
     END
      ELSE V6:=TRUNC (R);
IF V6=0 THEN V13:=V13*0.7;
RESET (EQUIPFILE,'*TRAILER.DATA');
SEEK (EQUIPFILE,V6);
GET (EQUIPFILE);
EQUIP:=EQUIPFILE^.NAME;
V20:=EQUIPFILE^.PRICE;
V21:=EQUIPFILE^.ELIFE;
V22:=EQUIPFILE^.ESALVG;
V23:=EQUIPFILE^.TLIFE;
V24:=EQUIPFILE^.TSALVG;
CLOSE (EQUIPFILE,LOCK);
IF V1=1 THEN
      BEGIN
      V28:=(1-CORPDISCOUNT)*V28;
      V20:=(1-CORPDISCOUNT)*V20
     END;
END;
```

```
(**************************************************)
(* PROCEDURE TO MANAGE DATA ENTRY AND COMPUTATIONS *)
(**************************************************)

SEGMENT PROCEDURE COMPUTE;
VAR REPLY                                  :CHAR;
    S                                      :STRING;

(**************************************)
(* PROCEDURE TO INITIALIZE VARIABLES *)
(**************************************)

SEGMENT PROCEDURE INITIAL1;

PROCEDURE INITIAL2;
VAR N:INTEGER;
BEGIN
(*$I-*)
RESET (DFLTFILE,'*MISC.DATA');
(*$I+*)
IF IORESULT <>0 THEN BEGIN
     GOTOXY (0,22);
     WRITE ('MISC.DATA FILE MISSING!!');
     PAUSE (4);
     EXIT (COMPUTE)
    END;
FOR N:=0 TO 15 DO BEGIN
     SEEK (DFLTFILE,N);
     GET (DFLTFILE);
     CASE N OF
          0:V9:=DFLTFILE^.VALUE;
          1:V11:=DFLTFILE^.VALUE;
          2:V12:=DFLTFILE^.VALUE;
          3:V13:=DFLTFILE^.VALUE;
          4:V14:=DFLTFILE^.VALUE;
          5:V15:=DFLTFILE^.VALUE;
          6:V16:=DFLTFILE^.VALUE;
          7:V17:=DFLTFILE^.VALUE;
          8:V18:=DFLTFILE^.VALUE;
          9:V19:=DFLTFILE^.VALUE;
          10:V25:=DFLTFILE^.VALUE;
          11:V26:=DFLTFILE^.VALUE;
          12:V27:=DFLTFILE^.VALUE;
          13:V33:=DFLTFILE^.VALUE;
          14:V34:=DFLTFILE^.VALUE;
          15:V35:=DFLTFILE^.VALUE
         END;
    END;
CLOSE (DFLTFILE,LOCK);
END;

(***********************************)
(*PROCEDURE TO GET DEFAULT VALUES *)
(***********************************)

PROCEDURE GETDEFAULT;
(*************************)
(* 0=MAXWT, 1=TRACWT,    *)
(* 2=TRLRWT, 3=TRLRCUBE, *)
(* 4=DENSITY, 5=V4,      *)
(* 6=V3, 7=V2, 8=V5,     *)
(* 9=TERMCHARGE, 10=V7,  *)
(* 11=V8.                *)
(*************************)

VAR N:INTEGER;

BEGIN
(*$I-*)
RESET (DFLTFILE,'*DEFAULT.DATA');
(*$I+*)
```

```
IF IORESULT <>0 THEN BEGIN
      GOTOXY (0,22);
      WRITE ('DEFAULT FILE MISSING!!');
      PAUSE (4);
      EXIT (COMPUTE)
     END;
FOR N:=0 TO 11 DO BEGIN
      SEEK (DFLTFILE,N);
      GET (DFLTFILE);
      CASE N OF
            0:MAXWT:=DFLTFILE^.VALUE;
            1:TRACWT:=DFLTFILE^.VALUE;
            2:TRLRWT:=DFLTFILE^.VALUE;
            3:TRLRCUBE:=DFLTFILE^.VALUE;
            4:DENSITY:=DFLTFILE^.VALUE;
            5:V4:=DFLTFILE^.VALUE;
            6:V3:=DFLTFILE^.VALUE;
            7:V2:=DFLTFILE^.VALUE;
            8:V5:=DFLTFILE^.VALUE;
            9:TERMCHARGE:=DFLTFILE^.VALUE;
            10:V7:=DFLTFILE^.VALUE;
            11:V8:=DFLTFILE^.VALUE;
           END;
     END;
CLOSE (DFLTFILE, LOCK);
END;

BEGIN
INITIAL2;
GETDEFAULT;
CORPDISCOUNT:=0.10;
RESET (EQUIPFILE,'*TRACTOR.DATA');
SEEK (EQUIPFILE,0);
GET (EQUIPFILE);
TRACTOR:=EQUIPFILE^.NAME;
V28:=EQUIPFILE^.PRICE;
V29:=EQUIPFILE^.ELIFE;
V30:=EQUIPFILE^.ESALVG;
V31:=EQUIPFILE^.TLIFE;
V32:=EQUIPFILE^.TSALVG;
CLOSE (EQUIPFILE,LOCK);
TX3:=V18/100;
STOPWAGE:=0.0;
NSTOPS:=0;
VHH:=0.0;
VDH:=0.0;
HHTIME:=0.0;
DHTIME:=0.0;
LTIME:=0.0;
UTIME:=0.0;
WTIME:=0.0;
OTIME:=0.0;
LCOST:=0.0;
UCOST:=0.0;
WCOST:=0.0;
OCOST:=0.0;
NTRUCKS:=0;
TIMECHEK:=FALSE;
SHIPCHEK:=FALSE;
WCAP:=0;
VCAP:=0;
MAXLOAD:=0;
AVGLOAD:=0;
NIGHTRATE:=15.00;
MEALRATE:=3.50;
MPDAY:=420.0;
MPMEAL:=200;
END;
```

```
PROCEDURE TIMES;
(**********************************)
(* PROCEDURE TO INPUT TRAVEL TIMES *)
(**********************************)

VAR N,LINE                              :INTEGER;
    H,M,MILES,SPEED                     :REAL;
    B                                   :CHAR;
    STR                                 :STRING;

BEGIN
WRITE (CHR(12));
UNITCLEAR (1);
RTMILES:=V3;
HHMILES:=V4;
DHMILES:=RTMILES-HHMILES;
VHH:=0;
VRT:=0;
VDH:=0;
GOTOXY (10,1);
WRITE ('** TIME  FUNCTIONS **');
GOTOXY (0,8);
WRITE ('WANT TO ENTER TRAVEL TIMES (Y,N)? ');
B:=YESNO (1,34,8,ESCAPE);
IF ESCAPE THEN EXIT (COMPUTE);
TIMECHEK:=FALSE;
IF B='Y' THEN BEGIN
     TIMECHEK:=TRUE;
     ERASE (0,8,40);
     GOTOXY (10,8);
     WRITE ('MILES  HOURS  MINUTES  SPEED');
     GOTOXY (0,10);
     WRITE ('LOADED:   ',TRUNC(HHMILES):6);
     IF DHMILES>0 THEN BEGIN
          GOTOXY (0,12);
          WRITE ('EMPTY:    ',TRUNC(DHMILES):6)
         END;
     N:=0;
     LINE:=10;
     REPEAT N:=N+1;
          REPEAT
               H:=0;
               M:=0;
               SPEED:=0;
               GETINPUT (1,18,LINE,3,0,900,H,ESCAPE,RETURN,0);
               IF ESCAPE THEN EXIT (COMPUTE);
               GETINPUT (1,27,LINE,2,0,59,M,ESCAPE,RETURN,0);
               IF ESCAPE THEN EXIT (COMPUTE);
               H:=H+(M/60);
               IF N=1 THEN MILES:=HHMILES;
               IF N=2 THEN MILES:=DHMILES;
               IF H<>0 THEN SPEED:=MILES/H;
               IF (SPEED>=15) AND (SPEED<=85) THEN BEGIN
                    GOTOXY (34,LINE);
                    WRITE (SPEED:5:1)
                   END
                    ELSE BEGIN
                    GOTOXY (0,15);
                    NOTE (30,20);
                    WRITE (SPEED:7:1,' MPH  IS UNREASONABLE.');
                    PAUSE (3.5);
                    GOTOXY (0,17);
                    WRITE ('PLEASE RE-ENTER TRAVEL TIME.');
                    GOTOXY (0,15);
                    WRITE ('                                         ');
                    GOTOXY (18,LINE);
                    WRITE ('                                         ');
                   END;
            UNTIL (SPEED>=15) AND (SPEED<=85);
        GOTOXY (0,17);
        WRITE ('                                    ');
```

```
            IF N=1 THEN VHH:=SPEED;
            IF N=2 THEN VDH:=SPEED;
            LINE:=12;
            IF N=1 THEN HHTIME:=HHMILES/VHH;
            IF N=2 THEN DHTIME:=DHMILES/VDH;
            IF DHMILES=0 THEN N:=2;
           UNTIL N=2;
     END;
 PAGE (OUTPUT);
 RETURN:=FALSE;
 END;

 BEGIN
 INITIAL1;
 UNITCLEAR (1);
 REPEAT
      WRITE (CHR(12));
      GOTOXY (7,6);
      WRITE ('** DATA ENTRY OPTIONS **');
      GOTOXY (4,10);
      WRITE ('1.  ENTER SHIPMENT DATA');
      GOTOXY (4,12);
      WRITE ('2.  ENTER STOP AND DELAY DATA');
      GOTOXY (0,23);
      WRITE ('<ESC>=RESTART  <RETURN> TO CONTINUE');
      REPLY:='*';
      RETURN:=FALSE;
      ESCAPE:=FALSE;
      REPEAT
           GOTOXY (0,21);
           WRITE ('ENTER NUMBER OF DESIRED OPTION: ');
           READIN (1,31,21,1,S,ESCAPE,RETURN);
           REPLY:=S[1];
          UNTIL (REPLY IN ['1'..'2']) OR (RETURN) OR (ESCAPE);
      CASE REPLY OF
           '1': SHIPMENT;
           '2': STOPS;
          END;
     UNTIL (RETURN) OR (ESCAPE);
WRITE (CHR(12));
IF ESCAPE THEN EXIT (COMPUTE)
     ELSE BEGIN
     SCREEN;
     READDATA;
     TIMES;
     COSTCOMP
    END;
END;
```

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