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Contents

Common Carrier System in a Modern Economy: Research Problems

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The common carrier system of the United States has been based on factors and information of the 1930s and 1940s when the Federal Coordinator, the Transportation Act of 1940, and the Board of Investigation and Research were prominent. Although provisional, the resources and enactments of this era have been used for 3 decades as the basis for policy and administration. Therefore, a new intellectual movement is necessary to realize the full potentials of the common carrier concept, formulate the design of a regulatory or policy system, and develop the demand and supply capabilities of a modern transportation system. Research hypotheses should be derived from a basic economic appraisal of demand and supply under current conditions. From such should follow legal research on the nature of obligation necessary to realize an extended common carrier system and the elements of a logistical system needed to redefine transportation demand or product lines, and to provide the bases for improved performance in the supply systems consistent with a modernization of the common carrier concept and the modern product line concepts consistent with logistical science. Such research should be institutionalized through the legislated creation of an official study organization so that both objective and authoritative attention can be given to leading transportation issues.

A study of the common carrier problem takes in 2 interrelated subjects: (a) growth potentials of the concept itself consistent with modern economic trends and (b) a study of demand and supply conditions for transportation service as a basis for carrier development. Consistent study of these two aspects of the common carrier problem will of necessity create an intellectual movement, a research agenda, that goes beyond the scope of current research programs. From such an intellectual movement will flow a family of studies in policy, transport markets and logistics, management, information, costing, and technology forecasting. This intellectual program should be more sharply focused and better organized than the elements of intellectual tradition out of which the current common carrier problem emerged. An official organization should be created through legislation to perform objective and authoritative studies.

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This paper will first review the evolution of the intellectual tradition in the study of common carrier problems and then will give some remarks and conclusions on general economic factors, the common carrier concept, and demand and supply factors affecting common carrier service. It will conclude with an examination of organizational alternatives for continuing studies.

INTELLECTUAL TRADITION

Consideration of the common carrier problem today is in the shadow of the research legacy of the 1930s. That was the era of the Federal Coordinator of Transportation, the enactment of the Transportation Act of 1940, and the Board of Investigation and Research, which grew out of that legislation (1). The intellectual resources were inadequate for the problem that faced even that era. This inadequacy was recognized by contemporaries, and their work by their own admission was considered provisional and experimental. For example, the coordinator's office was established as a temporary expedient with operating authority for only 3 years and in fact went out of business after 4 years. The Board of Investigation and Research was established to finish the work of the congressional groups that considered and enacted the Transportation Act of 1940, which itself was considered to be a provisional piece of legislation (2, 3). The provisional language of the Transportation Act of 1940 has become, however, an engraved fixture of the regulatory scene. Although Congress sought to find the economic bases of relative fitness and inherent advantages of competitive modes of transportation, its statutory language, cast in emergent or provisional form, has been interpreted for more than 30 years as definitive expression of intent. National transportation policy, the merger statutes, and the rule of rate making have had long administrative histories far transcending the limited experience of the legislature that enacted them to meet emergency conditions.

More significant, Congress established a research agency to assist in the evolution of transportation policy, but two generations later the research agency has been abolished and regulatory history has gone on. Regulatory activity has relied instead on the meager resources that survived the era. At first, it survived by using the actual data developed by the coordinator and the board. But, when these became too far out of date, regulatory activity had to limp along on continuing surveys that survived, such as the 1 percent freight waybill study, or the various cost studies such as the burden study, which extend from the limited data of freight flow. [The 1 percent waybill study is now performed by the U.S. Department of Transportation (DOT) under a delegation from the Interstate Commerce Commission (ICC). In January 1973, DOT prepared for 1969 a duplicate of the ICC "burden study" entitled "An Estimation of the Distribution of the Rail Revenue Contribution by Commodity Groups and Type of Rail Car, 1969."] Instead of a living tradition of economic research, regulation in the postwar era has been based on the sacred relics of works intended to be a provisional response to a crisis.

The modern era then has seen the common carrier isolated from the intellectual growth of its age, frustrated in not even realizing the intent of the framers of the Transportation Act of 1940 for a vital flow of economic knowledge into the policymaking process.

ECONOMIC FRAMEWORK

Regulatory policy has been a subject of national dispute since 1950 but has been argued with the outmoded intellectual resources of the 1930s. A particular need to aid in the discussion of the regulatory issue is the formulation of a general economic framework. Such a framework is needed as a guide to the scope of regulation, to the design of a regulatory system more consistent with modern conditions, and to the evaluation of the impacts of regulation on the economic system, something not attempted before.

Regulatory design is conditioned by the structures of markets and supply systems or industries being regulated. An elemental factor in structure is the degree of concentration among the firms on both the demand and the supply sides. The traditional regulatory situation is a case in which a concentrated supplier can abuse an unorganized and diffuse market. A concentrated buyer would have a similar power over a diffuse group of suppliers. Transportation regulation since 1920 has been concerned with both sides of the economic equation—the welfare of the buyers of transportation and the welfare of the carriers, who are the suppliers. Economic research has as yet reached no satisfactory conclusion concerning the structure of either the market or its supplier.

Observation of the emergence of competitive modes of transport over the past 50 years had led to speculation that the market may have taken on some of the structural characteristics of free competition; that is, with buyers and sellers so diffuse, the actions of any one of them would have no effect on price or service. It is not clear that such a situation has emerged. In fact, some limited evidence suggests that the buyers of freight transportation are highly concentrated; possibly the top 500 volume shippers control 80 percent of all freight traffic. If both sides of the economic equation—supply and demand—are relatively concentrated, then a close examination of existing regulatory policies and possibly new designs for regulatory actions based on detailed studies of the structure of demand and supply industries would clearly be called for. These speculations should lead to a number of precise research hypotheses followed by suitable studies to form the basis of the design of regulatory policies.

Benefits, which accrue to consumers and buyers, are balanced by costs, which are incurred by producers and sellers of transportation services. The economic results of potential regulatory situations can be laid out in clockwise fashion as shown in Figure 1. The following tabulation gives examples of four regulatory situations and the types of benefits and costs (from Figure 1) that correspond to them:

Situation	Benefits	Costs
Pollution regulation	Diffuse	Concentrated
Positive free enterprise	Diffuse	Diffuse
Safety regulation	Concentrated	Diffuse
Carrier oligopoly supplying concentrated market	Concentrated	Concentrated

The task of research is to locate transportation in this range of rational alternatives and then to prescribe policies for what research may find.

Policy prescription of the kind indicated may be conducted according to two alternative possibilities. If a degree of concentration is determined (or assumed) to exist among suppliers or buyers of transportation or both, a regulatory pattern based on incremental change in the current system might be indicated. Some of the dimensions of such changes are shown in Figure 2 for both demand and supply sides. On the other hand, if a greater degree of diffusion in both supply and demand is determined (or assumed) or desired, a different policy process emerges that is similar to what is commonly called deregulation. The actual design of a policymaking process will depend in this case on what research discloses. If economic trends are to bring both transport supply and demand closer to the competitive ideal, then deregulation is a logical possibility. If such a trend is not apparent but desired, then positive policies of breaking down existing concentrations are in order. The feasibility of such policies (e.g., breaking up the economic organization of the 500 leading industrial firms that ship goods for the sake of competitive transportation) is

Figure 1. Economic results of potential regulatory problems.

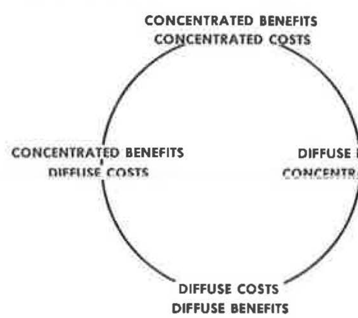

Figure 2. Rate-market relations in transportation.

Problems

Shipper *Passenger*	*Carrier*
Oligopsony	Oligopoly
Classmarket	
Below Cost Rates	Discrimination
Above Cost Rates	
Service Disability	Financial Instability
Service-Cost Hiatus	Service Competition
Absence of Market Information	Absence of Cost-Revenue Information

Solution I, Existing Market

Market Information	Cost-Revenue Information
Rational Programming and Supervision	Rational Programming and Supervision
Market Performance Criteria	Financial Performance Criteria

Solution II Changed Market

Competitive Industry	Competitive Regime
Broadened Market	

something that research should demonstrate.

Economic evaluation of the processes of regulation should be aided by modern advances in economic analysis. Two such processes should be mentioned: the modern study of industrial organization and administration and the methods of macroeconomic analysis, chiefly the input-output matrices. A principal contribution of recent economic research is an empirical evaluation of the deductive precepts of classical oligopoly theory (4, 5). From such evaluation, new theoretical concepts have emerged that relate to resource allocation, profits, innovation, and macroeconomic impacts (e.g., inflationary impacts of industrial concentration). The "new learning" in industrial organization has not yet been applied to transportation. To do so requires sustained research effort to define and assess measures of industrial performance.

Great progress has been made in the use of input-output tables in assessing the impacts of transportation policies although no regulation has yet resulted. (The DOT, through Jack Faucett Associates, has developed a method for developing full input-output detail for eight transport modes for all the basic input-output tables including 1947, 1958, 1963, and later series. This detail has been used in the projection of transportation requirements for national transportation planning. In addition, an extensive project under the university research program at Harvard University is developing a multiregional input-output study of U.S. commodity freight shipments.) DOT has accomplished a modal breakdown of the interrelationships of transport and other economic sectors, and assessments of labor interruptions have been made for railroads, trucking, and longshore operations. Input-output analysis has also been applied to interregional transport flows, relating them to interregional economic relations. A project under way at the Massachusetts Institute of Technology will assess the economic impact of regulatory change (Scenarios for Alternative Roles of the Federal Government in Transportation, Proposal of the Massachusetts Institute of Technology under the Supplemental Solicitation for Major Interdisciplinary Research Programs, FY 1975 Program of University Research, April 1975).

Something also should be said about productivity analysis when some progress has been made (6). Productivity change trends (in terms of labor, capital, and total factors) have been traced for all modes of transportation. The theoretical problem of accounting for productivity change in transportation has not been solved despite some speculation to the contrary. Little effort is being made to explore productivity change in more pragmatic terms through studies of particular processes and technology assessments. A good example would be a study of terminal operation through conventional engineering and time and motion study. [Some limited efforts may have been made from 1969 to 1974 by the National Commission on Productivity. Unfortunately, the final report of the task force on railroad productivity (November 1973) contained no such analyses.]

The following research agenda summarizes the discussion of the economic framework:

1. Studies of market structure and performance;
2. Studies of industrial organization and performance in transportation;
3. Formulation of market-industrial organizational example cases as a basis for regulatory policy design;
4. Input-output analysis of alternative regulatory example cases in relation to the economy of the United States;
5. Theoretical and empirical studies accounting for productivity change in transportation;
6. Empirical study of productivity change in a variety of transportation areas, notably terminals, scale of operations, management, and technology assessment; and
7. Review of information programs and specification for economic studies in transportation.

POTENTIALS OF COMMON CARRIER CONCEPT

The common carrier concept has received little research attention. It is a rational, legal concept that is similar in scope to other institutional problems such as eminent domain or civil rights. But there has been no tradition of legal research in the common carrier field. Hence the common carrier concept is often misunderstood; some economists may consider it a mere rationalization for limiting competition, an excuse for internal subsidization, or an archaic, outmoded institution. And yet it is a form of basic legal obligation analogous to many other institutions in economic life. Its background, implications, and potential for growth should be explored in the best tradition of legal research.

Common carriage as we know it is a survival of a doctrine in English common law that prescribed public obligations on a great variety of professions and business activities serving the general public (7, 8). Known as the common callings doctrine, it imposed through common law courts the fixing of reasonable fees, obligation to serve all within the limits of facilities or capacity, and prohibition of unreasonable discrimination in charges or terms of service. In the evolution of the law, the common callings doctrine in modern times appears to have receded for many professions but was strengthened and took on specific structural characteristics for transportation. Common law obligations for transportation were made more explicit and reinforced by a variety of statutory and regulatory provisions. One of the forces giving structure to the common law definitions of common carriers was the process of regulation and the concomitant doctrine of natural monopoly, which was not a part of the original common law doctrine but was fashioned apparently to cope with the power of railroad enterprises and to furnish a rationalization for regulation in an era of laissez-faire economics. With the passing of natural monopoly in transportation and other enterprises, regulation more recently has begun to be extended to a variety of businesses in a way reminiscent of the original purposes of the common callings doctrines. In Nebbia v. N.Y., 291 U.S. 502 (Sup. Ct. 1933), the natural monopoly theory was discarded and a doctrine of businesses "affected with a public interest" was adopted. The legislative branch was given the right to define such public interest in any reasonable manner as a result of the court's decision.

Common carriage today has a highly structured format; it has been restricted to a particular kind of service and excludes contractual transportation services or services involved with the management of the distribution function. Common carriage is defined by legislation and regulation on the basis of individual shipments, each of which has its peculiar documention. In fact, common carriage is defined as conformity to a documentary standard in terms of service obligation. The historic obligations of reasonable rates, obligation to serve, and prevention of discrimination and the public nature of operations remain, but in a highly restrictive context. In the motor carrier field, there is an abundant body of law that differentiates common carriage from contract service. Generally the definition of contract service has tended to be made more restrictive and limited to one or a few shippers for each contract. Contract carriers have also been restricted on the number of shippers they can serve. Dual operations and combinations of private and contract services have been severely restricted.

Restriction on common carriage also applies to the definition of transportation service. Transportation-related activities such as warehousing, financing of goods in transit, and other services connected with the physical distribution process tend to be restricted by the fiat of the regulatory process. Far from capitalizing on their potential service capabilities, common carriers today offer truncated services, filling orders of a very specific kind on the direct specification of the shipper. Even the process of payment is specified; time of payment is limited by statute or regulation to a short period, making transportation unique among businesses by the cash-and-carry relationship it maintains with its business customers. None of these restrictions comes within the purview of the historic common carrier obligation, which is stated in functional terms that define rights and obligations, not specific processes and institutions. The obligation of reasonable service without discrimination to the limits of capacity is the basic element of the common carrier doctrine. The same doctrine could apply to so-called contract service, to the extension of credit for the distribution function, and to performance of some aspects of distribution management.

Without the ability to specialize in the total distribution function, transportation management has atrophied because of the absence of any challenge for service expansion or any participation in a vital, growing industrial process. The cure for this atrophy is a widening of the common carrier doctrine to take in what is now known as contract carriage, to include many functions now listed under the definition of distribution management, and to relate transportation service to this wider context. The historic common callings doctrine has room for all these items within the purview of an industry affected with a public interest.

The research agenda in the common carrier field should include

1. A fundamental study of legal obligation as it applies to transportation and as it relates to other commercial law such as common law prohibitions of restricted competition;
2. A study of distribution management from the point of view of extended concepts of common carrier obligation; and
3. Empirical studies of contract carriage, private carriage, and exempt transportation from the point of view of obligation.

DEFINING TRANSPORTATION SERVICE FROM DEMAND POINT OF VIEW

Transportation, particularly freight transportation, requires a redefinition of the service that is sold. In other words, the product line of a common carrier is insufficiently specified for clarity in managing either (a) logistics for a shipping or receiving business or (b) a carrier enterprise itself in the modern sense. Public policies cannot be evolved properly for a public interest transportation system until a better concept of such a product line becomes operational. Because of the lack of such an operational concept, the services of the carrier to the shipper are inadequate, and too much burden may be placed on the shipper in managing his or her transportation needs.

Such a redefinition of service is essential to the expansion of the common carrier concept. Today, as noted previously, the common carrier concept is essentially a study in nominalism expressed by documentary standards in place of real service concepts.

It appears that the literature on distribution management, or logistics management, reflects the most advanced state of the art in terms of specifying the demand dimensions of transportation service in modern terms. The classic statements of distribution management appear to be by Heskett, Ivie, and Glaskowski (9) and Smykay, Bowersox, and Mossman (10). In this literature, distribution policies are stated in terms of deliveries, inventories, and the workings of a consistent system over time. The role of transportation in this system in practice may differ from the ideal expressed in the literature. Distribution policies appear to be developed unilaterally by shippers, and transportation requirements are specified in detail by buyers. The role of transportation is to supply the specified services in accordance with the prevailing documentary standards. When these standards prove inadequate or inconvenient, the buyer has increasingly come to assume the transportation function himself or herself. In some industries with particularly sophisticated transportation requirements, such as the petroleum industry, the buyer has assumed practically all the transportation management functions on a multimodal basis.

A lag probably also exists between the ideals of the literature of logistics management and the actual practices of shippers, which may be piecemeal or traditional. The inefficiencies of these practices may be covered in the overall marketing costs of the products, particularly in those industries with high concentration of ownership (oligopolies). There accordingly appears to be need for additional research in specifying the dimensions of a transportation service according to logistical principles. Such research might have 3 phases.

1. The concept of a transportation product line according to logistical science would be refined. The "stock-out policy" concept being developed at MIT seems to be the most advanced notion in the field today (11).
2. Existing shipping practices to map an approach to operationalize a product line concept should be studied under varying conditions. Included in such a study would be an overall management concept.
3. The demand features of such product line policies, including practical means of trade-off analysis among the various components of a logistical system, and the problem of cross-elasticity of demand among modes of transportation should be studied.

SUPPLY CAPABILITIES OF TRANSPORT SYSTEMS

Achievement of a modern specification of a transportation product line depends not merely on further research into the demand or logistical systems dimensions but more particularly on the supply capabilities of transportation systems to provide such product lines. Transportation today is supply oriented rather than demand oriented and may well reflect the futility of Say's classic statement that supply creates demand. Adjustment of the supply system to a demand-oriented product line may be the most difficult of all problems in the modern transportation economy. Information systems, modal organization, industrial and operational practices, in short, the entire transportation system, is organized on a theory totally inconsistent with modern logistical needs. The task of research is therefore to conceptualize consistent supply systems, specify their organizational and operational dimensions, and study the performance economies to be expected. A part of such a research program would be the organizing of a phasing operation so that the system could modernize incrementally with much of the current imperfect infrastructure.

Research issues with respect to supply capabilities are less a product of initial conceptual difficulty than they are a product of the complexity of the phenomena involved and the number of changes of various kinds that will be necessary. Some shortcuts are needed to get some useful work under way and bypass the incredible complexity of the transportation supply apparatus. Some of the network analysis being done at MIT for the northeast railroads will have a bearing on this problem (12). Such analysis can provide a basis of testing, under varying assumptions, the efficiency of parts of complex systems. The work done in DOT with respect to the use of sources and application of funds as a device for assessing common carrier revenue needs can provide a set of macrocriteria for cost and investment (13, 14, 15). Some of the work done with respect to transportation productivity may point the way to the measurement of performance. There is still need for analytical approaches for focusing research on useful changes for upgrading system performance.

Solution of the research problem in the supply area, to be manageable, might be focused incrementally on two areas of interest: (a) refinements and redefinitions of performance indicators and (b) assessment of system components in terms of performance and productivity as contributors to improved system performance. Rather than undertake at the outset massive systems studies, one might better deal with small cases to test procedures and establish analytical and operational foundations for supply system improvements.

Operation of the current transportation system would appear to offer abundant opportunities for such limited case analyses (e.g., the handling of the wheat exports to the Soviet Union by the railroads and the ports). What would an after-the-fact analysis of this performance reveal about performance expectations and definitions, the performance of terminal and line-haul functions, and the related rate incentives associated with this large surge movement? Another example might be the marketing of a particularly valuable but perishable seasonal commodity (16, 17). The study of the performance of carriers in marketing the cherry crop of eastern Washington State might be a good example of such a case study. The Washington State University agricultural economics group traced both rail and truck shipments all over the country and measured performance in terms of delivery times. Comparisons were made between closely measured delivery times and delivery performance as perceived by shippers. This comparison revealed the opportunity for creating new and more scientific concepts of performance management and description on the part of carriers and shippers. Such a study could also be extended to selected system components that would be useful in expediting the kind of shipment under study (e.g., economies and performance of refrigeration facilities, terminal switching, interchange, and relationships between costs and rates).

The aim of such supply studies would be to develop a transportation supply system capable of advanced logistical performance and to realize in practice a new concept of product line for common carriers by using such logistical concepts.

In summary, then, realization of improved supply performance might require these kinds of research:

1. Experimentation and perfection of systemwide analytical methodologies;
2. Study of improved financial and administrative tools for planning and managing supply systems that would build on the principle of sources and application of funds;
3. Improved information and costing systems consistent with planning and management tools, including better productivity studies;
4. Incremental studies of performance measurement and definition; and
5. Incremental studies of system component performance.

ALTERNATIVES FOR OFFICIAL RESEARCH ORGANIZATION

Interest in the results of research on the common carrier system is both large and conflicting. A highly focused effort, therefore, must be conducted by an objective organization not advocating a particular doctrinal solution. Moreover, the size and scope of the interests involved make it desirable that official recognition be given to the institution designated to perform the research tasks. Therefore, a conclusion of this paper is that legislation be enacted to establish an official transportation research organization to perform policy-oriented research on common carrier issues.

Precedents for such an organization exist in the legislation establishing the Federal Coordinator of Transportation (Emergency Transportation Act of 1933) and the Board of Investigation and Research (Transportation Act of 1940). A combination of objectivity and authoritative scope was desired in these two efforts. We now have 30 years of experience without such organizations, and we have not improved on the intellectual tradition that they established.

Students of transportation are well aware of the scope of conflict relating to common carrier policies, but the general nature of such conflicts in both private and public sectors should be indicated to demonstrate its dimensions.

In the private sector, we could identify the following areas of conflict:

1. Shipper and receiver versus carrier,
2. Producing versus consuming interest for social groups,
3. Producing versus consuming interest for regions,
4. Regional producing groups,
5. Common versus private carriage, and
6. Competition among regulated and unregulated common carrier modes.

In the public sector the following areas of conflict appear:

1. Federal versus state and local political interests,
2. Executive versus legislative interest,
3. Substantive versus legal interest centering in the federal courts,
4. Regulatory agency versus executive departments,
5. Conflict of interest among regulatory agencies, and
6. Conflict of interest among federal executive agencies.

Transportation is characterized both by wide areas of conflict and extensive experience with institutions for conflict resolution. The existence of an objective and authoritative research institution to bring policy analysis into legislative and other political processes could assist in the continuing process of conflict resolution. Some experience in this area is being gained in the efforts of individual states to regulate environmental matters through separate research organizations to serve objectively and authoritatively both adjudicatory and executive policy agencies (18).

Three models for such a research agency should be considered.

1. An independent agency could be established modeled after the Board of Investigation and Research. Such an agency could channel the resources of numerous governmental research organizations, solicit private and university cooperation, and have subpoena powers to compel data on vital issues.

2. An agency could be established within the framework of the executive branch. This agency might be managed by the U.S. Department of Transportation but would exist somewhat independently of its hierarchical structure.

3. A unique agency could be established by authority of Congress that would be owned and operated by carrier interests but would not be accountable to them. Supervision of such an agency would be a problem but might take the form of a public board combining private and official interests, supervision by an academic institution or the National Academy of Sciences, or supervision by a federal judge.

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New Planning Tool for Cargo Transportation in Foreign Trade

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This paper provides some highlights of new research methods and applications that were developed at the Port Authority of New York and New Jersey in foreign trade transportation. The accomplishments of this research have strongly demonstrated the usefulness of new kinds of data on the domestic origins and destinations of U.S. foreign trade. Some of the illustrations of application provided by the authors include aspects such as definition and analysis of the New York port hinterland for exports and imports and the implication to port planners, analysis of modal interface at the port and its importance in recognizing potential operating problems such as traffic congestion, implementation of specific economic studies to appraise the possible impact of international economic developments on the port, and refinement of econometric forecasting techniques of foreign trade mass shipped. These applications have proved highly significant for the New York port by enhancing planning efforts in both the short term and the long term. Some of the important findings pinpointed in this paper are the existence of a strong direct relationship between the value of cargo and the distance such cargo travels inland to and from the port, the division of inland transportation markets by modes (trucks predominate in all nearby territories and railroads are strong in more distant markets such as the Midwest), and the existence of a greater degree of dispersal for the port's export cargo origins compared to its import destinations. The paper points out other potentially useful applications in the transportation field based on the experience of the New York port.

Economic analyses of the flow of export and import cargo between the United States and its foreign trading partners have traditionally relied on statistical data that are regularly collected and published by the U.S. Department of Commerce. Monthly and annual government publications on foreign trade statistics provide a broad and meaningful base of information by describing the types of cargo shipped, their weights and values, the domestic and foreign ports at which cargo is loaded or discharged, and the mode of transportation used in overseas shipping.

Such information has been extremely valuable to transportation analysts because it provides the most fundamental quantitative inputs that can be applied to a large number of economic and marketing studies. For example, the data have been applied to such diverse studies as the analysis of market potentials for exports, competition by carriers on specific trade routes, and economic impact of ports. However, these foreign trade data in all their detail and fine breakdowns had, until recently, omitted one very important element of the total transportation picture. This element encompasses information on the transportation origins and destinations of exports and imports within the United States as well as the modes used in hauling this cargo domestically.

This information became available in 1972 as a result of a special survey conducted by the U.S. Bureau of the Census during 1970 and has been considered of great importance by transportation planners because it provided the missing link in the analysis of international cargo flows. The availability of these new data makes possible the evaluation of transportation patterns from the origins of shipments within the United States through ports of export to the foreign port of destination, and vice versa for imports. Knowledge of the total flow is significant not only because the domestic haul is at times more costly than the international freight bill and thus deserving of equal scrutiny but also because the economics of port-to-port movements are in part governed by the availability and quality of inland transportation systems and the strength of the hinterlands backing the ports.

Although the 1970 survey provides information for only 1 year, the new cross-sectional data constitute a unique and important benchmark. Its usefulness in transportation planning is broad and has been of some significance in the case of the New York port. Economists at the Port Authority of New York and New Jersey have made a major contribution to the state of the art of transport planning, as demonstrated by many of the analytical illustrations in this paper. Many of the theoretical methods, data refinements, and computer programming and practical applications devised by these economists appear to be readily applicable to a broad spectrum of other economic problems in the field of transportation.

DATA SOURCE

The new information supplied by the 1970 transportation survey (1) contained facts on most commodities traded

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internationally by the United States. It included all commodities usually classified as general cargo moving by either ocean or air modes across international boundaries and excluded a few bulk-type commodities such as petroleum, grains, coal, and ores. In addition, the survey excluded cargo that moved to and from Canada and Mexico by land. Some of the more relevant details reported by the survey included weight and value of shipments by type of commodity, states of origin and destination, the ports through which the cargoes passed, and the foreign areas of origin or destination. The survey itself employed a stratified sampling technique that yielded good estimates of actual volumes when expanded to the universe.

BROAD APPLICATION

Transportation planners, economists, traffic managers, and marketing analysts are but a few of the representatives of the transportation industry who can advantageously apply this new information in the decision-making process. This is true not only from the perspective of the carriers and the forwarders who actually perform the transport function but also from the point of view of the shippers, receivers, and those who operate ports, distribution warehouses, and numerous other establishments and services that regularly interface with carriers of international cargo.

Our extensive research indicates that the specific information on the origins and destinations of foreign trade shipments within the United States can be applied at two distinct levels. First, it may be used in solving day-to-day operational problems relating to shipment routing, choice of mode, and the like. Second, it can be used in devising long-term strategies and plans aimed at optimizing a given distribution system. Let us now illustrate the kind of short-term operational problems that could be more easily resolved with the aid of the new tool. An exporter, for example, can better determine the routing opportunities open for existing and new shipments to overseas markets. That is, the exporter can compare his or her own shipping practices (mode, port of exit) with those of other exporters within his or her region who are supplying the same foreign markets. Inland carriers of exports and imports can better assess their own operational performance vis-à-vis the competition on particular routes connecting ports and inland locations of origin and destination. Similarly, inland carriers and freight forwarders can improve their marketing efforts by using the information to pinpoint sources and destinations of cargo.

Some areas in which the new data may be applied to improve long-term transport planning would include development of new marketing strategies by international and domestic carriers who would be better able to direct their marketing efforts to regions showing the greatest cargo potentials; improvement of methods for projecting future capacity requirements by ports, warehouse operators, and other terminal operators based on new insights into the pattern of inland cargo flows; provision of more clear-cut criteria for the assessment of the economic potential of a given region to support an industrial park for exports or a free trade zone; improvement of shippers' ability to evaluate their total overseas distribution system and to devise new, more economical systems.

These few illustrations demonstrate how broad and significant the application of this new tool can be. Familiarity with the details of the survey as well as its proven applications will very likely be of some immediate and long-term benefit to most of its users in international cargo transportation.

NEW YORK PORT EXPERIENCE

Perhaps the most effective method of demonstrating the potential of this new tool is by examining some of the specific cases and problems to which it has been applied in the case of the New York port. It has been used by the New York port not only as a direct instrument in policymaking but also as a theoretical instrument in economic research affecting long-term port plans. The first, and probably the most obvious, way in which the data were used was in defining the New York port hinterland. This is an essential step if one is to understand the dynamics of a port and the functions it serves. Not knowing where the export cargo of a port comes from or where its import cargo goes to means that some operational policy decisions of a port are made in a partial vacuum. This may be somewhat comparable to the case of the manufacturer who sells goods in a market about which he or she has scanty information and, as a result, full potentials are not realized.

Some interesting facts were revealed about the hinterland of the New York port. Although export cargo loaded at the New York port was shown to arrive primarily from origins in the northeastern United States, significant volumes were also arriving from the Midwest and more distant areas in the South and the West. Similarly, for imports, large quantities of cargo were being shipped further inland to points throughout the United States despite the great concentration of destinations near the New York port. This pattern is given in greater detail in Tables 1 through 6. As may be noted, import destinations are relatively more concentrated about the New York port than are the origins of exports. The data show that the area within a 160-km (100-mile) radius from the New York port accounted for approximately 74 percent of the port's imports but only 55 percent of its exports. The major reason for this is that the New York region serves not only as an enormous market for consumption of imports but also as a warehousing center from which smaller shipments are distributed throughout the United States at a later time. Much of this cargo is also refined, packaged, assembled, bottled, or processed in various fashions locally before being distributed inland. Export cargoes, in contrast, generally arrive in New York from the point of last inland shipment in a state of readiness for overseas routing. Thus the data convey the reality of a more dispersed pattern of export distribution.

Further examination and analysis of the data provide new insights into how the New York port functions as a gateway for oceanborne cargo. Most of the New York port high-value exports originated outside the states of New York and New Jersey. For example, almost 80 percent of the New York port exports of machinery and transportation equipment, which had an average value of \$3488/Mg (\$3544/long ton) in 1970, were transported considerable distances to the port. The same applied to manufactured goods and chemicals, which averaged more than \$1279/Mg (\$1300/long ton).

In contrast, goods of lower value, such as crude materials, most of which were valued under \$197/Mg (\$200/ton), arrived in the port primarily from nearby origins. This fact reinforces the prevailing working notion that shippers of cargo with higher value per mass enjoy the advantage of being able to choose the most suitable port in terms of services required. They can do so because they are better able to absorb the cost of a long inland haul from the shipment origin to the port.

As in the case of exports, the states of New York and New Jersey were the two leading destination states for New York port imports. These nearby markets received large quantities of consumer goods to satisfy demand in local markets as well as large amounts of commodities of all types to be warehoused or further processed by local industry. In terms of absolute volumes, these two states alone received more than 5.9 million Mg (5.8 million long tons) of general cargo imports via the New York port. Although this traffic represented somewhat more than half of the port's cargo imports, substantial amounts were also being shipped directly inland to destinations throughout the United States. Even distant states, such as Florida, Texas, and California, ranked among the 20 leading state destinations of the port for its imports. Florida was the market for 38 136 Mg (37 535 long tons) of foreign products unloaded at port piers, and Texas and California received 34 972 Mg

Table 1. Inland modal distribution of oceanborne exports by distance from origin to port.

Kilometers From Origin to Port	Mass Transported (Mg)	Modal Shares (%) Rail	Truck	Air	Sea Vessel	Other
<40	2 355 784	26.1	48.5	—	21.9	3.5
40 to 80	520 574	1.8	88.1	—	8.4	1.7
81 to 160	518 039	7.6	91.0	—	1.4	—
161 to 320	380 441	14.6	82.5	—	1.9	1.0
321 to 480	219 974	18.1	80.3	—	1.6	—
481 to 800	479 977	46.7	51.0	—	0.8	1.5
801 to 1200	478 376	55.6	41.3	—	1.5	1.6
1201 to 1600	242 001	67.0	30.0	—	3.0	—
1601 to 2400	165 543	22.5	68.9	2.2	4.1	2.3
>2400	92 710	35.4	60.7	3.9	—	—
Unknown and transshipments	532 441					
Total	5 985 860	27.2	59.8	0.1	10.7	2.2

Note: 1 km = 0.6 mile. 1 Mg = 0.984 long ton.

Table 2. Inland modal distribution of oceanborne exports by state of origin.

State of Origin	Mass Transported (Mg)	Modal Shares (%) Rail	Truck	Air	Sea Vessel	Other
New York	1 952 562	12.2	62.0	—	23.7	2.1
New Jersey	1 518 685	28.6	62.3	—	5.7	3.4
Pennsylvania	373 678	34.7	64.2	—	1.0	0.1
Illinois	268 236	68.0	28.0	—	1.4	2.6
Ohio	204 049	60.2	37.9	—	—	1.9
Michigan	124 828	67.3	29.8	—	2.9	—
Massachusetts	105 524	7.5	88.8	—	—	3.7
Connecticut	89 884	—	100	—	—	—
Indiana	83 533	56.5	43.5	—	—	—
Wisconsin	83 425	54.6	45.4	—	—	—
Texas	69 128	5.8	88.6	5.5	—	—
Florida	55 883	35.1	58.4	—	6.5	—
West Virginia	42 819	8.5	83.0	—	8.5	—
Virginia	42 021	8.6	82.7	—	8.7	—
Iowa	41 367	84.2	15.8	—	—	—
Maryland	37 448	38.8	61.2	—	—	—
Kentucky	35 562	40.8	59.2	—	—	—
California	31 389	46.8	41.6	11.6	—	—
Other states	293 380					
Unknown and transshipments	532 441					
Total	5 985 842	27.2	59.8	0.1	10.7	2.2

Note: 1 Mg = 0.984 long ton.

Table 3. Inland modal distribution of oceanborne exports by commodity group.

Commodity Group	Mass Transported (Mg)	Modal Shares (%) Rail	Truck	Air	Sea Vessel	Other
Food and live animals	355 616	38.6	59.0	—	1.2	1.2
Beverages and tobacco	25 401	33.3	66.7	—	—	—
Crude materials	2 105 767	23.4	55.3	—	20.3	1.0
Gasoline and lubricants	152 407	7.3	43.9	—	39.0	9.8
Oils and fats	221 707	12.5	41.5	—	38.9	7.1
Chemicals	954 098	20.8	72.9	0.4	3.0	2.9
Manufactured goods	1 010 014	33.4	62.6	—	2.9	1.1
Machinery and transportation equipment	990 279	40.3	57.1	0.4	—	2.2
Miscellaneous manufactures	170 551	17.5	82.3	—	—	0.2
Total	5 985 840	27.2	59.8	0.1	10.7	2.2

Note: 1 Mg = 0.984 long ton.

Table 4. Inland modal distribution of oceanborne imports by distance from port to destination.

Kilometers From Port to Destination	Mass Transported (Mg)	Modal Shares (%) Rail	Truck	Air	Sea Vessel	Other
<40	5 070 254	2.7	71.4	—	7.7	18.2
40 to 80	524 084	1.3	84.2	0.4	8.1	6.0
81 to 160	372 317	7.9	84.4	0.1	2.8	4.8
161 to 320	528 640	11.4	81.0	0.6	6.2	0.8
321 to 480	139 513	24.5	68.9	—	6.6	—
481 to 800	255 113	41.6	56.2	0.1	2.1	—
801 to 1200	422 361	36.3	58.7	0.1	3.5	1.4
1201 to 1600	111 338	23.5	66.2	—	5.0	5.3
1601 to 2400	87 998	34.7	60.2	—	3.2	1.9
>2400	51 846	21.1	68.5	4.5	5.9	—
Unknown and transshipments	1 129 334					
Total	8 692 796	8.8	72.1	0.1	6.7	12.3

Note: 1 km = 0.6 mile. 1 Mg = 0.984 long ton.

Table 5. Inland modal distribution of oceanborne imports by state of destination.

State of Destination	Mass Transported (Mg)	Modal Shares (%) Rail	Truck	Air	Sea Vessel	Other
New York	3 462 132	2.5	79.1	0.1	3.4	14.9
New Jersey	2 455 379	3.8	65.8	0.1	13.1	17.2
Massachusetts	206 079	15.5	81.5	—	1.3	1.7
Pennsylvania	201 943	14.3	83.9	—	1.3	0.5
Illinois	201 122	29.3	64.9	0.2	2.9	2.7
Connecticut	184 134	2.5	83.7	—	10.2	3.6
Ohio	159 239	47.2	47.1	0.1	5.6	—
Michigan	100 525	56.0	41.2	—	—	2.8
Maryland	70 147	21.7	78.0	0.3	—	—
Wisconsin	53 179	21.2	78.8	—	—	—
Indiana	47 001	63.7	36.3	—	—	—
Florida	38 139	42.7	43.0	—	14.3	—
Texas	34 972	4.2	95.8	—	—	—
North Carolina	31 189	2.2	89.1	—	8.7	—
Georgia	29 420	21.2	78.8	—	—	—
Virginia	27 765	8.0	82.2	—	9.8	—
California	27 488	25.7	53.5	8.4	11.3	1.1
Minnesota	27 434	39.2	54.9	—	—	5.9
Missouri	23 704	41.9	46.6	—	—	11.5
Rhode Island	22 916	—	88.1	11.9	—	—
Other states	159 556					
Unknown and transshipments	1 129 334					
Total	8 692 797	8.8	72.1	0.1	6.7	12.3

Note: 1 Mg = 0.984 long ton.

Table 6. Inland modal distribution of oceanborne imports by commodity group.

Commodity Group	Mass Transported (Mg)	Modal Shares (%) Rail	Truck	Air	Sea Vessel	Other
Food and live animals	1 884 912	7.7	76.1	0.2	9.6	6.4
Beverages and tobacco	394 625	12.6	83.2	—	3.4	0.8
Crude materials	1 363 639	12.7	42.7	—	3.8	40.8
Gasoline and lubricants	297 014	—	20.7	—	41.6	37.7
Oils and fats	262 083	11.9	37.0	—	38.5	12.6
Chemicals	604 346	8.0	62.9	0.6	5.0	23.5
Manufactured goods	2 582 697	6.7	88.0	0.2	3.6	1.5
Machinery and transportation equipment	767 004	9.3	86.1	—	1.8	2.8
Miscellaneous manufactures	627 919	10.1	89.2	—	—	0.7
Total	8 784 239	8.8	72.1	0.1	6.7	12.3

Note: 1 Mg = 0.984 long ton.

(34 420 long tons) and 27 488 Mg (27 054 long tons) respectively. It is again significant that most of the cargoes that traveled relatively great overland distances from the port were high in value.

INLAND MODAL TRANSPORTATION

Although it is important for port planners to understand the locational distribution pattern of exports and imports within the United States, it is equally important for them to understand the prevailing modal characteristics in getting the cargo to and from the port. In practice, this kind of knowledge is extremely useful in evaluating the overall performance of a port as an interface for various modes. The extent to which a port is served by truck, rail, and barge will directly affect port operations in terms of equipment and work force requirement as well as in terms of the efficiency of cargo flow in and around the port. A good cargo interchange system between each of the inland modes and the oceangoing vessel is crucial if port congestion is to be avoided and operating costs are to be reduced. In keeping this perspective in mind, the experience of the port of New York is revealing. Based on the 1970 survey, it was shown that trucking is by far the major mode of inland transportation for the general cargo foreign trade of the port. Trucks performed the main haul for 9.75 million Mg (9.6 million long tons) between piers and inland origins and destinations. Railroads hauled 2.34 million Mg (2.3 million long tons), and domestic water carriers, primarily barge and feeder vessels, carried 1.22 million Mg (1.2 million long tons).

The dominance of highway carriers was notable for both exports and imports. They handled 59.8 percent of the exports arriving in the port compared with 27.2 percent for rail and 10.7 percent for vessels. Trucks handled an even higher share of the import cargo bound for inland markets, 72.1 percent; rail handled 8.8 percent and sea vessels carried 6.7 percent. The data tend to indicate that, in the case of the New York port, the greater predominance of trucking in imports probably results from the fact that import markets are relatively more concentrated around the port. In this short-haul market, trucks generally enjoy an inherent advantage. This particular relationship between distance and modal choice can also be observed and further verified by examining some state-by-state modal shares. For example, more than 62 percent of the exports originating in nearby northeastern states, such as New York, New Jersey, Pennsylvania, and Massachusetts, were hauled by truck. The reverse was true for midwestern states, such as Ohio, Illinois, and Michigan, where nearly two-thirds of the cargo bound for the New York port was moved by rail carriers.

These cargo transportation patterns at the New York port, which emerged clearly for the first time, have been useful in alerting port management to potential future developments and have prompted new studies aimed at evaluating the consequences of such developments. The high rate of truck use at the New York port, for example, has required steps to ensure that major congestions do not materialize and that cargoes continue to be expedited as truck volumes continue to grow from year to year. In this case, the data have been particularly useful because they provide not only the total volume of each mode but also the cargo profile of shipment sizes. As a result, some conclusions could be drawn with regard to the number of specific movements that entered and left the port.

ECONOMIC STUDIES

One additional area in which the new survey information has been of great use is in conducting economic studies of particular commodity groups and of foreign trading partners of the United States. Such studies have long been conducted as part of an ongoing program of evaluating the economic strength of the New York port and the impact of worldwide developments on it. These studies focus on a multitude of international economic factors ranging from changes in tariffs and freight rates to devaluations and cyclical economic fluctuations around the globe.

Incorporating relevant data on the domestic origins and destinations of cargo into such studies has greatly improved the analyst's ability to narrow the potential impact of international economic developments. For example, when overseas demand for U.S. exports softened because of recession, it was possible to estimate the potential impact on the New York port and its region by analyzing the relationship between the export base of the hinterland of the port and the commodity mix of exports on the affected trade route. Notably, because of the great diversity of port cargo and the large number of trading partners of the port, the impact of developments on particular markets was generally found to be of a limited nature. This kind of analysis has been successfully performed in response to several other economic developments that appeared to have repercussions for the New York port. The conclusions drawn from these studies have been helpful in setting policy.

ECONOMETRIC MODELING AND FORECASTING

One of the most fundamental aspects of long-term planning in port development is the forecasting of foreign trade volumes. Because modern port facilities generally require several years of physical planning and construction before they come on stream, accurate long-term projections of cargo are essential if the proper facilities are to be made available in time to meet future demand.

During the past 5 years, cargo forecasting at the New York port has become increasingly more sophisticated, and substantial reliance has been placed on econometric modeling techniques. The advantage of this method over simple extrapolation techniques has been clearly demonstrated by its ability to capture the dynamics of trade patterns and pinpoint and measure the various economic forces that affect it. However, to quantify these economic forces in a meaningful analytical format, one must have a good data base for each of these so-called variables. It is specifically this kind of information that the new origin and destination survey has made available.

In more precise terms, the information was useful in constructing an independent variable for a multiple regression analysis by which the sensitivity of foreign trade volumes handled at the New York port was closely associated with the economic well-being of the hinterland that it services. This particular line of analysis within the econometric forecasting model is based on the logical assumption that trends in exports and imports for any given region in the United States are, to a large extent, a function of the relative economic performance of the region. Therefore, a port that serves a dynamic and thriving hinterland should experience faster cargo growth rates than a port serving a slowly growing region.

The forecasts generated by the model for the New York port were highly meaningful statistically and are considered by port management as a significant contribution to the decision-making process.

CONCLUSION

After some intensive research and original applications of new data on the domestic origins and destinations of U.S. foreign trade, we can state with confidence that an important planning instrument has been added to the transportation analyst's arsenal. Broad and meaningful applications have been found and advanced in the areas of cargo forecasting, economic analysis of trade patterns, intermodal competition, and market analyses.

Although this paper has demonstrated the usefulness of such research in analyzing oceanborne cargo, studies of equal significance on international air cargo have been made. They have been utilized mainly on parallel lines with the ocean data, and with great success.

Our opinion is that the transportation industry could benefit greatly by undertaking additional surveys of this nature for selected benchmark years.

ACKNOWLEDGMENT

This paper expresses the views of the authors. It does not necessarily represent the views or policy of the Port Authority of New York and New Jersey.

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Perishables Transportation: A Fresh Look at Trailer on Flatcar and Container on Flatcar

Robert H. Leilich, Peat, Marwick, Mitchell and Company

This paper summarizes research on the economic feasibility of using a dedicated intermodal (highway-rail-highway) service to move produce from the West Coast to the Midwest and the East. From government statistics and interviews with growers and food industry personnel, the study identifies a volume of traffic sufficient to conduct a pilot operation of a dedicated train from the West Coast to the Chicago area on a year-round basis. The dedicated train should originate from the San Joaquin Valley or Sacramento area during the late spring, summer, and fall and from the Yuma area during the remainder of the year, thus serving growers within 160 to 240 km (100 to 150 miles) of the origin rail terminal. Points as far east as New York and Boston could be served from the Chicago-area rail terminal. The cars and locomotives should be supplied by the railroads, but trailers and containers to perform the service should be supplied and controlled by a shippers' association formed to represent the users of the service. In most situations, the proposed service would be economically competitive, faster, and more reliable than existing truck movement in spite of an assumed 100 percent empty return of equipment. Additional cost-reducing opportunities for the proposed service are discussed in the paper, as are areas requiring further study.

Dependable transportation of fresh produce from the West Coast to eastern markets at reasonable cost is a difficult problem for the food industry. The current low-cost mode, the railroads, has problems with transit time, reliability, and car supply. The alternative to railroad transportation is most frequently the use of carriers that handle exempt commodities as a specialty or as a backhaul. This service is characterized by a severe fluctuation of price and by the lack of a reliable supply of trucks. Although less than completely satisfactory, trucking is increasingly being used when its transit time and reliability advantages offset the lower cost of rail.

Use of the present intermodal service alternative, trailer on flatcar (TOFC) and container on flatcar (COFC), is actually decreasing because of problems with rate structures, service reliability, and equipment supply. However, it appears that, if properly organized, TOFC-COFC could be a superior mode of transcontinental produce transportation in both service reliability and cost (or productivity) and that this potential could best be realized with a coordinated highway and rail service dedicated to transportation of fresh produce.

OBJECTIVES AND SCOPE OF STUDY

The primary objective of the study was to investigate the economic feasibility of a TOFC-COFC train dedicated to the transportation of produce from the West Coast to the Midwest and the East. A secondary objective was the identification of potential traffic volumes, organizational needs, and potential problem areas. In scope, the study was limited to a preliminary investigation of the potential market for and operating costs of the service. A complete report of the study, which was performed for the National Commission on Productivity (NCP), is available elsewhere (1).

TRAFFIC POTENTIAL

A minimum traffic volume of produce shipments from California of 80 to 90 trailers and containers is required to support a dedicated daily, weekday departure, TOFC-COFC service. Although a comprehensive source of origin-destination flow data for this traffic does not exist, data on the total traffic flow were not necessary for the study. Rather, it was necessary only to develop information that would show that traffic volume could exceed the minimum required to provide a sufficient market to support the service. Two independent data sources were used for the study: (a) the U.S. Department of Agriculture (USDA) annual compilation of fresh fruit and vegetable unloads at selected cities and (b) a survey of food distributors and retailers performed to estimate produce sales in the destination areas of the proposed service. An analysis of both data sources indicated that sufficient traffic does exist to support the service. In addition, the estimates of both sources are known to be understated; it is therefore certain that the total potential traffic available exceeds that developed in the study.

Nine commodities, representing about three-quarters of the produce shipped from California to 41 selected

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U.S. cities, were reviewed: cantaloupes, carrots, celery, grapes, lemons, lettuce, oranges, strawberries, and tomatoes. Potatoes and other less perishable commodities were excluded from the study because they do not demand the same transportation speed and level of service as do more perishable types of produce.

The trend of total USDA reported produce unloads (expressed in carlots, a standard measure of volume, or carlot-equivalents) from California by rail (including TOFC) and truck for the studied commodities for 1966 through 1974 reveals that, although total shipments have remained relatively constant, there has been a decided shift from rail to truck. In 1966, about 44 percent of the shipments were made by rail; in 1974, about 31 percent were made by rail. The decrease occurred despite the intensive capital program of the railroads to provide modern, mechanically refrigerated cars. There are many causes for such a shift, including

1. Generally superior service reliability of motor carriers,
2. Improved trucking efficiency,
3. Improved ability of motor carriers to balance produce traffic with westbound freight,
4. Changing economies of total distribution costs (rail versus truck), and
5. Railroad car supply problems.

Nineteen of the USDA's selected 41 U.S. cities are in the Midwest and East and account for approximately 44 percent of the 41 cities' produce unloads (including citrus) originating in California. Shipments from California to New York and Chicago are very heavily oriented to rail (both carload and TOFC). Midwestern and eastern cities are more heavily oriented to rail than are the 41 cities as a whole because the remaining 22 cities are closer to the West Coast, where trucking is more competitive.

Survey of Food Distributors and Retailers

The volume of West Coast produce purchased by food distributors and retailers varies by season and by marketing practices. Because of variations in harvest location, commodity shelf life, and customer requirements, food retailers cannot level their requirements for produce. A review of monthly receipts from various parts of California suggests that a minimum basic requirement of 1 trailer-container load of California produce/day for every $200 million in total annual sales is a reasonable, conservative estimate for projecting produce traffic requirements of midwestern and eastern cities on a daily (250 days/year) basis. Full truckload requirements by major cities for produce from the West Coast are estimated to be almost 200 loads/day. This estimate includes only traffic for those facilities (the potential initial participants in the proposed dedicated TOFC-COFC train concept) having the capability of receiving at least 1 truckload/day. A substantial additional volume of produce is transported from the West Coast to facilities that cannot receive at least 1 truckload/day.

Concept Acceptability

The industry is not wedded to fixed distribution practices. Interviews emphatically confirmed that if the proposed dedicated service were economical and reliable it would be considered attractive. Supermarket chains were particularly concerned about the fact that, when a shipment (especially of lettuce) does not arrive on schedule, they may have to buy replacements at a premium of $300 to $1000/carlot-equivalent to keep grocery shelves stocked. This extra cost, the usually poor quality of the merchandise, the managerial inconveniences of covering shortages attributable to delayed shipments, and markdowns of excess stock after arrival of the late shipment are responsible for decisions by many distributors and retailers to use truck services, which, although higher in cost, are more reliable. In general, the responses indicated that

1. The idea of a dedicated TOFC-COFC service for perishables was appealing because of the potential for improved service reliability and increased control over individual shipments;
2. Many distributors and retailers would be willing to try the dedicated TOFC-COFC service if costs of the proposed service are competitive with those of the service currently used; and
3. The proposed service can help stabilize some of food distributors' and retailers' transportation costs, especially during harvest periods when unregulated transportation costs escalate in response to increased demand for trucking services.

OPERATIONAL CONCEPT

The proposed dedicated intermodal service would operate in the following manner:

1. Produce would be loaded into trailers and containers at the growing area;
2. Trailers and containers would be pulled by highway tractor to an appropriate central railhead or terminal in California;
3. Trailers and containers would be placed daily (5 days/week) on a dedicated train (of 40 to 45 flatcars) and moved by rail as a single unit to a central terminal in the Chicago-Peoria area;
4. Trailers and containers would then be pulled by highway tractor to distributing points and facilities in the Midwest and the East;
5. Empty trailers and containers would be returned to the railroad terminal, placed on the dedicated-train flatcars, and returned as a single unit to the West Coast railhead or terminal;
6. From the West Coast railhead or terminal, the empty trailers and containers would be pulled by highway tractor to a growing area; and
7. Backhaul traffic would be moved as permitted by economic, operational, market, and legal constraints.

It is assumed that the service will pick up fresh fruits and vegetables on the West Coast 5 days/week, 52 weeks/year, not including approximately 10 holidays. This means that the service will originate in California 250 days/year. Current service operates somewhat more frequently, but emerging contract patterns among the field laborers in California make Saturday and Sunday operation increasingly prohibitive.

Demonstration Project

The key factors in establishing a demonstration service are the participation of food distributors and retailers, selection of origin and destination terminals, and development of an operating schedule. A reasonable test case for this service would be to involve a number of distributors and retailers with facilities within 640 km (400 miles) of the selected destination terminal. The number of required participants would depend on the total volume of traffic that each could route by dedicated service.

This test would involve

1. Commitment by each participant for a specific number of trailer and container shipments each operating day,
2. Commitment of sufficient refrigerated trailers and containers to conduct the project, and
3. Assignment of staff to coordinate and control trailer and container movements.

The most promising route for the service is from central California to either the Chicago or New York area. Because of its greater distance (which makes the economies of rail more attractive) and potential volume, New York City (or the Philadelphia area) might appear to be the best destination point for a test operation. However, NCP-fostered improvements, such as the "fresh-from-the-West" service, which is a special produce train service operated on a fast, coordinated schedule from western growing areas to Chicago, New York, Boston, and other eastern points, have alleviated some of the service problems for traffic to the East Coast. Interviews indicated that a smaller midwestern city with few regular truck backhauls and unreliable train service has a more immediate need for improved service.

A midwestern location in or near Chicago could generate a minimum of 80 trailer-container loads/day within a 640-km (400-mile) radius. A midwestern destination would also involve participation of fewer railroads to initiate the service. Discussions with food distributors and retailers and railroads, as well as an examination of potential midwestern traffic, suggest that Chicago, Joliet, or Peoria would be among the most likely candidates for a midwestern terminal. If the first test service is successful, it would set a precedent for a similar service to the eastern seaboard.

A review of growing seasons and traffic patterns suggests two different patterns of shipment to the east from California. During the late spring, summer, and early fall, the bulk of the traffic is from the Salinas area and the San Joaquin Valley. Although these areas ship all year, volumes decline substantially during the winter. The Imperial Valley of California and the area around Yuma, Arizona, originate substantial volumes of produce during the winter months. An example of origination of a dedicated TOFC-COFC train might be from the San Joaquin Valley or Sacramento area in the late spring, summer, and early fall and from the Yuma area during the rest of the year.

If departures of 5 days/week are assumed, 6 to 7-day turnaround time for the railroad cars and 8-day turnaround time for trailers and containers [plus approximately 1 day for every additional 640 to 800 km (400 to 500 miles) from the rail terminal] could be scheduled. These times assume that 12 h are needed for loading or unloading at the field and warehouse, that trailers and containers returning to the origin on one day are used for loading on the next working day, that rail movement time does not exceed 56 h, and that trailer loading cutoff times at origin and trailer availability at destination are 1 h each.

Organization Concept

Because food distributors and retailers have the greatest interest in reliable transportation of perishable goods, the operation should be controlled by an independent shipper association organized by participants in the detailed TOFC-COFC service. Because the association may not want to become directly involved in day-to-day operations, it could contract with or establish a separate operating organization. That organization would set up the system for scheduling, coordinating, and operating the transportation system and would control all trailer-container movements. It would carry on day-to-day relations with growers, receivers, and carriers, and it could be delegated to negotiate tariffs and handle other carrier-related matters subject to approval of the association's membership or board.

The operating organization would develop and manage an information system (manual or computer) to maintain trailer-container control at all times, schedule operations for optimum equipment use, and maintain space control for the train. In accordance with policies established by the association, space on the train would be committed to specific member receivers who could trade space among themselves (through the operating company) when they needed additional space or had excess capacity. The operating organization's responsibility would also include securing backhauls when economically and legally feasible. Backhaul traffic, which could materially reduce the shipper association's cost of service to its members, is available and can conform to scheduled operating requirements.

ECONOMIC EVALUATION

Highway costs used in this study are based on customer interviews and do not represent engineering estimates of what actual costs should be. They are the most appropriate costs for this study because they represent costs that are perceived by potential users of a dedicated TOFC-COFC service and that would probably be used in evaluating the proposed service.

Long-Haul Truck

Most of the truck traffic from California to the Midwest and East is handled by owner-operators, contract trucking firms, or carriers dealing only in exempt commodities. Some private fleet operators in the East and Midwest who are interested primarily in westbound traffic use refrigerated trailers to secure return loads of exempt agricultural commodities. Although truck operators generally attempt to secure loads in both directions, they are not always successful. Long-term empty return costs are reflected in a distributor's and retailer's average cost per truckload. During the peak harvest seasons, when trucks are in great demand, negotiated per-trip costs can be double those charged during slow times of the year. During peak seasons, when truck demand is at its greatest, some operators find the price distributors and retailers are willing to pay so attractive that they return empty to handle more profitable eastbound produce traffic. Thus trip costs paid by a distributor or retailer are very difficult to quantify because they are negotiated rates (what the traffic will bear) and are influenced by many factors including distance, weight, shipment value, transportation demand, equipment availability, return traffic availability and proximity, and competitive transportation services and costs (principally rail). Fortunately for the consumer, produce prices paid by distributors and retailers are usually at their lowest when transportation costs are at their highest.

Based on an analysis of the interview results, a long-distance highway cost range of \$0.40 to \$0.53/truck-km (\$0.65 to \$0.85/truck-mile) to the Chicago area has been used for this study, reflecting a higher return load factor. To all other cities, a range of \$0.47 to \$0.59/truck-km (\$0.75 to \$0.95/truck-mile) has been used, reflecting a lower return load factor.

Short-Haul Truck

Short-haul truck costs are based on interview data relating to food industry private fleet operations. Such costs vary considerably because of substantial variations in labor and fuel costs. For privately operated fleets used primarily in short hauls of up to 400 km (250 miles), some distributors and retailers indicated that their full distributed costs per kilometer ranged as high as $0.45/km loaded ($0.72/mile loaded), including operation of the refrigerated unit. The median costs reported by the distributors and retailers were about $0.42/km ($0.68/mile). For the purposes of this study, an average cost of $0.43/loaded or empty trailer-km ($0.70/trailer-mile) was used because in specific situations, this cost may vary as much as 25 percent.

On short hauls, trailers and containers are usually returned empty. In conjunction with the dedicated train, trailers and containers are also assumed to be returned empty. These costs would be reduced to the extent that backhauls are available. Thus highway costs may be roughly approximated as $0.87/one-way km ($1.40/one-way mile) between destination rail terminal and customer warehouse and between a field loading point and origin railhead.

Rail Costs

Costs for the rail portion of the dedicated TOFC-COFC service were calculated by using the Interstate Commerce Commission (ICC) rail form A formula. The treatment of constant costs in this study differs from the ICC's form A approach. In the form A procedure, constant costs are uniformly distributed over all traffic on the basis of tons and ton-miles, thereby discriminating against or in favor of a given traffic depending on its weight and distance relative to the average weight and distance of all railroad traffic. For this study, use of a flat percentage increase over variable costs to cover overhead was considered more appropriate. Because the "average" constant cost determined by the ICC is about 30 percent of variable cost, a 30 percent markup on variable costs was used. The resultant fully allocated costs were then increased by an incremental profit margin of 10 percent over fully allocated costs as a minimum rate base attractive enough for the railroads to experiment with the proposed operation.

Cost Comparison

For purposes of comparison, highway and rail costs have been converted to trailer-container equivalents. A comparison of costs for typical origin-destination combinations is given in Table 1. The data given in the table show that the dedicated TOFC-COFC service concept is competitive with long-distance trucking even with the assumption of empty backhaul. It would appear from the table that conventional, single-shipment TOFC-COFC service is even more economical. This can be misleading, however, because of the potential for reducing the net cost of the dedicated service and the significantly better control of service and reliability.

Table 2 compares the costs per trailer of shipping from the San Joaquin Valley to midwestern and eastern cities by dedicated TOFC-COFC train and by truck. When one considers the Midwest as a whole, the economics of a dedicated TOFC-COFC service appear attractive, especially in view of a reliable, dependable service with stable and predictable costs. Minimum projected savings are in the range of 10 to 20 percent of current truck costs. To smaller midwestern cities, the intermodal dedicated service can be very attractive because service can be greatly improved at a cost lower than that now paid to the truckers.

Because of the long empty-truck backhaul, serving Boston and New York from the Chicago area appears to be economically less attractive than from a more eastern terminal, yielding projected savings of only about 1 to 5 percent. But, even with the high cost of highway operation, economically competitive service can be provided to the East. In this market, the economic advantage of the dedicated TOFC-COFC service could be significantly enhanced by the potential for trip leasing for backhauls from the New York and New England area to the Midwest.

Several areas of potential cost reduction exist for the dedicated TOFC-COFC service. They include possible reduction in train crew size, reduced trailer ownership costs, and reduced origin terminal costs.

Investment Requirements

Three major categories of capital investment are required for a dedicated TOFC-COFC train service: trailers and containers, terminal facilities, and railroad flatcars and locomotives. The requirement for investment in trailers and terminal facilities will be discussed in this section. It is assumed that flatcars and locomotives would be provided by the railroads because flatcars can be obtained readily from the trailer train fleet and locomotive requirements can probably be met from existing locomotive pools.

It is important to note that investment costs discussed here are included as part of the costs of ownership of equipment and facilities shown in the dedicated train cost calculations. Actual costs spread over appropriate service units [per trailer-container, per trailer-container-km (per trailer-container-mile), and so forth] may be more or less than the average costs used in study calculations.

Trailers and Containers

The primary investment by food distributors and retailers will be refrigerated trailers and containers. Shipper-furnished trailers and containers would relieve the railroads of problems associated with trailer-container control and equipment financing. In addition, the furnishing of trailers and containers by shippers would demonstrate shipper commitment to the success of the operation. It would also give the proposed shipper association and operating organization positive control over the trailer-container fleet.

If an average train size of 43 cars carrying 86 trailers, a nominal 8-day turnaround (about 6 sets of equipment because equipment would not be loaded on Saturdays and Sundays in the West or unloaded on Sunday in the Midwest and East), and 10 percent reserve are assumed, approximately 568 trailers would be needed for the service. Prices of refrigerated trailers have recently been quoted at $22 500 to $27 000, depending on the amount of insulation and other options. If an average cost of $25 000/trailer is assumed, new trailers needed to provide the proposed service would cost approximately $14 million. Recent quotes of equipment manufacturers indicated that refrigerated containers would cost about $17 000. Because about half the fleet is in transit (empty or loaded) at any given time, only about 284 chassis would be required. Net investment in containers and chassis, if purchased new, could amount to approximately $12 million.

If an 8-year life and a 10 percent salvage are assumed, nondiscounted cash-flow equipment costs would amount to approximately $6.30/day for a container plus half of a chassis versus $7.70/day for a trailer. If we add an

Table 1. Selected cost comparisons.

Destination	Cost From Origin ($) Salinas[a]	San Joaquin[b]	Desert[c]	Southwest[d]
Chicago				
Truck	1350 to 1420	1440 to 1990	1380 to 1810	1310 to 1710
Rail carload[e]	1390	1330	1230	1170
Conventional TOFC-COFC	1440	1390	1320	1270
Dedicated TOFC-COFC	1440	1410	1420	1250
Detroit				
Truck	1830 to 2320	1860 to 2360	1790 to 2270	1690 to 2150
Rail carload[e]	1520	1460	1370	1310
Conventional TOFC-COFC	1530	1480	1410	1360
Dedicated TOFC-COFC	1740	1710	1720	1570
Columbus				
Truck	1840 to 2330	1870 to 2370	1740 to 2210	1620 to 2060
Rail carload[e]	1540	1480	1350	1290
Conventional TOFC-COFC	1550	1500	1390	1340
Dedicated TOFC-COFC	1800	1770	1780	1630
Buffalo				
Truck	2030 to 2570	2060 to 2610	2090 to 2640	1860 to 2360
Rail carload[e]	1650	1580	1500	1430
Conventional TOFC-COFC	1630	1580	1510	1460
Dedicated TOFC-COFC	2100	2070	2080	1930
Boston				
Truck	2370 to 3000	2400 to 3040	2320 to 2940	2200 to 2790
Rail carload[e]	1900	1840	1790	1730
Conventional TOFC-COFC	1840	1790	1750	1700
Dedicated TOFC-COFC	2720	2680	2700	2550
New York				
Truck	2260 to 2860	2290 to 2900	2160 to 2740	2040 to 2580
Rail carload[e]	1850	1780	1670	1620
Conventional TOFC-COFC	1800	1740	1650	1610
Dedicated TOFC-COFC	2490	2460	2480	2320

Note: Data in this table are based on approximate highway kilometers for trucks, rail carload kilometers (converted from mileage given in Rand McNally Railroad Atlas) for main-line routes and two interchanges, and carload kilometers with local cartage added for conventional TOFC-COFC. Total trailer-container ownership costs and cost of two interchanges are included in all TOFC-COFC cost calculations.

[a]For dedicated TOFC-COFC: Salinas-Chicago railheads.
[b]For dedicated TOFC-COFC: Sacramento-Chicago railheads.
[c]For dedicated TOFC-COFC: Barstow-Chicago railheads.
[d]For dedicated TOFC-COFC: Yuma-Chicago railheads.
[e]Cost per equivalent trailer-container load (13 600 kg (300 cwt)/trailer-container and 20 400 kg (450 cwt)/carload).

Table 2. Dedicated TOFC-COFC train and truck costs per trailer of traffic originating in San Joaquin Valley.

Destination	Dedicated TOFC-COFC Train Costs ($)	Average Truck Costs ($)	% Savings With Dedicated Service
Chicago	1410	1715	18
Detroit	1710	2115	19
Columbus	1770	2125	17
Buffalo	2070	2335	11
New York	2470	2595	5
Boston	2680	2720	1

annual maintenance cost per trailer or container of $1000/year (including tires) and if we assume that equipment is in service 90 percent of the time, costs for trailers and containers would average roughly $10 and $11/serviceable day respectively. This compares favorably to the $15/day ownership cost used in the dedicated service cost calculations.

It should be emphasized that a $12 to $14 million capital expense is not required for the initial test operation. Existing equipment owned by distributors and retailers may be suitable; some equipment may be leased on a short-term basis from lessors; and the railroads may be willing and able to provide some equipment to the association for an experiment. Thus no commitment for a sizable capital expense need be considered until the test operation has proven the viability of the concept.

Terminal Facilities

TOFC-COFC terminal facilities are normally owned by the railroads. The existence of numerous large-volume facilities in the Chicago area makes it preferable to use one of the existing facilities at the destination of the dedicated train. At the origin, however, new or additional facilities may have to be constructed or at least expanded. Total facility costs, excluding land, could be approximately $500 000 to $600 000 (including 2 side loaders at $215 000 each). The trailer-container side loaders are semiportable and could be moved if the train origin shifts during the year.

CONCLUSIONS AND IMPLEMENTATION STUDY REQUIREMENTS

Even without a backhaul, a dedicated TOFC-COFC service for perishables operated between California and the Chicago area on a year-round basis by a shipper association is economically feasible as an alternative to highway trucking. It can offer shippers a reliability that can come only from a service that is under their control, eliminating the vagaries of truck operators and the unreliability of current railroad service. Because the energy efficiency of TOFC-COFC line-haul is greater than that of most competitive highway movements, energy savings can be realized. This, combined with increased economic productivity, makes the service attractive from a national policy point of view. Although these findings affirm the feasibility of the concept, further study in the following areas is required to support a management commitment to proceed with implementation:

1. Refined cost analysis,
2. Railroad impact,
3. Backhaul potential,
4. Legal and regulatory status, and

5. Implementation planning.

The information resulting from these investigations should provide sufficient background for a management decision regarding a test of the concept.

Refined Cost Analysis

Several areas of cost research offer potential for better defining the most cost-effective means of operating the service including

1. Detailed costs of a specific train service between one origin and one destination (including a more refined estimate of investment requirements),
2. Cost trade-offs between COFC and TOFC modes of operation, and
3. Cost trade-offs between the 56-h schedule and a shorter schedule with high-speed operation.

Railroad Impact

Railroads might be concerned with the establishment of rate precedents that could affect other shippers or commodities. They might also be concerned that the proposed train could divert existing perishable carload traffic and leave mechanical refrigerator cars idle. Availability of rail terminal facilities and equipment to load and unload the train in a short time on a regular schedule may require difficult negotiations especially if the origin point shifts one or two times during the year.

Backhaul Potential

A qualitative description of potential backhauls is needed. The following, beginning with those that appear to have minimal legal obstacles, should be investigated:

1. Movement to west coast warehouses of goods owned by members of the shipper association,
2. Trip-leasing of trailers for return hauls by highway from destination areas to the Chicago area dedicated train terminal, and
3. Coordination with shipper associations (or freight forwarders) engaged primarily in westbound traffic.

Legal and Regulatory Status

The Interstate Commerce Act defines and governs the freedom of shipper associations and the construction of railroad tariffs. Previous ICC and court proceedings have inhibited the establishment of contract rates that would be desirable in the proposed concept. There is, however, increasing pressure for relaxation of regulatory constraints with regard to such contracts. A rate structure and form that could be approved by the ICC must be designed carefully. Investigating the legal status of various potential backhauls is also important.

Although the precedent of shipper associations is firmly established, the activities of these associations are not defined clearly and precisely in the Interstate Commerce Act. Although shipper associations do not violate antitrust provisions per se, all implications or potential problem areas should be reviewed. The use of association-furnished equipment for backhaul loads may or may not infringe on carrier rights, interests, or the Interstate Commerce Act itself. Regulatory approval is another item that should be studied because an attempt to implement the concept without considering the nature of protests that might arise could cause lengthy delays.

Implementation Planning

Efficient management, scheduling, and control of trailers throughout the year will require full cooperation of the growers, receivers, and carriers. Establishment of authority, communication links, and levels of participation will have to be carefully worked out. In addition, the contractual relationships among the parties and with the railroads must be carefully considered. In implementation, the following steps should be considered:

1. Determine parties interested in participating;
2. Develop structure and detailed roles of the shipper association and operating company;
3. Develop a detailed operating plan that includes coordination with railroads, establishment of trucking operation to loading points, and determination of methods of trailer movement from rail terminals to destination; and
4. Construct a proposed rate structure and contract form for negotiations with the railroads.

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Economic Approach to Allocating Curb Space for Urban Goods Movement

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The curb lane on urban street systems is subject to severe user competition. The primary competitors are the static users (parked vehicles) and dynamic users (vehicular traffic and surface transit). In downtown areas, the pickup and delivery of goods are almost exclusively done at curbside and, thus, goods-movement vehicles must compete with the other curb space users. Standards for the allocation of curb space for pickup and delivery (PUD) vehicles are nonexistent. The purpose of this paper is to present a method for determining curbside spatial requirements for PUD vehicles. The method outlines a process whose solution answers the question, Given a set of conditions, what are the curbside spatial requirements for PUD vehicles that would keep the total costs to society (the relevant portions) to a minimum? "Society" includes vehicular traffic, carriers, shippers, curbside automobile parkers, surface transit, and the community at large. This paper presents the components of each societal group that would be affected by varied spatial allocations at curbside and outlines the method for searching out the least cost solution. In addition to the method presentation, a case study is put forward to show that application of the least cost principle does in fact give results that are practical and implementable on urban street systems.

The vast majority of pickup and delivery (PUD) vehicles destined to the downtown area park at curbside to transfer goods. The demand for use of this curb space is high and supply is limited. The management of curb space and the rational allocation of this space among the competing users to satisfy specific needs thus become a critical issue. In one case, the need might be expediting traffic flow; in another, it might be increasing curbside automobile parking to promote local business interest; in yet another instance, a need might be to specifically provide loading zones for PUD vehicles. A lack of recognition of the need to adequately accommodate such vehicles contributes to overall downtown congestion (2).

The approach to curb use allocation described herein is based on the quantification of costs resulting from the allocation of space to the competing users. Specifically, it deals with the determination of dollar equivalents of the impacts of curb use allocation between PUD vehicles and other users. The outcome of the method application would be to allocate curb space to keep costs to society (the relevant portions) to a minimum. These costs include traffic and carrier costs, as well as automobile parking costs and the costs to the public at large.

WHO COMPETES FOR CURB SPACE USE?

In downtown areas, two basic pressures govern curbside usage: to allow parking for all or certain types of vehicles (static users) or to prohibit parking in favor of the more efficient movement of traffic on the street (dynamic users). These two basic user populations compete for use of the limited curb space. The competing users for curb space are not always in severe conflict with each other because of the natural temporal separation in user need patterns. Figures 1 and 2 show typical user demand patterns of curb space. Demand is measured by arrival patterns of these potential users. Although all data are characteristic of downtown Brooklyn, it is believed to be generally representative of large urban central business districts (CBDs).

WHEN DOES COMPETITION OCCUR?

The general identification of conflicting users of curb space in time is required. Before 7:00 a.m., curb demand in the CBD is relatively low for all users. However, just after 7:00 a.m. and continuing to about 10:00 a.m., dynamic user demand for curb space becomes significant. During this period, several static users' demands also show peaking especially in the non-shopping-related automobile populations. The 7:00 a.m. to 10:00 a.m. period is one of multiple conflicts in downtown areas; surface transit competes with other elements of moving traffic. Subgroups of the static user population are in competition with each other, and an overall high degree of dynamic and static user competition on a group user basis also exists.

The period between 10:00 a.m. and 4:00 p.m. is one when the static users mainly compete with each other for curb space usage. The amount of double parking, circulating, and the like that result depends on the severity of this competition. From 4:00 p.m. to 7:00 p.m., the

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dynamic users again show heavy demand patterns and the static user groups show relatively low demand characteristics during this period. The 4:00 p.m. to 7:00 p.m. period is, therefore, less difficult in resolving conflicts than the 7:00 a.m. to 10:00 a.m. period because of the relative absence of static-user competition.

In view of this information, three distinct conflict periods (CPs) can be defined for evaluation: (a) CP 1 is from 7:00 a.m. to 10:00 a.m.; (b) CP 2 is from 10:00 a.m. to 4:00 p.m.; and (c) CP 3 is from 4:00 p.m. to 7:00 p.m. There is sufficient difference in curb space user demand in these three conflict periods to warrant separate consideration from the curb management viewpoint, at least in initial phases of the evaluation.

OVERVIEW OF PUD PROCESS

Before we discuss the curb space allocation method, the PUD process as it generally occurs in a large CBD needs to be briefly characterized. The basic operational characteristics (e.g., dwell times, trip generation, and parking patterns) are necessary inputs to the model. The values presented in the following sections were collected in the Brooklyn CBD; however, we believe that the values presented are reasonable estimators for most large CBDs.

Parking Patterns of PUD Vehicles

Observations from 686 samples in downtown Brooklyn showed that 98 percent of all PUD vehicles were parked within 30 m (100 ft) of the destination establishment. This pattern was followed independently of curb parking regulations. If a driver did not find a curb parking space within 30 m (100 ft) of his or her destination, he or she would double park to pick up or deliver goods. This parking pattern is a result of driver habit, truck security, and efficient truck operations.

Dwell Times

Data on vehicle dwell time for pickup and delivery of goods by land use were also collected. Table 1 gives the summary of findings. Two dwell times are shown for the other retail or commercial land use because the legality of parking had a significant effect on length of stop. For the other land uses, no significant differences were found.

Trip Generation

The analysis of the number of PUD vehicle trips generated by sample sites in a large CBD was done by Loebl (12). His work demonstrated that the number of PUD vehicles generated by a retail or commercial establishment is a function of the number of different commodities typically picked up and delivered to that establishment in an average week (Monday through Friday). This number of different commodities was defined as the specialization index of the establishment and was labeled C. Table 2 (12) gives the specialization indexes for retail and specialty establishments. Dividing Loebl's weekly generation by 5 to get daily generation gives $T = -3.3 + 1.8C$ where C = specialization index of the site. For example, an appliance store would be expected to generate $-3.3 + (1.8 \times 3) \cong 2$ PUD trips on the average day.

OVERVIEW OF ECONOMIC RATIONALE

A decision to allocate a portion of the curb space in the CBD for loading and unloading of goods will inherently result in impacts to varied interest groups. Providing no space for goods movement at curbside increases the probability of a double-parked PUD vehicle that would adversely affect traffic flow. The provision of a segment of curb space (in time) for goods movement would reduce the traffic impact but increase the impact on the curbside parkers who must seek alternate accommodations. If the quantification of these varied impacts can be brought to a common basis, then a curb use allocation governed by the minimization of this denominator should be possible. Such a minimum-impact allocation procedure could be justifiable as a rational tool for CBD application.

The base to which the varied impacts will be reduced in this study is equivalent dollars because data are available to attempt such a quantification of impacts. The object, therefore, would be to choose a curb allocation scheme based on a set of given conditions that would keep the costs of impacts on society to a minimum. The cost to society for allocating curb spaces to PUD vehicles can be expressed as

$$C(s) = c_1(s) + c_2(s) + c_3(s) + \ldots \quad (1)$$

where $c_i(s)$ = cost to interest group i of allocation spaces. Because the individual $c_i(s)$'s in equation 1 are not all analytically expressible, the procedure for finding the minimum cost solution would be to evaluate C(s) for increasing values of s (beginning with s = 0) until the minimum C(s) is achieved.

IDENTIFICATION OF SOCIETAL COSTS

A PUD vehicle arrives and the driver, seeing no available parking space for his or her vehicle within search range, double parks. This paper will first evaluate the costs associated with S = 0 (no allocation). The cost of dislocating one or more automobile parking spaces from curbside to accommodate the PUD vehicle or vehicles at the curb is then determined for various sizes of loading zones.

Cost of Zero Allocation

The cost of an illegally double parked PUD vehicle is borne by the affected traffic and the community through increased delays, air pollution, and road user costs. It has not been substantiated that accident rates vary with vehicle speeds [between 16 and 40 km/h (10 and 25 mph)] typical of urban street system conditions (4, 5); therefore, this element has been omitted at this time for evaluating costs of alternatives.

The travel delays caused by a double-parked PUD vehicle can be estimated by using the Urban Traffic Control System Simulator (UTCS-1). The UTCS-1, a microscopic-oriented program, can simulate the incremental effect on "normal" traffic operations of a blocked lane for given base conditions, such as traffic volume, block length, and cycle length (6).

The dollar cost of the delays attributable to the double-parked vehicle is calculated by applying a value of time to these delays. This paper assumes $2.20/h/person as the cost of time for passenger delays (automobile and public transit) and $6.00/h for truck drivers. The value of time has been shown to depend on trip purpose, income of traveler, and the size of a trip delay (7). The values used in this paper are representative of current findings and, in our opinion, reasonably conservative.

The increased operating costs due to incremental congestion are primarily attributable to the increased number of stops and starts caused by the blockage. This increased number of stops results from maneuvering as well as from missed progression in the signal system.

The UTCS-1 outputs data on the number of stops as well as average travel speed before, during, and after the blockage. Curry and Anderson, in a 1972 study (8), evaluated the increased cost of stopping and regaining speed. Because of the recent dramatic increase in operating costs, the values developed in that 1972 study have been increased by 50 percent to approximate 1976 conditions. The incremental operating cost of a blockage if a 25-km/h (40-mph) speed after stopping is assumed is about $6.00/1000 stops for automobiles, and $12.00/1000 stops for buses and trucks.

Incremental air pollution can be estimated from UTCS-1 output data by using an equivalent vehicle-kilometer of travel per minute of delay. If a vehicle spends 1 min of extra time on a block, then the amount of air pollutants emitted by that vehicle during that minute is the incremental pollution. The number of kilometers that this vehicle would travel in 1 min is equal to the speed before blockage times 1 min. Table and charts for air pollution give values per vehicle-kilometer of travel. The vehicle-kilometers of travel (actual) do not increase because of the blockage; therefore, the estimation of an equivalent vehicle-kilometer of travel is necessary. The quantity of incremental air pollution (carbon monoxide and hydrocarbons) after the equivalent vehicle-kilometers of travel have been calculated can be estimated from the research findings of Beaton, Skog, and Ranzieri (9). The U.S. Environmental Protection Agency's estimates for oxides of nitrogen for 1975 vehicles (typical mix) is about 3.2 g/km (1.99 g/mile) (13).

To quantify the economic impact of this increased pollution on the public at large, a dollar cost per unit of pollution is necessary. Pylyp's research (10) evaluated the cost to the community of these pollutants as they affect health, vegetation, residential property, and the like. The values recommended are as follows:

1. 0.0004 cent/g for carbon monoxide,
2. 0.04/cent/g for particulates,
3. 0.10 cent/g for sulfur dioxide,
4. 0.03 cent/g for hydrocarbons, and
5. 0.02 cent/g for oxides of nitrogen.

Some of these unit costs are applied to the incremental pollution to determine dollar impact.

Consumer costs are not included in the evaluation because these costs are reflected in the resultant cost to the carrier as part of the traffic stream. As was discussed in the section on parking patterns, there does not appear to be any measurable cost to the trucker if parking is or is not available (except for parking tickets).

Cost of Nonzero Allocation

The costs associated with allocating specific segments of the curb to trucks relate to the impact of dislocating automobile parkers from curbside plus the resultant impact incremental to moving traffic. This incremental impact should decrease as spatial allocation increases. The major portion of this cost is the cost of dislocating parkers from the curb and, as a result, the replenishment of an equivalent amount of off-street parking spaces (these vehicles cannot be displaced to other curb space because the supply of such spaces is not expandable). The cost of providing parking spaces for displaced parkers is construction cost, maintenance and operation cost, and land acquisition costs. These off-street parking spaces may be in garages or in parking lots.

The cost to the parker of being dislocated is primarily in time lost in parking and unparking the vehicle in an off-street facility as opposed to curbside parking. The other cost to the displaced curb parker is the additional parking fees paid for off-street parking. This cost, however, has already been included by the consideration of construction costs, maintenance costs, and the like for providing the additional off-street spaces that are paid for by parking fees. Thus inclusion of the incremental parking fees would be double counting.

The perceived cost of loss of business by the retailer when curb space is removed from shopper use is a cost that need only be evaluated for CP 2 because of the patterns associated with these users. This perceived cost can be neglected altogether if all off-street spaces are located in a manner such that the shopper patterns are unaffected. If the shoppers are displaced to an area undesirable to the parker or if the shoppers' needs are not satisfied, then the actual and not the perceived cost of loss of business must be considered. The concept, therefore, of replenishing parking spaces at desirable locations when they are removed from curbside for the accommodation of PUD vehicles is one that is consistent with CBD economic enhancement.

The difference in the parking and unparking time for curb and off-street spaces is a delay cost to the parker. The maneuvering time for entering and departing a parallel curb parking space has been shown to be about 1 min (11). The amount of time spent in an off-street facility will vary widely with the type of facility. For lots, the parking plus unparking time may be 2 to 4 min; the time would be as much as 10 min for large garages. The difference between the parking plus unparking time at the curb and at the off-street facility is translated into cost with the use of $2.20 as the value of time.

Providing off-street parking facilities for the automobile parker has the benefit of reducing to almost zero the circulating time usually consumed in the search for a curb parking space in the CBD. Depending on the downtown area this circulating time may or may not be significant. The value of this benefit would primarily be the time savings to the parkers times the value of their time in dollars. Another potential benefit to providing off-street parking would be the reduction in accidents while the automobiles are circulating on the street in search of a curbside parking space. Accidents are not included because savings are negligible compared to the other costs included (less than 0.001 accident/displaced automobile parker/year).

COMPARISON OF ALTERNATES

In the simplest sense, if the cost to society caused by double-parked PUD vehicles is not greater than the cost to displace automobiles from curbside, then the PUD vehicles should remain double parked. The displacement of curbside spaces will depend on the existing as well as short-term future traffic conditions on the street, for the severity of impact of a double-parked vehicle will increase with traffic volume. The higher the impact on traffic is, the more curbside spaces there will be that can be displaced to ensure that PUD vehicles do not double park.

The first step is evaluating the $S = 0$ condition to determine societal costs. If $C(0)$ is less than the cost of displacing two automobile spaces (one truck space) from curbside, then the least cost solution is $S = 0$ or no loading zone. If $C(0)$ is greater than the cost of displacing two curbside automobile spaces, then $C(S = 1, 2, 3, \ldots, n)$ are evaluated to find the value of S that minimizes $C(S)$.

APPLICATION OF LEAST COST APPROACH TO A CASE STUDY

The case study described is a street with three moving lanes for traffic in each direction and curbside parking. A 180-m (600-ft) block face was considered in the case study with 60-s cycle lengths and a 50-50 split. The PUD vehicle was double parked in the model at various points along the block face to evaluate the impact of double-parking location on resulting delays to moving traffic.

Cost of Zero Allocation

In the case study, the UTCS-1 was run for a simulation period of 4 min to achieve a stable flow of traffic. Then, a blockage was placed in the right lane for a period of 12 min, the typical double-parking dwell time (Table 1). The blockage was then removed from the lane and flow was allowed to resume in the three lanes along the block face for a period of 8 min to determine when "stable" conditions again prevailed. The volume to capacity ratio v/c was varied in different simulations to evaluate the effect of different traffic flows. v/c ratios of 1.0, 0.95, 0.85, 0.75, and 0.50 were tested.

Data for estimating incremental time delays, operating costs, and air pollutants were developed from the UTCS-1 simulations for various traffic volumes and different double-parking locations along the block face. Figure 3 shows the results of the simulation for incremental delays to traffic caused by the lane blockage. From Figure 3, one can see that the amount of incremental delay to the traveling public does vary with the v/c ratio and the location of the blockage.

Figure 4 was developed by using data from several simulations and calculating the annual cost of the blockage on the traffic stream (of one typical 12-min stop made daily) and on the community through increased air pollution. This figure shows the annual cost of one daily 12-min lane blockage for a family of conditions that can occur on a three-lane street with parking when an arriving PUD vehicle double parks in one of the travel lanes. The difference between the curves for CPs 1 and 3 and CP 2 in Figure 4 is that, in CPs 1 and 3, 5 percent buses (35 persons/bus) is assumed for calculations and, in CP 2, 2 percent buses (20 persons/bus) is assumed.

The term block section is defined as a 60-m (200-ft) section of the block face. This definition is desirable because, as presented previously, drivers will park their vehicles within 30 m (100 ft) of their desired destination, which implies a 60-m (200-ft) parking section for PUD vehicles.

Cost of Nonzero Allocation

The annual cost associated with displacing one curbside automobile space in downtown Brooklyn is approximately $1150 in CP 1 and CP 3, and $1050 in CP 2. These costs are derived from the assumptions presented previously.

Least Cost Solution

Finding the least cost solution is aided by transforming the impact on traffic of one typical double-parked vehicle into an equivalent number of curb spaces that could be economically displaced. Table 3 gives the impact on traffic of one daily double-parked PUD vehicle in terms of equivalent displaced automobile spaces (EDAS). Table 3 was developed by dividing the costs of impacts on traffic from Figure 4 by the cost of displacing one curbside automobile space (typical values presented previously). It is noted that the v/c ratio of 0.50 is the practical lower bound value below which, for this case study section (three lanes), the impact of double parking on traffic is not clearly identifiable.

On most block sections, the double-parking rate of PUD vehicles is rarely 1/h daily. Therefore, the actual number of double-parked vehicles as well as the resultant impact on traffic must be estimated. If a moving lane is blocked for T min in an hour, the impact on traffic can be conservatively estimated at T/12 times the impact of the standard 12-min lane blockage. A more elaborate explanation of this is available elsewhere (1). Within any 60-m (200-ft) block section, there are about five loading spaces for PUD vehicles in the moving lane. For typical retail or commercial activity, the average dwell time when the PUD vehicle is double parked is 11 min. The UTCS-1 simulations considered 12-min blockages after additional time for "parking" maneuvers was taken into account.

The moving lane is blocked when one or more PUD vehicles is double parked at any time. The five possible truck spaces for PUD vehicles in a 60-m (200-ft) section can be considered as five independent servers each with an exponential mean (though more precisely, a gamma mean in which A = 1.25) of 12 min. The independence of servers can be assumed because the portion of the dwell time that most detracts from this independence is internal time, which is a small portion of the total stay (3). For office buildings and retail food establishments, the internal time is independent of parking conditions because of the type of internal functions performed by the driver at these land uses.

It should also be noted that not all arriving PUD vehicles will double park; therefore, the double-parking population must first be extracted from the gross arrivals. If a Poisson arrival pattern for double-parking PUD vehicles within each hourly period is assumed, then the probability of having no double parkers in the system at any time can be readily estimated, given that no more than five such parkers can be accommodated at any one time. Table 4 gives these estimates.

Sample Block Segment

Applying the known information to develop curb space usage is now considered for a case study midblock segment [60 m (200 ft) long] that generates PUD vehicles. This block segment has two restaurants, two shoe stores, two clothing stores, a jewelry store, an appliance store, and a bank. Table 5 gives the arrival pattern of PUD vehicles to this block segment.

The procedure for determining curb usage based on the given conditions (traffic, street section, and PUD vehicle generation) is as follows. The overall PUD vehicle generation rate to the sample block section is determined for each hour of the typical day (only 7:00 a.m. to 7:00 p.m. need be considered). From this overall generation, the arrival rate for the double-parking population is calculated by using the findings from Figure 2, Table 2, and Table 4. By using the procedure outlined previously, one estimates the number of minutes in each hour that the moving lane is blocked due to a double-parked PUD vehicle. From this estimate, the equivalent 12-min impact is read directly from Table 4. The annual cost of the impact of double-parked PUD vehicles on traffic is the value read from Table 4 multiplied by the equivalent 12-min impacts in each hour. The total impact in the conflict period is thus the sum of the hourly impacts.

From Table 5, the societal impacts in CP 1, CP 2, and CP 3 are 10.8, 2.7, and 0.1 EDAS respectively. Therefore, in CP 3, the least cost solution would be to have zero allocation because to provide one truck space would be to incur a societal cost of at least 2.0 EDAS. However, in CP 1 and CP 2, the least cost solution may or may not be zero allocation and can only be determined by further calculations.

Table 6 gives a summary of the calculations for CP 1 and CP 2 to determine societal costs and thus the least cost solution. In CP 1, one can see that, as zone size S increases, traffic impact decreases and displaced parking impact increases. The least cost solution in CP 1 is to have a loading zone capable of accommodating two PUD vehicles at the same time. In CP 2, the least cost solution is to provide no space for PUD vehicles even though this is the period when most of these vehicles pick up and deliver their goods.

OVERVIEW

Changing policy to establish curbside loading based on least cost could find justification in cities that must improve air quality (as traffic delay decreases so do air pollution emissions). However, to improve this environmental aspect, local governments, most of which are

Figure 1. Typical nongoods curb space demand patterns.

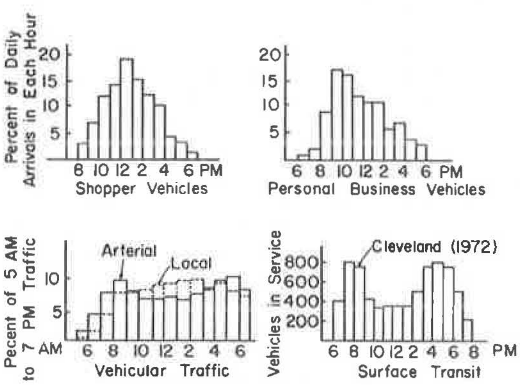

Figure 2. Selected hourly PUD vehicle arrival patterns by land use in Brooklyn CBD.

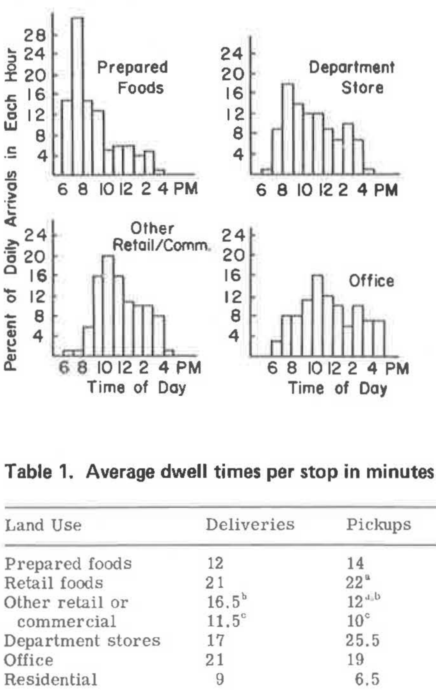

Table 1. Average dwell times per stop in minutes.

Land Use	Deliveries	Pickups	All
Prepared foods	12	14	12
Retail foods	21	22[a]	21
Other retail or commercial	16.5[b]	12[a,b]	15.5[b]
	11.5[c]	10[c]	11[c]
Department stores	17	25.5	18
Office	21	19	20
Residential	9	6.5	8

[a]Estimated from very small sample.
[b]Legal curb parking.
[c]Illegal curb parking.

Table 2. C-values for retail and specialty establishments.

Type of Establishment	C-Value	Type of Establishment	C-Value
Prepared foods	5	Fabrics	3
Shoes	3	Banks	4
Clothing	4 to 5[a]	Appliances	3
Furniture	3	Electrical and camera	3
Jewelry	3	Retail foods	4 to 7[a]
Department store	15	Flowers	3
Wigs	3	Liquor store	4
Drug store	6 to 8[a]	Miscellaneous	3
Stationery	2		

[a]Size dependent.

Figure 3. Incremental traffic delays per 12-min blockage.

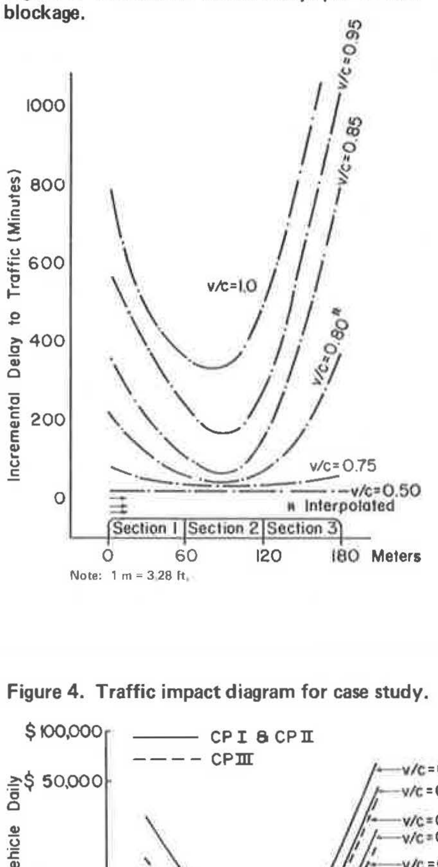

Figure 4. Traffic impact diagram for case study.

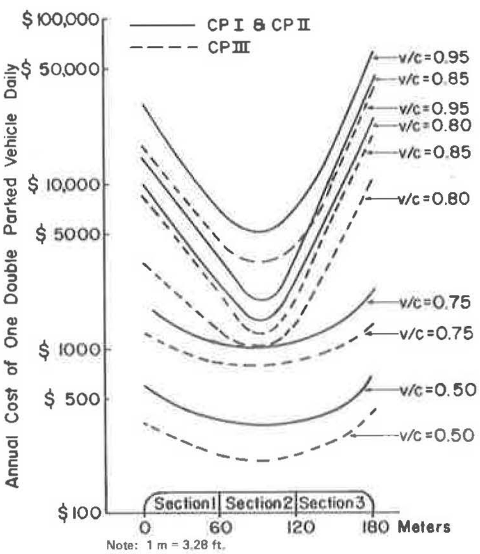

Table 3. Curb space equivalents of traffic impact of one 12-min double-parked goods vehicle daily in CBD.

		EDAS		
Conflict Period	v/c ratio	Section 1 Block	Section 2 Block	Section 3 Block
1 and 3	1.00	17	10	27
	0.95	11	5	17
	0.85	6	2.4	11
	0.80	5	1.7	7
	0.75	1.1	1.0	1.2
	0.60	0.7	0.6	0.9
	0.50	0.3	0.2	0.3
2	1.00	10	6	15
	0.95	6	2.8	10
	0.85	3.3	1.3	6
	0.80	1.6	1.0	3.1
	0.75	0.7	0.6	0.5
	0.50	0.2	0.2	0.2

Note: v/c ratios of 0.80 and 0.60 were interpolated.

Table 4. Estimates of lane blockage by arrival rate.

Double Parker Arrival Rate Per Hour[a]	P(0)[b]	1 - P(0)	Minutes Occupied	T/12
0.5	0.90	0.10	6	0.5
1.0	0.82	0.18	11	0.9
2.0	0.67	0.33	20	1.7
3.0	0.54	0.46	27	2.3
4.0	0.43	0.57	34	2.8
5.0	0.34	0.66	40	3.3
6.0	0.25	0.75	45	3.8
7.0	0.18	0.82	49	4.1
8.0	0.12	0.88	53	4.4
9.0	0.08	0.92	55	4.6
10.0	0.05	0.95	57	4.8

[a]25 percent of arrivals double park from 6:00 a.m. to 8:00 a.m.; 37 percent double park from 8:00 a.m. to 9:00 a.m.; and 49 percent double park after 9:00 a.m. (1).
[b]Probability of no lane blockage.

Table 5. Estimating impact of PUD vehicles by displaced curbside automobile parking spaces.

Critical Period	Time Period	v/c Ratio[a]	Gross Generation Rate Per Hour[b]	Double Parker Arrival Rate Per Hour	Equivalent 12-Min Impacts	EDAS
1	7:00 a.m. to 8:00 a.m.	0.85	3.1	0.8	0.7	1.7
	8:00 a.m. to 9:00 a.m.	0.95	2.7	1.0	0.9	4.5
	9:00 a.m. to 10:00 a.m.	0.85	4.7	2.3	1.9	4.6
	Total					10.8
2	10:00 a.m. to 11:00 a.m.	0.75	4.9	2.4	2.0	1.2
	11:00 a.m. to 12 noon	0.60	4.1	2.0	1.7	0.5
	12 noon to 1:00 p.m.	0.70	3.0	1.5	1.3	0.6
	1:00 p.m. to 2:00 p.m.	0.55	2.6	1.3	1.1	—
	2:00 p.m. to 3:00 p.m.	0.50	2.7	1.3	1.1	—
	3:00 p.m. to 4:00 p.m.	0.70	1.9	0.9	0.8	0.4
	Total					2.7
3	4:00 p.m. to 5:00 p.m.	0.75	0.2	0.1	0.1	0.1
	5:00 p.m. to 6:00 p.m.	0.75	—	—	—	—
	6:00 p.m. to 7:00 p.m.	0.50	—	—	—	—
	Total					0.1

[a]v/c ratio past the sample block face in one direction. [b]Using Table 2 and Figure 2.

Table 6. Identifying the least cost solution.

Conflict Period	Zone Size	Traffic Impact (EDAS)	Displaced Parking Impact (EDAS)	Total Impact (EDAS)
1	0	10.8	0	10.8
	1	5.8	2	7.8
	2[a]	0.5	4	4.5
	3	0	6	6.0
2	0[a]	2.7	0	2.7
	1	2.3	2	4.3

[a]Least cost solution in respective conflict period.

economically strained, would have to explicitly accept in principle to construct off-street automobile spaces as defined in the methodology. Actually, in our opinion, the establishment of loading zones based solely on least cost will result in an overall increase in the on-street automobile parking supply over current conditions.

There are several assumptions in the method, one of which is the assigning of a value to time. A higher value of time would place more pressure for the removal of additional curbside automobile spaces. The methodology does not restrict itself in any way, and the only reason for the use of any figures, costs, and the like in this paper is to show that reasonable results would be attainable when typical characteristics were assumed.

One potentially important by-product of the approach described in this paper concerns the impact of traffic as a function of block length. Figure 3 shows how the location of a double-parked vehicle affected delays. Although only 180-m (600-ft) block length was evaluated in the case study, the findings have implications concerning the inefficiency that is built into street systems that have short block lengths. One notable street system is that of Manhattan where the block lengths on the major arteries are only 60 m (200 ft). Congestion from goods movement in Manhattan has prompted studies to achieve more efficient operation. It may not be that goods movement process is inefficient but that the very short block lengths contribute disproportionately to the congestion where, in another CBD with the same goods movement activity, resultant congestion would be less severe because of longer block lengths.

This least cost approach is not directly sensitive to environmental considerations in terms of relative weight. This is a problem faced by most economic-based solutions to transportation problems. One method of circumventing this limitation would be to develop a "perceived cost" of air pollution and input this cost into the total cost function.

Goods movement has to be treated as one element in the urban transportation picture and not be treated as an entity. The least cost approach to solving curbside spatial allocation responds to this principle. The approach is one whose rationale can be identified. It is an economic rationale, a least cost approach for a given set of conditions. The method for finding this least cost solution does reflect reasonable curb management conclusions for the CBD. For roadways with high v/c ratios, the least cost solution shows that ensuring no double parking in travel lanes by PUD vehicles can be justified and, on low volume streets, that the installation of loading zones by removing on-street automobile space is a questionable practice.

ACKNOWLEDGMENT

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Economic Rationale for Establishing Off-Street Loading Requirements in the City Center

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Off-street loading requirements for goods movement in existing zoning ordinances do not seem to be based on any general form of objective rationale. Thus there is a lack of uniformity in application in downtown areas in the nation's cities. This paper presents a unique process for public-interest planning for off-street loading facilities. The process addresses the question, What are the off-street goods movement loading requirements for a specific site or group of sites that would keep the costs to society (the relevant portions) to a minimum? The carriers, the developers, the tenants, those who drive and park, and the community at large are all vested-interest groups affected by loading standards. There are direct costs to the carriers incurred by waiting for loading space, and there are developer's costs for providing this space. Queued trucks cause increased road user costs when local traffic volumes are high enough to be adversely affected. Providing curbside queuing space also has costs associated with the depletion of the on-street parking supply. Air and noise pollution caused by queued trucks impairs health, decreases land values and retail sales, and has other adverse effects on the community. It is necessary, therefore, to evaluate all direct and indirect interest-group impacts, reduce these impacts to a common base (for this paper, constant dollars), and then set criteria for off-street loading requirements that minimize societal costs. This paper presents a method for determining these direct and indirect costs of interest-group impacts as they relate to off-street loading facilities and introduces a case study to show that practical application produces realistic results.

Policy decisions regarding off-street loading facilities for goods movement in the central business district (CBD) are very sensitive to economic impact on developers. This may be one of the reasons why standards for off-street loading facilities vary so widely among cities. Because economics plays such a crucial role, an economic tool should find fundamental application for this type of decision making.

This paper outlines a method based on the consideration of the principal direct and indirect costs associated with the provision of off-street loading facilities in the CBD. The method addresses the question, What should the off-street loading requirements be for a specific site or group of sites so that the resultant costs to society (the relevant portions) can be kept to a minimum?

There are pertinent reasons why a large generator of pickup and delivery (PUD) vehicles should provide off-street facilities. Some of these reasons are to reduce on-street traffic and pedestrian conflicts, minimize visual intrusion, and increase security. There are also reasonable arguments against providing off-street loading facilities in the CBD. Some of these are increased cost to the developer (and thus to the tenants), potential access problems, truck queues that usually result when insufficient berths are provided, and difficulty in estimating off-street loading requirements due to the possibility of use change in the structure over time.

Quantifiable costs are associated with most arguments for and against off-street facility provision. This paper deals with the development and evaluation of an economic approach for determining the number of off-street loading facilities that should be provided for a newly constructed building in the CBD.

INTEREST GROUPS

The impacts on interest groups of policies concerning off-street loading facilities are given in the following tabulation:

Interest Group	Excessive Berths	Insufficient Berths
Carrier	Low	High
Those who drive and park	Low	High
Community	Low	High
Street parkers	Low	High
Developer	High	Low

This tabulation gives the impacts on the interest groups depending on whether the loading facilities are too numerous or too few with respect to PUD vehicle demand. It seems clear that the impact on the developer conflicts with all other impacts on the remaining interest groups. That is, any savings to the developer translates into a cost to all other interest groups. From a formal survey of traffic engineers in the nation's largest cities (1), it is evident that a good deal of the responsibility for off-street loading provision is retained by the developers. It seems evident to us that any regulatory policy that places such responsibility completely on the developer must ac-

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cept the result, which would usually be underdesigned off-street loading facilities and their resulting impacts.

OVERVIEW OF ECONOMIC RATIONALE

If a new structure is to be built in the CBD, then a total cost function could be formulated with the number of off-street berths remaining a variable. The costs would be the dollar value of the impacts on the interest groups given in Table 1. The cost function would be in the form:

$$C(b) = c_1(b) + c_2(b) + c_3(b) + \ldots \quad (1)$$

where

b = number of off-street loading berths and

$c_1(b)$, $c_2(b)$, and $c_3(b)$ = functions relating number of berths to the cost of impact on the interest groups.

Finding the value of b that would minimize this cost function would be to equate dC/db to zero and solve for b. However, as will be shown in the following section, the individual cost functions generally cannot be expressed algebraically because at this time many impacts still have to be developed by computer simulations of the goods-movement process. Therefore, the procedure to find the value of b that minimizes the total cost function is to calculate the total cost of several probable numbers of berths. The minimum cost value would then be evident.

COST TO INTEREST GROUPS

Carrier Cost

The cost incurred by the carriers (and therefore the consumers through passed-along charges) at off-street loading facilities is primarily determined by delays caused by truck queues. When the dispatcher figures the truck routing before departure from the terminal, he or she usually knows the area and its traffic characteristics, and, as a result, normal traffic delays are compensated for in this scheduling. However, when a PUD vehicle has to queue up at a specific location, this delay is usually extraneous to the original routing schedule, and, as a result, this delay will set back the driver, forcing overtime work or redelivery (there are additional charges for redelivery). Interstate Commerce Commission (ICC) regulations stipulate that the carrier must wait a half hour before detention charges can be levied against the account. However, many private carriers cannot charge detention fees because of the competitive nature of their business. Many for-hire carriers also do not charge detention fees in fear of losing a large account.

Estimating the carrier's cost for waiting requires the evaluation of queues for the different numbers of berths being analyzed. If the dwell time distribution of the PUD vehicle at the dock is exponential (or close to it) or if only one berth is being evaluated, queuing statistics could be determined analytically. The dwell time distribution is not exponential (2), and, for most analyses, more than one berth has to be considered. Statistics for waiting times in queues can be estimated by simulating the arrival and dwell patterns for PUD vehicles at the off-street facility. The arrival pattern is dependent on the land use, and the dwell time is influenced by type of land use. Figure 1 shows the arrival patterns for office buildings and department stores in the CBD. A simple general purpose simulation system (GPSS) model (3) was developed for use in this study.

Drivers of queued PUD vehicles have been found to have a tendency to leave engines on while waiting. This waste of fuel is also a carrier cost. Methods of quantifying this fuel consumption are given in the section on community costs.

Developer Costs

The cost to the developer can be estimated from two different conceptual viewpoints. These two viewpoints are given in this section and will be referred to throughout this paper.

One method of calculating the developer's cost for providing off-street loading facilities is to estimate the construction cost of the docks plus the lost revenue (opportunity cost) had the developer used this space for some revenue-generating purpose. The construction cost of the docks minus the construction cost of the revenue-generating facility when capitalized over the life of the building is usually not a very sizable amount and can be neglected in most analyses. The cost to the developer approximates the annual cost of lost revenue due to "wasted space." This developer cost is passed along to the tenant, who, in turn, passes the cost along until the consumer finally pays the bill. This method of developer cost estimation is referred to herein as the total cost method.

The other method for calculating developer cost is to consider that tenants will be willing to pay the cost of providing off-street loading facilities to the extent that these facilities are serving the tenant. Thus, the cost to the developer would only be that portion of the time between 7:00 a.m. and 7:00 p.m. when the facilities are not used. This utilization method would conclude that, if a developer provided an off-street facility that was occupied 100 percent of the time, the resultant cost to the developer would be zero. If the facilities were occupied 50 percent of the time, then the cost to the developer would be 50 percent of the cost according to the total cost method.

The advantage of the utilization method is that it makes the developer's cost sensitive to use change in the structure because, if more PUD vehicles were generated by a subsequent use, the cost to the developer would change accordingly. The disadvantage of the utilization method is that one may lose track of the actual cost of providing the off-street facility.

The GPSS simulation is one available tool that estimates facility utilization and, therefore, the developer's cost in the utilization method.

Traffic Costs

Queuing of vehicles at loading facilities can adversely affect traffic flow depending on the volume of traffic, street width, and dock configuration. Evaluating the impact on traffic is most tedious, requiring the use of the Urban Traffic Control System simulator, UTCS-1 (4). The cost of land blockages is borne by the affected drivers and parkers and the community through increased delay, air pollution, and road user costs. That accident occurrence increases under these low-speed conditions has not been substantiated, but one would expect such an increase.

The UTCS-1 simulates the effect of the lane blockage on traffic characteristics for a given set of network conditions such as traffic volume, block length, and cycle length. All impacts are incremental impacts caused by the lane blockage because, in normal traffic, delays are normally encountered. The delays of concern here are the delays over and above those normally occurring. Similarly, this incremental aspect applies to air pollution and vehicle operating costs.

The specific location of the lane blockage along a block face will influence the severity of impact to moving traffic. Figure 2 shows the expected impact on traffic as the blockage moves along a block face. If a lane blockage is in the upstream section of the block, the result will be much maneuvering at the upstream intersection causing delays. As the location of the blockage moves downstream toward the middle of the block face, the incremental delays result from a blocked lane while traffic is moving, and, unless the traffic is high, the resultant delays are expected to drop because of the increased distance in which the lane-changing maneuver can be made. As the location of the interference approaches the downstream intersection, any blockage will reduce the number of approach lanes by one and cause delays the severity of which will vary with the volume of traffic.

The dollar cost of the delays attributable to the double-parked vehicle is a matter of applying a value of time to these delays. This paper assumes $2.20/person/h as the cost of time for passenger delays (automobile and transit) and $6/h for trucks. The value of time has been shown to depend on trip purpose and income of traveler and the size of a trip delay. The values used in this paper are representative of current findings (5).

The increased operating costs due to the incremental congestion are primarily attributable to the increased number of stops and starts caused by the blockage. The increased number of stops results from maneuvering as well as from missed progression in the signal system. The UTCS-1 outputs data on the number of stops and average travel speed before, during, and after the blockage. In a 1972 study, Curry and Anderson (6) evaluated the increased operating costs of stopping and regaining speed. Because of the dramatic increase in the operating costs recently, the values developed in that 1972 study have been increased by 50 percent to approximate 1975 conditions. The incremental operating costs of blockage [assuming a 25-km/h (15-mph) speed after stopping] are about $6/1000 stops for automobiles and $12/1000 stops for buses and trucks. We consider these values conservative.

Incremental air pollution can also be estimated from UTCS-1 output data by using an equivalent vehicle-kilometer of travel per minute of delay. If a vehicle spends 1 min of extra time on a block, then the amount of air pollutants emitted by that vehicle during that minute is the incremental pollution. The vehicle-kilometers of travel (actual) do not increase because of the blockage, and, therefore, the estimation of an equivalent vehicle-kilometer of travel is necessary. The quantity of these pollutants can be estimated from the research findings of Beaton, Skog, and Ranzieri (7). The findings referred to above do not include methods of estimating the quantity of oxides of nitrogen but only carbon monoxide and hydrocarbons. The U.S. Environmental Protection Agency's standard for emissions of oxides of nitrogen (NO_x) for all 1975 and newer automobiles and trucks is 0.6 and 1.7 g/km (1.0 and 2.7 g/mile) respectively and is quite insensitive to speed.

The result of multiplying equivalent vehicle-kilometers of travel and the quantity of pollutants per kilometer will give the amount of grams of pollutants per kilometer of the three main pollutants. The dollar value per gram of these pollutants was the subject of a study by Pylyp (8). He evaluated the cost to the community of these pollutants as they affect health, vegetation, residential property, and the like and recommended unit costs of 0.0004 cents/g for carbon monoxide (CO), 0.03 cents/g for hydrocarbons (HC), and 0.02 cents/g for oxides of nitrogen for urban centers.

Displaced Parking Costs

Providing curbside space for the storage of queued PUD vehicles comprises the cost of dislocating parkers from the curb and, as a result, the provision for an equivalent amoung of off-street parking spaces, for these vehicles cannot be displaced to other curb space because the supply of these spaces is not expandable. The cost of providing parking spaces for displaced parkers is construction cost, maintenance and operation cost, and land acquisition cost. These off-street parking spaces may be in garages or in parking lots.

The cost to the automobile parker of being dislocated is primarily in time lost in parking and unparking the vehicle in an off-street facility as opposed to curbside parking. The other cost to the displaced curb parker is the additional parking fees paid for off-street parking. This cost, however, has already been included by the consideration of construction costs, maintenance costs, and the like for providing the additional off-street spaces. Thus inclusion of the incremental parking fees would be double counting.

The perceived cost of loss of business by the retailer when curb space is removed from shopper use is a cost that can be neglected altogether if all off-street spaces are located in a manner such that the shopper patterns are unaffected. If the shoppers are displaced to an area undesirable to the parker or if the shoppers' needs are not satisfied, then the actual and not the perceived cost of loss of business must be considered. The concept, therefore, of replenishing parking spaces at desirable locations when they are removed from curbside for the accommodation of PUD vehicles is one that is consistent with CBD economic enhancement.

The difference in the parking and unparking time for curb and off-street spaces is a delay cost for this alternate. The maneuvering time for entering and departing a parallel curb parking space has been shown to be about 1 min (9). The amount of time spent in an off-street facility will vary widely with the type of facility. For lots, the parking plus unparking time may be 2 to 4 min; the time would be as much as 10 min for large garages. The difference between the parking plus unparking time at the curb and at the off-street facility is translated into cost with the use of $2.20 as the value of time.

Providing off-street parking facilities for the automobile parker has the benefit of reducing to almost zero the circulating time usually consumed in the search for a curb parking space in the CBD. Depending on the downtown area, this circulating time may or may not be significant. The value of this benefit would be the time savings to the parkers times the value of their time in dollars. Another potential benefit to providing off-street parking would be the reduction in accidents while the automobiles are circulating on the street in search of a curbside parking space. Accident savings (or costs) are not included in this paper because it is not certain how having trucks park at curbside would influence accident rates (as opposed to having automobiles remain at curbside and the trucks double park). Furthermore, if there are such accident savings, they would probably be negligible.

It should be noted that the value of a parking space changes over the day because of trip purpose, automobile occupancy, and other factors. The values developed in this paper are different for three distinct periods: conflict period (CP) 1 is from 7:00 a.m. to 10:00 a.m.; CP 2 is from 10:00 a.m. to 4:00 p.m.; and CP 3 is from 4:00 p.m. to 7:00 p.m. The values are annual costs typical

Figure 1. Hourly arrival patterns for pickups and deliveries.

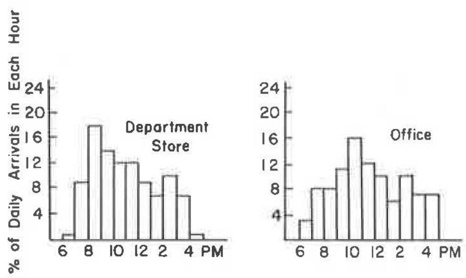

Figure 2. Delay pattern for various double-parking locations for constant traffic volume.

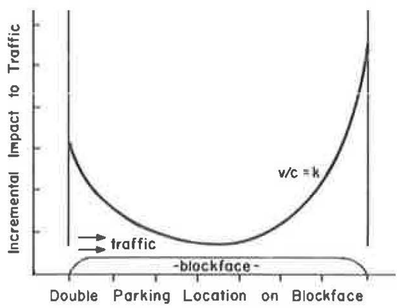

Figure 3. Typical cost function.

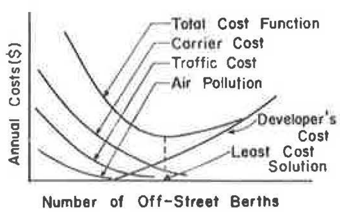

Figure 4. Case study conditions.

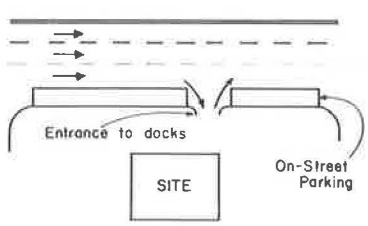

Table 1. On-street traffic conditions.

Time Period	v/c Ratio	Time Period	v/c Ratio
7:00 a.m. to 8:00 a.m.	0.85	1:00 p.m. to 2:00 p.m.	0.55
8:00 a.m. to 9:00 a.m.	0.95	2:00 p.m. to 3:00 p.m.	0.50
9:00 a.m. to 10:00 a.m.	0.85	3:00 p.m. to 4:00 p.m.	0.70
10:00 a.m. to 11:00 a.m.	0.75	4:00 p.m. to 5:00 p.m.	0.75
11:00 a.m. to 12:00 noon	0.60	5:00 p.m. to 6:00 p.m.	0.75
12:00 noon to 1:00 p.m.	0.70	6:00 p.m. to 7:00 p.m.	0.50

of displacing an automobile space from curbside to a garage in downtown Brooklyn.

Community Costs

The impacts of off-street loading facilities on the local community include visual intrusion, pedestrian interference, and air pollution. The primary consideration here will be air pollution. It is highly likely that noise levels increase also, but, in downtown areas, the noise as an environmental impact is considerably overshadowed by air pollution.

Air pollution impacts due to incremental congestion resulting from land blockages have been presented. However, data collected in the downtown Brooklyn study (2) also indicate that, when PUD vehicles are queued up and waiting for access to off-street loading facilities, many drivers tend to leave their engines idling. This adds more air pollution emission to that resulting from incremental traffic congestion (which is included in the costs to moving traffic).

The data for downtown Brooklyn indicate that about 54 percent of queued vehicles left their engines running for 42 percent of the queued minutes. Because other data are not available, these statistics will be used as estimates for evaluating air pollution impact on the community. The simulation of the arrival process gives statistics on queues; thus estimates of engine idling minutes can be translated into quantity of pollutants by using certain conversions (1): The typical idling fuel consumption rate is 4.9 liters/h (1.3 gallons/h). The pollution emitted is (a) 16 CO/minute of idling, (b) 1.3 g HC/minute of idling, and (c) negligible NO_x/minute of idling.

MINIMUM COST SOLUTION

The minimum cost solution to determine the required number of off-street loading berths is found by observation of the sum of costs for the different number of berths analyzed. Figure 3 shows a typical cost function from the summary of costs to the interest groups. It would be desirable to evaluate the cost function based on the total cost and utilization methods. In some cases, the resultant minimum cost value for the number of berths will not be the same for each method.

The result of the total cost method would be useful to planners to justify their off-street loading requirements to developers. The utilization method, which may give a higher minimum cost value for the required number of berths, could be used as the basis for "trading" between the planner and the developer. That is, the utilization method will give the cost to the developer that he or she might not normally be able to charge tenants and remain competitive in the rental market. This cost could be "refunded" to the developer through the relaxation of zoning ordinances to allow additional rentable space for the developer to recoup the lost revenue.

SENSITIVITY

Determining the least cost solution would not necessarily be an end in itself. Estimating the cost function sensitivity to changes in PUD vehicle generation at a proposed site would be appropriate. This sensitivity analysis is required to evaluate the effect of an inaccurate initial generation estimate as well as the impact of use change in the structure.

The sensitivity analysis would be governed by the type and size of the structure. If a large office building were being evaluated, it would be likely that the structure

Table 2. Hourly arrivals to case study office building.

Time Period	Arrivals %	Arrivals Number	Time Period	Arrivals %	Arrivals Number
7:00 a.m. to 8:00 a.m.	5	3	1:00 p.m. to 2:00 p.m.	10	6
8:00 a.m. to 9:00 a.m.	8	5	2:00 p.m. to 3:00 p.m.	9	5
9:00 a.m. to 10:00 a.m.	15	10	3:00 p.m. to 4:00 p.m.	7	4
10:00 a.m. to 11:00 a.m.	15	10	4:00 p.m. to 5:00 p.m.	3	2
11:00 a.m. to 12 noon	15	10	5:00 p.m. to 6:00 p.m.	2	1
12 noon to 1:00 p.m.	11	7	6:00 p.m. to 7:00 p.m.	0	0

Table 3. Truck waiting times in minutes per day.

Number of Berths	7:00 a.m. to 10:00 a.m.	10:00 a.m. to 1:00 p.m.	1:00 p.m. to 4:00 p.m.	4:00 p.m. to 7:00 p.m.
2	35	80	113	128
3	18	53	63	29
4	2	12	23	19
5	0	8	4	1
6	1	0	1	0
7	0	1	1	0
8	0	0	0	0

Table 4. Developer's cost.

Number of Berths	Annual Cost by Total Cost Method[a] ($)	Facility Use	Annual Cost by Utilization Method[a] ($)
2	30 000	0.969	900
3	40 000	0.729	10 800
4	50 000	0.482	25 900
5	60 000	0.451	32 900
6	70 000	0.322	47 500
7	80 000	0.330	53 600
8	90 000	0.320	61 200

[a]Annual costs assume 7 percent interest for 25 years.

Table 5. Sample traffic impact for five berths.

Time Period	v/c Ratio	% Zero Queue	Annual Cost of Traffic Impact ($)
7:00 a.m. to 8:00 a.m.	0.85	94	770
8:00 a.m. to 9:00 a.m.	0.95	94	1610
9:00 a.m. to 10:00 a.m.	0.85	94	770
10:00 a.m. to 11:00 a.m.	0.75	73	1030
11:00 a.m. to 12:00 noon	0.60	73	520
12:00 noon to 1:00 p.m.	0.70	73	860
1:00 p.m. to 2:00 p.m.	0.55	9	1200
2:00 p.m. to 3:00 p.m.	0.50	9	960
3:00 p.m. to 4:00 p.m.	0.50	9	960
4:00 p.m. to 5:00 p.m.	0.75	28	4120
5:00 p.m. to 6:00 p.m.	0.75	28	4120
6:00 p.m. to 7:00 p.m.	0.50	28	820

Table 6. Idling air pollution and fuel consumption costs.

Number of Berths	Air Pollution Annual Cost ($)	Fuel Consumption Annual Cost[a] ($)
2	300	4700
3	250	2000
4	200	700
5	Negligible	200
6	Negligible	Negligible
7	Negligible	Negligible
8	Negligible	Negligible

[a]Assumes 12 cents/liter (45 cents/gal) exclusive of taxes and 42 percent of waiting time with engines on.

would remain an office building; therefore, the sensitivity analysis would be confined to the evaluation of inaccurate generation estimates.

CASE STUDY

Applying the least cost rationale and the evaluation methodology is essential to judge the applicability of the process. The case study is a 74 322-m^2 (800 000-ft^2) office building whose ground floor uses are small shops. Off-street loading facilities are, therefore, only planned to accommodate PUD vehicles destined to the office uses in the building. The site is located at midblock of a 185-m-long (600-ft-long) block face in the CBD. The abutting street is three lanes in each direction and has metered parking along the curbside. Figure 4 shows case study conditions. Traffic conditions are given in Table 1.

Arrival Patterns

A 74 322-m^2 (800 000-ft^2) office building will generate PUD trips at an average rate of approximately 0.86 trips/1000 m^2/day (0.08 trips/1000 ft^2/day) (1). That is an overall rate of arrival of 64 trips on the typical day. The hourly arrival pattern is drawn from data on typical office building arrivals in downtown Brooklyn. Table 2 gives the expected arrival pattern for the case study site. The 6:00 a.m. to 7:00 a.m. arrivals are omitted because they were not considered in the analyses.

GPSS Simulation

The specific data elements to be used from the outputs of the GPSS simulation of PUD vehicles at the proposed office building are

1. Percent zero queue (moving lane not blocked),
2. Average facility use (developer's cost),
3. Average queue wait (carrier costs),
4. Average queue given queue (idling air pollution),

and

5. Average queue length (traffic impact).

The simulation model used for estimating facility requirements was run for each dock configuration with three different seeds for the random number generator. In addition, to enhance the stability of the process, each simulation was run for four 3-h periods instead of twelve 1-h periods (the typical day is 7:00 a.m. to 7:00 p.m.). An average arrival rate for each 3-h period was estimated from the hourly patterns as given in Table 2.

Parking Displacement Costs

The annual costs associated with displacement of one curbside automobile space in each conflict period are $1150 for CP 1, $1050 for CP 2, and $1150 for CP 3. These costs are based on the following assumptions: (a) displacement to an off-street garage, (b) construction

Table 7. Total annual cost function and components.

Number of Berths	Carrier Cost[a] ($)	Traffic and Parking Cost ($)	Developer Cost ($) Total Cost Method	Developer Cost ($) Utilization Method	Fuel Cost ($)	Total Annual Cost ($) Total Cost Method	Total Annual Cost ($) Utilization Method
2	190 800	67 100	30 000	900	4700	292 600	263 500
3	99 600	40 700	40 000	10 800	2000	182 300	153 100
4	29 400	14 400	50 000	25 900	700	94 500	70 400
5	6 300	3 600	60 000	32 900	200	70 100	43 000
6	—	400	70 000	47 500	—	70 400	47 900
7	—	1 000	80 000	53 600	—	81 000	54 600
8	—	—	90 000	61 200	—	90 000	61 200

[a]Based on $9/h of waiting.

cost of $8000/space, (c) annual maintenance of $350/space, and (d) overall time savings of 3 min/displaced parker. These figures are for downtown Brooklyn and are not untypical of other large downtown areas.

Carrier Cost

The carrier cost for waiting is the hourly rate times the daily delay at the docks (access delays). The data given in Table 3 show how rapidly the average waiting times decrease with increases in number of berths. At the seven-berth configuration, the average waiting times are negligible. The dollar cost to the carriers can be estimated from the above data by applying a value of time. This case study considers that the value of time for a PUD vehicle waiting in a queue is 1.5 times the delay cost when the vehicle is part of the traffic stream. Therefore, the penalty to the carrier for waiting in queues would be $9/h.

Developer Cost

As was presented, there are two methods of calculating developer costs. The total cost method is merely the cost of providing and staffing the off-street facility whether it is used or not. The utilization method would only consider the developer's cost when the facility is not used. For the case study, it is assumed that the developer could have rented the space that is to be devoted to the off-street loading facility for $160/m^2/year ($15/ft^2/year) (10). Each off-street berth plus dock is assumed to have an area of 61.3 m^2 (660 ft^2). The case study also assumes that the docks will be supervised against theft, permanently parked trucks, etc. The annual cost of this inspection is $10 000 for the case study. Table 4 gives the developer cost by both methods.

Traffic Cost

The impact on traffic can be estimated by combining two pieces of data available from the standard GPSS output—percent zero queue and queue lengths. The percent zero queue gives an estimate of what portion of the time a moving lane is not blocked. The queue lengths are needed to estimate the impact of lane blockages on traffic because the tail of the queue influences the severity of the impact. Table 5 gives a typical calculation for estimating traffic impact. This calculation is for one computer run of the five-berth configuration. In this example, the impact on traffic is equivalent to $5530 annually in CP 2 (10:00 a.m. to 4:00 p.m.); thus up to five automobile spaces (at $1050/space) could be justifiably displaced to accommodate the queued PUD vehicles.

Air Pollution and Fuel Consumption Costs

The cost to the community due to increased air pollution from idling queued trucks is given in Table 6. Also given in Table 6 is the cost of the fuel being consumed while idling (a carrier cost). These two costs are relatively small and do not have a significant effect on the total cost function. This is one possible shortcoming of this or any other economic approach. Environmental consequences are underestimated.

Summary of Costs

Table 7 gives the total annual costs for the cost function. The costs are separate for the total cost and the utilization methods of estimating developer's cost. The data in Table 7 show that the number of berths that would minimize societal costs is five for both methods. This table also shows how rapidly the cost function approaches "reasonable solutions," which, in the case study, is five or six berths.

The resultant traffic impact for the least cost solution is such that two automobile spaces could justifiably be displaced for use as a single-truck storage area. Although the actual design of the off-street facility is not considered in this study, if the configuration of the berths is such that more than the approximately two on-street automobile spaces required to provide an access point must be displaced, then this automobile-space displacement cost must also be included in the cost function.

It may be recalled that, in the introduction of this paper, it was pointed out that there was a lack in consistency among the cities that had off-street loading requirements in the CBD. If the case study building was constructed in the Atlanta CBD, 10 off-street berths would be required as stipulated in the city's zoning ordinance. If the same 74 322-m^2 (800 000-ft^2) office building was built in the Pittsburgh CBD, six berths would be adequate. In Cincinnati, four berths would satisfy that city's requirements. As such, application of the last cost approach produces realistically implementable results for field application.

OVERVIEW AND CONCLUSIONS

The method described is flexible in application and can be used for any type of land use, even those not typically found in the CBD. The sensitivity of the method to traffic volume, developer's cost, carrier delay, and the like also enhances universal application. Low-volume streets would tend to require a lower number of off-street berths than would sites located on heavily traveled arteries. A reduction in the developer's cost (as in non-CBD developments) would tend to increase requirements, if all other elements are equal. If the hourly change of driver delays due to queued PUD vehicles changed, the facility requirements would change accordingly. Each new development, therefore, would merit separate consideration because of the lack of uniformity of the impacting variables even in the same CBD.

The review of current zoning stipulations for off-street facilities indicates a lack of uniformity. Moreover, many cities do not even have requirements in the CBD. The application of the proposed methodology by planners in various cities will provide a rational basis for explaining to developers the reasoning for off-street loading facility provision and quantification. But there is one problem. Because the methodology does not lend itself to rigid application, it is not well suited as part of a zoning ordinance. The principal attribute of the methodology, its flexibility of application, would be lost if relegated to an ordinance.

The local planner in city planning departments would be the person that determines the required number of berths for a given set of conditions. All formal off-street loading requirements would be removed from zoning ordinances. However, these ordinances may include the size of building above which at least one berth is required [for the case study, this is about 18 580 m^2 (200 000 ft^2)].

The analyses to find the least cost solution also produce a range of berths that, given the accuracy of the inputs, is more helpful than a single solution. This range identification (five to six for case study) allows the planner to tailor the final off-street requirements to specific site conditions that may not show up in the analysis procedure.

Because the method is structured to consider the impact groups specifically, application to other than the city center is feasible. Traffic may be less of an influence on the final solution than in the city center. However, comparing carrier costs to developer costs should, as a minimum, provide the least cost solution under any conditions.

Existing policies on off-street loading facilities are vague at best because their position in the urban transportation scene is not defined. Therefore, adopting a policy favorable to a specific economic decision-making tool could not be contrary to administrative practice or to transportation planning goals. Further research in this area is required to develop a manual for local use. Having to run a UTCS-1 each time a loading standard is required is beyond the capabilities of most planning agencies. The development of this manual, leaving specific inputs as variables to be applied in a case-by-case situation, is essential to promoting acceptance and maintaining flexibility.

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Demand for Urban Goods Vehicle Trips

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This paper describes the results of the first of several investigations that have explored the relationship between the generation and distribution of intraurban goods vehicle trips and the spatial structure of the Boston metropolitan region. An aggregate trip-end generation model is presented that illustrates that zonal trip-end generation rates vary systematically with the density and mix of socioeconomic activities, the usage of vehicles of different sizes, and the location from the center of the region. An industry-specific direct demand model is employed to analyze the generation and distribution of trips in delivery routes as a function of the supply of transportation and activity systems variables. The linked nature of goods vehicle trips is found to require modifications in the formulation of planning models and to give rise to the differential contribution of goods-producing and goods-consuming activities to levels of goods vehicle traffic.

A well-recognized need exists for improved models of urban goods vehicle movements (1, 2, 3). This need stems from the practical requirements of urban planning for goods and passengers as well as from the substantial potential of quantitative models for increasing our understanding of urban goods transportation and its relationship to the spatial structure of metropolitan areas.

There are two basic analytical approaches to investigating the short-term relationship between the transport of goods and urban spatial structure (4). In the first approach, the demand for urban goods vehicle trips is viewed as a direct function of the location, intensity, and mix of socioeconomic activities. In the second approach, the demand for goods vehicle trips is a function of trade in commodities, which is, in turn, a function of the spatial pattern of activities and their production and consumption of goods. Each of these approaches has been explored in empirical research conducted by me at the Centre for Land Use and Built Form Studies, University of Cambridge, and the Transportation Systems Center, U.S. Department of Transportation. The first approach, the implementation of which is described here, has the virtue of requiring only available survey data, is most relevant to obtaining near-term improvements in existing planning models, and provides a natural format for testing hypotheses that pertain to vehicular trips.

In this paper, trip generation and attraction and trip distribution have been analyzed with two empirical models as a function of the spatial patterns of socioeconomic activity and the supply of transport. First, a trip-end generation model was used to test alternate functional forms and to explore the differential impacts of groups of activities on levels of trip making. Second, trip generation and distribution were modeled simultaneously with a direct demand construct that was used to assess the influence of transport supply and the effect of route choice behavior on goods vehicle traffic.

Each of these models was estimated by using data collected during 1963 and 1964 as part of the Eastern Massachusetts Regional Planning Project, a comprehensive transportation and land use planning study (5). These data, graciously made available by the Massachusetts Department of Public Works, consisted of measures of industrial and residential activity in each of the 626 traffic zones that cover the region, a matrix of interzonal travel times, and the results of an origin-destination survey of goods vehicle movements (6).

PREVIOUS RESEARCH

Analytical consideration of the relationship between the transport of goods and urban spatial structure dates from the earliest metropolitan transport studies undertaken following World War II. The first explorations of this relationship were largely confined to simple tabulations, but, in the Detroit study (7), and subsequently in the Chicago Area Transportation Study (8), zonal goods vehicle trip generation for specific land uses was assumed to be proportional to person trip generation. The alternative and now dominant approach, that urban traffic be viewed as a function of activities (or land use), was most prominently articulated by Mitchell and Rapkin (9). They submitted that this now familiar proposition was equally applicable to both truck and passenger trips.

In 1965, Hill (10) formally proposed the sequence of models for predicting truck traffic that is in widespread

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use today. This method, identical to that employed at the time in the analysis of passenger travel, entailed the estimation of goods vehicle trip generation equations and the use of gravity models for predicting trip distribution.

Studies of establishment truck trip generation have been conducted by Starkie (11); Bates (12); Christie, Prudhoe, and Cundill (13); and Hutchinson (14). Aggregate zonal trip generation models have been constructed by Peat, Marwick, Mitchell and Company (15) for the data employed in this study and by Saunders (16), among others.

The models that have been employed to estimate the relationship between goods transport and metropolitan spatial structure are open to criticism on several grounds. They are, for the most part, characterized by the absence of a strong theoretical base specifying either the choice explanatory variables or the functional form of the relationship. As a result, model forms have frequently been dictated by ad hoc specification marked by the omission of important variables such as measures of transport supply or cost or, in aggregate (over industries) models, measures of activity in freight transport and warehousing. Further, Starkie (3), Saunders (16), and Slavin (4) have shown that, in addition to failing to achieve acceptable levels of statistical explanation, estimates of existing planning models may frequently fail to conform to the assumptions that underlie least squares estimation.

Finally, existing models that relate goods transport and urban spatial structure have not taken account of a fundamental feature of intrametropolitan freight transport and urban truck trips—urban goods vehicle trips are organized in routes composed of multiple numbers of trips. As will become evident, this fact strongly influences the demand for intraurban truck trips. Because of all these deficiencies, the nature of the relationship between goods transport and urban spatial structure remains an important research topic.

GENERATION OF GOODS VEHICLE TRAFFIC

The formulation of the model for analyzing zonal trip generation was guided by a number of hypotheses concerning the determinants of urban goods vehicle trips. These determinants included the mix of zonal activities and their intensities, the intraregional location of activities, patterns of intraregional and interregional trade, and the technology of urban goods transport.

As evidenced in Figures 1 and 2, substantial variation exists in both the percentage of urban truck trips made by various activity groups and their trip generation rates. For this reason, the choice of activity variables is of the greatest importance in the specification of aggregate zonal trip generation models. For this analysis, the

Figure 1. Percentage of total goods vehicle trips by activity.

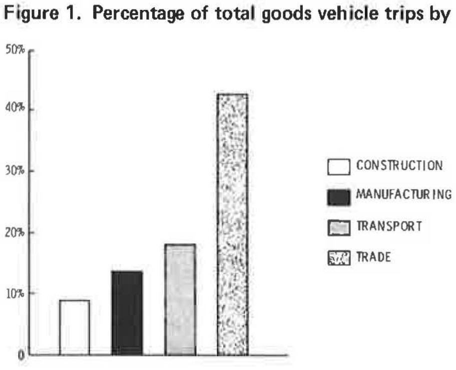
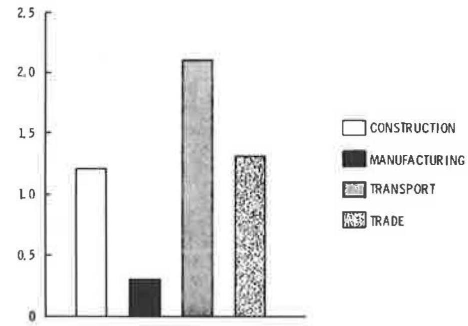


Figure 2. Daily trips generated per employee.



choice of the activity variables was based on distinguishing between those activities that both receive and ship goods and those that primarily receive shipments but do not produce output transported by motor freight modes. Production and distribution activities fall in the former category and households and services fall in the latter. Services also generate goods vehicle trips for business purposes although households, in general, do not. Based on this classification of activities, residential population and employment in manufacturing, wholesale and retail trade, motor freight transport and warehousing, and all other activities combined were selected as initial variables. Extensive examination of correlation matrices and preliminary equations suggested that the best results were to be obtained with these variables. However, the residuals from preliminary model estimates were found to be correlated with zonal intensities of development and location.

Because economic (production and consumption) and transport effects are not differentiated in trip generation models, nonlinearities and locational effects can stem from either source. Economies of scale in production, for example, would lead, if all other things are equal, to higher trip generation rates for the shipment of output with increasing scale as output/employee ratios increase. However, economies of scale derive from greater levels of output per unit of other factor inputs as well and possibly achieve a reduction in the amounts of transportable inputs required per employee. This may yield, if all other things are equal, fewer trips for obtaining inputs per employee and perhaps offset the increase in trip generation for the distribution of output.

Locational effects on trip-end generation may arise from external economies and trade considerations. External economies derive from the colocation of activities, are thus most prevalent in the densest areas of the region, and may cause increased transport demand per unit of output. For small plants, which Starkie (11) has suggested have higher trip-end rates per employee, external economies may be of greater consequence than internal economies of scale.

Local market activities also have higher intraurban road transport demands than activities that specialize in interregional trade have. The former activities will also tend to be located in relatively central locations and thus at higher densities. As a result, at locations of increased density, one would expect to find activities that interact more frequently with one another and over shorter distances than at distal locations within a region.

Goods transport demanded by firms is also likely to be influenced by levels of inventories of inputs and outputs. Firms that hold high inventories may require fewer goods vehicle trips. Because the price of space declines significantly with distance away from the center of metropolitan regions, this too would imply that increased trip-end rates will be observed in central locations rather than in distal locations where the land and space inputs needed to hold higher stocks are of reduced cost and increased availability.

The technology of urban goods transport reinforces these density and locational effects. At higher densities, serving multiple collection and delivery points is relatively more efficient. In these locations, market thresholds are of considerably smaller spatial extent (17, p. 271) than at lower densities of activity, and the distances between customers are relatively short. Where the possibilities of serving more than one customer on the same route are slight, there is an increased inducement to economize on trips and achieve higher load factors particularly when the line-haul component of transport costs is large. This applies especially to firms that are heavily engaged in exporting their output. Furthermore, in the case of the Boston region, which is abutted by other dense concentrations of activity, more transport demand is presumably satisfied at the periphery of the region by road transport services produced in abutting regions.

The linked nature of goods vehicle trips has several specific impacts on the relationship between traffic and location of activities. [Slavin (4) offers a fuller exposition.] First, because the destinations of most trips are the origins of succeeding trips in route sequences, there is a rough equivalence between zonal trip origins and destinations unless many trips span spatial or temporal accounting boundaries. For the Boston region data, the correlation of zonal trip origins and destinations was 0.995. As a result, model equations were developed to explain the sum of zonal trip origins plus destinations, which are referred to as trip ends.

Second, the linked nature of goods vehicle trips accounts for the fact that many trips connect activities and locations that are distinct from the activity and location at the origin of a route. This leads to the spatial disparity between the respective origins and destinations of commodity flows and the truck trips that effectuate them.

Third, the fact that most intraurban truck trips connect consumers of goods follows directly from the occurrence of trips in routes and the predominance of delivery routes over all other types of routes. As a result, higher trip-end generation rates are associated with the consumption of goods rather than the production of goods.

Finally, the level of trip-end generation, which holds production and consumption rates constant, should also be a function of the mix of goods vehicles used; in this case fewer trip ends are associated with large vehicles. Because of congestion, this effect may also result in locational variation where high density and municipal regulations impose impediments on the use of heavy vehicles in central locations.

These arguments resulted in the formulation of the trip-end models with employment variables expressed as densities, a location variable, and a submodal split ratio. The inverse of travel time to the center of the region was used as a measure of location. After some experimentation, the zonal ratio of heavy truck (those with 3 axles or more) trip ends to total trip ends was selected to test for the influence of vehicle size. The model, which follows, proved to be vastly superior to previous versions in terms of theoretical consistency, the degree of explanation obtained, and conformance to ordinary least squares assumptions.

$$T/A = 1.41 + 0.45E_1/A + 0.91E_2/A + 0.29E_3/A + 6.63E_4/A + 0.07E_5/A + 0.20P/A - 4.7R + 90.8(1/C) \quad (1)$$

where

T = trip ends,
E_1 = employment in manufacturing,
E_2 = employment in wholesale trade,
E_3 = employment in retail trade,
E_4 = employment in motor freight transport and warehousing,
E_5 = employment in all sectors other than those explicitly represented,
P = population,
R = ratio of heavy vehicle trip ends to total trip ends,
A = area, and
C = travel time to the center of the region in minutes.

In this model, $r^2 = 0.93$ and $F = 1006.2$ for 626 observations.

The overall equation and all the variables, with the exception of the vehicle mix ratio R, are significant at the 1 percent level; R is significant at the 10 percent level. The regression coefficients are of the correct sign, and the regression residuals are random with respect to the patterns of development. Furthermore, the model significantly outperforms a log-linear equation with the same variables.

Inspection of the coefficients in the model illustrates the differential impacts of the various activity sectors on trip-end rates. In particular, the influence of E_4 is striking because it implies that the location of new terminal facilities will exert a substantial influence on the generation and attraction of goods vehicle trips. Explicit representation of this variable in aggregate goods vehicle trip generation equations would seem imperative because the consequence of aggregating it with other variables is to grossly underestimate goods traffic. E_2 also has a relatively high impact on trip-end generation when compared to other activities, as might be expected. In contrast, the smaller effect of E_3 is possibly the consequence of consumers' substituting passenger transport, in the form of shopping trips, for delivery services.

As hypothesized, increased travel times from the center of the region are associated with decreased levels of trip making. A negative relationship between the proportion of heavy vehicle trips and trip-end generation is also in evidence. This last finding would be easily explained by the carriage of larger loads in heavier vehicles.

In the model presented here, travel time is entered as a locational variable and not strictly as a measure of transport costs. In the remainder of this paper, the influence of transport supply on trip generation and distribution is assessed more fully.

MODEL OF GENERATION AND DISTRIBUTION OF GOODS VEHICLE TRAFFIC

Previous models of goods vehicle trip generation have characterized the level of commercial vehicle traffic as wholly inelastic with respect to the supply of transport in viewing traffic solely as a function of activities. A direct demand model has been used to examine the more comprehensive hypothesis that both the generation and distribution of goods vehicle traffic are a function not only of the location, intensity, and mix of activities but also of the supply transport. At the same time, this analysis illustrates some special considerations that must be taken into account in modeling urban goods vehicle trips and provides a demonstration of the effect of route making on the relationship between goods transport and urban spatial structure.

Although the model formulation is more general, its estimation has been based on a subsample of the survey data restricted to trips made in a subarea of the region by a single industry group in delivering its output. These restrictions are consistent with aggregation over behavioral units with a presumed similarity in the factors that influence their transport operations, including their location, market areas, commodities produced, and vehicle fleet mix.

Data

The subsample chosen consisted of 139 light (2-axle) goods vehicle trips that were made by manufacturers of food products within 16 contiguous suburban traffic zones located in Boston's North Shore. Restricting the sample to a small area reduced the amount of variability that might be introduced as a result of locational influences. Although long journeys were thus excluded, the model results will illustrate that, even in this context, there is sensitivity to small variations in transport supply (travel time).

As indicated by the land use matrix (Table 1) specifying the incidence of trips between land use classes, the output of the food processors is distributed primarily to retail outlets (restaurants and retail food shops) and to households. Thus, most of the trips connect these activities with themselves.

The number of home-based trips is remarkably small, which indicates that most of the food distribution trips within the subsample study area were made by vehicles that were based elsewhere. This is one natural feature of the linkage of commercial vehicle trips.

Model Specification

When the transport behavior to be examined is extended to include both trip generation and trip distribution, the problem of destination choice as it appears to decision makers must be considered. For trips within delivery routes, the set of alternate trip destination (and origin) choices is postulated to include alternative consumers of the commodity distributed and the home base (for the return journey). Thus the set of possible trip connections between activities is defined as the set of all ordered pairs of activities $(a_1, \ldots, a_n) \times (a_1, \ldots, a_n)$ where $(a_1, \ldots, a_n)$ = the set of all activities that occur in the same vehicle routes.

The maximal set of activity variables relevant to explaining the generation and distribution of trips then can be specified as those variables that correspond to the set of activities that either generate or attract trips, or, in other words, those variables that correspond to the activities for which row or column sums of the land use matrix are greater than zero. If A_k^i is a measure of the level of activity a_k in zone i, then it is hypothesized that the number of trips between zones i and j, which is T_{ij}, is a joint function of the elements of the sets of activity variables $\{A_k^i | a_k \epsilon R\}$ and $\{A_\ell^j | a_\ell \epsilon C\}$ where R = the set of activities at which trips originate and C = the set of activities at which trips terminate.

The set of (nonspatial) activity variables relevant to explaining trip generation and distribution may be thought of as maximal for one conceptual and two empirical reasons. First, further disaggregation may be desirable in modeling trips when disjoint subsets of activities are served by disjoint subsets of trips. Second, a very low incidence of trips between zones i and j may render certain activity measures insignificant in explaining trips. Last, selecting a subset of activity variables may be necessary if multicollinearity is severe.

Various behavioral paradigms of route formation [Webb (18) and Slavin (4)] suggest that T_{ij} is also a function of the spatial separation between zones i and j. In other words, the likelihood of the linkage of destination pairs is dependent on the distance between the two activities.

The preceding characterization of destination choice results in the following functional relationship

$$T_{ij} = f\left[\left\{A_k^i \mid a_k \epsilon R\right\}, \left\{A_\ell^j \mid a_\ell \epsilon C\right\}, g(t_{ij})\right] \tag{2}$$

where $g(t_{ij})$ = a function of the travel time t between zones i and j. Aggregating over activities, as just shown, is consistent with representing alternative destination choices in the same equation and requires that decision makers respond to travel times in uniform fashion for all alternative destinations.

The traditional direct demand model functional form (19) has been adapted for use in estimating the generation and distribution of goods vehicle trips. Thus, with the notation that has been defined, flows are postulated to be represented by the following function in which the c_i's are coefficients to be determined and the activity variables are chosen in the manner described:

$$T_{ij} = c_0 (A_1^i)^{c_1} (A_2^i)^{c_2} \ldots (A_m^i)^{c_m} (A_1^j)^{c_{m+1}} \ldots (A_n^j)^{c_{m+n}} g(t_{ij}) \tag{3}$$

Because the number of trips arriving at an activity in a zone is equal to the number of trips leaving the activity in the zone (if there are no import and export trips), the influence of an activity variable on trip origination must be equal to its influence on trip destination. For this reason, identical activity variables must be constrained to have equal coefficients when they appear as both generation variables, superscribed i, and attraction variables, superscribed j. If we group the same activity variables, the previous equation can be rewritten to this end (for n = m) as follows:

$$T_{ij} = c_0 (A_1^i A_1^j)^{c_1} \ldots (A_n^i A_n^j)^{c_n} g(t_{ij}) \tag{4}$$

Because, in general, all activities that generate trips will attract trips and all activities that attract trips will generate trips (i.e., n = m), all activity variables can be grouped in pairs in most cases. If, however, an activity generates trips but does not attract trips or vice versa, the corresponding activity variable or variables will appear singly with separate coefficients with no loss of generality.

Based on the findings from the trip-end model, density variables were selected as the appropriate activity measures. Viewed in these terms, the generation and distribution of trips are, if all other things are equal, proportional to the spatial extent (areas) of the origin and destination zones. Following Wohl (20, p. 26), we constrained the coefficients of the area variables to be unity, which yields the function in equation 5 that is linear in the logarithms and, for $g(t_{ij}) = t_{ij}^{-\beta}$, has been estimated with ordinary least squares.

In initial testing, the food manufacturing employment density coefficient, which was not significant at the 50 percent level, was deleted from the model. This was not

Table 1. Trips between land use classes.

From	To: Manufacturers	Retailers	General Population
Manufacturers	0	3	0
Retailers	2	68	2
General population	0	2	60

an unanticipated result because so few trips originated or terminated at this activity.

Model Results

The final form of the model is as follows:

$$\ln(T_{ij}/A_iA_j) = -10.7 + 0.41 \ln [(R_i/A_i)(R_j/A_j)] + 0.31 \ln [(P_i/A_i)(P_j/A_j)] - 1.2 \ln (t_{ij}) \quad (5)$$

where

T_{ij} = trips between zones i and j,
A_i = area of zone i,
R_i = retail in zone i food employment (shops and restaurants),
P_i = residential population of zone i, and
t_{ij} = travel time in minutes between zones i and j.

In this model, $r^2 = 0.80$ and $F = 51.7$. As is evident, the model performs rather well in explaining the generation and distribution of the trips in the subsample. All of the coefficients, as well as the overall relationship, are significant at the 1 percent level. The coefficients are all of the correct sign; there are positive elasticities of demand with respect to the activity variables and negative elasticity of demand with respect to travel time.

The model illustrates that a consequence of the occurrence of trips in delivery routes is that trip generation and distribution are strong functions of the location of consuming activities. The model also provides additional support for the existence of the density relationship described previously. Removing the zonal area terms from the equation, as was done in one experiment, reduced r^2 to 0.52.

Slavin (4) has suggested that a variety of paradigms that describe the formulation of routes by dispatchers provide a behavioral basis for gravity trip distribution of intraurban truck movements and has argued that the distribution of goods vehicle trips should be extremely sensitive to interzonal travel times or distances as a consequence. The model results are in accord with this hypothesis particularly when one considers that more than 90 percent of the trips in the data were less than 10 min in duration. Thus the estimation indicates the sensitivity of interzonal trips over this narrow range.

Although not attempted, disaggregation of the demand model to explain submodal split would be perfectly consistent with the modeling framework and with aggregating over goods vehicle routes because the submode is obviously employed on each trip within a route. The specification of the activity variables, however, might have to be modified if, for a given submode, a smaller set of activities are found to be considered as alternative destination choices. Also, the submode split must be presumed to be influenced by the supply of vehicles, commodity characteristics, average delivery sizes, and other factors. Thus further research and better data will be required to achieve a deeper understanding of this aspect of urban goods movement.

The reasoning employed in the formulation of this model of trip generation and distribution may also be transferred to conventional urban transport model sequence. Required would be the construction of separate trip generation and distribution models disaggregated so that trips are modeled in a manner consistent with aggregation over routes and with disaggregation to ensure that only alternative destination choices are treated simultaneously.

CONCLUSIONS

In this paper, the relationship between the transport of goods and the spatial structure of a metropolitan region has been explored with two analytical models framed to examine the hypothesis that goods vehicle traffic is a function of the location, intensity, and mix of socioeconomic activities. Each model provides strong empirical support for this hypothesis.

An important finding of this investigation is that zonal trip making is a strong function of activity densities and proportional to zonal area. This formulation consistently outperformed other alternatives in both models.

The trip-end model demonstrates that, because of the density relationship and locational effects, higher rates of trip making are present in the most congested portions of metropolitan regions. This would suggest that greater attention should be paid to planning for urban freight traffic.

The assessment of the differential contribution of different sectors to trip-end generation underscores the relative importance of distributive activities in this regard. Because of its large effect on the level of traffic and its potential role as a policy and planning variable, a measure of motor freight and warehousing activity should be entered explicitly in aggregate trip generation models.

The direct demand model illustrates that the supply of transport as represented by a function of travel times between zones substantially affects the generation and distribution of urban truck trips. This is consistent with the hypothesis that the distribution of goods vehicle trips is strongly determined by route choice behavior. Further study broadened to consider the interrelationship of other supply variables, route decision making, and submodal choice would be a logical extension of this research.

As assessed by the direct demand model, the generation and distribution of trips made by food manufacturers in delivering their products were governed by the location, intensity, and type of consuming activities. The model thus provides an illustration of the differential contributions of goods production and goods consumption to truck trip generation. This is a consequence of the linkage of goods vehicle trips in routes that imparts special characteristics to the relationship between goods transport and urban spatial structure.

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Aspects of Demand for Urban Goods Movement in City Centers

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The demand for urban goods movement (UGM) is a case of derived demand. Derived demand refers to the fact that demand for UGM trips can be derived from the demand for goods in an area. That is, there exists a joint demand for the goods by themselves and for their availability at the sale location, which in turn creates the need for their transport from their storage location to the point of use. Thus the demand for UGM, or goods trip generation, is correlated to the level of economic activity of the area.

TRIP GENERATION MODEL

The analysis of the patterns of UGM presented here corresponds to the first steps of a model of use of pickup and delivery (PUD) facilities that is being formulated with the aid of two companion studies (1, 2).

Application of the model starts with evaluation of the nature of the economic activity of the area being studied (usually a block face or a collection of block faces). This is accomplished by the assignment of a specialization index (C-value) to each location. C is measured by counting the number of commodity categories present at the location according to the standard transportation commodity classification (TCC) (3).

The UGM trip generation rates for downtown locations can be expressed generally by the relation

$$T = -16.6 + 9.0\,C \qquad (2 \leq C \leq 23) \tag{1}$$

where

T = total weekly trips to a location and
C = specialization index for location.

The trip generation expression (equation 1) can be applied to any downtown area with a land use mix similar to that of downtown Brooklyn. It is especially applicable to areas where retail and commercial uses are predominant and tests performed outside the survey area have supported these conclusions. On the other hand, land use classes with high product specialization (e.g., manufacturing or industrial zones) are not suited for the application of the equation because its predictive power will be reduced as the number of trips represented by each commodity category increases. Two conclusions on the nature of UGM can be noted in equation 1.

1. Locations that possess similar economic structures (locations that sell the same products and have the same specialization index) can be expected to produce the same number of UGM trips regardless of other factors such as size, volume of sales, or location of the establishment.
2. The number of trips generated at a location will remain constant for a certain value of C unless the ratio of trips per commodity (the regression coefficient of equation 1) changes. This ratio can be reduced by means of PUD policies such as consolidation where different commodities share PUD trips. Because only a small portion of all trips in downtown are subject to consolidation, the savings in UGM trips are expected to be small. Thus any short-term approach to improved goods movement operational efficiency will have to concentrate on the facilitation of PUD operations.

The weekly trips to a location, as determined through equation 1, represent average generation rates only. To obtain the fluctuations of trip generation through the year, one can use seasonal factors (determined from business activities in the area) as modifiers. In addition, there is reason to expect that economic indicators (e.g., a ratio of disposable income to wholesale prices) can be related to the generation rates to measure the variations in trip generation with the oscillations of business cycles.

The modified trip generation rates can be converted into trip loadings for the particular period of time studied for the location by the application of daily and weekly arrival factors developed elsewhere (1), and the results for the individual locations aggregated as follows:

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$$TT = \sum_{i=1}^{n} E \cdot S_i \cdot W_i \cdot D_i \quad (-16.6 + 9.0\, C_i) \qquad (2)$$

where

- TT = total trips for the study period,
- n = number of establishments in the block face,
- E = economic activity factor (if necessary),
- S_i = seasonal arrival factor for location i,
- W_i = weekly arrival factor for location i,
- D_i = daily arrival factor for location i, and
- C_i = specialization index for the location.

If the study period selected is the peak period (e.g., for Brooklyn, a midmorning weekday in the pre-Christmas rush), the critical trip loadings for the facilities can be determined.

The trip loadings can be translated into facility usage terms by the use of criteria given by Ken Crowley and others (1) and Habib (2). The level of use of the facilities can then be evaluated, and the need for additional facilities can be established.

SPECIALIZATION INDEX

The specialization index is only one of the measures of the nature of the economic activity at a location. The notion of specialization is used in management theory to represent division of labor and in the field of marketing to indicate the specific consumer products, brands, or services available at a location. The index of specialization as used in this study denotes this latter concept and is measured by the number of standard commodity categories [according to the TCC (3)] that are present during PUD operations. Table 1 gives typical index values found during the study.

Some limitations exist on the applications of the specialization index that have to be specified. The specialization index has proved to be an adequate predictor of UGM demand for typical downtown land uses such as retail and commercial, office, and residential uses. But initial applications to other fringe uses, such as manufacturing or warehousing, have proved inadequate because of the high ratio of goods trips to commodity categories. The specialization index, although not a direct measure of economic activity, reflects in turn the economic characteristics of the demand for UGM. This index includes in it a measure of size because, as was found during the analysis, the number of commodity categories present at a location is correlated to the size of the location. Equation 1 indicates that an additional commodity category at a location represents nine more weekly PUD trips. Yet the commodities are not expected to contribute equally to the trip generation formula because of their different nature. But it happens that, as the size of an establishment grows and the demand for its commodities increases, additional commodities will also be demanded. Excessive demand for one commodity thus creates the demand for ancillary commodity categories.

Observation of equation 1 raises the question of whether the number of PUD trips can be reduced. Trips have been shown to be dependent on the number of commodity categories, and this variable cannot be controlled because presumably the locations will resist reducing the number of product lines being handled. Therefore, reducing the number of trips will have to mean reducing the number of trips each commodity represents, which is indicated in equation 1 by the regression coefficient. Because, as it appears, the volume of UGM will not be easily reduced, any short-term approach to improve the efficiency of UGM will have to concentrate on the facilitation of PUD operations.

Downtown areas are critical areas in the conduct of UGM operations, and the specialization index has proved to be an effective predictor for downtown. A comprehensive UGM model will have to include other areas for which the concept of C has not been tested. From the nature of C it can be expected that the index can be applied to other UGM locales in urban areas within the limitations described before. Scattered surveys in major retail locations (a shopping center in Long Island, New York, and a highway strip in Detroit, Michigan) were used for comparison purposes, and the results showed better than 70 percent accuracy.

SUMMARY, CONCLUSIONS, AND RESEARCH NEEDS

The practice of UGM in downtown areas will not change appreciably with time, either in nature and composition or in the volume of trips demanded. This study found that UGM demand is dependent only on the mixture of land uses present in the area. This means that other factors, such as size, sales volume, and location, do not influence the volume of the demand as much as the nature of the economic activity of the establishment.

The concept of the specialization index is but a first step in the development of a comprehensive model for UGM. The analysis of the patterns of goods movement should prove to be of great value in formulating short-term solutions for UGM. Yet, for the planning and the design of middle- and long-term goods movement programs, to be able to comprehensively model the goods distribution pattern is of critical importance. With such a capability, alternate programs for improvement can be assessed, and their environmental, social, and economic impacts on UGM operations and the community can be evaluated.

Because this work represents the first time that the

Table 1. Measuring C-values for downtown land uses.

Land Use Class	Type of Store	C-Value	Land Use Class	Type of Store	C-Value
Prepared foods	Bar	2		Appliance store	3
	Luncheonette counter	3		Camera and photography shop	3
	Fast-food restaurant	4		Jewelry store	4
	Sit-down restaurant	5 to 7[a]		Books and stationery store	2
Retail foods	Specialized food store	3		Furniture store	2 to 3[a]
	Grocery store	4		Drug store	5
	Supermarket	6 to 8[a]		Miscellaneous retail, services	3
Specialized retail	Shoe store	3	Department store	Department store	15
	Clothing store	4 to 5[a]	Offices	Bank	4
	Wig store	3		Office building	12
	Fabrics store	2			
	Electronics store	2	Residential	Apartment building	20

[a]Depending on variety of economic activity and size of location.

specialization index has been used, only preliminary conclusions on its applicability could be presented. With extended applications and further study, the role of C as an adequate estimator of UGM in retail centers should become clearer and the limitations on its application should be eliminated.

ACKNOWLEDGMENT

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Abridgment

Suggested Approach to Urban Goods Movement and Transportation Planning

David A. Zavattero, Chicago Area Transportation Study

In view of the importance of goods movement to the efficient functioning of the urban system, it is remarkable that so few studies have been devoted to the analysis of freight transport demands. Only recently has the problem of urban goods movement received a significant amount of attention from transportation planners. Several conferences involving transportation researchers, planners, operators, shippers, and other users have been called in an effort to develop some consensus on the nature of the problem and the most effective way to approach it (1). These dialogues have revealed the seriousness of the problem as well as the current lack of analytical and operational capacity to deal with it.

Clearly a comprehensive transportation plan must be based on reliable estimates of the demands of all users. In this respect, two fundamentally different categories of demands can be distinguished—those of people and those of freight. Because the larger share by far of urban traffic (in vehicle trips) consists of person travel, the problems associated with these movements have been more visible to both planner and user, and consequently data collection and modeling efforts have been concentrated on these travel demands. When the standard transportation models consider goods movements at all, they typically assume freight-oriented trips to be some (constant) proportion of person trips and obtain estimates of commercial vehicle traffic by applying these trip rates to the previously calculated person trips. Although this procedure may provide reasonable estimates of overall vehicle traffic it does little to explain the basic nature of freight transport demands and is likely to be misleading when specifically freight-oriented plans or facilities are being evaluated. The planning goal of an efficient transportation system must include the objective of minimizing the inevitable conflicts between person and freight movement. To achieve this requires independent forecasts of each of these basic demands. This suggests that significant improvement in the applicability and performance of the urban transportation planning (UTP) process can be expected should goods movements be separately estimated. The research being undertaken at the Chicago Area Transportation Study (CATS) attempts to fill this obvious gap in transportation study methods through the development and testing of a model focusing directly on the volume and patterns of intraurban goods flows and resultant vehicle traffic.

It is felt that freight transport demands can be modeled within the sequential framework commonly applied to person travel demand forecasting and referred to as the UTP process. This method includes separate generation, distribution, modal choice, and assignment models and has been shown to be well suited to modeling the spatial-location and macroeconomic determinates of travel over complex networks with the many substitute destinations, modes, and routes characterizing transport in urban areas. However, some changes in the structure of the process and the specification of particular submodels are necessary to reflect the emphasis as freight rather than person movements (2, 4, 5).

Two categories of urban goods movement planning models can be identified. Each is predominately public sector oriented and concentrates on the demand side of the freight transport market. The two categories of models are (a) commodity-based models that focus initially on the underlying goods movements before estimation of derived vehicle flows and (b) vehicle-based models that deal directly with vehicle traffic. Clearly the commodity-based models are more comprehensive and theoretically appealing, but they also require substantially more data and are considerably more complex and costly to calibrate and apply. Ultimately, of course, the choice of approach must be dictated by the objectives of the specific study being undertaken.

This paper briefly outlines at a conceptual level the commodity-based model currently under development at CATS. The goods movement model structure and its relationship to the person travel demand models is shown in Figure 1. An analogous framework has been applied to a vehicle-based model consisting of commercial vehicle trip generation, distribution, and assignment submodels. Because the specification of the models is

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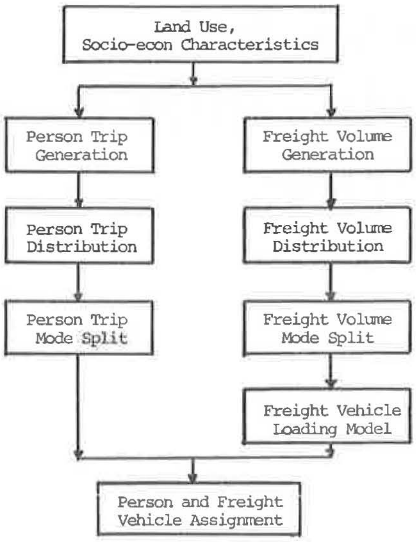
Figure 1. Revised UTP process with commodity-based freight model.



similar, only the commodity-based model will be discussed. However, the modifications required for the vehicle-based model will be suggested where appropriate.

The model forecasts first the commodity flows between the differing activities in each geographically distinct zone and then the vehicle volumes over each of the routes in the network. The model is aggregative in that its ultimate concern is with the total volume of goods and vehicles flowing between zonal areas where both the goods being transported and the activities requiring these movements are classes of similar, but not identical, units. In brief, the model begins with the land use and spatial-location characteristics of subareas of the region and derives, from the relevant zonal attributes, the commodity volumes produced and consumed by the activities in the particular zone (6). This generation model may be expressed as:

$$ {}^kO_i^{p*} = \alpha_0 + \alpha_1 Z_i^p + \alpha_2 H_i \qquad (1) $$

and

$$ {}^kD_j^{*p} = \beta_0 + \beta_1 Z_j^p + \beta_2 H_j \qquad (2) $$

where

- ${}^kO_i^{p*}$ = volume of commodity k generated by all type p activities in zone i;
- ${}^kD_j^{*p}$ = volume of commodity k attracted to land use p in zone j;
- Z_i^p = vector of characteristics (e.g., floor space, employment, land area, and the like) of land use class p in zone i; and
- H_i = vector of characteristics of zone i itself (e.g., industrial composition, accessibility, and the like).

For the vehicle-based model, the origin and destination (O-D) volumes are expressed in terms of truck trips perhaps disaggregated by type of truck.

Subsequent models have taken these generated and attracted volumes as demands that must be satisfied and have added the necessary directional and interindustry dimensions. That is, type of activity, extent, location, and other zonal characteristics are taken as exogenous inputs to the generation submodel. This model provides estimates of the commodity volumes flowing to and from the several land use classes in each zone. These generated volumes are then distributed over a network specified in terms of times and costs including commodity-specific line-haul, terminal, and handling charges. The gravity model, which has been successfully applied to interregional goods movements, is used to distribute these goods over competing land uses and zones. The model must be modified, however, to take into account the important interaction between differing types of land uses that is characteristic of goods transport. Input and output concepts are used to establish the distribution of these commodity volumes over the competing land use classes within each zone before their distribution among zones (3).

The distribution submodel proceeds as follows. From the transportation O-D survey data a basic linkage volume (or more conventionally a transaction) matrix ${}^kV = ({}^kv^{pq})$ can be derived for each commodity group.

The typical element in this matrix, ${}^kV^{pq}$, indicates the volume of good k (or type of truck k) flowing from land use class p (at origin) to land use q (at destination). Summation over the columns of this matrix yields the commodity volumes originating from each of the types of land uses; summation over rows yields the volumes destined for each activity class.

Two additional matrices can be easily derived from this basic linkage volume matrix. These are termed the generation and attraction linkage matrices and are denoted by G^k and A^k respectively. These matrices are used to stratify the previously generated and attracted commodity volumes (equations 1 and 2) by type of activity at the currently unconnected trip end. Specifically, ${}^kG = ({}^kg^{pq})$ is obtained by dividing each element of k_V by the appropriate row total to obtain a matrix of row proportions whose typical element ${}^kg^{pq}$ represents the fraction of the volume of good k generated by land use p that is destined for land use q. The attraction linkage matrix ${}^kA = ({}^ka^{pq})$ is obtained in analogous fashion by dividing each element of ${}^kV$ by the relevant column total. The typical element ${}^ka^{pq}$ represents the share of the volume of good k attracted to land use q having been generated by land use p. Again it should be noted that there will exist a set of these matrices ${}^kV$, ${}^kG$, and ${}^kA$ for each commodity group.

By combining the information obtained in these linkage volume matrices with that developed in the generation model, one can derive land use stratified commodity (or vehicle) volumes. These are given by

$$ {}^kO_i^{pq} = {}^kO_i^{p*}\ {}^kg^{pq} \qquad (3) $$

for generated volumes and

$$ {}^kD_j^{pq} = {}^kD_j^{*q}\ {}^ka^{pq} \qquad (4) $$

for attracted volumes. ${}^kO_i^{pq}$ is the volume of goods k flowing from land use class p in zone i to land use type q in an as yet undetermined destination zone. Similarly ${}^kD_j^{pq}$ may be interpreted as the volume of goods k attracted to land use q in zone j having been generated by land use class p in an unspecified origin zone. It is precisely these unknown geographic links that will be supplied by the spatial distribution model. This is the required modification and, after it is performed, it provides the necessary input to the gravity model. Thus, by using input-output concepts, the commodity volumes linked to land use can be estimated with the spatial dimension being determined by the gravity model.

Finally, the pairwise substitution of these land-use-specific commodity volumes to the gravity formulation yields forecasts of the volume of each type of commodity flowing from land use type p in zone i to land use q in zone j. These flows are denoted ${}^kS_{ij}^{pq}$ and given by

$$ {}^kS_{ij}^{pq} = {}^kA_i \, {}^kB_j \, {}^kO_i^{pq} \, {}^kD_j^{pq} \, {}^kF_{ij} \qquad (5) $$

where A and B = empirically determined constants chosen to satisfy the production and attraction balancing constants and are anticipated to vary over commodities and zones. The ${}^kF$ are impedance factors written in general form that also are expected to vary over type of commodity. The only requirement on the ${}^kF_{ij}$'s at present is that they decrease as cost or distance increases.

Because the primary concern is with intraurban goods movement, no modal-split submodel is necessary at this stage. Modal choice is not a significant problem for intraurban shipments because the vast majority of this freight is carried by motor trucks. Two points may be mentioned here. First, to consider other possible (and perhaps hypothetical) modes in meeting freight transport demands may be desirable in developing plan alternatives. Because the model structure being developed focuses directly on the commodity volumes in the generation and distribution phases, evaluating other modes in relation to these forecast freight flows is possible. This is an obvious advantage of the approach. Second, it must be recognized that the intraregional movement being analyzed may be but a part of a longer interregional shipment for which the modal-choice decision again becomes relevant. A modal-choice submodel could conceivably be added to the model being considered at the terminal point in the intraurban flow. This represents a logical extension and would allow total freight demands (i.e., both intraurban and interurban) to be analyzed.

For planning purposes, these distributed commodity volumes must be converted into transport vehicle traffic over specific routes. This is accomplished by the vehicle loading and assignment submodels. The vehicle loading model is intended to reflect existing usage rates for trucks as well as the fact that a single vehicle can, and typically does, serve several shippers simultaneously. After the vehicle traffic between zonal pairs has been established, the routes over which this traffic will flow must be determined. Assignment of vehicles to network links is performed with existing minimum path algorithms though some changes in the network are anticipated to account for commercial vehicle restrictions. Basically, however, freight vehicle assignment should occur simultaneously with person vehicle assignment. This approach allows a more thorough examination of person-freight conflicts and resulting congestion.

This method parallels the person travel demand model sequence and suffers from the same shortcomings. Obviously important simultaneity exists between transportation and location decisions. These procedures abstract from much of this simultaneity and are therefore first approximations of the resulting transport demands. The model derives much of its predictive capability through extrapolation of existing relationships. If a relatively short planning period is involved, these sequential approximations are not likely to cause major distortions because any change in the transport system will be reflected in trip making rather than location. But, as the time horizon lengthens, these network characteristics will substantially affect location choice and the derived travel demands.

Essentially two types of data are needed to calibrate, test, and apply the model just described. First, data on commodity and motor vehicle movements throughout the region are required. This information can be obtained from the CATS Commercial Vehicle Survey. These data were collected in 1970 and consist of an O-D survey of freight-carrying truck trips in the Chicago region. Data were collected on motor vehicle and commodity movements within the 8048-km^2 (5000-mile^2) study area by sampling Illinois and Indiana motor vehicle registration lists; the appropriate sampling rate depended on type of truck. The vehicle owners or operators were asked to record the movements and loads of the sampled vehicle on a specified survey date. Information on type of truck, truck base, trip origins and destinations, trip times, purposes, and loads was collected. Types and weights of commodities as well as type of land use at trip origin and destination also were recorded. The sample consists of approximately 26,000 raw data records (20 000 for Illinois and 6000 for Indiana); each record represents a vehicle trip. Approximately 7500 individual vehicles were sampled (5000 for Illinois and 2500 for Indiana). This sample was later expanded based on sampling and response rates and adjusted to reflect independent screen-line traffic counts to represent the universe of all truck trips made in the Chicago region on an average day. This sample will provide the necessary vehicle and commodity information though extensive manipulation of the file is required to derive the commodity flows from the recorded vehicle trips. Second, information on the land use and activity levels for each analysis zone is needed. These data are currently available for 1970 from the Northwestern Illinois Planning Commission and Northwestern Indiana Regional Planning Commission surveys of employment and land area (for the entire region) and the Chicago Department of Development and Planning survey of floor space. The zonal and land use classification systems of both data sources are compatible and should, when combined, provide the data required by the proposed freight transport demand model.

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Trunk Route Analyses: A Useful Tool for Statewide and Regional Rail Planning

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The underlying purpose in developing and applying a truck route analysis procedure was to (a) prepare reliable estimates of traffic likely to use the various main lines that make up a rail system and (b) transform resulting traffic flows into estimates of railroad costs and revenue on the basis of links, nodes, corporate systems, and regional rail systems. The objective is to identify the overall effect of proposed changes in facility usage, routings, and corporate ownership through identification of the difference between the current system and alternative plans. The developed procedure used traffic assignment principles applied to rail freight. Key steps involved (a) establishing geographic and physical facility characteristics, (b) obtaining traffic and revenue data, (c) preparing the various inputs (physical characteristics of links, zone-to-zone traffic, and likely routings), and (d) assigning traffic and calculating associated costs and revenues by using a specially prepared computer program. The procedure, developed for the Pennsylvania Department of Transportation, was used to evaluate the United States Railway Association's Preliminary Systems Plan (for reorganizing bankrupt railroads in the Northeast and Midwest) and a simple plan proposed by the commonwealth of Pennsylvania. The resulting procedure helps fill the void for rapid, large-scale tools for policy and systems level planning. Although developed for statewide and regional rail planning purposes, the procedure and supporting computer program are general enough to permit their application to other freight modes of an intercity character.

Government involvement in rail planning at the regional or statewide level is relatively new. Planning differs from regulation, the long-standing government control mechanism over the private sector. It is born of rising interest in comprehensive, intermodal transportation planning on the one hand and the current rail crisis in the Northeast and Midwest on the other. Seven bankrupt railroads, not reorganizable by traditional means (section 77 of the Bankruptcy Act), are being consolidated under the provisions of the Regional Rail Reorganization Act of 1973 as a new private, for-profit carrier backed by large infusions of federal money for start-up expenses, plant rehabilitation, and labor protection. The dominant role in the restructuring process has been assigned to the federal government through the United States Railway Association (USRA) and the Rail Services Planning Office (RSPO) of the Interstate Commerce Commission (ICC). The role envisioned by the act for states and lesser units of government is primarily one of presiding over the ultimate disposition of light-density branch lines not included in the ConRail system, an issue separate from that of trunk route planning.

Since the issuance of the Secretary of Transportation's report (1) giving recommendations with respect to "the geographic zones within the region in and between which rail service should be provided," much public discussion of the potential abandonment of a large number of light-density lines has taken place. Release of the Preliminary System Plan (2) and testimony given at subsequent RSPO hearings on that plan have attested to the great concern being given by state and local governments and shippers to the issue of light-density lines. Although much of this focus has been needed to point out supposed analytical mistakes or data errors made in deciding whether a particular branch line generates sufficient revenue to cover the costs incurred, it has tended to divert the attention of state and local officials away from the more important issues involved with future trunk route service.

Several states (Pennsylvania, New York, Iowa, Wisconsin, and Michigan) have shown interest in the ultimate trunk route system for the Northeast and Midwest. At least one state (Iowa) is deeply concerned over the ultimate disposition of the Chicago Rock Island and Pacific Railroad Company (Rock Island Lines). In practically all cases, the approach has been conceptual or built around suggested restructuring criteria; in most instances, it has not included quantitative analyses. Crises have the by-product of promoting interest and concern where there was none before. Practically no interest has been shown by states not facing actual or threatened railroad bankruptcies, their presumption being that the current method of operation will continue unabated.

Of all the states, Pennsylvania has probably shown the greatest interest in the subject of main-line structure. The reasons for this are numerous: historic interest and involvement with railroads (the commonwealth was an original investor in the Pennsylvania Railroad), industry and natural resource dependency on railroad service, concern over possible loss of railroad employment and

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lowered service levels adversely affecting industrial investment, further loss of interrailroad competition in eastern Pennsylvania through inclusion of the Reading, Lehigh Valley, and Erie-Lackawanna railroads in an even larger and potentially less manageable railroad system blanketing the state, and the possibility of creating an even larger financial fiasco than that involving Penn Central. Governor Milton J. Shapp of Pennsylvania has advanced his own reorganization or system plan as well as a rehabilitation funding proposal through a trust fund similar to that in existence for highways (3). Instead of leaving the problem (which is admittedly regional in scope) solely in federal hands (with only a critique or comments on the output documents), Pennsylvania has chosen the independent course of conducting its own quantitative analysis of the reorganization proposals advanced in the USRA Preliminary System Plan. The method developed for conducting trunk route analyses is the subject of this paper.

WHY UNDERTAKE TRUNK ROUTE ANALYSES?

Why should a state not facing the problems associated with ensuring the continuation of essential rail services become involved in rail planning? Why undertake trunk route analyses? Isn't this the responsibility of the federal government and the private carriers? These are very real and difficult questions.

We must define what we mean by trunk route analysis. The term refers to the systematic process of assigning zone-to-zone traffic flows, expressed as carloads, mass transported in megagrams, and revenues to a "main-line" regional rail network for the purpose of quantitatively estimating overall costs, revenues, car-kilometers, and megagram-kilometers with appreciable detail or precision. Conceptually it is similar to highway traffic assignments but differs in that rail traffic assignments cannot be made solely on time, cost, or distance relationships because of corporate policies, intercorporate relationships, and the like. Portions of it can be computerized; other portions (such as routings) must be done manually. Different levels of analysis are possible. Large-scale planning would be involved with traffic flows over competing trunk route configurations and resulting corporate costs and revenues. Operations studies would be concerned with track capacity, train performance, train delays, and optimizing yard-to-yard movements. These are more typically done by railroad management to improve the efficiency of internal operations. They are generally not of direct concern to government. [USRA, in developing its Preliminary System Plan (2), undertook quite extensive operations planning to derive the costs of operating a ConRail system. The Federal Railroad Administration (FRA) and RSPO participated in several of these studies.]

It is important to understand where railroads stand and where they are headed. Industrywide, the return on investment has been low. Consequently, investment in plant, especially in track and other roadbed improvements, has been low. This has led to large amounts of deferred maintenance of ties and rail. A recent study (4) has estimated that the nation's rail system needs about $5.8 billion just to replace worn-out rail and ties. Roughly 80 percent of this deferred maintenance estimate is for materials. The cost of rail and ties has escalated sharply in recent months. Faced with such capital investments, railroads are increasingly forced to take a hard-nosed stance against the continuation of light-density lines not yielding a sufficient return on past or required future investment. This reassessment will ultimately be extended to routes carrying overhead traffic as well. Route consolidation and reduction in plant are increasingly becoming an economic necessity. The abandonments of the past may seem tame compared to plant rationalization proposals likely over the next decade. There may also be further corporate mergers, facility consolidations through trackage rights, and the like.

States must become prepared to respond intelligently and quickly to such proposals. The main question is, How can a state successfully affect such decisions and what leverage does it enjoy? There are many possible approaches, such as (a) lobbying to change law or regulatory mechanisms, (b) using state financial assistance either for operating expenses or capital investment, and (c) negotiating through a third party with carriers, unions, and shippers to bring about desired change. Such tactics by themselves probably are not adequate over the long term. One of the best ways is to develop an in-house professional capability to perform trunk route and similar technical analyses in order to quantitatively judge the effects of specific plant rationalization proposals. This, of course, would greatly aid and support the aforementioned approaches.

The trunk route analysis procedure developed for the Pennsylvania Department of Transportation and used in assessing the USRA Preliminary System Plan (2) and the Pennsylvania Plan (3) is entirely suitable for application by other states to the variety of rail system proposals likely to occur in the future. The process is applicable to

1. Testing alternative trunk route rail networks;
2. Examining where state money can best be used in supplemental subsidy and capital improvement programs;
3. Assessing the effects of consolidations, mergers, and track abandonments;
4. Studying traffic generation, yards, interchange points, and their effects on the railroad system;
5. Determining rail line profitability;
6. Analyzing rail freight pricing policies; and
7. Studying the traffic distribution patterns of various commodities such as coal or iron ore.

TRUNK ROUTE ANALYSIS PROCEDURE

The underlying purpose of any trunk route analysis procedure is to (a) prepare reliable estimates of traffic likely to use the various main lines that make up a rail system and (b) transform resulting traffic flows into estimates of railroad costs and revenue on the basis of links, nodes, corporate systems, and regional rail systems. The objective is to identify the overall effect of proposed changes in facility usage, routings, and corporate ownership through identification of the difference between the current system and alternative plans. This procedure is an input in the preparation of net railway operating income statements, a commonly used means of comparing alternative rail systems.

Establishing Geographic and Physical Facility Parameters

The four initial steps required in any quantitative analysis procedure are (a) determining the geographic area to be divided in the analysis, (b) establishing a zonal system for aggregating rail traffic originations and terminations, (c) selecting the railroad lines to be included as trunk routes, and (d) developing a link and node system to represent trunk routes and the principal interconnections occurring within the selected geographic area.

Figure 1 shows the geographic area and the zonal system used in the Pennsylvania Department of Transportation study that focused on rail systems located in the northeast and midwest portions of the United States except for the northern New England states. A total of 71 zones (25 zones in Pennsylvania to identify impacts to a greater detail) were used for traffic aggregation purposes. [Zone size may be varied to meet analytical requirements. The "building block" is the standard point location code (SPLC) that identifies geographic areas by means of a six-digit code. In the Pennsylvania Department of Transportation study, zones are aggregations of states or counties within a state. Finer breakdowns are possible, however.] The basic rationale underlying zone delineation is to identify tributary areas for main-line traffic wherever possible while keeping the number of zones (and hence the number of separate interchanges) to a minimum (primarily to minimize the amount of preparatory or setup work).

The selection of rail lines should be based on criteria separating trunk from branch lines. Usually factors such as traffic density; operating characteristics (maximum speeds, number of tracks, train control systems); and connectivity between cities of a certain size and larger enter into such delineation. It is important to realize that discrete categories and firm criteria have not yet been established; therefore judgment must be based in part on a knowledge and feel for the rail system being classified. Criteria can differ according to the purpose of the analysis; often including low-density lines carrying overhead traffic is desirable if such routings offer distance savings over more heavily used routes. However, the addition of substantial kilometers of low-density lines has relatively little effect in terms of increasing the proportion of the total traffic assigned to the trunk route system. A relatively sparse system can still account for a high proportion of the total traffic. The Pennsylvania Department of Transportation study found that about 89 percent of all rail traffic moving on bankrupt railroads was assigned to the base network. Also links on the periphery of a regional system need not be included where alternate routings are not a factor.

Figures 2 and 3 show the schematic network structure used for the base case and for testing the USRA Preliminary System Plan respectively. Approximately 214 links and 67 nodes were coded in the Pennsylvania Department of Transportation study. The basic network included more than 25 750 route km (16 000 route miles) and 15 different railroads.

Obtaining Traffic and Revenue Data

The key to rail system network analysis is assembling suitable traffic and revenue data. Although this information exists, most of it is considered proprietary by railroad companies and has not been made available to public agencies. Until recently, the only public information was the state-to-state and territorial statistics contained in the 1 percent waybill study conducted periodically by the ICC and more recently by the FRA. The waybill sample by itself is unsuitable for detailed network analyses. This lack of detailed information has discouraged public agencies from undertaking rail network analyses in the past (e.g., in preparing a comprehensive statewide transportation plan).

The Pennsylvania Department of Transportation study used portions of two different but overlapping origin-destination (O-D) data sets plus supplementary estimates of the amount of traffic handled by solvent railroads between selected zone pairs. The two primary data sources were the 1972 ICC-FRA waybill study data (a readily available O-D file prepared on a periodic basis from a 1 percent sample of the waybills of all railroads in the U.S.) and a USRA-assembled data file composed of abstract data for interline shipments and waybill data for local shipments representing the full record of traffic over each bankrupt railroad in 1973. Existence of and release of this latter file to states made detailed rail network analysis possible. Information sought included carloads, net mass transported in megagrams, and cor-

Figure 1. Trunk route analysis zones.

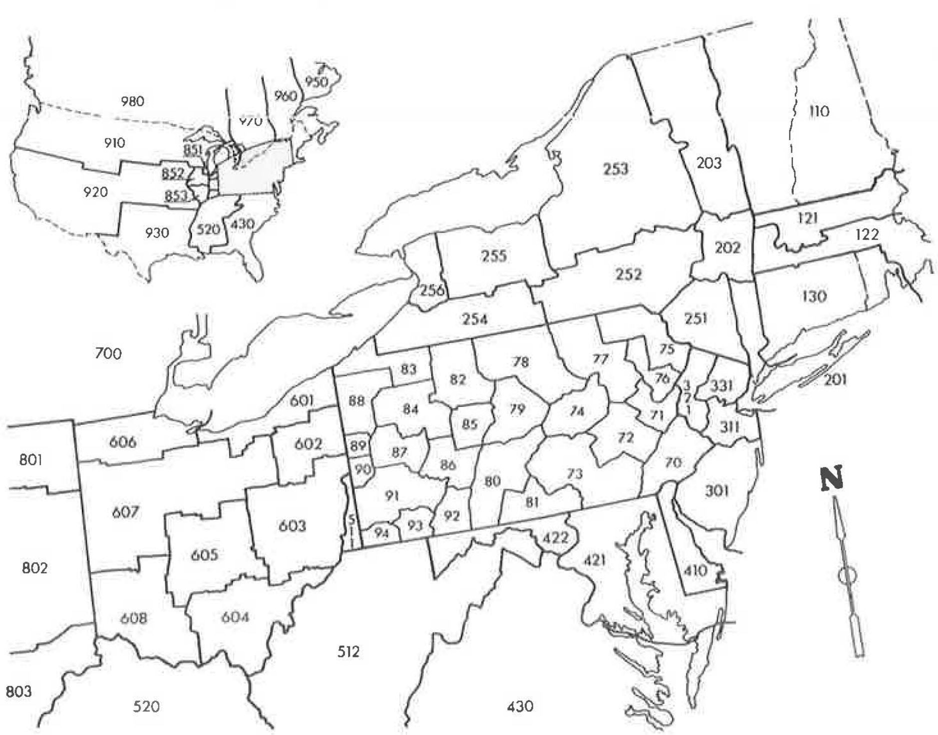


Figure 2. Trunk route analysis for existing system.

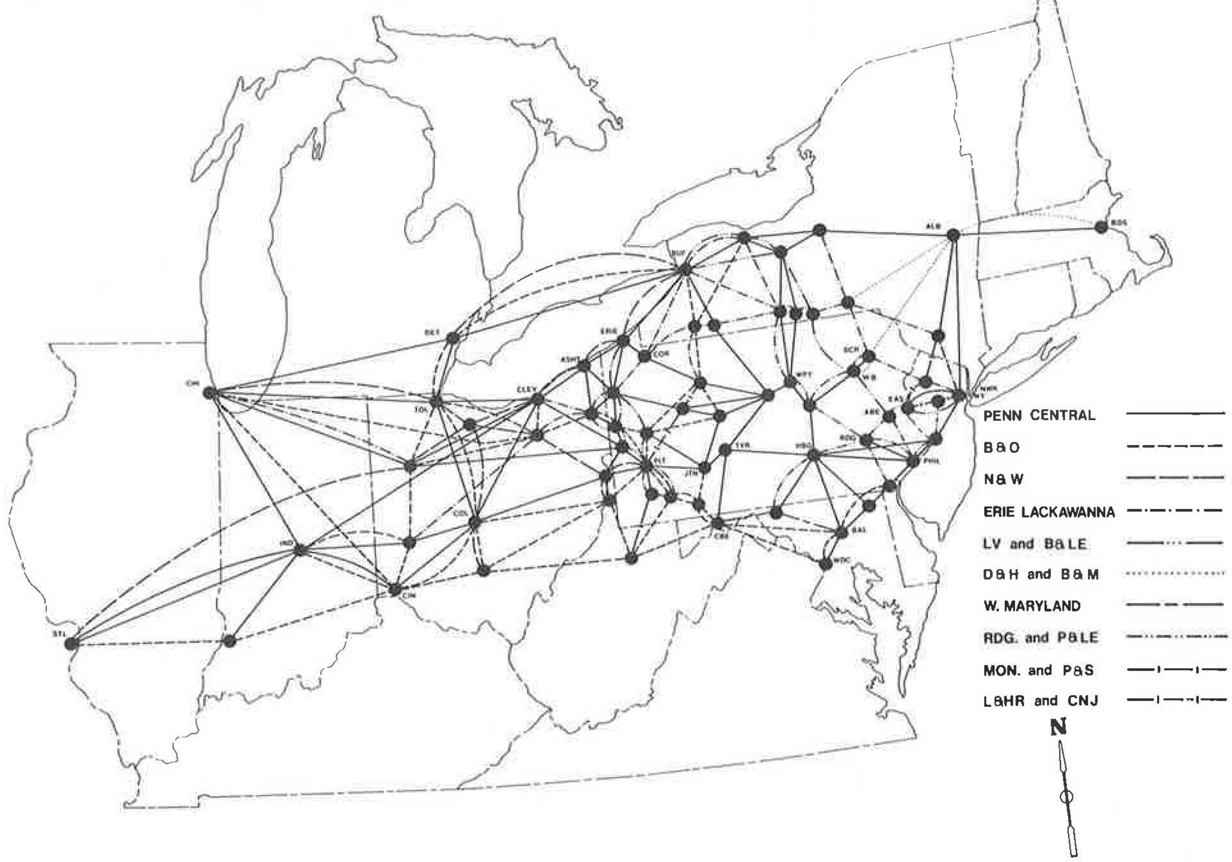
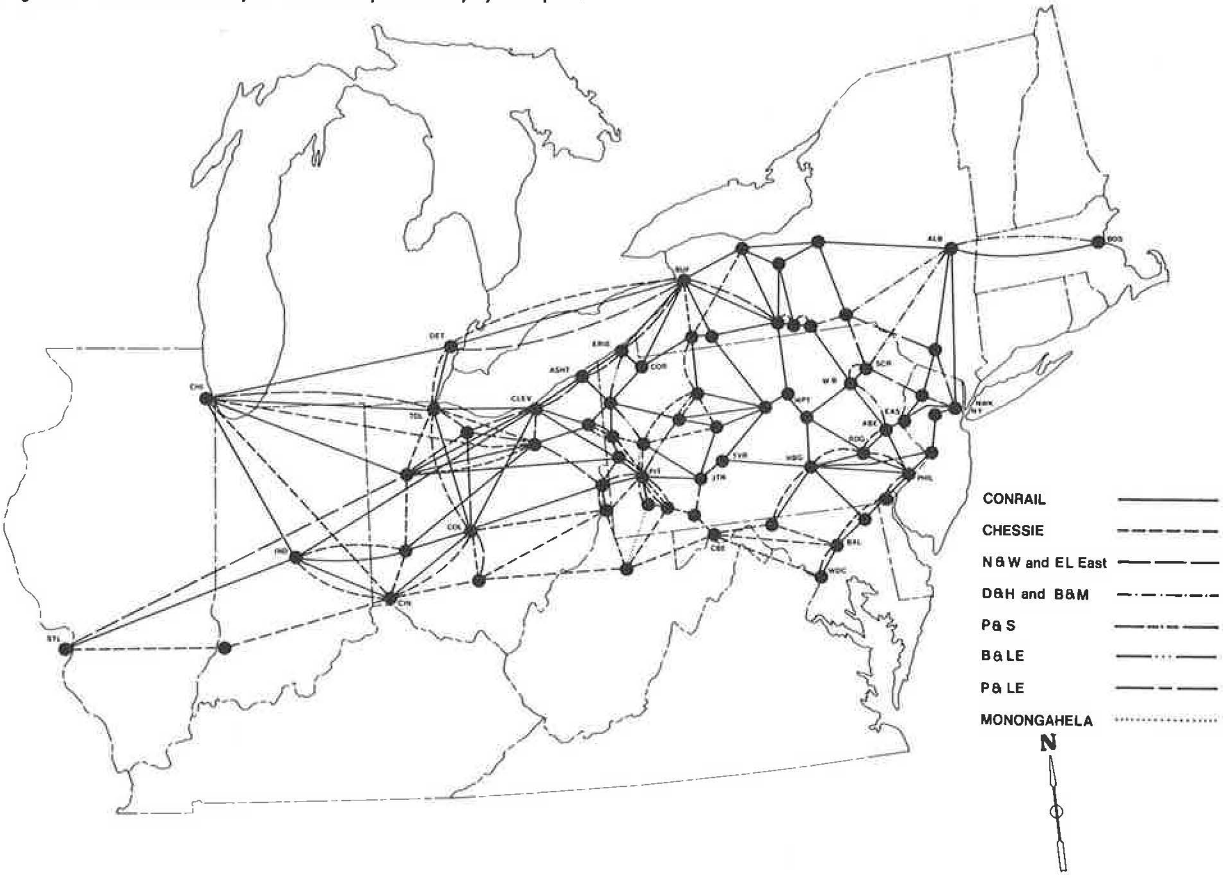


Figure 3. Trunk route analysis for USRA preliminary system plan.



porate and rail system revenues. (ICC waybill sample data also include information on type of commodity, haul distance, type of rate ascribed to the movement, freight car used in the move, and rail carrier.)

Several modifications were necessary to make the two data files usable in the Pennsylvania Department of Transportation study. First, the traffic origination and termination coding in each file had to be converted into the zone coding system previously described. (A conversion table of department zones and SPLC codes was provided to FRA to prepare computer tabulations of the ICC waybill sample.) Second, the ICC-FRA data had to be expanded and adjusted to represent 1973 traffic. Third, the overlap between separate railroad USRA files, such as that which occurs on interline shipments handled by two or more bankrupt railroads, had to be identified and eliminated. After these modifications were completed, the remaining task became one of choosing which portions of the two files should be used in the subsequent network analysis.

Both source files have important limitations. The ICC-FRA data were geographically and corporately complete, although the small sampling rate results in very high statistical variability. On the other hand, the USRA files contain the desired census-type data, but are limited to the seven bankrupt railroads. The solution was to select the strongest portions of the two source files. The USRA data set was used for interchanges between internal Pennsylvania zones and for interchanges with zones outside Pennsylvania. Such movements are characterized by small zone size (in Pennsylvania) and a high incidence of movements over bankrupt railroads. This was supplemented by separate estimates of the traffic using solvent railroads only. The ICC-FRA data set was used for interchanges between zones outside Pennsylvania where the aggregation from using larger zones reduced the variability resulting from the small sampling rate. The resulting data base was representative of the traffic originating in, terminating in, or passing through the defined geographic area.

Both source files have revenue data, although in the ICC-FRA file the amounts shown were total revenues and in the USRA file were revenues attributable to the reporting railroad. In the Pennsylvania Department of Transportation application, the revenue data from the USRA file were used because the revenues earned by railroads outside the region were not of concern. This was supplemented by ICC-FRA data for zonal movements not served solely by bankrupt carriers. Revenue data were extracted as an average dollar figure per carload for specific zone-to-zone interchanges.

Preparing Inputs

There are three basic inputs to the computerized trunk route analysis procedure: (a) a "link" record describing the physical characteristics of different segments of the rail system, (b) a zone-to-zone "traffic" record, and (c) a "routing" record identifying the commonly used sets of links for movements between zone pairs.

Coding Route Physical Characteristics

The link record provided the mechanism for inputting needed transport and cost characteristics. Basic physical characteristics are length (route- and track-kilometers) and unit operating costs; other characteristics can be included for more sophisticated analyses. Included for information purposes was a numeric and geographic identification of the delimiting nodes and its corporate association (the railroad company owning and operating the link). Link records can be added or deleted at any point to represent trunk route system changes or the granting of trackage rights. Similarly, the corporate association identified can be changed to represent the different reorganization proposals. Thus the link record contains the control characteristics that shape the program outputs.

Inputting Traffic Data

Total zone-to-zone traffic volumes, expressed as total carloads, net mass transported in megagrams, and average revenue per carload, are input directionally for each zone-to-zone pair. As previously stated in the Pennsylvania Department of Transportation study, these data were derived from computer tabulations of the ICC-FRA and USRA files supplemented occasionally by independent estimates of traffic handled solely by solvents within, to, or from Pennsylvania. Traffic data would normally remain constant unless different time periods were being analyzed.

Determining Likely Routings

The step involving the greatest amount of preparation is that of directionally delineating interzonal routings and estimating market shares by competing routings. These judgments are based on such factors as competitive relationships, past "friendly" connections (or antirelationships), comparative access to zonal originating traffic, physical and operational characteristics of the alternative trunk line routes, and the common practice of maximizing the length of haul by the controlling (originating) carrier. Routings are created by sequentially listing the links traversed in moving traffic from one zone to another. The number of routings to be designated depends on the amount of interrailroad competition between the two zones and the volume of traffic involved. Only the principal routings should be considered, because of the time involved in manually making assignments. It makes little sense to hypothesize an alternative routing if only a handful of carloads would ultimately be assigned to such a routing.

The work involved in designating routings is best done by analysts having railroad traffic department experience. Only in this way is there a reasonable guarantee that the routings reflect what is indeed happening or likely to occur under alternative corporate arrangements. [Additional information on route choice theory and behavioral considerations underlying rail freight route choice is available elsewhere (5).]

Assigning Traffic and Calculating Associated Costs and Revenues

The trunk route analysis procedure used a specially prepared computer program to accomplish the accounting work required. The program itself consisted of three major phases. The first phase was to set up the several arrays in which carload, mass transported, revenue, and cost data could be aggregated on the basis of links, nodes, and corporate systems. In the second phase, traffic and associated routing records were read by the computer, which then prorated the traffic and revenue data to available routings on the basis of market share estimates for each routing and then allocated it to the affected links, nodes, and corporate systems. After all traffic and routing records had been read, the third phase computed traffic (megagram-kilometers and car-kilometers), revenue, and cost for each of the arrays and printout summaries.

The program is dependent on a number of unit costs used in the computation of total costs. Among these are a series of variable costs for carload origination or termination, carload interchange, mass transported origination or termination, and revenue-car-kilometer and megagram-kilometer charges and a fixed cost per kilometer of route operated. [Unit cost data were developed by R. L. Banks and Associates by using information contained in annual reports to the ICC. The variable unit costs were $60.80/carload origination or termination, $20.74/carload interchange, $0.1061 for origination or termination/Mg ($0.0963/ton), $0.170 818/revenue·car·km ($0.274 906/revenue-car-mile) and $0.001 88/Mg·km ($0.002 74/ton-mile) respectively. The fixed cost was $12 698/km ($20 436/mile) of route operated.] The car-kilometer and megagram-kilometer costs are system averages. Some segments have higher or lower costs because of the physical characteristics (such as grades) of the route segment. These costs were adjusted in the program proportionally to fuel consumption, which was found by analyzing the outputs from RSPO train operating simulations, which took into account the topographic features of various lines.

The program also depends on proportioning the revenue received among the participating carriers. Replication of actual revenue divisions was beyond the capabilities of the Pennsylvania Department of Transportation study. As a substitute for this, 10 percent of the revenue was assigned to the originating and terminating carriers and the remainder was apportioned on the basis of revenue-megagram-kilometers. In many cases, the originating or terminating carrier is located outside the region; in these cases, the arbitrary (10 percent) origination or termination charge would not be assigned to the network.

Checking the Results

Most traffic assignment processes include a checking phase in which the resulting link volumes are compared against independently obtained traffic counts to see how closely the simulated system replicates the actual. If there are major differences, the characteristics of selected links of the simulated network are refined to produce a closer match. Checking is required mainly because of imperfections in the data or because of extraneous behavior patterns.

Such a check is possible and indeed is recommended with rail analyses. Although the routings may appear to be obvious, the market penetration or proportional split of the traffic in a zone among competing routings is not. Thus a comparison of assigned traffic with reported link densities is desirable. The latter is usually expressed as millions of gross megagrams per year; the net mass assigned to the network must be expanded to reflect the mass of locomotives, cabooses, empties, and nonrevenue freight traffic. Railroad annual reports to the ICC (from R-1) can be used for this purpose. The results of this comparison will quickly show where there are major differences requiring reconciliation.

The adjustment process can be cumbersome, tedious, and time consuming. To reduce the manual searching, an option was included in the computer program (sometimes called a select link option) to list out, in order, all the zone-to-zone traffic movements using a particular link. Thus the analyst can readily identify the principal movements using the link and make any adjustments desired by changing the routing percentage or adding or deleting routings.

How well did the process work in the Pennsylvania Department of Transportation study? The following tabulation gives the mass transported across Pennsylvania borders in 1973 (1 Mg - 1.1 ton):

State Border	Actual Railroad Density Records (millions of Mg)	Simulated Base Case (millions of Mg)
West	152.5	152.6
South	76.5	74.8
North	68.4	68.3
East	29.9	30.0
Total	327.3	325.7

As can be seen, the agreement between railroad data and the simulated base case is extremely close.

A further comparison was made on an individual link basis. Although there was appreciable variation on some links between railroad data and that simulated, there was reasonably good agreement overall. For example, in Pennsylvania the sum of gross megagrams on links came to 2276 million (2509 million tons) for simulated traffic versus 2291 million (2526 million tons) reported by the railroads. The high volume links generally were within 10 percent of reported densities.

Analyzing Alternative Plans

The same basic process described above can be used for testing alternative plans. In such analysis, the zone system, the traffic inputs, and the unit costs remain constant. Link records can be deleted to reflect proposals for consolidating service from existing parallel routes or the elimination of low-density routes currently carrying overhead traffic. Link records also might be added to reflect trackage rights. The corporate designation can be modified to reflect a change in ownership. The routing records can be changed to reflect different patterns brought about by changed corporate relationships.

The overall effect of an alternative plan is obtained only by determining the resulting differences in car-kilometers, megragram-kilometers, costs, and revenues between a base case and the alternative being tested.

Using the Procedure Results in Preparing Net Railway Operating Income Statements

The traffic estimates cover railroad operations for those portions of the system included on the network. To prepare total system estimates, off-network revenues and expenses must be estimated and added to the totals obtained earlier. Adjusting traffic and revenues to reflect what is anticipated to happen at some future point in time (short-term projections) may also be necessary. This can usually be done as a multiplier applied to the basic results.

ARE THERE OTHER ANALYTICAL TOOLS?

FRA has also developed a network model to assist railroad planners in developing and analyzing traffic loadings on a link-by-link basis. Basically, the model is a modified version of the Federal Highway Administration's highway assignment package. This program is being made available to states for rail planning purposes. The FRA model (6) can produce graphic displays of various data items (such as line plots of network configurations). Its principal virtue is its potential as a repository for detailed network information stemming from the size and extensiveness of the network already coded. (The U.S. rail network consists of almost 20 000 links and 16 000 nodes). The model has three major drawbacks. First, the use of minimum path routings resulting from the use of an internal algorithm probably does not depict real-world rail routings, which are often quite circuitous because they are influenced by corporate management policies. Second, multiple routings between two points are not possible, even though such interrailroad competition is frequent. Third, the size of the FRA-developed network and computer program is large and quite complex, which makes its application relatively time consuming and costly.

The trunk route analysis model developed for the Pennsylvania Department of Transportation (a) permits multiple and circuitous routings, (b) is flexible, (c) produces full output including node interactions and corporate system summaries, (d) has extensive internal data editing capabilities, and (e) requires relatively little computer time. It does depend on manually prepared routings that are time consuming to develop. In its current form, it does not have all the niceties that ultimately would be desirable such as real time network and routing updating, parameter card input of unit costs and other constants, and inclusion of coordinates for computer prepared graphic displays. These can be readily added, however.

SUMMARY

We feel that the trunk route analysis procedure described in this paper helps fill the void for rapid, large-scale tools for policy and systems level planning. Although developed for statewide and regional rail planning purposes, the procedure and supporting computer program are general enough to permit their application to other freight modes of an intercity character.

In short, the procedure is a simple, straightforward, pragmatic adaptation of computer-based accounting in support of manual estimates of the distribution of traffic among competing carriers made by experienced analysts. The procedure does not rely on theory or algorithms for routing decision making. The process can be influenced by subjective biases, although the checking process is included to uncover major distortions. The computer program is relatively quick and inexpensive to operate. The interaction process between the analyst and computer can and should be further refined to reduce the efforts involved in changing data entries. The procedure is a start; further improvements will come as the process is applied to similar freight transport problems.

The field of freight transport planning is nearly a virgin territory in terms of availability of analytical planning techniques. What has been presented is only a start. Indeed, it is only through beginning with relatively simple tools, such as the one described in this paper, that advances in technology emerge over time.

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