density flows. Flow maps for freight are also generally lacking; they represent a starting point for all studies and are a necessary requirement for freight system analysis.

2. Careful determination of specific data needs and their uses should be made before data collection programs are launched. This is a fundamental point that cannot be overemphasized; the data needs must be carefully structured to be consistent with problems to be solved. Although basic density data are considered essential as discussed above, additional data acquisition should be carefully defined and justified to avoid the possibility of securing data that may not be relevant or may be of such magnitude that they cannot be easily incorporated into the decision process.

3. Many freight data are available and could be used if they were identified and classified.

4. Freight data available from private agencies should be secured through joint cooperation. Private agencies, especially the railroads, have a wealth of data that could be useful for statewide transportation planning. The ability to secure these data often depends on the good faith of both parties. Clearly, if the data are to be made available to the state, mechanisms must be developed whereby the transfer of data is in the interest of both parties.

5. Supplementary special purpose data should be collected as necessary to analyze particular problems and planning issues.

HIGH-PRIORITY RESEARCH PROBLEM AREAS

The discussions within the workshop identified 11 areas of research that related to the needs and issues previously described. Of these, 3 areas were identified as representing high-priority topics for which immediate research efforts should be undertaken.

1. Freight data requirements for statewide systems planning. This research would identify minimum freight data necessary for statewide planning purposes, identify data already available, design data collection programs where appropriate, and test the design within a statewide transportation planning program.

2. Carrier facility curtailments and abandonments. This research is of immediate relevance; it relates to the current crisis of the railroads. However, states are not in a position to evaluate rail abandonments and to understand the impact that these have on the state's economy, energy, and travel redistribution.

3. Simple freight demand models. A strong need in the area of methodology relates to development of demand models for forecasting freight flows and evaluating alternative policies and systems. As has been noted earlier, these models should not follow the traditional UTP process, but should be structured in a form that is readily usable and not heavily data-dependent.

Resource Paper

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Within their respective areas of concern, the 2 resource papers on systems planning and programming methodology serve 3 stated objectives: (a) to identify and evaluate the current techniques being used to develop statewide multimodal transportation plans, priorities, and programs; (b) to recommend improvements in planning methodology, including essential data and management elements; and (c) to develop a recommended program of research in needed methodology for statewide multimodal transportation planning.

In serving these objectives, this paper reservedly focuses on the task of presenting a generalized synthesis of the current and potential state of the art in statewide freight transportation planning and programming. The emphasis on potential capability is essential simply because minimal technical activity is being directed currently to freight analysis at the state level.

Hence, the paper draws on selective methodological capability in other planning contexts (e.g., the Northeast Corridor Transportation Project) for possible incorporation at the state level. Except for the most obvious matters, such as the pressing need for integrated assembly of goods movement data, the paper generally refrains from any strong advocacy and purports merely to raise major issues.

Planning and programming for freight transportation systems at the state level are practically virgin territory, as highlighted in a recent report (34, p. 31): "It seems that we are in the infancy of long-range goods movement system planning. It is a period during which planners must obtain data and develop analysis techniques before even attempting to simulate those systems." This embryonic status of freight transportation planning represents an appraisal relative to all accomplishments in statewide transportation planning, which itself is approaching adolescence at best. According to Creighton and Hamburg (11, p. 21):

> The position of statewide transportation planning in 1972 has advanced to about the position of urban transportation planning in 1955 Fortunately, to improve this position, we have the advantage of knowing a great deal more about planning processes, goals, simulation, data collection, and evaluation. However, statewide comprehensive transportation planning is a larger and more complex subject than urban transportation planning There are more modes. Both public and private organizations provide the services And freight movement is a vital half of the problem.

Because this entire subject area is so embryonic and raises a somewhat bewildering variety of issues throughout all aspects of the planning and programming process, defining an overall organizational framework is essential for discussion. Figure 1 shows the planning and programming process in terms of developing alternative transportation plans, analyzing their respective consequences or effects, performing a comparative evaluation of those alternatives in terms of their estimated effects, and programming specific projects. The elements of plan development and plan evaluation represent procedures for utilizing analytical techniques to derive most appropriate courses of action. A fourth element, data collection, basically provides quantitative foundation for the analysis of plan effects. The programming of particular projects constitutes the final step in this process leading to implementation. Obviously, execution of this entire operation first requires that the relevant planning instruments (or controls) and the relevant effects (or criteria) be defined.

The discussion of methodological issues in this paper is organized in reference to this skeletal structure of the planning and programming process. The first section begins with an attempt to define the overall scope and character of the process and culminates in several premises regarding appropriate state responsibilities. Sections 2 and 3 discuss and define the relevant control variables (analytical parameters for specifying proposed courses of action) and effect variables (criteria for evaluating alternative plans) respectively. Section 4 discusses data collection efforts, and section 5 discusses analytical techniques; the most specific, hard-nosed issues are raised in these 2 sections. The final section highlights major methodological issues. Selective references are included to give direction to particular concerns for various problem areas cited throughout the paper.

Figure 1. Skeletal structure of planning and programming process.

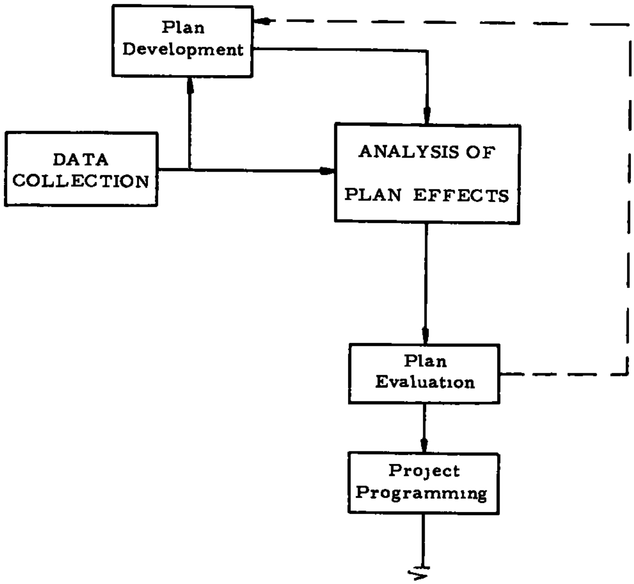
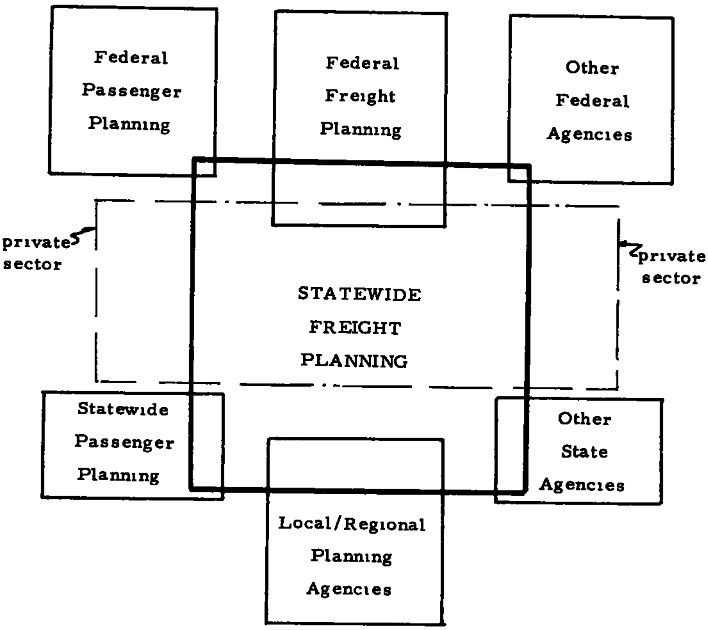


Figure 2. Jurisdictional context for statewide freight transportation planning and programming.



SCOPE AND CHARACTER OF STATEWIDE FREIGHT TRANSPORTATION PLANNING AND PROGRAMMING

The scope and character of planning and programming methodology at the state level obviously depend on the types and degrees of jurisdictional authority vested in that governmental body. The nature of such authority conditions the particular courses of action to be considered by technical analysis. Although specific matters of appropriate jurisdiction were addressed by the Workshop on Policy Planning, some basic observations are in order here, particularly to help define the relevant "control variables" for planning and programming techniques at the state level. In other words, part of the intent here is to lay groundwork for identifying the "knobs," which are within the province of state-level methodology, to manipulate in exploring alternative courses of action.

This matter is not altogether straightforward, inasmuch as any such endeavor is necessarily sandwiched between a variety of overlapping private and public parties, as shown in Figure 2. Obviously the state has a direct interest in affecting the economics of competition among intrastate carriers (e.g., through regulation of rates, route structures, and rights of entry), especially when competitive conditions in one part of the state interact with conditions in another part. On the other hand, state planning presumably would have negligible concern with the house-to-house distribution of parcel post shipments in local communities and certainly could not take on a comprehensive systems analysis of transcontinental rail-merger proposals.

Within this broad spectrum of freight transportation problems, the appropriate role of state planning and programming must be defined in accordance with institutionalized jurisdictional authority. Technical methodology must be considered in terms of relevant endogenous control variables, for they specify in analytical terms the alternative courses of action to be studied. [Endogenous control variables are those parameters that state planning manipulates (e.g., intrastate rates). Exogenous control variables are those parameters that are prescribed by other decision-making bodies, as shown in Figure 2 (e.g., federal import quotas or fuel rationing), and that directly affect state planning.] This section then summarizes the types of instruments that the state generally may exercise in freight transportation. Some exemplary problem areas of major public concern are cited, and from this discussion several raisons d'etre for state planning and programming are inferred. Several premises are next advanced regarding the appropriate scope and character of such a process. Then the limited activities of states to date are summarized in reference to this prescribed scope and character.

Overview of Instruments Within State Jurisdiction

At any jurisdictional level, government typically may exercise 4 distinct kinds of interventional instruments that address the following concerns (31): improvement of resource allocation, improvement of wealth distribution, protection of individual freedoms, and maintenance of social and economic stability. Governmental involvement in transportation (especially freight) is predominantly concerned with instruments of resource allocation to achieve economic efficiency and less concerned with inequities among carriers, modes, and various shipping interests.

Governmental bodies may affect the pattern of resource allocation in terms of 4 basic instruments: (a) direct investment in facilities and services with either public or private operating responsibility; (b) "hard" promotional programs such as subsidies and tax advantages; (c) regulatory controls over the private sector "in the public interest"; and (d) "soft" promotional programs such as information assembly, research, and coordinative planning.

As a whole, the national system of freight transportation is largely an operation of the private sector; the regulatory instrument is the paramount form of governmental involvement. For some modes (notably truck, water, and air) fixed-way facilities generally are provided by direct public investment, and fleet operations are left to private sector decisions. To a limited though increasing extent, the federal government has executed promotional programs of both the hard variety (e.g., investment tax credits for rail fleet acquisition and the Regional Rail Reorganization Act of 1973) and the soft variety (e.g., research on fleet utilization, national transportation surveys, and a national network model of long-distance freight movement). Otherwise, the regulatory instrument has prevailed as the key means for influencing resource allocation in freight transport, and the other types of actions are left largely to private initiative.

The role of state government generally follows a parallel pattern, except for an almost total absence of promotional strategy. State agencies administer the provision of highway facilities and some air and water facilities. Otherwise, although promotional subsidies are provided to local passenger operations, the state's control in freight transportation is decidedly regulatory. Except for a few cases (notably Connecticut, New York, Pennsylvania, and Wisconsin) state planning specifically for freight transportation has remained nominal, especially within agencies empowered to make regulatory decisions. Applications of individual carriers are treated on a piecemeal, case-by-case basis in the form of adversary proceedings that are devoid of any comprehensive in-house compilation of objective and systematic impact analysis.

State administrative and regulatory responsibility traditionally has been diffused among a number of departments, commissions, and authorities holding jurisdiction over intrastate traffic. Although the establishment of transportation departments has consolidated some of these responsibilities, state regulatory functions have been incorporated only in the New York transportation department; most other states have retained these powers within a public utilities commission. In all cases of separate regulatory authority, supportive technical methodology remains piecemeal or nonexistent.

State regulatory powers typically include the licensing of carriers, evaluation of rate and route applications, and evaluation of service curtailment and abandonment petitions. Although the apparent intent of relevant legislation generally is to provide regulatory jurisdiction over all intrastate traffic, in practice these powers apply unambiguously only to strictly intrastate carriers. The intrastate movements of interstate carriers fall into a gray area of interjurisdictional responsibility, and federal agencies generally exert more influence. [Volotta (63) presents a case study that contains a revealing elaboration of state transportation regulation.]

Although such ambiguities exist, technically the state has control over the same basic parameters of freight transportation systems—technology, network structure, capacity, service attributes, and costs to operators and users—as those that have been incorporated into passenger systems planning institutions to date. However, the direct influence of those parameters through outright provision of capital facilities and equipment is more limited in the state freight context (primarily highways and, to a lesser extent, air and water facilities). The more prevalent instrument is the regulatory one, which essentially leaves proposals for modifying the aforementioned parameters to the initiative of individual carriers; in this respect state control is less direct, for it basically adopts a binary approval-disapproval approach in decision-making. The utilization of more positive promotional instruments such as subsidies and tax credits has been minimal, and supportive planning efforts have been nominal or, at best, far too piecemeal. Beyond these forms of intervention, the state also has some opportunity to express its interests in freight transportation to appropriate federal agencies (e.g., as an interested party in the piecemeal adversary proceedings of the Interstate Commerce Commission or through the National Transportation Needs Study of the U.S. Department of Transportation).

Exemplary Problem Areas in Freight Transportation

The need for coordinated planning in freight transportation at any jurisdictional level arises from a growing number of outstanding problems that have not been resolved under prevailing institutions. Extensive compilations of specific issues are adequately documented elsewhere. [The Transportation Association of America (52) identified and updates annually a comprehensive set of outstanding issues. The 1972 National Transportation Report (58) also gives a noteworthy summary of some major issues in commodity transportation.] The intent here is to highlight a few major problems that serve to identify distinct raisons d'etre for freight planning and programming at the state level. In general, these problems relate to the roles of competition and coordination (within and between modes) and associated shortcomings of resource allocation. The key point is that these various issues are manifested at different levels of spatial and political jurisdiction.

Consider first some exemplary problems that are of relatively localized relevance. Urban areas are vitally dependent on the efficient distribution of fresh and frozen produce commodities from line-haul carriers to local retail outlets. The typical urban produce yards consist of deteriorated facilities designed for an outmoded era predating urban sprawl, and the efficiency of such operations has been hampered by automobile congestion and by the growth of large-scale food chains with independent distribution systems. If the needs of urban consumers are to be met adequately now and in the future, new distribution systems must be planned and most likely supported by some degree of public subsidy.

In a rural context, the problem of rail branch-line abandonment has developed into immense proportions during recent years. Trunk-line interstate carriers maintain that conditions of intermodal competition for long hauls have made them far more sensitive to the economics of allegedly marginal or unprofitable branch-line operations. The problem has reached the point where the negligence of maintenance on many such lines is noticeable to the "layest" of lay persons. Prospects of abandonment threaten the captive existence of shippers on such lines, and local communities face losses in economic base and tax revenues. Railroads are claiming that public subsidies must be forthcoming if such operations are to continue, at least under their operation.

The most pervasive issues in freight transportation relate to the economics of intramodal and intermodal competition for line-haul movements. Where such movements are of an intrastate nature, state planning has the potential to coordinate heretofore piecemeal perspectives. The exempt status of the private motor carriers is one such issue, which has drawn the following position statement in the New York state master plan (46, p. 50):

> Freight movement by private truck dominates freight transport The remaining freight haulers–the for-hire carriers–are, to varying degrees, subject to economic controls that hamper them in exploiting their inherent advantages and thereby deny them a fair opportunity to compete effectively against private carriage

Another such issue arises when a state regulatory commission approves a rate or route application for one mode in an intercity corridor and has only a very speculative notion, at best, of shipper cross elasticities and consequent impact on competing modes.

Issues of considerably greater complexity arise when any regulatory decision for a carrier in one part of a state may increase or decrease the traffic movements via connecting carriers in other parts of the state. Indeed, the totality of such piecemeal decisions can have a marked influence on the distribution of industrial development throughout a state. The point here is that a variety of physical and economic interdependencies exist in statewide multimodal freight networks and must be considered within an integrated perspective that transcends individual carriers, modes, and local areas.

Similar interdependencies of an interstate character raise similar issues at a suprastate level. Interstate railroads, for example, are burdened with excess trunk-line capacity that has promoted many proposals for intramodal consolidation involving the entire national rail network. Moreover, the growing need for intermodal transfer facilities (especially line-haul to line-haul) is widely recognized, producing proposals such as ship-to-pipeline oil transfer in coastal states, auto-train terminals, or even the concept of a transcontinental land bridge from coast to coast. Such interests in coordination have prompted selected initiatives toward industrial reorganization in the form of single-ownership, multimodal transportation companies. These kinds of issues pertain to interstate traffic, yet may have substantial impacts on the individual states.

This selective discussion of major problems in freight transportation suffices to distinguish several essential levels within an ideal hierarchy of systems planning and programming.

1. Problems of predominantly local concern, i.e., those that are relatively isolated or self-contained within lower jurisdictions of government (but that may be shared by peer jurisdictions throughout a state or the nation and require supportive funding);
2. Problems that require a systematic analytical perspective to integrate the piecemeal proposals of individual carriers by considering the full extent of intrastate interdependencies among various carriers, modes, and geographic areas within the state; and
3. Problems that require the same approach as suggested in level 2, but from an interstate perspective.

Premises Regarding Scope and Character of State Planning and Programming

Obviously we cannot expect any state to take on all of these responsibilities. However, certain premises may be set forth here in order to articulate the appropriate scope and character of statewide freight transportation planning and programming.

1. The planning of relatively localized projects (such as access and terminal facilities) eventually should be executed by local or regional planning agencies. Where such projects warrant state promotional intervention (e.g., through direct or federally channeled subsidy, tax exemptions, or use of eminent domain powers), the projects would be programmed at the state level. Where such problems are common to many peer jurisdictions, they may warrant special research efforts—sponsored by state or federal agencies—to help develop appropriate analytical methodology. State sponsorship would be warranted only for problems relatively unique to the particular state.
2. The problems of the second kind require in-house statewide planning and programming that use systems-analytic methodology with sufficient spatial detail to account for important intrastate origin-destination markets. Techniques of spatial demand analysis, modal-choice analysis, and network analysis are essential to consider fully the economic and physical interdependencies among different carriers, modes, and geographic areas within the state. As necessary and feasible (see premise 3 below), patterns of interstate flow should be superimposed onto such statewide systems analysis. The supportive technical methodology for this activity should be explicitly sensitive to all transportation system parameters that may be influenced by state agencies through direct investment, promotion, and regulation.
3. The problems of the third kind must be treated at the federal level by means of technical methodology similar in kind to that described in premise 2 above for statewide planning and programming. Coordination of this effort with the statewide endeavor is essential, especially in respect to mutual exchange of information. It is assumed that the ongoing statewide process described in premise 2, together with any special studies implemented according to premise 1, will provide adequate basis for advocacy of a state's interests within broader transportation decision-making institutions at the federal level.

These premises define the main concern of statewide planning and programming methodology as the systems analysis of nonlocal intrastate carriage (and related impacts) in a spatial context, but allow for selective special studies for common local problems.

State of the Art: An Overview

The scope and character of current state-level planning and programming generally are very remote from that prescribed above. The closest approximation to this comprehensive approach (save for the few exceptions noted below) is the inclusion of truck-flow estimates in statewide highway traffic assignments where such procedures are used (20, 59). The typical condition at the state level beyond this consideration of trucks as automobile equivalents involves a regulatory commission resolving piecemeal carrier proposals by means of an adversary process, without any consistent technical estimates of likely impacts. The first national transportation study (58), though oriented to passenger transportation needs and to aggregate data summaries by state, at least seems to have created a consciousness of pressures for statewide freight planning and programming.

Several states have broken some substantial ground in proceeding toward the scope and character prescribed above. The Connecticut Interregional Planning Program conducted special statewide surveys of truck and certain rail freight movements during the mid-1960s and projected origin-destination patterns to the year 2000 (8). The Wisconsin Department of Transportation has taken noteworthy initiative toward a state census of transportation with careful consideration of potential primary and secondary data sources for freight (16). The New York Department of Transportation has taken vanguard steps to integrate regulatory decision-making into a statewide planning and programming process (46), although data collection and analytical techniques remain in an exploratory phase.

Thorough inventories of freight facilities have been conducted for Pennsylvania (65) and Tennessee (67), and the Illinois Department of Transportation currently is attempting to procure link density data for all railroads operating in that state. Elaborate data collection and modeling methodologies have been designed for California (39) and Pennsylvania (6), but have not been implemented. Undoubtedly some other states have taken limited initiative at least in data collection activities.

Despite these instances of meaningful initiative, little has emerged insofar as operational analytical methodology is concerned. The California and Pennsylvania studies developed comprehensive planning methodology in considerable detail, but some elements of each require rather elaborate data collection. The other states cited above either have not developed any analytical methodology at all (beyond data collection) or are just beginning to do so, and documentation is not yet available or—in the case of Connecticut—methodology has been adapted directly from first-generation techniques of urban transportation planning.

State-level programming methodology for freight transportation is even more embryonic. Within those agencies with direct investment responsibilities, programming for freight-serving facilities generally has been treated as described in the Workshop 3A resource paper on passenger planning and programming. Such facilities typically have had a primary orientation to passenger service; freight-serving functions are considered subordinately. Otherwise, the programming of regulatory actions generally has been left to a piecemeal adversary process, and systematic technical methodology has been totally lacking. In effect, priorities are set by the pattern of applications that emanate from the private sector.

Special studies of relatively localized but commonly shared freight problems have been conducted in numerous instances, though with very little involvement at the state level. An extensive body of literature on terminal planning and design has developed through the research efforts of individual private carriers and modal industrial associations (e.g., the Railway Systems Management Association). The federal government (particularly the Federal Rail Administration in recent years) has sponsored various studies of intramodal operating problems such as fleet utilization, car supply, and service reliability. All of these efforts, however, have been directed to the internal operations of individual carriers—in some cases, they consider federal regulatory policy such as per diem car-holding charges, but not any significant role for the state.

Problems of urban goods movement have drawn increasing attention in recent literature; excellent state-of-the-art summaries lead such developments (23, 25, 26). Again, however, these studies have not focused on any planning role for the state. State subsidies for remedial courses of action are occasionally advocated, which would suggest some state-level programming activity. In general, the involvement of states in this area has been limited to advisory participation in the efforts of urban and regional transportation planning agencies (the New York master plan indicates exceptional initiative in promoting urban goods distribution). The point is that some worthwhile technical methodology has emerged for urban goods movement, but whether such methodology should be incorporated into state planning instead of local and regional planning is open to serious question. Given the general trends recently toward greater self-determination at local levels, it would appear appropriate to have local and regional agencies be responsible for such special planning studies and to limit state involvement to the programming of state or federally channeled funds for such projects.

The problem of rail branch-line abandonment has recently catalyzed, mainly through federal sponsorship, selective studies that assume a supralocal perspective. Two studies of particular note pertain to excess trackage in Iowa: developing analytical methodology appropriate to intermodal regional planning and to intermodal statewide programming. A study by Iowa State University (4), sponsored by the Federal Rail Administration and private interests, applied mathematical programming techniques to determine optimal truck-rail collection of grain for a multicounty region in north-central Iowa. The scope of this physical distribution study also included the consideration of grain-elevator configurations within the region. Earlier work at Iowa State University (49) studied the impact of transportation equipment shortages on grain distribution.

A study just initiated by the University of Iowa (54), sponsored by the U.S. Department of Transportation with the cooperation of local and state agencies, is developing procedures for statewide abandonment programming on the basis of trade-offs between freight service economics and reuse potential. This study focuses mainly on rail branch-line problems, but also is considering the abandonment of local airports and secondary roads. Also, the Iowa Office of Planning and Programming has recently completed an in-house study of 2 rail abandonment proposals (45).

Some states are now in the process of inventorying rail branch lines, particularly since federal legislation (through the Regional Rail Reorganization Act of 1973) specifically provides funds for state-channeled subsidies to continue services that are unprofitable but are beneficial to local economies. Section 402(c) of the act stipulates (56, p. 28), among other provisions, that eligibility for such federal assistance requires that

> .the State has established a state plan for rail transportation and local rail services which is administered or coordinated by a designated State agency and [that] such plan provide for the equitable distribution of such subsidies among State, local, and regional transportation authorities

Such determinations of subsidy requirements may be made by state, local, or regional transportation agencies as long as they follow specified standards of comparative cost analysis. The responses of individual states are unclear at this writing, except that the demanding deadlines of the rail act have set off a flurry of activity. Public hearings currently are under way to solicit responses to the initial reorganization plan (60). For more long-term purposes, the question of local-level planning versus state-level programming arises just as described earlier for problems of urban goods movement. Again, it would appear more appropriate for local and regional agencies to assume responsibility for technical planning methodology and for the state to assume responsibility for statewide project programming.

Having identified these special problem areas, I will concentrate throughout the rest of this paper on statewide systems methodology as defined earlier (premise 2). Again, development of freight-system methodology has been minimal at the state level per se. Moreover, most studies of urban goods movement focus on access elements of intercity transport and, hence, are not directly transferable to the statewide context. Given the embryonic state of the art in this area, much of the following material represents a fresh approach to the problem; it draws on supportive literature (e.g., that pertaining to larger regions) as appropriate.

CONTROL VARIABLES FOR STATEWIDE SYSTEMS ANALYSIS

As mentioned earlier, the instruments typically available at the state level for affecting its freight transportation system include the following:

1. Direct investment in physical facilities for motor carriers and, to a lesser extent, for air and water commerce;
2. Regulatory authority over intrastate commerce via all common carriers in the sense of binary approval-disapproval of individual carrier proposals; and
3. Potential promotional strategies (e.g., subsidies, use of eminent domain powers, and tax credits).

All of these instruments eventually are manifested in terms of the following 6 characteristics of the transportation system: network structure, technology, carrier ownership identity and regulatory status, capacity of facilities, carrier and user costs and rates, and service attributes (e.g., transit time).

As in the established procedures of passenger-oriented urban transportation studies, this kind of systems-analytic approach requires the definition of traffic analysis zones throughout a state (plus external zones as necessary to account for relevant interstate movements). All important state-level courses of action, via any of the aforementioned instruments, would be represented in terms of an abstract network to be superimposed on the system of traffic analysis zones.

Thus, for example, a speed limit of 55 mph for all trucks would be reflected in the transit time value for individual highway links. A rate change for any mode on a given commodity type would be represented in terms of the user cost for the particular origin-destination movements affected. Abandonment of any given line would be reflected analytically by reducing its capacity to zero. A merger of 2 trucking firms would give the 2 carriers the same identity label. These various parameters constitute the control variables within statewide multimodal systems planning and programming for freight transportation.

The level of spatial detail to be used will vary according to the size and development of each state. Freight movements for distances of less than 35 miles are likely to be of more concern to Rhode Island than to Texas. Predominantly rural states will generally involve a relatively longer average haul of shipments and a higher proportion of "bridge" (i.e., through) traffic; this suggests larger analysis zones and less detail in network coding. [The Connecticut Interregional Planning Program defined 15 analysis regions. The Pennsylvania methodological design advocated between 15 and 40 for freight analysis (that state has 67 counties).]

Besides the spatial dimension, the question of time scale for planning and programming requires resolution. This matter is treated in some depth by the preceding paper by Pecknold on passenger methodology; he makes the basic points that capital-intensive investment decisions suggest a long-range planning horizon, yet political realities argue for more short-term responsiveness. The latter factor is especially persuasive in freight planning and programming, for many proposals for system modification emanate from the private sector. Therefore, the appropriate time span for statewide freight planning—in terms of when proposed courses of action should take place—should be perhaps on the order of 5 to 10 years. Ideally, the programming function would be integrated within such a time span, perhaps with annual review and respecification.

RELEVANT EVALUATION CRITERIA

According to the framework set forth in the introductory section of this paper, the process of statewide systems planning and programming calls for analytical methodology that will estimate the relevant effects of proposed courses of action. The control variables identified in the previous section provide for specification of particular courses of action in analytical terms. The next issue logically refers to the definition of relevant effect variables, or criteria, by which alternative courses of action may be evaluated.

In theory, the identification of relevant evaluation criteria should proceed from a prior definition of goals and objectives (48). In practice such definition at the statewide level has been directed toward passenger transportation if at all existent (35). As for any freight orientation, the following statement of the Connecticut Interregional Planning Program (8, p. 28) is typical:

> Requirements for the movement of goods vary in the same way as needs for the movement of people For some goods, such as fuel, cost is the primary factor and speed is relatively unimportant. On the other hand, components needed to repair a complex piece of factory machinery must arrive quickly in order to reduce costly delays in the production of goods Therefore, the overall goal in planning goods movements is to achieve a system that is efficient and can provide for diverse needs. This requires a variety of modes, a minimum of cost, and sufficient capacity to supply urban and industrial concentrations efficiently.

The New York State master plan for transportation (46, pp. 50-51), which is unique in its integration of regulatory policy into the statewide planning and programming effort, states that policy quite clearly:

> The department's freight transportation policy relies on privately owned and operated common carriers, and utilizes the advantages of competition and private enterprise to define the role of for-hire transportation The allocation of resources among transport markets should depend heavily on competitive market forces to achieve greater economic efficiencies and to lower the total cost of transportation services to the public The department plan calls for modification of economic and safety regulation, modification of taxation of the various modes, and identification of public assistance responsibilities in a comprehensive program to strengthen competition and achieve those development goals which are noneconomic and are not served by the marketplace.

These 2 statements highlight the overriding importance of economic efficiency (i.e., improvement of resource allocation in terms of direct cost-performance characteristics of the transportation system) in statewide freight planning and programming. The New York statement also articulates concern for development goals. Moreover, it is generally agreed (or even self-evident) that the actions of state government must respect environmental concerns, however defined. Also, as observed in an earlier quote from the Regional Rail Reorganization Act of 1973, some sensitivity to the distribution of economic impacts (at least in a spatial sense) is emerging. In summary, for our purposes here the following goal dimensions are of relevance: (a) economic efficiency (overall system cost-performance), (b) statewide economic development, (c) environmental quality, and (d) reasonable equity in the distribution of costs and benefits.

These dimensions suggest a straightforward taxonomy, given below, of relevant effects, which draw pertinent distinctions for guiding methodological design.

Effect	Consequence
Production-related	
Direct	Capital resource commitments
Indirect	Localized externalities (displacement or disruption of socioeconomic and physical activities)
Consumption-related	
Direct	System operating efficiency (system cost performance)
Indirect	System externalities (environmental pollution and development patterns)

Production-related effects refer to consequences that occur by sheer virtue of facility construction (or removal), whereas consumption-related effects refer to "post-ribbon-cutting" consequences (i.e., patterns of system usage or operation and related impacts). Direct effects pertain to characteristics of the transportation system itself, and indirect effects refer to any impacts on that system's surrounding economic, social, and physical environments.

In these terms, the overriding concern for economic efficiency embraces all direct effects, including all system (capital and operating) costs and the patterns of commodity movements and service levels in a network context. Broadly interpreted (e.g., as in the Action Plan Guidelines promulgated by the U.S. Department of Transportation for state transportation and highway agencies), the concern for environmental quality embraces all production-related localized externalities and use-dependent pollution levels throughout the state. Developmental effects are identified as a separate concern for the effects that actual operating conditions have on the spatial patterns of economic growth (or decline) throughout the state. Distributional considerations may be incorporated not only by spatial analysis throughout this scheme but also by accounting for the major "incident parties" throughout (e.g., shippers, carriers, and the local or statewide community).

This taxonomy suggests a somewhat complex methodological framework, which is shown in Figure 3. The framework consists of analytical models that must be calibrated to data compiled through a base-year inventory. Once calibrated, each of these models addresses respective types of effects as defined above. Capital costs are determined as a function of technological and operating parameters for given facility locations, and production-related externalities (economic, social, and physical disruption or displacement or both) are estimated by superposing facility corridor locations on surveyed data for economic, demographic, and environmental units in such locations.

The more complicated aspects of this framework address patterns of system performance and consumption-related indirect effects. The analysis of system performance requires techniques for estimating goods movement patterns (e.g., by generation, distribution, and modal-split models) and, at least for the motor carrier mode, for determining equilibrium patterns of network utilization (e.g., by assignment models). Environmental externalities such as air and noise pollution are analyzed once a projection of system utilization patterns is accomplished.

A particular complication, not easily understood oftentimes, arises because of the inherent mutual interaction between patterns of economic development, commodity movement patterns, and transportation system attributes. Spatial patterns of economic development must be projected before commodity flows can be analyzed, for the origin-destination characteristics of goods movement depend directly on how traffic-generating activity is distributed over space. However, albeit with some lag of several years or more, the spatial distribution of economic development is itself sensitive to the configuration and service levels of the statewide transportation network. Figure 3 shows the provision for a "small-area activity allocation model," which is rendered sensitive to the attributes specified in any proposed transportation plan and allows for any necessary feedback of equilibrium service levels from network analysis.

No such methodology, in the degree of comprehensiveness presented here, currently exists at the statewide level even for passenger transportation planning and programming. With regard to freight, practically none of these elements has been implemented at the state level beyond the inclusion of truck vehicle flows in statewide highway planning analyses. Clearly all of the elements shown in Figure 3 cannot be developed expediently, but this framework offers a structured perspective from which major thrusts for research can be considered.

The discussions of data requirements and analytical techniques in the next 2 sections focus mainly on the problem of system performance analysis as the matter of utmost importance in methodological development. Attendant consideration is also given to the need for policy-sensitive activity allocation analysis and environmental impact analysis.

DATA REQUIREMENTS

As noted in the introductory section of this paper, the largest impediment to implementation of statewide freight transportation planning and programming is the severe lack

Figure 3. Comprehensive analytical methodology for statewide freight transportation planning and programming.

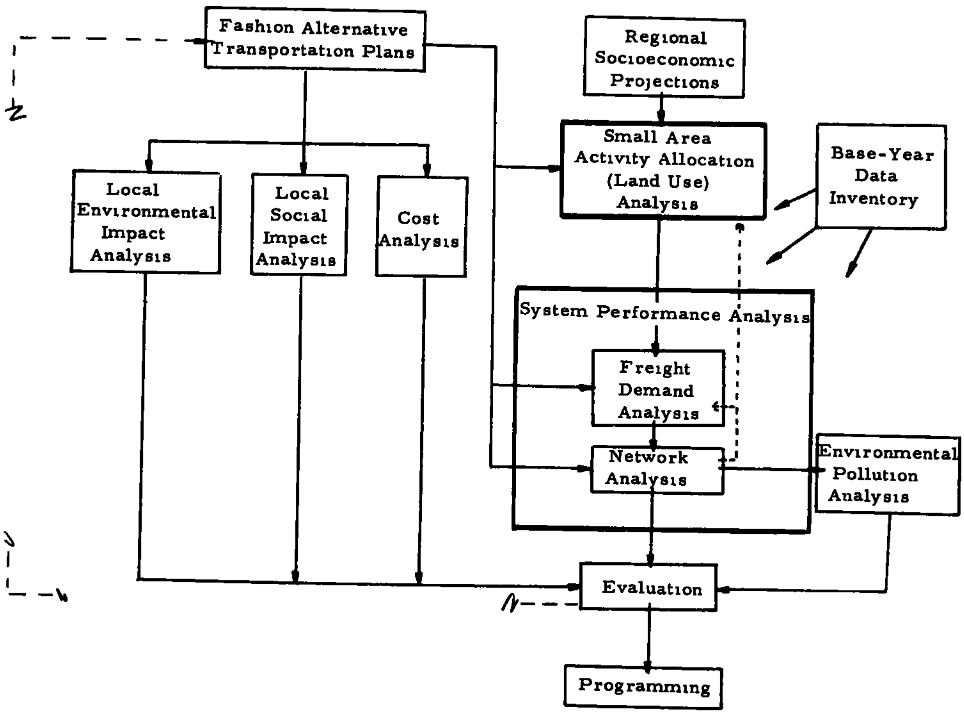


Table 1. Percentage of shippers by rank order of factors influencing mode selection.

Factor	1	2	3	4	5
Availability of equipment	15	19	20	22	24
Freight charges	42	18	16	13	11
Elapsed time in transit	20	33	21	19	7
Freight loss and damage experience	3	6	13	25	53
Dependability of delivery	22	26	29	19	4

Table 2. Percentage of major eastern shippers by factors influencing shift from rail to truck.

Rank	Factor	Percent
1	Faster transit times	24 7
2	Dependable transit times	12 5
3	Convenient frequency	12 5
4	Equipment available when needed	12 1
5	Minimum weights	9 0
6	Lower rates	8 7
7	Specialized equipment	6 5
8	Equipment conditions	4 1
9	Prompt claims handling	3 6
10	Traffic solicitation	2 7
11	Delay notification	2 2
12	Better billing procedure	1 4

of data. The recent NCHRP report on statewide transportation planning (34) stressed this point. That document structured data requirements in terms of 3 categories, which serve as the basis for discussion here: actual goods movements, transportation facilities, and spatial arrangement of human activities and natural resources.

Data on goods movements measure the realized demand for the existing (base-year) transportation system, and a facilities inventory measures the corresponding supply in spatial terms. Information on the spatial distribution of socioeconomic activity and natural resources establishes the traffic-generating capability for different traffic analysis zones, i.e., the ultimate bases for origin-destination demands. From all of this information, forecasting relations may be developed to estimate future patterns of goods movement as a function of zonal activity levels and the attributes of the proposed transportation systems. Zonal measures of socioeconomic activity also are necessary for the calibration of an activity allocation model.

Goods Movement Data

Data on commodity flows represent the dearest information of all for statewide freight transportation planning and programming. Such data preferably would be available in terms of consistent tabulations for origin-destination movements and corresponding link densities for each mode by commodity type.

Most states collect field data on vehicular truck movements for purposes of highway planning. During the mid-1960s, the Connecticut Interregional Planning Program (8) obtained data on motor carrier commodity flows by means of roadside interviews and selective interviews with trucking firms. CIPP also executed a 4-month sample of the New Haven and the Central of Vermont railroads. The information collected included commodity type, origin and destination, number of cars, hundredweight, and character of movement (interstate originated, interstate terminated, local, or bridge traffic). Also, CIPP made noteworthy use of information from the 1963 Census of Transportation to compile aggregate modal flows to and from major regions throughout the nation.

The CIPP experience is unique in that it constitutes the only known effort of a state to collect comprehensive freight flow data for all modes on an origin-destination basis. Some states (e.g., Illinois, Iowa, and Ohio) currently are attempting to compile rail freight density maps for purposes of branch-line abandonment programming. Also, data on origin-destination movements and link densities may be published for selective trunk-line carriers in the evidence and discovery exhibits of particular ICC merger hearings. Otherwise information on freight flows is practically nonexistent beyond the private files of individual carriers and shippers.

NCHRP Synthesis 15 (34) advocated direct surveys of waybills for the various modes, i.e., sampling individual carriers as the ICC used to do in compiling its series of state-to-state rail freight tabulations. That report also noted that the New York transportation department has proposed to conduct a direct survey of shippers, which would permit a more explicit determination of behavioral factors that influence choice of mode, route, and so forth. The methodological design for Pennsylvania proposed a very elaborate survey of shippers to obtain interindustrial flow data for 40 spatial zones and as many as 80 industrial sectors (at an estimated cost approaching $3 million).

It is this author's conviction that the most important research need for statewide freight planning and programming, by far, is to develop feasible strategies for compiling multimodal origin-destination and link density data. NCHRP Synthesis 15 offers basic recommendations on this matter, advocating procedures of waybill sampling through the cooperative efforts of carriers. This direct survey approach (or acquisition of primary data) should not be considered without also giving careful inquiry to the possible acquisition of secondary data via special tabulations (on contract) from the 1963 or 1967 Census of Transportation or both. Prior experiences of this author in compiling commodity flow data for the Northeast Corridor Transportation Project and for a special analysis of the Rock Island merger proposals determined that the U.S. Bureau of the Census would provide special tabulations for subareas within states—at some appreciable compromise of commodity detail—within the constraints of legal disclosure restrictions. During the course of the original survey planning, Donald Church gave public notice of this potential service in the following remarks before the 1963 Transportation Research Forum:

> If our publication plans do give the specific detail you need, we shall be pleased to prepare special tables on a reimbursable cost basis, provided (1) the sample is adequate to give useful data on the special subject, (2) the information can be released within the confidentiality rules that apply to data collected by the Census Bureau, and (3) the special work does not unduly interfere with other programs

A major limitation of this source (i.e., the Commodity Transportation Survey) is its restriction to manufactured products; hence, it would be of less value to agricultural states than to more industrialized states.

The thrust of research on this matter should consider all such sources of secondary data integrally with prospects for direct surveys of carriers or shippers or both. Particular attention should be paid to the trade-offs between areal detail and commodity stratification for a given level of expenditure and to the legal disclosure restrictions applicable in each state. Also, any direct survey effort must anticipate considerable difficulty in securing the cooperation of all carriers, especially those private and contract operators that are exempt from regulation. Those who organize and execute efforts to collect flow data should be very alert to potential sources of information within the freight industry (e.g., trade associations). For example, one mode-choice study conducted at Northwestern University (5, p. 63) was able to procure from the Chicago Board of Trade "detailed data on the quantity of freight shipped by truck and rail each month to Chicago from Midwest communities in which grain elevators are located."

Transportation Facility-Service Inventory

NCHRP Synthesis 15 also addressed the need for data on existing transportation facilities or a characterization of system supply. Information on operating services and carrier operating costs are essential ingredients in such an inventory as are strictly physical parameters of facilities. This aspect of data collection is considerably less difficult than the determination of goods movement patterns because confidentiality is not so sensitive an issue.

The information desired in this inventory should encompass all of the facility and service parameters defined in the earlier section on control variables: technology, operator (carrier) identity, operator regulatory status (private, contract, common), facility capacity (vehicular and tonnage), rate structure (and special charges), average operating costs, and service attributes (e.g., transit time). Much of this information is on file in administrative and regulatory agencies, but supplementary field contacts are necessary and quite feasible. An excellent model for all states to follow is provided by the inventory that was conducted for Pennsylvania (65). Also, the experience of the Northeast Corridor Transportation Project in coding freight networks provides valuable guidance (40).

This author's experience in studying patterns of shippers' route choices for transcontinental rail freight service (15) suggests a strong point of caution regarding the determination of service levels. For ascertaining service attributes such as transit time, the obvious strategy is to consult the published schedules of common carriers. Often, however, the actual service levels realized by carriers are substantially different from those advertised in schedules. Some special investigation of the average relation between scheduled and actual performance levels would appear to be warranted in this regard. DeHayes (12) offers guidelines for studying transit time performance of various freight modes.

Spatial Activity Data

Information on the spatial distribution of socioeconomic activity represents the least cumbersome aspect of data collection. Sources such as County Business Patterns, the Census of Manufactures, and the Census of Agriculture may be consulted to ascertain measures of economic activity (in terms of employment if not actual output levels) for reasonably coarse analysis zones, e.g., no smaller than the county. Data on land use, which are of less relevance to freight than to passenger analysis except for data on mineral resources, may be compiled from county records although tacky problems of incompatible use classifications should be anticipated. (Pressures are mounting in Congress for a national land use policy that would involve systematic statewide land use inventories.) Time-series data on activity levels should be abstracted from the aforementioned sources if an activity allocation model is to be developed, for temporal lags often need to be built into such analyses of locational responses to transportation system improvements. Control-total projections of future socioeconomic activity for individual states and multicounty areas are provided by the Bureau of Economic Analysis within the U.S. Department of Commerce (57) and the National Planning Association (36).

Time-Series Monitoring Versus Base-Year Data Collection

Compilation of base-year data for statewide freight transportation planning and programming is a task of substantial proportions. Yet the needs for relatively continual updating of that data base are well known and would appear to be especially important in the freight context since the private sector is responsible for so many decisions. Let it suffice here to state that any state-level effort to assemble base-year data should be designed to maintain organizational arrangements for contacts with individual carriers, at least, so that updating may be accomplished feasibly. For this purpose full consideration should be given to the use of highway traffic counts, tallies of applications to regulatory bodies, annual national statistics (prepared by federal agencies and by carrier trade associations), and even emerging remote-sensing technology.

ANALYTICAL TECHNIQUES

The overriding priority in development of analytical techniques for statewide freight planning and programming is the matter of system performance analysis, especially the estimation of commodity flow patterns. This section discusses major issues regarding analytical techniques for estimating system performance and related impacts.

According to established modeling taxonomy within the realm of (passenger-oriented) urban and regional transportation planning, the analysis of system performance translates a projected spatial distribution of socioeconomic activity into an estimated spatial pattern of origin-destination flows by mode (commonly referred to as demand analysis) and then assigns these flows to specific links as appropriate. Indirect impacts (e.g., those on socioeconomic development and environmental quality) are then analyzed as a function of system performance levels. Approaching the context of statewide freight analysis from this familiar perspective, the following methodological issues emerge as major concerns:

1. User versus operator behavior,
2. Aggregate versus disaggregate analysis,
3. Sequential versus direct demand analysis,
4. Specification of relevant service variables,
5. Relevance of network analysis,
6. Activity allocation analysis, and
7. Environmental impact analysis.

Obviously a host of more detailed issues could be identified, but the perspective here must be more fundamental (e.g., the relative merits of gravity and opportunity models could be debated again for freight traffic distribution). The following discussion elaborates on each of these major issues, cites pertinent past work as appropriate, and suggests tentative positions on each.

User Versus Operator Behavior

Within the established contexts of urban and regional transportation planning, most operators typically are under direct public control. The planning process under such circumstances can propose fare levels and be reasonably certain that public operating authorities will follow suit with such prescriptions. In the context of statewide freight, however, the lack of direct governmental control precludes such prescriptive certainty. For example, if a public utility commission grants a rate increase to regulated carriers for one mode in a given region, competitive market forces may act to change the rate structures of private (unregulated) carriers. This phenomenon may not be especially crucial under current conditions, but may become very important if, for example, the relaxation of regulatory controls as advocated by the New York plan should be realized. It raises a basic technical issue of whether models of carrier rate-setting behavior might become necessary for a proper analysis of system performance.

In other words, if origin-destination movements are to be estimated as a function of the rates charged to shippers, then the competitive rate-setting behavior of carriers would have to be predicted first. Obviously the interaction here between traffic volumes and free rate structures is simultaneous, and the question opens a can of worms that stirs uncomfortable fantasies of a general equilibrium model! A variety of single-carrier optimization models exist, but are quite expensive beasts to operate. [Representative literature in single-carrier optimization is reviewed by Drake (15, ch. 5).] For the purposes of statewide planning and programming, such models of competitive rate-setting behavior would be prohibitive.

Rather, this complication may be incorporated in an approximate way by developing carrier operating cost relations and, in turn, translating these costs into predicted rates (where necessary) as a function of the particular regulatory policy to be executed for rate-setting (e.g., value-of-service, marginal cost). [The literature on freight transport economics is replete with studies of regulated rate structures (13, 18, 21, 22, 33, 38, 43, 64).] Straightforward regression analysis should suffice for this purpose, e.g., using length of haul, average size of shipment, and average operating speed as determining variables. Such analysis should take particular care to incorporate sensitivity of carrier costs, and shipper rates by implication, to the prices and possible rationing of fuel inputs. Continual updating, obviously, seems highly desirable here.

The classical work in developing empirical cost functions for different freight modes, within a consistent framework, is that of Meyer et al. in 1959. Since than a number of cost analyses have appeared for individual modes, especially for rail freight, but it remains almost impossible to synthesize the results of these mode-specific studies into comparative terms.

A very important contribution to the literature on passenger cost analysis, which not only achieved this virtue of consistency but also defined output multidimensionally so as not to deny different technologies their inherent advantages, was developed by Morlok (32). It would seem well worth pursuing the adaptation of Morlok's methodology to the freight context.

Aggregate Versus Disaggregate Analysis

One of the strongest contentions about demand analysis that has emerged from recent reflections on urban transportation planning is the argument for disaggregate analysis. Basically, the argument is one of statistical validity and parsimony in developing travel demand models, although the approach lends itself quite appealingly to the consideration of door-to-door service attributes and behavioral attributes of the individual household.

The statistical argument is quite compelling in that it cites the relative amount of variation of household trip-making behavior, which is virtually ignored by zonal-level analysis. Aggregate zonal analysis develops statistical relations based only on observed variation between zones, whereas it has been shown that within-zone variation can be as high as 80 percent of the total variation (17). Demand relations that are developed at the household level (and then aggregated to the zonal level) address all inherent variation and, therefore, offer more promise of temporally stable parameters. This argument is reinforced by the ability to consider behavioral factors, and the transferability of results from one study area to another is alleged to be comparatively high. The main problem in applying such techniques (aside from some computational complexity in the modal-split operation) is that the future values of behavioral variables are difficult to specify.

Although this author personally is inclined to favor the disaggregate approach in urban transportation contexts, the argument appears less compelling for statewide freight analysis. First (and perhaps of equal relevance to statewide passenger analysis), the statistical argument for disaggregate analysis arises from empirical circumstances in which urban traffic zones have been highly heterogeneous in composition; chances seem reasonable that this heterogeneity problem would be less serious for statewide analysis zones, at least in the more rural states. (Clearly this issue commands preliminary research into zone definitions and studies of relative variation before any large-scale commitment to the disaggregate approach is endorsed.) Second, in the case of freight one may expect to encounter stiff resistance by shippers (the individual behavioral unit in this context) to disclosure of behavioral information.

In any event, a disaggregate approach to statewide freight analysis would not be a venture totally lacking in theoretical foundation. Lave (28) has set forth a basic microeconomic framework for transportation demand analysis. In its initial work on freight modal split for the Northeast Corridor Transportation Project, Mathematica (30) developed microeconomic models of shipper mode choice in terms of the individual firm, including optimization of trade-offs between stationary and in-transit inventory costs. Later research by the same consultant (30) reformulated this inventory-theoretic model into an approach that, using complex nonlinear estimation procedures, could be calibrated to aggregate data (taken from the Production Area Series of the Commodity Transportation Survey by the U.S. Bureau of the Census). Also, the work of Beuthe and Moses (5) developed a behavioral model that examined time and cost trade-offs in reference to the firm's production function. These sources constitute valuable points of departure for exploring the application of disaggregate behavioral models to freight analysis.

Sequential Versus Direct Demand Analysis

Apart from the aggregate versus disaggregate issue, there remains a question of whether to develop a sequential set of models as in urban transportation methodology (generation, distribution, and modal split) or to integrate these elements into one direct model form. Actual implementation of either approach at the statewide level has been limited to the Connecticut experience (8) which used a trip distribution model. The methodological design for Pennsylvania proposed to integrate the generation and distribution of freight movements within an elaborate interindustrial econometric model and to subsequently analyze modal split according to abstract-mode concepts (27).

The arguments for and against either the sequential or the direct approach have already been articulated at some length for passenger-oriented analysis (44) and are reviewed to some extent in the preceding paper by Pecknold on passenger methodology. The sequential approach is relatively cumbersome to execute but—as long as internal consistency among service variables is maintained (67), including transport-sensitivity in generation analysis—is generally accepted as forthright. The direct abstract-mode approach (30) has the advantages of not requiring such an exhaustive data set, allowing the introduction of new technology, and rendering total demand sensitive to the range of alternative modes available for shipping. Also, it permits straightforward interpretation of own and cross elasticities (constant parameters in the usual loglinear form).

The bulk of the literature on freight-flow forecasting generally consists of simple models that correspond to the generation or modal-split operations. Such techniques include straightforward trend analysis (51), empirical studies of price (rate) elasticities (41), and identification of modal shares (usually as a graphical function of distance and size of shipment) from data obtained in the U.S. transportation censuses (7, 47). Although these studies are of interest in their revelation of national trends, they generally have considered little if any spatial detail.

With regard to spatial models, although the direct approach has been applied in selective intercity passenger contexts, applications to freight seem to have been shelved in favor of one or more elements of the sequential approach. Again, the Northeast Corridor Transportation Project stands out as the main contribution here, through the efforts of CONSAD Research Corporation (10) and Mathematica (30). CONSAD developed origin-generation and destination-generation models and a gravity distribution model for 40 superdistricts in the Boston-Washington corridor. Employment variables were used in the generation regressions; the largest methodological issue was to determine an appropriate association between commodity classes and relevant receiving sectors in destination generation.

Sensitivity to network impedances was incorporated only in the gravity model; truck transit time was used. This use of a single mode's attribute—and only one attribute at that (as opposed to inclusion of rates and perhaps other service variables)—typifies the problem of internal consistency mentioned earlier. Composite impedance measures ideally would be used in all models of the complete sequence. The CONSAD study devoted considerable effort to developing composite impedance measures (friction factors) as a function of truck and rail time and cost, but statistical fits were modest ($r^2 = 0.5$). These results may have reflected the difficulties in ascertaining actual versus scheduled transit times for common carriers.

Again under sponsorship of the Northeast Corridor Transportation Project, Mathematica developed a multistaged approach to freight forecasting that was akin to the sequential strategy discussed above. This approach began with spatial trend projections of national commodity outputs as a function of national economic growth indexes, allocated these national tonnage estimates to origin-generation and destination-generation volumes for individual "production areas" as a function of various local economic indexes, allocated these results to interareal flows by using multiple linear regression (including distance and transit time measures for network sensitivity), and allocated these interareal flows to individual modes by using an abstract-commodity model.

> A commodity being shipped by different modes of transportation can be described abstractly in terms of certain transportation characteristics [e g , weight, haul, value per ton, perishability, and rate] The main advantage of this abstract commodity approach is that it enables us to determine the choice of mode for nonexistent future commodities or commodity groups that follow any grouping scheme

Thus, just as the abstract-mode concept interpreted technological options for transport, this approach characterized commodities not in terms of sheer nominal identity but rather in terms of their intrinsic attributes. Modal shares were determined by developing linear regression relations as a function of weight and distance class intervals of commodities. The results exhibited some inconsistencies in the signs of certain coefficients, perhaps because specific modal attributes were not considered. Nevertheless, the abstract-commodity concept, possibly combined with the abstract-mode concept, is intuitively appealing and should be seriously considered in statewide methodological development.

These experiences provide valuable benchmarks for developing statewide freight demand models, although the relative promise of the direct versus the sequential approach is not immediately apparent. For sheer efficiency in technical analysis, it would be desirable to use the same model structures for both passenger and freight; the direct versus sequential issue should be addressed from this pragmatic perspective.

Specification of Relevant Service Variables

Regardless of the overall modeling approach, it is of obvious concern to identify the various measures of freight service to which shippers are generally sensitive. Models that use distance only are clearly inadequate. Rate and transit time are obviously important, although the point bears repeating that actual times are preferred to scheduled times in modeling.

Three sources in the literature offer some valuable guidance in this matter. In developing his inventory-theoretic model of mode choice, Baumol (30) proposed the following attributes that reflect the role of inventory considerations: (a) shipping cost per unit (including freight rate, insurance); (b) mean shipping time; (c) variance in shipping time; and (d) carrying cost per unit of time while in transit (interest on capital, pilferage, deterioration). Baumol elaborated on these measures in terms of their respective theoretical contributions to total costs of the firm. Allen (2) elaborated, in theoretical and empirical terms, on the conditional influence of loss and damage upon demand.

Woods and Domencich (68) present a quite valuable treatment of rail-truck service differentials for selected measures. They summarize the results of 2 shipper surveys conducted during the early 1960s. These results, given in Tables 1 (37) and 2 (53), indicate those attributes that influence modal choice most significantly.

This author's study of transcontinental rail-freight route choice (15) revealed the importance of certain fixed-network measures to shipper decisions in multicarrier routing contexts. For longer hauls with a variety of routing options, the number of carriers involved (presumably as an index of loss and damage likelihood) was found to be a sensitive consideration. Also, limited microscopic analysis of individual carload data identified the captive influence on routing decisions of single-carrier access at ultimate origin or destination (especially the latter), i.e., a condition of carrier access monopoly. The same persuasion could apply, obviously, to mode choice. Finally, in multicarrier routings it generally is in the shipper's interest to maximize the haul of the originating carrier, for that carrier's division of revenue for a shipment is directly related to its participation in any route.

These observations are offered as food for thought. Obviously any advocacy of specific service measures must consider feasibility of data collection, as discussed earlier.

Relevance of Network Analysis

Given the estimation of origin-destination commodity flows by mode, there remains the question of whether more detailed network analysis is necessary and what its character should be. Elaborate traffic assignment models have been developed for urban transportation analysis, including capacity-restraint features that account for facility congestion and serve to bring the entire system of forecasting models into equilibrium.

Clearly some form of network analysis—perhaps merely a straightforward minimum-path algorithm—is essential to statewide freight planning and especially programming in order to translate origin-destination flows into likely loadings of individual facilities. Obviously such an operation for motor carrier movements could be integrated with passenger assignment analysis. At this point the author would simply like to question whether capacity restraint—which greatly complicates the procedures of network analysis—is at all essential for other freight modes. Certainly the line-haul capacity of rail and water facilities is substantially in excess of likely flows. Some congestion may be significant at terminals, but for our purposes it may be quite valid merely to use educated estimates of actual processing times in developing impedance measures for demand analysis. Otherwise, we must open a can of worms that invites complicated techniques of network simulation. [Guidelines for such an undertaking are provided by the preliminary investigations of the National Bureau of Standards into the feasibility of freight network simulation for the Northeast Corridor Transportation Project (14).] Again, this question should be considered integrally with the parallel issue in passenger methodology.

Activity Allocation Analysis

The development of a model for statewide activity allocation analysis should be given serious consideration to avert the problem of underestimating the effects of induced development on corridor flow patterns (for both freight and passenger analysis). The purpose of such a model would be to estimate the spatial distribution (i.e., values for the various analysis zones) of socioeconomic activity as a function of transportation network attributes.

The state of the art in this area is reasonably well developed (though infrequently integrated into agency study frameworks) for urban contexts (3, 24), but initiative at the state level has been very limited. The New York State Department of Public Works sponsored the development in the mid-1960s of a direct allocation model that adapted concepts of opportunity-accessibility from urban analysis, but the model was designed for regional application within the state. The California and Pennsylvania study designs cited earlier proposed quite elaborate interindustry econometric models, but these approaches are extremely demanding of data; hence, implementation efforts have not yet emerged and are not likely to for some time. The one case in which a transport-sensitive activity allocation model was developed and implemented for statewide analysis was sponsored by the Connecticut Interregional Planning Program (1).

This approach utilized techniques of shift-share analysis to allocate projected statewide economic growth to individual towns as a function of each town's relative accessibility to such activities as employment centers. The model included 2 policy-determined capacity constraints for each town, namely holding capacities for manufacturing employment and additional population. (Note the value here of accounting for "exogenous" policies on patterns of statewide development.) Its analytical structure consisted of 9 interdependent equations, 6 of which determined areal employment levels for various industrial sectors and 3 of which determined areal population levels for graded incomes.

In contrast to the more elaborate approaches that integrate interregional commerce with interindustrial input-output techniques (9, 29, 42), this more modest approach seems to offer an appealing precedent for first-order approximations. Its adaptation (or the adaptation of any urban accessibility model) to states larger than Connecticut, however, must reconsider 2 basic aspects of methodological design. First, for larger states (with larger analysis zones), activities with smaller supply-market areas may face locational decisions that constitute an essentially intrazonal search; hence, interzonal accessibility would not be a relevant determinant for these categories of industry. Second, activities with larger supply-market areas (e.g., those heavier industries that are treated exogenously as unique locators in urban models) may warrant endogenous analysis since their locational decisions may consider various areas within a state. A corollary of both points is that accessibility calculations—heretofore based on passenger network impedances in models for smaller study regions—should be based more on measures of freight network service. Third, regardless of a state's size, the design of such a model should allow for a lag effect between the response of industrial development and the stimulus of transportation network improvements.

Environmental Impact Analysis

Environmental impacts are of obvious importance to statewide transportation planning for both passenger and freight systems. Process guidelines for consideration of such impacts have been drafted, according to FHWA directives, in the form of state action plans. Although these procedures (to be fully implemented in November 1974) are highway-oriented and remain in need of complementary analytical methodology, they address issues that are equally germane to various freight modes in many respects. It, therefore, would appear advisable to consider analytical methodology for environmental impact analysis in a manner that embraces passenger and freight systems integrally.

A distinction was drawn earlier between production-related and consumption-related impacts. Environmental effects follow this dichotomy well in that localized displacement or disruption impacts are associated with facility construction and various forms of pollution are associated with facility use. Proposals for new facilities (with the exception of terminal facilities) are not so prevalent in freight as in passenger contexts; indeed, proposals for facility abandonment are perhaps more frequent. In this sense, the production-related impact of various courses of action in freight may actually be beneficial, e.g., releasing land to other uses such as recreation. The current study of reuse potential for transportation property abandonments cited earlier (54) provides a good example of this interpretation.

Of course, many proposals for freight system modification would affect operating patterns and, hence, would suggest analysis of contributions to air and noise pollution. Emission rates for trucks for both types of pollution have been estimated in conjunction with highway-related studies (35). For rail locomotive units, the Environmental Protection Agency has developed average emission rates for noise (61) and for various forms of air pollution (62). Guidelines for determining modal energy consumption as a function of modal traffic volumes have been advanced by Tihansky (50).

The technical capability outlined above can be quite useful for comparative analysis of different modes for individual corridors. Given the emerging character of proenvironmental court actions, we should anticipate the need to prepare environmental impact statements for entire statewide systems instead of individual route sections.

HIGHLIGHTS OF MAJOR ISSUES

Workshop 3B was charged with the responsibility to consider the state of the art, recommend potential improvements, and develop a program of research in needed methodology for statewide multimodal transportation planning. In the case of freight transportation, the embryonic nature of the state of the art has placed an open-ended spectrum of issues before us. Emphasis must lie on specifying the potential state of the art and drawing on a dispersed body of literature that generally has focused on contexts other than the state level per se.

As identified throughout this paper, the major issues that appear to merit discussion in defining such potential fall into 3 general areas: (a) the scope and character of statewide freight systems planning and programming, (b) information systems requirements, and (c) analytical methodology. Points of primary concern within each of these 3 areas are recapitulated below.

Scope and Character

1. What constitutes the appropriate hierarchical structure of state-level planning and programming responsibility (e.g., how much should the state be concerned with methodology for urban goods movement and rail branch-line abandonment)?
2. What degree of spatial detail and system representation is appropriate to different hierarchical levels and functions?
3. Considering the key role of the private sector in initiating proposed courses of action, what is an appropriate temporal horizon in freight planning and programming?

Information Systems Requirements

4. What specificity—in kind (i.e., spatial, commodity, shipper, or consignee) and in degree of stratification—is necessary for useful commodity flow data (e.g., what types of problems require or do not require origin-destination data)?
5. What are the economic trade-offs between primary and secondary data sources and between spatial and commodity detail for each such source?
6. What constraints might formal disclosure restrictions or the guardedness of individual carriers and shippers place on primary data collection efforts? On secondary data collection efforts?
7. What are the differences between actual service levels and the service levels published in carrier schedules? Are published measures adequate for systems planning and programming purposes?

Analytical Methodology

8. Given the absence of direct control over freight carriers (yet the intractability of single-carrier optimization models for most large-scale networks), to what extent must the laissez-faire rate-making behavior of competitive carriers be modeled in a predictive sense?
9. How might we develop operating cost relations that are consistent among all modes and that are sensitive to fuel-input prices? How might we develop the capability to translate such operating cost information into shipper costs as a function of rate policy?
10. Even though it has statistical virtues, is a disaggregate approach to freight demand analysis warranted (in terms of zonal heterogeneity) or feasible in terms of disclosure restrictions?
11. Are sequential constructs for modeling freight demand cost-effective in the statewide context? Is it essential to separate captive from choice market phenomena in this endeavor?
12. What are the best attribute measures by which to characterize the service levels of freight transportation in terms of shipper sensitivity?
13. Considering the excess line-haul capacity available for some modes, to what extent is capacity-restrained network analysis necessary for statewide freight planning and programming? To what extent is even a free assignment analysis necessary?
14. How should statewide activity allocation models differ from their urban counterparts in terms of endogenous industrial classification, incorporation of natural resource endowments, sensitivity to developmental policy, role of the freight system in determining industrial accessibility, and time lags in the response of industrial growth to network improvements?
15. What shall be the methodological character of multimodal, statewide systems analyses of environmental impacts, given that emerging court actions are pointing toward such a requirement?

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Discussion of Resource Paper

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Drake has thoroughly and capably presented the existing state of the art of statewide freight systems planning methodology. He indicates that the state does have a role in freight movement, particularly with respect to investment in freight-serving facilities, tax and subsidy programs, regulation, and research and development. Thus, there is a need for adequate freight system planning capabilities at the state level.

Our capability to address these questions, however, is undeveloped in almost every respect. We have few data on freight flows at the state level, almost no information on the spatial distribution of freight-producing activities, no inventory of the supply of state freight systems, no developed capacity to simulate state freight movement, and little understanding of the costs and benefits to freight movement of alternative state transportation plans, programs, and policies. In short, we have grossly inadequate knowledge of the freight phenomenon at the state level and, consequently, a similarly inadequate capability to address the critical state freight planning questions that confront us.

Drake identifies the critical elements of statewide freight planning that must be developed. Most particularly, he identifies the following needs:

1. Compilation of basic data on goods movements, freight transportation facilities, and spatial arrangement of freight producers and consumers;
2. Development of capability to simulate freight movements, particularly intermodal trade-offs and activity allocation;
3. Development, application, and evaluation of different analytical techniques; and
4. Empirical investigation of critical freight questions such as investments in alternative freight-serving modes, potential rail branch-line abandonments, subsidies, taxation and regulations of competing modes, investments in freight distribution systems, and rationalization of freight-producing activity locations.