IMPROVING TRANSPORTATION EFFECTIVENESS: AN ORGANIZATIONAL APPROACH

by

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1. INTRODUCTION AND OVERVIEW

A central issue, in many countries, is how to improve the effectiveness of transportation organisations. This paper summarises a conceptual framework which has been developed in recent research.

In today's world, it has become increasingly important to focus attention on the ways in which the delivery of transportation services can be improved, whether or not major resources can be devoted to that effort. Thus, the focus of research and policy analysis in many countries has shifted from the development of long-range plans for major investments, to short-run action-oriented strategies (in the U.S., this has been called "Transportation System Management," perhaps inappropriately). What has not gotten sufficient attention is that this focus has to deal with the organisational aspects of transportation: transportation service is delivered by organisations, and improvements in the effectiveness of those organisations can often be substantial.

The content of the approach which is emerging can be summarised as follows:

1. Scope of concern: The scope of concern of the transportation professional consists of three major elements:

   - the system being controlled - the transportation system
   - the system controlling the transportation system - the control system - consisting of one or more organisations (a carrier; an executive agency or regulatory agency trying to influence the operations of a carrier or agency building or maintaining facilities, etc.)
   - the transportation professional's strategy for intervening in one or both of these systems to bring about change.

2. The controlling system:

   a. The control system can be characterised as consisting of three major dimensions: organisation structure and processes; information systems; and decision-making processes, which may include the use of analytical tools.

   b. A hierarchy of control tasks can be identified which can be mapped onto specific functions to be performed in the organisation at various levels and in different functional areas.

   c. Three major levels of control tasks can usually be identified: stragegy formulation, planning, and implementation.

   d. The control system should be congruent with the functions of the organisation. In transportation, the functions of the organisation can be identified as primary or secondary. In the case of transportation organisations and drawing on the theory of transportation systems analysis, these are usually as follows: the primary function is service delivery, which includes marketing and transportation operations. The important secondary functions are concerned with resource management: the fleet, the infrastructure, the personnel, and

other resources.

3. The system being controlled: The theory and methods of transportation systems analysis can be used to understand the system being controlled. This includes developing understandings of the causal interrelations in the system being controlled, which is useful for human decision processes as well as a basis for development of improved analytical tools to support decision processes and improved information system capabilities. The theory can also be used to identify priorities for influencing the controlling system, and to identify the priority linkages between the controlling system and the system being controlled (e.g., performance measures).

4. The professional's intervention strategies: The development of change strategies for the professional's intervention involves several features:

- a commitment to managing change: this involves planning change and introducing changes in a staged, evolutionary manner
- assessing change priorities in all three dimensions: organisation, information, and decision processes
- using improvements in information systems and/or analytical tools as part of a planned change strategy, involving explicit choices of intervention priorities.

5. The roles of information systems and analytical tools: Improvements in information systems and analytical tools can be useful as components of change strategies:

- improvements in these technical dimensions should be staged, and managed so as to be highly user-responsive in each stage.
- these technical improvements should be coordinated with, and supportive of, changes in organisational aspects to be fully effective.
- the concept of "responsive analysis" is particularly useful, in which the professional has available a variety of different models and can choose among various degrees of simplification or complexity as improvements in decision processes are implemented in stages.
- microcomputer software and distributed processing concepts can in some situations be useful techniques in a planned change strategy.

6. Improvements in the control systems: Often, a high priority target for improvement will be the basic control system itself, as reflected in some or all of these elements:

- program management, in all of its dimensions (organisational, information, decision processes)(a broader definition of "project programming")
- use of performance measures and goals, formulated in part as standards (e.g., service standards, cost budgets)
- establishment of interdepartmental linkages cutting across traditional organisational boundaries
- focus on operations/service planning as a priority task
- focus on strategy formulation and its linkages to planning and implementation as an alternative priority task.

In following sections, we elaborate on some of these points.

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II. MANAGEMENT AS CONTROL

We have been doing research on ways of improving organisational effectiveness in transportation firms and agencies. In this work, we have found it especially useful to draw upon theories and techniques of management control and of organisational behavior.

1. A broad view of control: Management control has been defined as "the process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organisation's objectives." (Anthony, 1965, p. 27) "Based on this definition, most managerial activities (organising, analysing, communicating, etc.) are undertaken to achieve 'control.' " (Philip, p. 70-72) The control system is the set of processes through which the productive activities of the organisation are controlled. This system has a dual function: it must (1) identify the proper actions to be taken and (2) motivate the appropriate individuals to take those actions. (Philip. p. 75)

The first task involves these six steps:

1. monitoring the system being managed - the transportation system - and its external environment, by collecting data on the status of the system and preparing analyses of the data, on a regular basis;

2. formulating or revising goals;

3. evaluation of progress toward achieving desired goals by comparing actual system status with objectives, and identifying needed directions for change in the system being controlled;

4. analysing possible changes, by developing and evaluating possible changes;

5. making decisions on which changes to implement;

6. implementing the changes by making adjustments to actions previously initiated or by initiating new actions of a positive or corrective nature, or by changing goals.

These activities form the basic steps of an effective management control process.

This cycle is performed periodically: annually for budgetary and other mid-range planning processes; quarterly and monthly for operations planning and control; quarterly or semi-annually for service planning; and weekly, daily, or sometimes hourly for operational control purposes.

So far, these steps appear to be nothing more than the traditional cybernetic view of control processes. One often finds an interpretation of control as being essentially a mechanical process. One must recognise that the second task, motivating the appropriate individuals to take desired actions, is essential to having an effective process. There are a variety of means of influencing people in organisations, ranging from completely participatory and egalitarian approaches, to exercise of direct authority.

Recognition that this task - motivating individuals - is essential led Philip to propose a set of concepts which we have found useful in our research:

- implementation of an organisation support system
- structuring of a control task hierarchy

Before turning to these concepts, however, we should examine the goals of a transportation organisation.

2. The functions of a transportation organisation: The design of a control process must be reflective of the functions of the organisation. For transportation organisations, it seems clear what those functions are, and how they might be reflected in the design of a control system.

The primary function of a transportation organisation is service delivery: providing transportation as a service to users. The two major components of this function are marketing and operations. Marketing is concerned with deciding on service targets (deciding what services should be offered, to whom, where, when, and at what prices) and with selling the service (including sales and promotion). Operations is concerned with producing the service - for example, in a railroad, with running trains and managing terminals (both yards and stations).

Supporting this primary function are secondary functions. These are concerned with resource management, through which the primary function of service delivery is facilitated. In most transportation operating organisations, the major resources to be managed are: vehicle fleets, infrastructure, personnel, and financial and other resources. Vehicle fleet management is often most critical; the only way to provide service to customers, and thus earn revenues, is by the movement of people or freight in vehicles between two points.

In management of this fleet, the tradeoffs of service levels and resource levels are the primary focus. In order to address these tradeoffs, both marketing and operating perspectives are central.

In general, in many decision situations, the operator is continually trying to balance resources consumed and service levels provided. From an efficiency perspective, the operator can ask: Am I getting the maximum service levels from the resources I am expending? Can I maintain the same service levels for less resources? From an effectiveness perspective, the operator can ask: If I increase service levels, what will be the corresponding increase in resources, and will the gain in revenues (and other benefits) be sufficiently attractive to justify the increased costs? If I decrease service levels in order to reduce costs, will the cost savings be sufficiently attractive to justify the losses in revenues and in service to users?

In some contexts, the management of the operating personnel is also very important, especially when personnel costs outweigh the costs of equipment.

This conceptualisation of the functions of a transportation operating organisation can be useful in developing operational goals, and, as we will see below, in analysing other aspects of the control system. (Of course, one should always test whether this conceptualisation is valid in the particular situation.)

3. The organisation support system: In analysing how railroads manage the distribution of rail cars, Philip proposed the concept of an ORGANISATION SUPPORT SYSTEM as the combination of "the organisational relationships, information system, and decision processes" of a transportation organisation (a-

dapted from Philip, 1979). We will utilise Philip's framework, with some modifications and extensions. (In current MIT research on management of railroad locomotive fleets, this theoretical framework is being refined and extended by Mao, 1983; also see paper presented at this conference.)

The basic tasks to be accomplished in Philip's approach are:

1. characterise the control tasks which the organisation performs
2. characterise the decision processes
3. characterise the information system
4. characterise the organisation structure

These tasks are accomplished first in a diagnosis stage, to identify the strengths and weaknesses of the organisation. Then, potential improvements are identified in terms of changes to each of these elements. Finally, the change strategy which is selected proceeds to bring about incremental evolution in various of these elements.

4. The control tasks: An organisation, especially a transportation organisation, can be usefully described as controlling a system of productive activities. In the case of a public works or highway agency, the system being controlled is the construction and maintenance of a system of highways or other facilities. In the case of a transportation carrier such as an airline, railroad, or transit agency, the system being controlled is the delivery of specific transportation services over a network of routes. In the case of a railroad or transit agency, the primary function, as stated earlier, is service delivery, and this should be the central focus of the control process.

In developing a characterisation of the control process in a particular organisation, it is useful to:

1. identify the major productive activities actually or potentially being performed in the transportation system (for example, locomotive management, train dispatching)
2. identify the control activities being undertaken in the organisation to manage these productive activities (including but not restricted to those activities performing the functions identified in section 2)
3. characterise the control activities in terms of the following variables:
   - 3.1 system state variables - characteristics of the performance of the activities which the organisation is seeking to control
   - 3.2 system control variables - "those factors which can be altered by the organisation to change the state of the system." (Philip, p. 75)
   - 3.3 uncontrollable variables - "those events or actions which change the state of the system, but which are not controlled [directly by the organisation or] by that part of the organisation being analysed. Control of these factors may be by other parts of the organisation, or by forces outside of the organisation altogether." (loc. cit.)

5. The hierarchy of control tasks: It is almost always essential to view the control process as a hierarchy of control tasks. In almost all except the very smallest of transportation organisations, the control system must operate in a hierarchical manner. "Defining objectives and constraints in a social organisation, and translating these into more specific objectives and constraints which can motivate action by people in any single part of the organisation, are [sic] often the most complicated and problematic aspects of the control problem." (Philip, p.76) To accomplish this, the various levels of an organisation engage, in principle, in a sequential, hierarchical search process, going from top to bottom of the organisation (and sometimes iterating back up) until a detailed plan is developed which is sufficiently defined to be implementable (Manheim, 1966; Emery, 1969).

Philip proposes essentially a three-level hierarchy:

- corporate direction-setting
- tactical system planning
- decision implementation.

For public works organisations, Manheim (1981) has suggested the following:

- organisation direction-setting - the selection of goals and objectives, and missions for the organisation.
- organisational development strategies - general plan for the overall evolution of the organisation, including resource development strategies.
- program management - the control of current resources to effectively manage a number of projects.
- project development - the development and analysis of specific action proposals for changes in the system.
- decision implementation - the execution of specific decisions made with respect to the controllable variables.

For example, in the past a state or national highway agency set its directions in terms of the general levels of highway construction and maintenance to be achieved, and this was primarily driven by the annual or biennial budgting process. Organisational development strategies were primarily concerned with progressively building up and expanding the organisation's personnel and construction force base to achieve the usually-growing magnitude of the program. At the lowest level, project development activities included each of the various sets of technical and managerial tasks involved for a particular project as it moved in relatively orderly fashion from initial conception through the various stages of planning, preliminary and detailed design, and right-of-way acquisition and construction. Intermediate between project development activities and resource development was program management. The program management tasks were primarily concerned with controlling the flow of work in an orderly sequential process as projects moved through their various phases of development and allocating priorities within the available and projected resources.

The key point is that the control process in a transportation operating organisation must be viewed as a hierarchy of tasks. The choice of a specific hierarchical structure is to some extent specific to the organisational context. In section III-2 below, we describe the hierarchy we found useful for guiding the design and implementation of a planning and control system for a major railroad.

6. Organisation structure: Key features of the organisation structure include:

personnel authority relationships: the formal reporting relationships established between individuals; for example, as described in organisation charts

task authority relationships: assignments of individuals to specific tasks;
- task enumeration and description-general tasks, specific subtasks
- formal job descriptions
- informal job descriptions
- task authority matrices, showing major participants in each task and relative roles of each in that task
- communication locus analyses, showing sequence of interactions of individuals over time in accomplishment of a specific task (cf. Mao, 1983)

task accountability relationships: how accountability for tasks is allocated, where same as or different from task authority relationships

informal structure
- friendship patterns
- power relationships
- communication networks

and others (cf. Philip, 1979).

7. Decision processes: Once the hierarchy of control tasks in the organisation has been identified, it is then useful to characterise the decision processes which take place at each level of the organisation and in each area of functional responsibility that is to be analysed. These can be characterised in terms of the types of variables identified earlier - system control variables, system state variables, and uncontrollable variables - and also in terms of various stages in the decision process. These include: intelligence, search, prediction, evaluation, and choice activities. The elements of the decision processes can be identified for particular tasks or subtasks, for particular units or individuals: (cf. Manheim, 1966, 1979; Simon, 1970)

intelligence procedures: ways information about the environment is searched for detection of conditions calling for consideration of action

- information sources actually used
- organisational elements actually influencing
- conditions monitored:
  - system performance
  - organisational events
  - events in external environment

search procedures: basic nature of search processes - systematic, satisficing, optimising , heuristic

specific techniques - human, mechanical, or electronic

prediction procedures: ways in which impacts of alternatives are identified
basic nature of prediction procedures - informal and formal components (if any); for each component:

decision variables incorporated explicitly
impacts predicted explicitly
exogenous variables considered explicitly
- events external to the organisation
- events internal to the organisation but external to the decision unit

formal theories embodied in prediction procedures
degree of empirical verification in procedures

evaluation procedures: ways in which impacts are assessed and communicated to responsible decision-makers
basic nature of evaluation procedures - formal or informal, specific techniques used, form of product of evaluation

choice procedures: ways in which decision is reached on course of action
participants and roles
information available, used

implementation procedures: ways in which resulting decisions are translated into implementable actions and communicated appropriately.

8. Information systems: An organisation utilises an information system with a number of components. Usually these components are scattered over different levels and functional activity areas of the organisation. Some of the information system components may be computer-based; others may be manual or informal.

The elements of the information systems which it is potentially useful to identify include (Philip, 1979):

data sources: where data originates, procedures used to acquire it

transformation processes:
(processing of raw data,
channeling of data,
structuring of data,
filtering and editing,
processing of data into reports, reporting processes)

information available to users of information:
information provided, by:
type of report (manual or electronic information display, one-way or two-way, etc.)
date types and items included:
types:
state of system
state of decision variables
state of exogenous variables
state of impact variables
state of performance indices

time perspective:
real time data
historical data
forecast (predicted) data

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III. APPLYING THE FRAMEWORK

The transportation professional is often concerned with improving the effectiveness of transportation organisations. Sometimes, the professional is a member of the organisation, either in line management or in staff positions. Sometimes the professional is outside the organisation, either a consultant or located in another agency or firm with some degree of influence over the operating organisation. Sometimes, the professional has an explicit mandate to improve the organisation; sometimes, he has another responsibility - such as to improve some model or analytical or computer techniques - in which case the organisational dimension is only implicit. In all cases, the professional should be concerned with all the elements identified above; to be effective in accomplishing change requires a broad perspective, in our view.

1. Intervention process:

A general process for formulating and managing a strategy to improve organisational effectiveness might have these components:

1. reconnaisance and description of the key features of the controlling and controlled systems
2. analytical description, using the conceptual framework presented briefly above
3. diagnosis of strengths and weaknesses in the controlling system
4. assessment of possible directions for improvement: formulation of goals for change, identification of possible directions for change, evaluation of possible changes
5. selection of a change strategy
6. implementation of first stage
7. monitoring of change process, assessment, and reevaluation, repeating above steps to select a revised strategy based upon progress achieved and problems encountered.

Thus, in developing a specific plan for improvement of organisational effectiveness, the previously-described conceptual framework can be very useful. The framework provides a guide for describing the organisation's present processes and procedures, for developing candidate directions for change, and for developing specific techniques which can be implemented if appropriate.

Clearly, the most important element of the framework is the argument that implementation of change in an organisation requires coordinated actions in all three dimensions of the organisation support system: organisation structure, information systems, and decision processes. It is generally NOT sufficient to simply develop a new model - e.g., a rail line capacity model - (the prediction component of the decision process for a particular task). Rather, appropriate steps must be taken in all three dimensions, in a carefully-planned and managed manner; if the model is to be used in a way that results in benefits for the organisation, attention must be given to the organisational context in which it will be used, and how it will relate to the overall information system and decision processes involved in the relevant control tasks. If these issues are not addressed, the technical tool may simply sit on the shelf and not be used.

While the conceptual framework is broad, it does not imply that all aspects of the organisation must be analysed before any changes can be implemented. On the contrary, the effort may focus initially on only a small subset of the control

tasks listed above, or may work on improving organisational performance on a number of tasks simultaneously.

2. An example:

In a recent study, we applied this framework in preparing a plan for developing a planning and control system for a major national railroad. In this study, we recommended that priority be given to strengthening the control system with the following control task structure (Manheim, Martland and Humphrey, 1982a, b). Particular priority was placed on developing an overall progress management (programming) process at the strategic level which was coordinated with the control tasks at other levels and in certain priority functional areas:

A. STRATEGY:

- A-1. CORPORATE OBJECTIVE-SETTING
- A-2. PROGRESS MANAGEMENT

B. PLANNING:

- B-1. OPERATIONS/SERVICE PLANNING
- B-2. INFRASTRUCTURE PROJECT PLANNING
- B-3. FLEET PLANNING

C. IMPLEMENTATION:

- C-1. PROJECT IMPLEMENTATION
  - C-1.a Infrastucture construction
  - C-1.b Infrastructure maintenance
- C-2. OPERATIONS CONTROL
- C-3. FLEET CONTROL
  - C-3.a Car control
  - C-3.b Locomotive control
  - C-3.c Container control

3. Relation to uses of computers and analysis techniques:

Modern analysis methods, including the use of models and computers, offer substantial potential for improving organisational effectiveness. It is important to recognise, however, that conventional approaches to using these methods are being replaced by approaches that differ in some very important ways.

a. Responsive analysis: In the past, in many transportation organisations attention was focussed primarily on getting one model or technique operational. Today, the emphasis is being placed on a style called "responsive analysis." The central idea here is that one should have available a variety of different models and other types of analysis tools. Then, whatever the analysis task, whether long-range planning or short-run crisis problem-solving, one can choose the techniques appropriate to the situation - for example, simple and approximate methods when time for problem-solving is short, or more detailed and more complete methods when time and resources permit.

This is practicable today because there is a basic theory which is used for analysing transportation systems problems which can be drawn upon to develop a range of practical models (Manheim, 1979). In applying this theory, the specific details of the models will of course vary greatly, depending on many factors. We have used the term "responsive analysis" (Manheim, Salomon, Furth., 1978; Manheim, 1979) to emphasise that models can be constructed in a wide range of styles.

For example, a demand model can be: (1) a formal econometric model, using the powerful techniques of disaggregate econometric modelling; (2) a simple elasticity, used directly or in a "pivot point" model in a pocket calculator; (3) or a structured set of judgements produced by marketing people who understand a particular group of travel markets well. Thus, there is a very wide range of ways in which the theory can be implemented.

In general, it is highly desirable to have available a repertory of alternative models, so that the analyst, confronted with a particular issue, can choose the particular set of models most appropriate to his analysis needs for that issue - for example, alternative demand models, alternative link capacity and service level models, etc.

Correspondingly, one can implement a set of models in stages. One can begin with a set of simple models, consistent internally and with the theory, and with parameters estimated against very aggregate data or by judgement. Then one can progressively refine the models, adding detail and using more and better data to develop better, more accurate models, as experience is gained (Bien, Bourgin and Manheim, 1976). The full set of models thus developed should be treated as a resource, such that an analyst can choose a model appropriate to the task at hand for each analysis.

b. Utilisation of microcomputers: Recall the three dimensions of implementation described above: organisation structure, information systems, and decision processes. Most transportation organisations are complex and bureaucratic, whether public, private, or mixed in ownership. Most such organisations already have some, or even substantial computer support and capabilities. Generally, these capabilities are not used in a significant way by top-level or even middle-level managers with functional responsibilities for analysis of the decisions open to them (though such managers often do receive computer-generated reports, such reports rarely play important roles in management decisions except to highlight the existence of a problem). Improving the computational capability available to middle and top-level managers may be very important in improving the organisation's management effectiveness, if it is done as part of an overall strategy.

The new technology of microcomputers is a powerful technology to assist in the process of increasing organisational effectiveness. There are many reasons why microcomputers appear to be very effective even in large organisations: direct physical access, high responsiveness, reinforcement obtained by getting results quickly and in a way responsive to the user, availability of simple programming languages or software packages, rapid development and modification of programs, graphics, immediate results, privacy of use, and others. Many people in many organisations find that they are more comfortable with, and get more support from, microcomputers. This is especially true of managerial and technical personnel who have not previously used computer capabilities; powerful software packages make it feasible for individuals to utilise microcomputers themselves without programming skills or the intermediation of programmers. (Cf. paper by Manheim and Thompson at this conference.)

Thus, use of microcomputers provides an avenue for gaining rapid acceptance of new technical or organisational approaches. This is especially important for improving management control systems in the dimensions described above.

4. Staged, user-responsive implementation:

Improvement of the management control system is a major task for any organisation. Until a few years ago, the tendency would have been to follow a classical systems design strategy in which the first step would be to prepare a comprehensive and detailed design of the full system of models and procedures. Then,

specifications would be prepared for each element, and the overall design and detailed specifications reviewed and, after modification, submitted for approval. Then, the organisation changes would be implemented, the system of models and procedures would be implemented, training programs would be conducted for the organisation's personnel, and, after inevitable modifications, the system would be accepted (if successful). This process would generally take several years and very substantial amounts of resources, both in terms of money and of staff time and effort.

This kind of comprehensive, one-pass system design and implementation strategy is sometimes desirable. However, today, a different design philosophy has emerged. While usually described primarily in terms of computer software, under the label of "decision-support systems" or DSS, the philosophy applies to all aspects of improving management control systems (Keene and Scott-Morton, 1978):

- the user should play a key role in designing the system,by testing initial capabilities, reacting to them, and causing redesign;
- to the maximum extent feasible, the user should be able to change the design of system capabilities himself (this is achieved by use of user-responsive capabilities);
- a system should be implemented in stages, with the user accepting and putting into productive use each stage before development is allowed to proceed to the next stage;
- the system should be capable of continual evolution as the user's needs change; preferably most of this evolution can be accomplished by the user himself;
- the system should, as a consequence of the above techniques, be designed to support the needs of users, rather than the conceptions of analysts (Manheim and Bien, 1976; Keene and Scott-Morton, 1978; Stewart, 1982);
- microcomputers can support this strategy: Microcomputers can usually be the primary environment for development, testing, and use of initial improved information systems and analysis capabilities. As capabilities are developed, they should be tested in use and modified rapidly to respond to users needs more appropriately. After capabilities have been accepted in the microcomputer environment, or as data and processing capacity requirements expand,more comprehensive capabilities should be designed and implemented in the organisation's mainframe computer environments.
- priorities should be established as follows: First priority should be placed on supporting the central tasks of the management control process. These include:
    - an inventory of candidate projects and projects in implementation
    - impacts of alternative projects-predicted, and, for implemented projects, observed
    - status of projects
    - and other related information
    - with appropriate analytical models to provide a resource for "responsive analysis," to support prediction of selected impacts at alternative levels of detail and of data and other resource requirements.

IV. CONCLUSIONS

In this paper, we have provided an outline overview of one emerging approach to improving the effectiveness of transportation systems by focussing on improving the effectiveness of the transportation organisations. This view suggests a number of directions for needed research. It also suggests the need for major changes in education of transportation professionals. Space prevents us from exploring these issues here; we leave these topics of research and education for the open discussion sessions.

REFERENCES

1. Anthony, R.N.,PLANNING AND CONTROL SYSTEMS: A FRAMEWORK FOR ANALYSIS, Harvard University Press: Cambridge, MA, 1965.

2. Bien, G., Christian Bourgin, and Marvin L. Manheim, "Dossier de Lignes d'Autobus - Note Metholodogique No. 2 IRT," April 1976.

3. Emery, James C., ORGANISATIONAL PLANNING AND CONTROL SYSTEMS: THEORY AND TECHNOLOGY, New York: MacMillan, 1969.

4. Keene, P.G.W. and M.S. Scott-Morton, DECISION SUPPORT SYSTEMS: AN ORGANISATIONAL PERSPECTIVE, Addison-Wesley, 1978.

5. Manheim, Marvin L., HIERARCHICAL STRUCTURE: A MODEL OF PLANNING AND DESIGN PROCESSES, Cambridge, Mass: M.I.T. Press, 1966.

6. Manheim, Marvin L., Peter Furth and Ilan Salomon,"Responsive Transportation Analysis: Evaluation of TSM and other Strategies Using Pocket Calculators," MIT Center for Transportation Studies, presented to the Transportation Research Board, January 1978.

7. Manheim, Marvin L., FUNDAMENTALS OF TRANSPORTATION SYSTEMS ANALYSIS, MIT Press: Cambridge, MA, 1979.

8. Manheim, Marvin L., "Transportation Decisions in an Era of Certain Uncertainty," paper presented at the IX World Meeting of the International Road Federation, Stockholm, 1981.

9. Manheim, Marvin L., Carl D. Martland and Thomas F. Humphrey, "A General Planning Framework for Implementing the Plan General de Ferrocarrilles," Final Report to RENFE, Department of Civil Engineering, MIT, Cambridge, MA, 1982a.

10. Manheim, Marvin L., Carl D. Martland, and Thomas F. Humphrey, "Implementing the Concepts of the General Planning Framework," Technical Paper for RENFE, Department of Civil Engineering, MIT, Cambridge, MA, 1982b.

11. Manheim, Marvin L., Paul D. Thompson, and Howard Simkowitz, "Microcomputer Applications in Transportation: A Strategy for Improving Organisational Effectiveness," presented to the 1983 WCTR, Hamburg, West Germany, April 1983.

12. Mao, C.K., "Integrating Organisational and Technological Perspectives - An Approach to Improve Rail Motive Power Management," Ph.D. thesis, MIT, 1983.

13. Philip, Craig E., "Improving Freight Car Distribution Organisation Support Systems: A Planned Change Approach," MIT Studies in Railroad Operations and Economics, Vol. 34, 1979.

14. Simon, Herbert, THE SCIENCES OF THE ARTIFICIAL, Cambridge, MA: MIT Press, 1970.

15. Stewart, J.C., "A Decision Support System for Railroad Freight Operations Management," MIT Studies in Railroad Operations and Economics, Vol. 33, 1982.