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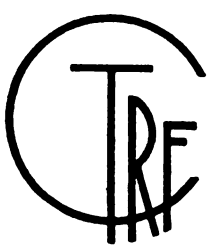

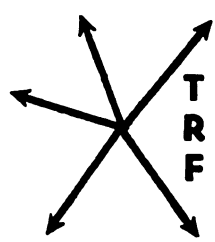

CANADIAN TRANSPORTATION RESEARCH FORUM

TRANSPORTATION RESEARCH FORUM

The Impact of Technology on Internal Organization of the Urban Passenger Transportation Enterprise†

by Itzhak Wirth and Edward R. F. W. Crossman**

WITH 60 to 70 percent of total operating costs allocated to wages, salaries and associated fringe benefits, work organization represents the single most sizeable item in the budgets of all urban transit enterprises. Thus, one of the most important problems arising at an early stage of the development of a new system is that of the forming and shaping of a new work organization to operate and manage the system successfully. This is normally accomplished by intuitive methods based on experience of like situations plus trial and error.

The present paper introduces methodology, data analysis, and quantified results, directly relating work organization structural characteristics to urban passenger transportation technology. Data were gathered in three enterprises —taxicab company, bus service, and rail rapid transit.

Technology as an independent variable is qualitatively scaled according to Vehicle Loading Capacity, Service Controllability and Capital Intensiveness.

Characteristics used to distinguish quantitatively among varying organizational structures are Time Span of Discretion (TSD) and Discretionary Resource Rate (DRR) at the various hierarchical levels, along with their product —the Position Power (PP). The role of technology as a determinant of the organizational structure associated with it is demonstrated.

Closing the paper are conclusions and recommendations for further needed research.

INTRODUCTION

Extensive concern with urban passenger transportation at the research and development level evolved most probably as part of a growing interest in the patterns that were shaping up in the dynamics of urban living. While existing urban transportation systems are gaining new momentum in support of their operation and further development, and while new transportation enterprises across the land are at varying stages of planning, design and construction, little if anything has been proposed to help in the design of the internal management and organization of such transportation undertakings.

The present paper describes a newly developed quantitative method for the study of the internal structure of an organization, and presents field study results based on the operation of three urban passenger transportation enterprises. This and subsequent research work are expected to help in the development of needed structural models for transit work organizations, in support of their successful management.

With 60 to 70 percent of total operating costs allocated to wages, salaries, and associated fringe benefits, the work force represents the single most sizeable item in the budgets of all urban transportation enterprises. This is demonstrated in Table 1, where transportation labor costs are presented as a fraction of total operating expenses for the three independent urban transportation enterprises participating in the present study: a taxicab company, a bus service, and a railway rapid transit operation.

Much of the urban transportation enterprise internal management structuring was traditionally left to trial-and-error based policies. Some management practices, particularly in railway rapid transit, drew from experiences accumulated in the intercity railway industry. On the other hand, urban bus service managements were shaped by their individual experiences and histories, recruiting their managerial staff from within the organization by promotion. Early organizational errors can prove costly and difficult to rectify, while at times, extensive efforts and large capital investments are allocated to the development of advanced transportation technologies, with the expectation for future manpower savings in return.

Consequently, one of the important problems arising at an early stage of the development of a new transportation enterprise, or expanding an existing one, is that of the forming and shaping of a new work organization to operate and manage the system successfully.

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TRANSPORTATION LABOR COSTS IN RELATION TO TOTAL OPERATING EXPENSES

Enterprise	Total Annual Operating Expenses $*	Annual Labor Costs		Depreciation Costs	
		$*	%	$*	%
Taxicab Company	5,295,595	3,365,305	63.5	245,850	4.6
Bus Service	27,380,105	16,878,442	61.6	1,456,270	5.3
Rail Rapid Transit	4,393,575	2,255,365	51.2	935,010	21.3

*Source: *1973 Company Annual Reports*

TABLE 1

In the results introduced in the present work initial attempts are made to acquire more precise knowledge on organizational structure in an effort to develop specific prescriptions for the early design of organization.

LITERATURE REVIEW

With the prospect of extensive growth of the urban passenger transportation industry in the immediate future and during years to come, efforts to discover prescriptions for management structuring and organizational design superior to those presently available seem to be urgently needed. So far, studies of organization applied to the transportation enterprise are scarce, highly sporadic, and generally represent only isolated case study observations. The relevance of Koontz's statement in this respect is in order: "It is, indeed, high time that both transportation companies and transportation specialists within companies should realize more fully the important role of transportation management." (Koontz, 1966). Koontz stressed the role of management and suggested a set of standards for the manager in transportation. With some emphasis, Koontz pointed out the need for formal management education coupled with appropriate financial allocations for that purpose.

Awareness of the impact of technological modernization on the internal organization of British Railways is expressed in Dunbar's paper on staff relations on the railways (Dunbar, 1960). Dunbar focused upon management-union relationship, outlining in some detail management's role particularly under circumstances of technological modernization generating redundancy of manpower. Major consideration was given to manpower costs, estimated at least at 60 percent of the overall system operating expenses. This called for higher productivity through "better use of manpower by mechanization and improved methods." With the threat of increasing redundancy of manpower in sight, British Railways management and trade unions successfully agreed upon security provisions for workers due for displacement (Dunbar, 1960).

Transportation technology may affect also behavioral characteristics of the organization. Fielding and Shilling expanded on the role of communications in the internal organization of Dial-A-Ride systems (Fielding and Shilling, 1974). They pointed at two results of improved communications within an organization. Those are, promotion of employee attitudes favorable to the organization, and more effective management control over the organization. Both results, according to Fielding and Shilling, are demonstrated in the Dial-A-Ride work organization.

A comparative review of urban transportation management was offered by Kiepper and Neidell (1974). Three alternative managerial philosophies were delineated in the organization of a railway rapid transit system under construction: The San Francisco Bay Area Rapid Transit District (BARTD) had adopted the policy whereby an entire design and construction effort was turned to an outside contractor's group. The Washington, D.C. system had undertaken the opposite approach, handling most of its design and construction operations by its own organization. Both organizations experienced unsatisfactory results. While BARTD increased its own supervisory responsibility relative to its outside contractors, Washington, D.C. ended up contracting its project to three separate professional firms, for architectural design, engineering design, and construction management. Following an intermediate approach, a third organization, the Metropolitan Atlanta Rapid

Transit Authority (MARTA), had assigned the entire design and construction to a single outside contractor; however, it maintained a strong engineering staff of its own retaining supervision and control over the project as a whole.

The San Francisco Planning and Urban Renewal Association (SPUR), published a report on San Francisco Municipal Railway (MUNI) pointing at deficiencies in its organizational structure. In the absence of relevant organization modelling the report resorts to Alameda-Contra Costa Transit District (ACT), a neighboring organization of better public reputation, as a reference for direct comparisons (SPUR, 1973).

THEORETICAL MODEL OF THE ORGANIZATION

In the absence of any one coherent structural model directly applied to the urban transportation enterprise, the working hypothesis for the present study is more general and based on concepts developed in organization theory, associated with the socio-technical system approach to organizations. This hypothesis suggests that organization structure is determined by two factors: one is the type of technology which the organization employs, and the other is the socio-economic environment external to the organization itself.

Major contributions which led to the establishment of this hypothesis were mostly presented by sociologists who studied organizations of a large variety of manufacturing and service enterprises (Woodward, 1965; Emery and Trist, 1969; Hickson et al, 1969; and others). The descriptive organizational model that emerged from these studies is built upon a technical-core unit—that part of the organization which operates the technology owned by the organization—and boundary units surrounding this technical core and specialized to transact with various segments of the socio-economic environment impinging upon the organization.

According to the prescription of the socio-technical model of the organization, boundary units are based upon more flexible hierarchy structure promoting participative group work and consultative decision making among peers as well as subordinates and their superiors. This flexibility is assumed essential in dealing with fluctuating forces of the socio-economic environment external to the organization.

The technical core unit is largely isolated from the environment. Its structural characteristics remain subject primarily to the technology employed by the organization. Early studies in the manufacturing industries broadly suggested variation in major structural characteristics associated with technological change. In particular, differences were noted in the number of hierarchical levels, skilled manpower distribution across departments, administrative and direct labor ratios, and related personnel data.

APPLICATION TO THE TRANSIT ENTERPRISE

Urban passenger transportation enterprises are generally identified as services to the public in urban and suburban areas to facilitate the movement of people from place to place. The technology, or transit mode, of a transportation enterprise is selected depending on demand perceived, availability of funding, given urban structure, and other socio-political and technical factors. Urban passenger transportation technologies are relatively distinct one from another in their basic characteristics. The major technologies are taxicab, bus, and rail rapid transit. Less common, but in varying stages of active design, experimentation, and use in many cities, are other transit technologies such as dial-a-ride, jitney, and streetcar.

Three attributes provide sufficient differentiation among transit technologies and can be eventually quantified if more precise ordinal scaling of technological level is required. Those are:

1. Vehicle loading capacity, indicating the capacity of a single vehicle used.
2. Service controllability, expressing the extent to which actual service rate complies with pre-planned schedules.
3. Capital intensiveness, representing the required amount of capital invested for an added unit of service.

The three transportation technologies, taxicab, bus, and rail rapid transit chosen for the present study were qualitatively scaled according to the above characteristics. This is presented in Table 2.

Transportation technologies are managed by a well identified network of positions within the enterprise manpower organization, which is referred to as the organization's technical core. This organizational section is in most cases identified as part of the operations or transportation department appearing on most formal organizational charts. In the present paper the technical core is referred to as the Direct Transportation unit. It generally comprises some 70 to 80 percent of total organization employment, including vehicle operators, their superiors and managers and all other personnel who are occupied in the execution of direct transportation tasks of the service on a full time or part time basis. Supporting the techni-

URBAN PASSENGER TRANSPORTATION TECHNOLOGY SCALE

Enterprise	Transportation System Characteristics			Overall Level of Technology
	Vehicle Loading Capacity	Service Controllability	Capital Intensiveness	
Taxicab	Small	Low	Low	Low
Bus	Medium	Medium	Medium	Medium
Rail Rapid	Large	High	High	High

TABLE 2

cal core are specialized units matched with segments of the organization's socio-economic environment. Common to most urban transportation enterprises are such units as the board of directors, accountable to the enterprise owners, stock holders, tax payers and other sponsors; personnel management unit which is assigned to deal with employment, labor relations, unions, and related areas; and marketing and sales units which are expected to cope with competition, promote service, and increase sales volume. In a similar manner, specialized internal organization manhours are distributed across the organization among peers and throughout hierarchical levels to accommodate the successful execution of other organizational tasks and managerial policies.

ASSESSMENT OF ORGANIZATIONAL STRUCTURE

An organized network of positions specialized to perform a given task can be viewed as a hierarchy of administrative levels of responsibility. A position at a given level of responsibility is traditionally assessed by its individual job description. However, the complexity and abstraction of many managerial positions, and their multi-dimensional character, most often prohibit their comparison and direct measurement on a single level of responsibility scale.

Researchers of job design and individual career progression developed measurable criteria which can be used for the scaling of organizational positions in terms of their level of responsibility. It is assumed that level of responsibility can be equated with the amount of authority or power assigned to a given position because only then can the task assigned to that position be carried out as required. Position Power (PP) is defined as the product of two factors—namely, Time Span of Discretion (TSD) and Discretionary Resource Rate (DRR).

Time Span of Discretion is "the longest period which can elapse in a role before the manager can be sure that his subordinate has not been exercising marginally substandard discretion continuously in balancing the pace and the quality of his work" (Jaques, 1964). In essence, TSD approximates the period of time which elapses between two consecutive supervisory reviews of the task performance in a given subordinate position. Discretionary Resource Rate is defined "as the extent of resource deployment (per unit of time) reached before the superior decides it is time to review the subordinate's discretion" (Crossman, 1969). Fixed assets, equipment, materials and supplies, as well as manpower are included in varying combinations within the DRR allocated to organizational positions.

Once the TSD of a given task oriented position is identified and its associated DRR evaluated, their product, PP, is determined and can be used as a formal representation of that position's level of responsibility.

With respect to the preceding conceptualization, quantitative data were gathered from three urban passenger transportation organizations managing varied technologies. Structural differences among the organizations were identified and associated with respective levels of technology.

FIELD DATA ACQUISITION

The theoretical model of the organization constituted a technical core unit surrounded by a "buffer zone" of boundary units oriented to cope with fluctuating conditions in the socio-economic environment while providing a relatively stable state for the technical core operation.

The objective of the field survey was to identify and isolate the technical core unit at each of the three subject organizations—a taxicab company, a bus service, and a rail rapid transit operation. The structures of these units were then to be drawn, analyzed and compared to identify the impact of technology on some of their basic characteristics. This was accomplished in accordance with the following two steps:

1. An interview schedule was designed preceded by a preliminary familiarization study of the subject organizations and their environments. Fifteen to twenty personal interviews were then conducted (each lasting for a period of 1 to 2 hours) at all levels of each organization; and all major organizational positions were included. For the purpose of the present study interviewees provided the following information items: (a) A breakdown of theirs and their subordinates long-term responsibilities into specific task assignments. (b) Estimated amount of time allocated to each of the specified task assignments. (c) Estimated Time Span of Discretion associated with each of the specified task assignments.

Appendix I is a sample of a typical interview report. Position wage or salary was obtained from company personnel records.

2. All task assignments identified as technical core activities—that is, activities involving direct transportation and its supervision—were segregated from other activities contained in interviewee job descriptions. Their aggregated manpower at each hierarchy level is presented as Managerial Full-Time-Equivalent (FTE) at Level (Table 3, Column 3). This is followed by the Total Annual Pay at Level (Table 3, Column 4) prorated based on the corresponding Managerial FTE. DRR is represented by its manpower component. Thus, the cumulative total pay below a given hierarchy level per managerial FTE is introduced as DRR at that level (Table 3, Column 7). The product of DRR values and their corresponding TSD values (Column 8) lead to the PP at each level. For more comprehensive analysis the data is represented in a graphical form in Figures 1 through 4. TSD and DRR data, and their product, PP, are plotted with respect to formal Hierarchy Level in Figures 1 through 3, along with their linear regression lines, on a semi-logarithmic scale. The emerging relationship among TSD, DRR, and PP, independent of Hierarchy Level, is shown in Figure 4, scaled logarithmically on both axes.

ANALYSIS OF DATA

Marked differentiation is noted among Direct Transportation units of examined urban passenger transportation technologies. This is more visibly demonstrated for TSD data than for DRR data as they are plotted against Hierarchy Levels in Figures 1 and 2. The differentiation among the corresponding PP

Organization Structure Data of Direct Transportation Management

1.	2.	3.	4.	5.	6.	7.	8.	9.
Transportation Technology	Level of Supervision	Title at Level	Managerial FTE at Level	Total Annual Pay at Level	Cummulative Pay Below This Level	Discretionary Resource Rate at this Level per FTE Manager	Time Span of Discretion at This Level	Power at This Level
			FTE*	$('000)/year	$('000)/month	$('000)/month	Months	$('000)
Taxicab Service	1	Dispatcher & Road Supervisor	27.75	270.0	129.3	4.7	0.24	1.1
	2	Personnel Manager	0.65	7.8	151.7	233.4	1	233.4
	3	Operations Manager	0.15	3.0	152.4	1,015.7	3	3,047.1
	4	General Manager	0.125	3.8	152.6	1,220.8	6	7,324.8
Bus Service	1	Dispatcher & Road Supervisor	58.25	987.7	862.0	14.7	1	14.7
	2	Chief Clerk	2.4	37.0	944.3	393.4	3	1,180.2
	3	Division Superintendent	1.5	63.2	947.4	631.6	6	3,789.6
	4	Transportation Manager	0.6	34.3	952.6	1,587.7	9	14,289.3
	5	General Manager	0.043	1.9	955.5	22,481.7	24	539,560.8
Rail Rapid Transit	1	Control Towerman	2.6	34.1	66.9	25.7	3	77.1
	2	Rapid Transit Superintendent	0.6	16.1	69.7	116.2	9	1,045.8
	3	Transportation Manager	0.1	3.1	71.1	793.9	18	14,290.2
	4	General Manager	0.013	0.6	71.3	5,705.3	36	205,390.8

*Full Time Equivalent (FTE) unit represents 2,000 manhours per year or 167 manhours per month.

TABLE 3

TIME SPAN OF DISCRETION (TSD) vs HIERARCHY LEVEL

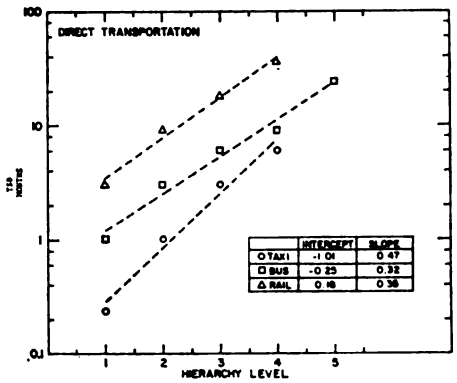

FIGURE 1

distributions across Hierarchy Levels (Figure 3) is therefore largely contributed by TSD as a subject of varied levels of technology. The results suggest that for matched Hierarchy Levels, positions in transportation enterprises employing higher technologies, are equipped with more Position Power (PP).

Higher slopes with respect to Hierarchy Levels indicate increased delegation in the organization. Bus service appears to score lowest in this respect (0.3, 0.7, and 1.0 on TSD, DRR, and PP

DISCRETIONARY RESOURCE RATE (DRR) vs HIERARCHY LEVEL

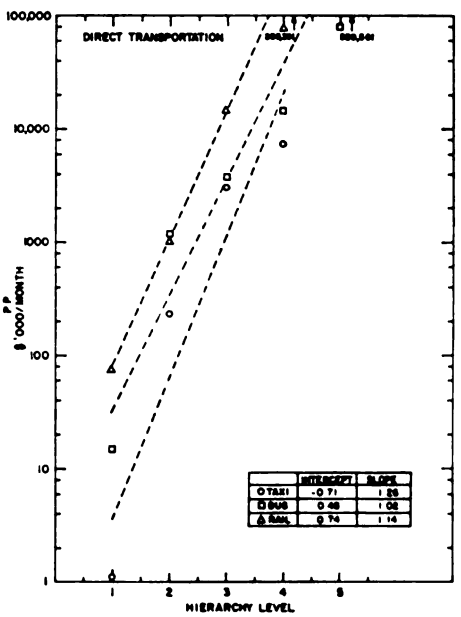

FIGURE 2

POSITIONAL POWER (PP) vs HIERARCHY LEVEL

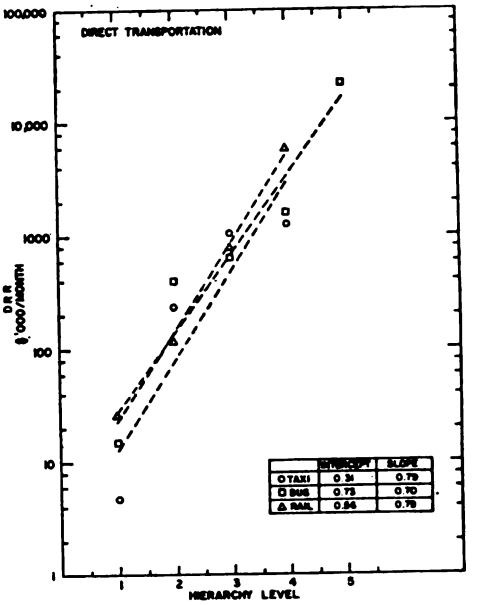

FIGURE 3

respectively, Figures 1, 2 and 3). This may be attributed to the larger number of levels (5 as compared to 4) in the bus service organization stimulating closer supervision across levels and thereby reduced delegation of responsibility.

A prescriptive model of formal organization structure is introduced in Figure 4. It emerges from the data presented in Figures 1 through 3. This graphical model portrays organizational structure in terms of objectively-measured field data, independent of formal Hierarchy Levels subjectively defined by interviewed job holders of the organizations investigated.

The organization can be introduced as a structure of power levels, and posi-

TIME SPAN OF DISCRETION (TSD) vs. DISCRETIONARY RESOURCE RATE (DRR)

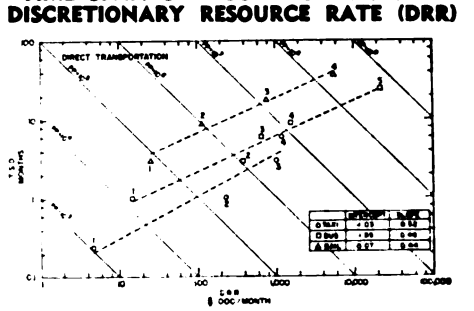

FIGURE 4

tions at varied enterprises can be defined and compared as intersection points of power and level of technology. Lacking in the model is a quantified presentation of technology level, for which the need may arise with the increase of technological alternatives in the urban passenger transportation enterprise.

The general trend of higher technologies to be associated with relatively more powerful positions is demonstrated for most Hierarchy Levels. (Hierarchy Levels are indicated by their numerical order for each position in Figure 4.) This is particularly visible for first line supervision (position 1), and for top management (position 4). Some ambiguity appears at middle management levels (e.g., level 2 of rail rapid transit has less power than level 2 of bus service), and definitive conclusion cannot be drawn before a larger sample study has been undertaken. The fifth level in the bus organization is an apparent exception to this rule. However, it can be excluded from the comparison since there is no matching fifth level in either of the two remaining technologies, and its presence is attributed to the significantly larger managerial structure (a total of 62.8 Managerial FTE as compared to 28.7 in the taxicab organization, and 3.3 in the rail rapid transit organization, as obtained from Table 3) of the bus service direct transportation.

Slopes of TSD regression lines on DRR (Figure 4) indicate incremental changes in TSD and DRR representing the change in Position Power when going from one position to the next higher position. Nearly identical slopes of all three technologies (approximately 0.5) suggests a fixed relationship between TSD and DRR closely described by equating the DRR value with the square of the corresponding TSD value.

CONCLUDING REMARKS

The present study has established a preliminary framework for a quantitative approach to prescriptive modelling of the formal organization structure. It is more easily applicable to the urban passenger transportation enterprise than to most other industries because of the highly distinctive characteristics of varying transit technologies.

Objective measures, TSD and DRR, are used to describe the structure of direct transportation management organization in terms of Position Power (PP) distribution and the levels of responsibility this distribution implies.

Further research is needed to validate the proposed model. There is a need to extend the present study in two directions: First, a stratified sample based replication of this work is needed to refine the model. Second, organization units other than the technical core itself, such as, equipment maintenance, marketing and sales, finance and accounting, should become subject to a similar research approach with an effort to identify associations of their structural characteristics with varying conditions in their immediate socio-economic environment.

APPENDIX I

Interview Report

1. Organization: Bus Service
2. Division: Transportation Department, Division B
3. Job Title: Time Keeper
4. Direct Superior: Chief Clerk
5. Direct Subordinate: Student (Temporary)
6. Name of Interviewee: Mrs. J. Clark
7. Date: May 2, 1974
8. General Notes:
   In the absence of the Chief Clerk, the Time Keeper reports to the Assistant Superintendent or the Superintendent himself. Time Keeper is a union member and pays union dues. It is the same union as the bus operators. The Time Keeper is equipped with office space, office equipment including a typewriter, and the necessary company forms. The Time Keeper does not have any direct subordinates. Periodically, she is requested to train another person on her job.
9. Job Characteristics: (on next page)

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Task	Work Time	Time Span
Filling Work sheet by names of extra Board (using Daily Detail Sheet received from Chief dispatcher).	1 hr. per day	1 day
Time recording for Extra Board. Putting time record on Guarantee Sheet on which a weekly summation is obtained every Friday. Xerox the daily record and send copy to Head Office.	2-3 hrs. per day	Maximum 7 days
Recap of Work Sheet and Pay Sheet (time keeping) for the day. Filling Daily Operation report. Send to Transportation Manager, after checking and signing by Division Superintendent.	1/4 hr. per day	1 day
Group reliefs operators to be recorded in the Synopsis of Runs book. Includes: Regular operators weekly 2 days off; long term absence; vacation.	3/4 hr. per day	Between 1 and 7 days
Assignment of Detail List in the book for the next day.	3 hrs. each afternoon	1 day
Recording daily vacation pay and mail to Head Office, to payroll and data processing.	1/2 hr. per day	1 day
Training a student (for relief of Timekeeper, 2 replacement persons are regularly needed).	3 hrs. per day for 3 weeks, once in 6 month period	2 weeks

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