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Development of a Detailed Model of Motor Carrier Operations

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I. INTRODUCTION

In today's highly competitive operating environment, one of the major goals of motor carrier managers has been the development of information systems responsive enough to provide the kinds of information required to make intelligent decisions. The responsiveness of such information systems can be measured in two ways: in terms of the time it takes to generate needed information and in terms of the adequacy and appropriateness of available information. In the first area, the infusion of computers into the industry has greatly reduced the time required by many carriers to process available information and to provide needed reports for management use. While this infusion has been somewhat impeded by the need to develop software compatible to motor carrier use, significant improvements have been achieved.

The second area has progressed more slowly. This area is concerned with defining the types of information needed for decision-making and the levels of detail reguired to provide sufficient information upon which to base decisions. The general types of information required for decision-making have been discusses often[1]. The levels of information required for decision-making are less well defined. One way to identify required information levels is through the use of deterministic models that facilitate the evaluation of "errors" introduced into system analyses as the level of available information is varied. This paper describes the first step in this process—the development of a detailed, deterministic model of carrier operation.

Specifically, the paper describes the appropriateness of simulation as a basis for motor carrier modelling, the overall form of the model, data sources used as a basis for its development, the types of data synthesis required to define the model, and its present and potential uses.

II. SIMULATION AS A BASIS FOR MODEL DEVELOPMENT

The use of simulation as a basis for evaluating system relationships is most appropriate where complex forces are at work. In general, transportation operations are very complex. Even the operations of smaller general commodities carriers, such as the one used as the basis for the model described in this paper, inherently involve highly complex relationships. This model represents the operations of a ten terminal carrier system with traffic moving between each terminal pair. This movement requires the coordination of 138 trailer movements and supervision of the actions of over 600 people to service more than 2,200 shipments of all types each day.

To successfully represent this carrier's operations, using other than broad system averages that are not appropriate for system evaluation, required the development of highly detailed information base describing those operations. While this information base could have been developed in a variety of ways, the task required definition of relationships that were too complex to be defined effectively using most standard statistical techniques. Therefore, it was decided that simulation techniques should be used as the basis for the model.

Once this decision was made, the simulation could have taken either of two basic but highly different formats. The first would have involved a "building up" of systems data through the incorporation of detailed "building blocks" representing segments of the carrier's operations. For example, each terminal's dock might have been viewed as one or a series of work stations employed to process freight. This would have required the development of a series of refined submodels defining the relationships between specific shipment characteristics and the dock handling input required for shipment service. In addition, it would have necessitated the development of a highly detailed "population" of simulated traffic to be "moved" through the system. While such a model could be developed—and, indeed, the definition of dock handling/traffic characteristic relationships has been the topic of many studies—such models are seldom suitable for large scale system simulations[2]. The problem is that system "slack" introduced in actual operations is seldom effectively accounted for when subsystem results that have been accumulated into overall system totals are compared to actual operating results.

Since they are based on detailed definitions of operating relationships, such models can provide important insights into the nature of carrier operations; but their use would not have insured that better information would be obtained in this instance. In addition, since such models incorporate a level of detailed information well beyond that normally generated by a carriers for management purposes, the importance of having very highly detailed data to make decisions could be overstated. In other words, if such information is made available artificially, its use could lead to the conclusion that it is necessary. Such a conclusion should not be reached without careful consideration of the real world costs associ-

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ated with gathering that information and an assessment of the benefits gained by its accumulation. In addition, the potential benefits to be achieved through use of a very highly detailed model were not felt to be sufficient at this stage of the project of warrant the extensive development effort required.

Therefore, a second approach was used. This approach is based on the types of information defining personnel and equipment utilization relationships most normally available to a carrier and involved the development of a data base providing an image of the carrier and its operations such as would be seen by an outside evaluator. This structural framework is based on a skeleton that clearly reflects the results of carrier operation; but that, also like a skeleton, is hidden from view. In other words, the user of the simulation does not see its inner workings, but the model accurately reflects changes in costs, revenues, and so on that correspond correctly to experienced or anticipated changes in operating conditions. Specifically, this simulation of carrier operations is based on data reflecting income generation, cost incurrence, equipment and personnel utilization, traffic attributes, and other carrier operating characteristics. This data is accumulated and organized in a manner and at a level of abstraction that reflects the gathering of similar data by the real carrier from typical reporting and traffic control documents. A more specific description of the form of the model is presented in the next section of this paper.

Although the model is designed to project an "outside in" perspective of carrier operation, as it is used to evaluate more and more specific aspects of carrier decision making, more detailed information can be incorporated into the simulation. This addition of detail can be done selectively, in a manner somewhat reflecting the "building block" approach described above, facilitating fuller evaluation of specific analysis techniques and increasingly smaller segments of carrier operation. In effect, such refinements can be limited to small, well defined portions of carrier operation without altering the overall model design. An example of model refinement might involve the development of detailed data related to the traffic moved for one customer. The model's continued usefulness, in this case, would be predicated on how accurately the added traffic and operating data relate to the information detailing remainder of the simulated carrier's traffic and its overall operations.

III. THE OVERALL FORM OF THE MODEL

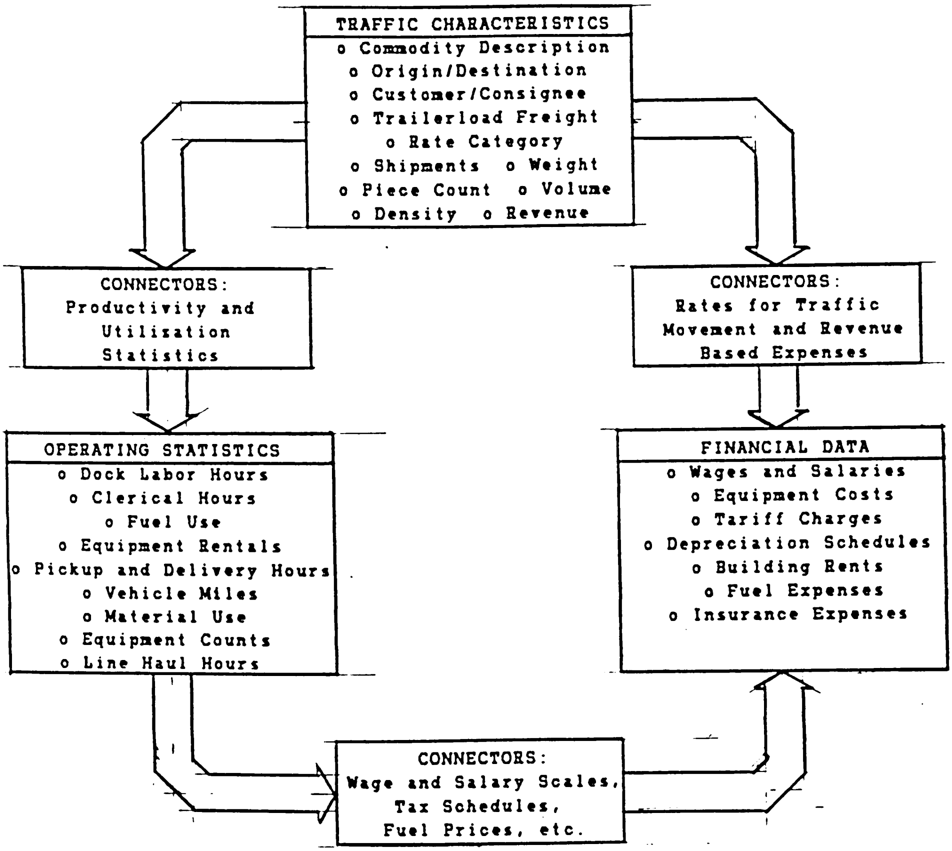
As was stated above, the purpose of the model is to reflect operation of a motor carrier in terms of generally reported information as opposed to a simulating carrier operation by creating information as "traffic" is cycled through simulated carrier operating segments. The latter type of simulation is similar to a queueing theory evaluation of work stations developed by an industrial engineer while the former reflects a management accountant's view of operations and information management.

This reflective model simulates the results of carrier operation in terms of carrier traffic throughput and the inputs required to service that throughput. It used data inputs similar to those found in carrier operating records, in terms of such things as monetary information related to costs and revenues, direct and indirect labor requirements, vehicle needs, fuel use, and supplied needed. While such data is generated in great detail in the process of facilitating freight movement, it is normally accumulated by a carrier on an aggregated basis to facilitate the preparation of annual reports required by regulatory agencies and for income reporting purposes. This aggregated data generally includes statistics related to overall traffic mix, such as tons and shipments transported, ton-miles generated, vehicle-miles generated, pickup and delivery vehicle hours, revenues generated, and costs incurred by either natural (e.g., wages or building rents) or functional (e.g., platform or linehaul) account category.

Conceptually, the model is made up of three parts. The first part, and the core of the model, defines system traffic characteristics. These characteristics include data related to the number of shipments moved, whether the shipments originated and terminated on the carrier's system or were interlined, whether they were truckload or less-than-truckload movements, and their weight characteristics. The second part includes carrier operating statistics and defines the carrier's infrastructure. This data includes information on the company's operating equipment and its utilization, the number of vehicle-miles generated in line haul service, staffing levels and personnel use, and individual terminal characteristics. The third part of the model contains financial information related to the company's operations including balance sheet, revenue, and cost information related to the traffic and operating statistics. The major parts of the model are connected through the use of defined relationships between each of the three parts. These include relationships between traffic characteristics and operating requirements, such as productivity levels related to freight handling, operating requirements and accounting data, such as pay scales for drivers, and traffic characteristics and accounting data, such as line haul rates and revenues. The general form of the model is shown in Figure 1.

For the model to be used to evaluate decision-making information needs, the data used to develop the model had to be refined to the point that disaggregated data was available for each traffic category by type of service and traffic lane and for most carrier activity areas. This concept is illustrated by traffic data breakdown shown in Figure 2. In this case, aggregated traffic flows for the company as a whole are broken down by origin/destination pair and then by weight category within origin/destination cell. This type of breakdown was required for each data type incorporated in the model. While the data would have appeared in highly disaggregated fashion on the source documents used by the carrier to accumulate the aggregated data, this detailed information is normally either lost or too difficult to reconstruct from highly dissimilar, misplaced, or unorganized files. For example, production records often record time spent dealing with individual shipments, but this data is usually combined to provide summary shift reports reflecting all shipments processed during the shift. Going back to isolate and relate specific shipment and dock worker production data is generally too difficult or not thought to be useful.

Figure 1.
General Model



V. DATA SOURCES FOR THE MODEL

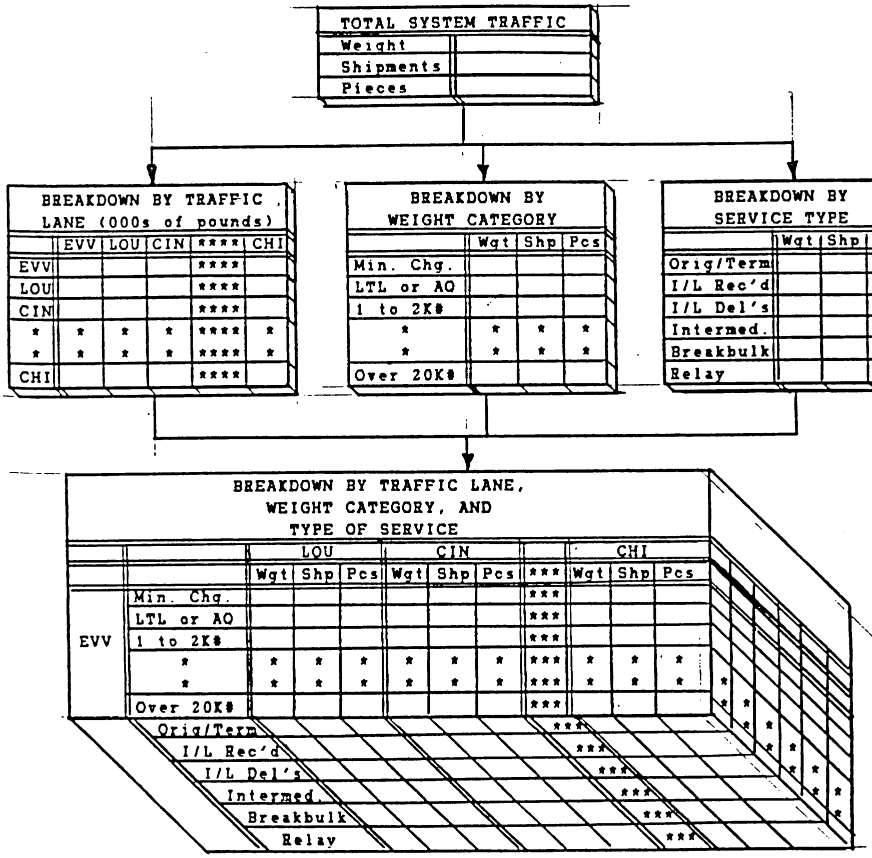
In the course of their daily operations, motor carriers are forced to generate a great deal of information. This information is required to facilitate traffic flows, to monitor and control equipment and personnel use, and to generate needed financial data documents[3]. If captured in an organized fashion, this information could be used as a basis for the most complete of data support systems to aid in carrier management decision-making. Because of the transitory nature of much of this information, such as that recorded in a dispatcher's reminder of a shipment pickup, and the volume of information to be processed, it is often difficult to retain the bits and pieces of detail in an organized, readily retrievable fashion. While not the primary topic of this paper, the planning required to systematically collect data is often lacking—and collection of any data apart from that retained in file cabinets "for future reference" purely coincidental.

Therefore, one of the major goals of this project was development of a data-based model of carrier operation that incorporated data required for decision making and formatted in a manner similar to data gathered from typical carrier source documents. This data needed to reflect the traffic, equipment, personnel, and financial characteristics of the simulated carrier's operations. Because of difficulties encountered in finding a single-carrier source for this data, due to the aforementioned general lack of carrier data need planning ad the complexity of most carrier operations, it was necessary to construct the model as a composite derived from a series of data sources. Each of these sources, and its appropriateness, is discussed below.

A. The Underlying Carrier Model

The underlying model is based on the operations of an existing Midwestern, short haul, general commodities carrier. Much of the original data was collected in the mid-1970s, requiring adjustment of the financial data to make it reflect current cost levels. The nature of the physical attributes of the carrier's

Figure 2.
Breakout of Data from Aggregated System Data



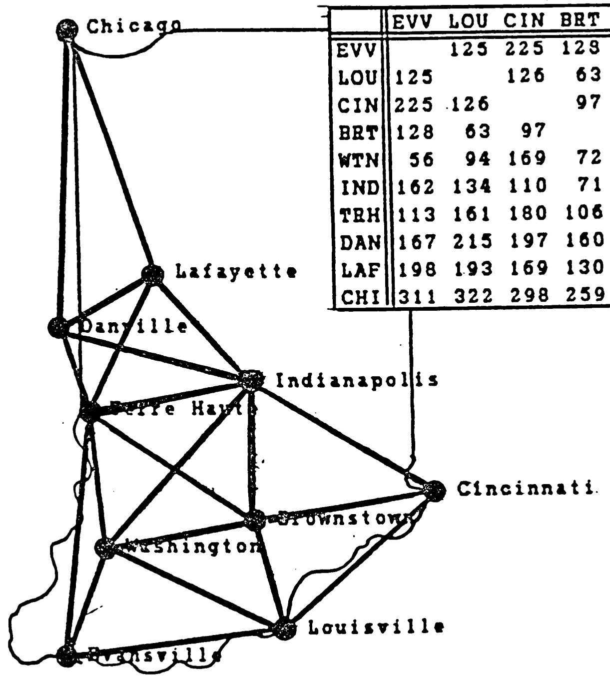
operations was such that no changes were required to modify the traffic, personnel, and equipment statistics apart from changes incorporated to protect the carrier's identity. A map of the simulated carrier operating system is shown in Figure 3.

The original carrier data included such things as staffing levels by operating segment, traffic characteristics by traffic lane and broad traffic category, equipment and facility attributes related to operations by terminal or other activity area, and financial and accounting information related to overall company operations. At the time the data was collected, the carrier was moving approximately 2.75 million pounds of freight per day through its ten terminal system, using an average of 138 trailers to support the line haul movement and employing 674 people in all phases of its operations. Its desirability as a model base was related both to the relative completeness of the available data concerning the carrier's operations and the variety of those operations. In essence, the company was large enough to provide examples of several kinds of service, including truckload, less-than-truckload, interline received and delivered, peddle, breakbulk, and relay traffic, but not so large as to be unmanageable from the perspective of model building. This combination of variety and manageability provided both a reasonable level of complexity and sufficient variety to facilitate the evaluation of a wide range of data base needs. While the data collected was less complete than the required to define the model, it did provide a sound basis for overall development.

B. Traffic Data Expansion

As is typical of most carrier data collection systems, the available statistics related to traffic movement were sufficiently complete in the aggregate but substantially less adequate when disaggregated. The study carrier collected data on terminal throughput, in total, and traffic lane traffic flows related to specific origin/destination pairs. A summary of this data is presented in Table 1. In addition, the carrier made available sampled and original data related to more specific aspects of traffic flow. Therefore, it was

Figure 3.
Simulated Carrier Operating System



Mileage Chart

	EVV	LOU	CIN	BRT	WTN	IND	TRH	DAN	LAF	CHI
EVV		125	225	128	56	162	113	167	198	311
LOU	125		126	63	94	134	161	215	193	322
CIN	225	126		97	169	110	180	197	169	298
BRT	128	63	97		72	71	106	160	130	259
WTN	56	94	169	72		106	67	121	152	265
IND	162	134	110	71	106		70	87	59	188
TRH	113	161	180	106	67	70		54	85	198
DAN	167	215	197	160	121	87	54		54	144
LAF	198	193	169	130	152	57	85	54		129
CHI	311	322	298	259	265	185	198	144	129	

possible to base simulated traffic flows on actual carrier data, with some increase in absolute traffic level to reflect the general desire to mask the carrier's identity. In addition, the carrier made available good information relating to interline traffic and breakbulk traffic.

While this information provided a sound basis for the model, it was insufficient to detail traffic flows to the overall level of disaggregation desired. As a result, traffic data from a number of proprietary sources, Interstate Commerce Commission traffic studies, and other traffic studies developed by the author and others were use to "flesh out" the model. This involved the breakdown of data into weight classes by traffic lane and type of traffic (e.g., class versus commodity rated and interline versus originated freight). This breakdown represents a first order disaggregation of carrier operating statistics, providing the detail required to begin to perform analyses of specific traffic group profitabilities and

Table 1
One-Month Freight Flows by Origin/Destination
(thousands of pounds)

From/To	EVV	LOU	CIN	BRT	WTN	IND	TRH	DAN	LAF	CHI	Total
EVV		475	155	139	398	2074	153	103	205	817	4520
LOU	1217		110	635	1115	897	494	178	254	754	5654
CIN	297	711		1159	1159	1415	624	20	772	231	6387
BRT	130	210	814		49	1045	2	6	16	583	2855
WTN	298	461	414	8		2031	69	61	21	1138	4501
IND	1435	3215	556	1019	2408		1276	1034	3482	669	15093
TRH	226	195	533	35	232	1031		82	221	482	3038
DAN	98	262	145	80	65	2026	7		721	185	3588
LAF	88	302	1029	1	29	2267	144	242		2524	6626
CHI	942	915	255	580	448	1842	1212	85	2048		8328
Total	4731	6746	4011	3655	5903	14629	3981	1811	7740	7382	60590

evaluations of carrier productivity. More specialized evaluations can be facilitated by further detailing specific segments of "carrier" operation. These evaluations could include tests of the necessity for specific types of detail in specific decision-making situations, in effect facilitated through the use of sensitivity analysis.

The data breakdowns revolve around the specification of total weight, total shipments, and total piece counts related to each major weight classification. The traffic breakdowns were developed by moving purposefully away from the aggregate, breaking company-wide data down into weight groupings and then spreading the data from this disaggregation by traffic lane. In particular, traffic was first broken into the rate/weight categories shown in Table 2.

Table 2
Traffic Breakdown

RATE CATEGORY	WEIGHT RANGE
Class Rated Traffic:	
Minimum Charge	1 to 242 pounds
Less-than-Truckload or Any Quantity Traffic	243 to 947 pounds
1,000–1,999 pounds	948 to 1,875 pounds
2,000–4,999 pounds	1,876 to 3,603 pounds
5,000–9,999 pounds	2,604 to 8,073 pounds
10,000 pounds and over	8,074 pounds and over
Commodity Rated Traffic	Generally trailerload traffic in excess of 10,000 pounds

In addition, total traffic within each category was defined in terms of total weight contained within the category, the number of shipments represented by that weight, and, in the case of terminal throughput, the number of pieces contained in those shipments. The data represents the types of data required to generate estimates of dock handling times and pickup and delivery stop times. The results of this system level spread of traffic data by rate category is presented in Table 3. This data was then broken out by traffic lane and terminal to provide detailed descriptions of carrier traffic statistics. In addition, the makeups of specialized traffic categories, such as breakbulk traffic, were then derived from the traffic lane breakdowns. The intent in each case was to provide variety within the system while both reconciling total system statistics and maintaining plausibility within the data set.

The end results were compared qualitatively with traffic statistics from a number of sources and analyzed by an outside evaluator highly familiar with a wide range of motor carrier operations. This was viewed as sufficient to support the internal validity of the model for its intended use. In addition, while this level of disaggregation provides a significant increase in the type of information available, it could be used with reasonable accuracy to develop estimates of staffing and equipment requirements for the model that go beyond those provided in the original carrier data.

C. Staffing Requirements

The estimate of staffing requirements also began with the actual figures taken from the study carrier. These numbers were evaluated in light of the traffic data revisions described above and revised where necessary to reflect the traffic increases that were introduced. The changes were based on traffic handling estimates produced through the use of a variety of labor estimating procedures derived from ICC and other studies. While greatly oversimplified, the following example serves to describe the basic methodology used to make these estimates. A widely used "rule of thumb" in the motor carrier industry is that a dock worker can handle approximately 2,000 pounds of freight per hour worked. Therefore, if 120,000 pounds of freight were handled over a carrier's dock, it could be estimated that 60 labor hours would be required to transfer the freight (120,000 pounds divided by 2,000 pounds per labor hour). A more complete model relating freight transferred to dock labor requirements would include shipment and piece count data for a variety of more specific traffic types, but would work in much the same manner[4]. In addition, estimated developed using industry study relationships were compared to the study carrier's actual productivity figures and further

Table 3
Summary of Expanded Traffic

RATE CATEGORY	TOTAL WEIGHT	SHIPMENTS	AVG WGT	PIECES	AVG PCS
Class Rated Traffic:					
Minimum Charge	3,438,700#	22,771	151.0#	102,697	4.51
LTL or AQ	8,960,300#	13,716	653.3#	213,009	15.53
1,000–1,999	8,175,000#	6,270	1,303.8#	205,405	32.76
2,000–4,999	7,926,900#	3,420	2,317.8#	177,634	51.94
5,000–9,999	5,624,700#	960	5,877.3#	79,018	82.31
Subtotal	34,143,600#	47,137	724.3#	777,763	16.50
Class Rated TL	2,593,600#	199	13,033.2#	25,124	126.25
Commodity Rated	23,852,600#	1,518	15,713.21#	316,670	208.61
Subtotal	26,446,200#	1,717	15,402.6#	341,794	199.06
All Traffic	60,589,800#	48,854	1,240.2#	1,119,557	22.92

subjectively evaluated for "realism." For line haul operations, only minor revisions were required to reflect increased traffic estimates. A personnel summary for the simulated carrier is presented in Table 4.

D. Equipment Requirements

Equipment requirements for pickup and delivery operations and line haul operations were derived in much the same manner as the personnel requirements described above. For example, expected pickup and delivery driver productivities and relative driving time/stop time relationships from a variety of studies were used as one basis for determining the probable number of vehicles required to service individual terminal throughputs[5]. Terminal characteristics and dock handling equipment requirements were taken directly from the study carrier statistics. One-month trailer movement totals for the system are presented in Table 5.

E. Financial Data Update

Because the data was collected some time ago, it was necessary to make adjustments for inflation and other factors changing the cost of personnel, equipment, and material inputs required to produce transportation services and the revenues generated through those service offerings. The data required to make these adjustments was acquired from a number of sources including more current financial reports from other carriers, periodic reports on general carrier operations produced by the American Trucking Associations, general inflation indices, and other relevant sources[6].

Development of current financial and accounting statistics involved a two-step process. In the first step, data for the "real world" carrier was revised to reflect changes incorporated in the model to disguise the carrier's identity. This involved analysis of the variability of costs in each account category and adjustment of the data accordingly. The second step involved an account by account adjustment of fig-

Table 4—Staffing Summary

BRANCHES:	EVV	LOU	CIN	BRT	WTN	IND	TRH	DAN	LAF	CHI	TOTAL
Managerial	1	1	1	1	1	2	1	1	1	2	12
Supervisory	2	2	2	1	2	8	1	1	2	4	25
Clerical	3	3	4	3	3	9	1	1	3	7	37
Dock	14	11	19	9	15	76	9	6	22	24	205
Pickup/Delivery	15	13	29	11	18	78	12	8	31	26	241
Yard and Other	1	1	2	1	1	5	1	1	2	3	18
TOTAL	36	31	57	26	40	178	25	18	61	66	538

GENERAL OFFICES:		LINE HAUL:	
Corporate Staff	5	Managerial	2
Secretarial	9	Clerical	1
Administration:		Road Drivers	55
Corporate Relations	1	TOTAL	58
Traffic	4		
Customer Service	4	MAINTENANCE:	
General Accounting	3	Managerial	1
Credit/Collections	14	Clerical	1
Operations	1	Mechanics	14
Sales	8	TOTAL	16
Safety and Insurance	1		
TOTAL	52	JANITORIAL	10
TOTAL	52	JANITORIAL	10

TOTAL COMPANY EMPLOYMENT—674

Table 5—One-Month Trailer Movement by Origin/Destination

From/To:	EVV	LOU	CIN	BRT	WTN	IND	TRH	DAN	LAF	CHI	Total
EVV		23	8	9	26	128	9	7	11	48	269
LOU	83		29	53	71	62	23	17	9	39	386
CIN	14	28		42	39	57	23	3	28	6	240
BRT	9	14	54		3	85	9	9	9	37	202
WTN	23	26	25	14		134	6	6	0	63	297
IND	75	207	34	61	125		75	73	141	27	818
TRH	24	14	27	0	18	65		9	13	23	193
DAN	0	11	6	3	0	88	0		26	6	140
LAF	3	11	48	0	0	118	9	8		111	308
CHI	38	52	9	20	15	81	48	17	80		360
Total	269	386	240	202	297	818	193	140	308	360	3213

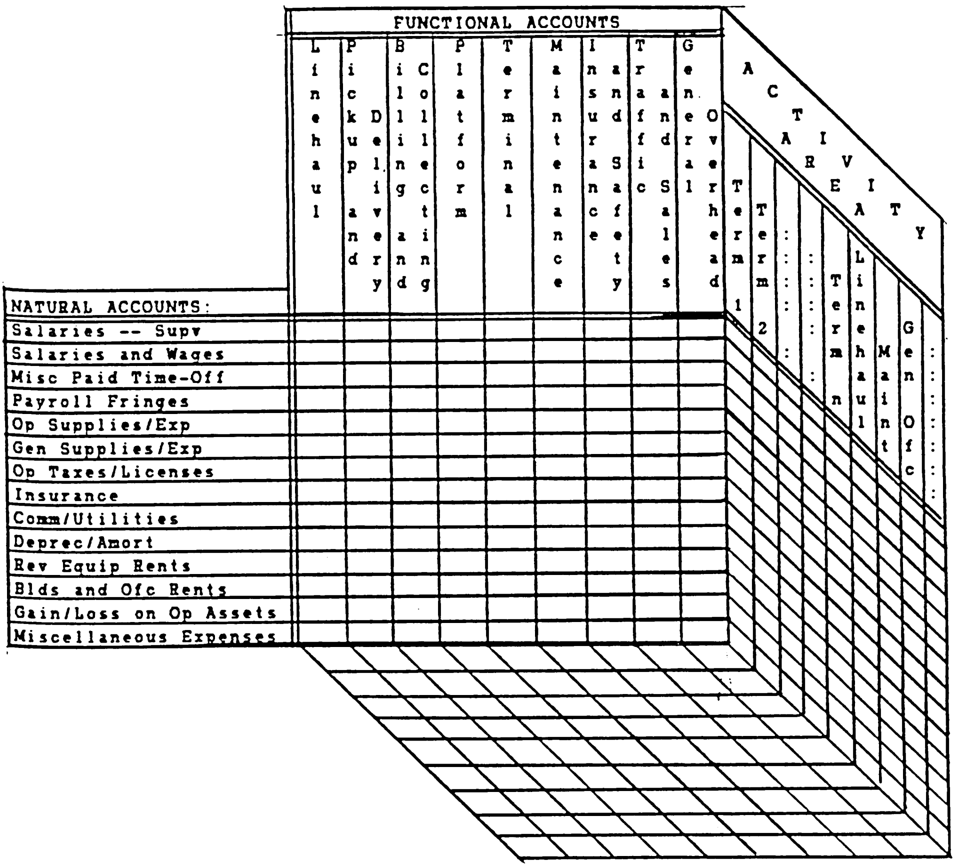
ures to reflect changes in cost levels since the data was originally collected. While it would have been better to use actual figures for current carrier operation, almost any model would have been based on historical data and have required some update. Comparisons of average system costs for the model carrier and current industry costs were made periodically to provide assurance that data incorporated in the carrier model continued to reflect acceptable levels of realism. While a lack of absolute accuracy in this area would not significantly detract from the expected end use of the model, the acceptability of the results obtained through its use would be enhanced by added accuracy. The development of cost estimates was also balanced against the personnel, equipment, and terminal characteristics identified when the physical model of the carrier system was being developed. The physical attributes of the system were also used as a basis for spreading costs across account categories and for accumulating costs by terminal and/or activity area. While the categories were broken down more finely than shown in Figure 4, this figure demonstrates how the overall cost subsection of the model was structured.

VI. TRANSLATING THE MODEL TO A DATA BASE ENVIRONMENT

The model described in this paper was designed for use in a microcomputer environment similar to that often seen in the motor carrier industry. To facilitate development, the model was created as a series of interrelated matrices describing the carrier's operations. While this format was useful from a design perspective, it was felt that presentation of the data in a format similar to that likely to be used for "real world" data evaluation would also be useful.

As a result, the finished model data set was translated into strings of data such as are found in most data base systems. For example, development of data-based information strings for classes of shipments would detailing origin and destination points, routes traveled, terminals passed through, nature of the traffic (e.g., interline/breakbulk, number of pieces, weight), and special services required, among other things, by shipment class. In other words, the types of data that could be gleaned from bills of lading, route manifests, waybills, freight bills, pickup and delivery route records, and other

Figure 4.
Accounting Data Matrix



similar carrier operating documents for individual shipments would be drawn more highly aggregative, simulated "original source" data strings. Data required for specific types of analyses could then be drawn from these "typical" data bases. For example, the data might organized as a string of information inputs detailing the traffic class origin terminal, destination terminal, route, weight category, number of shipments, total weight, piece count, interline received, breakbulked, trailer type, nature of pickup and delivery service, etc. An example of the way input data might be broken down to isolate traffic categories and the types of data strings used to describe specific situations are shown schematically in Figure 5.

VII. INTENDED USES OF THE MODEL

As stated in the introduction, the model described above is to be used as a basis for evaluating methods of analyzing carrier operations. The model simulated the operations of a medium-sized, general commodities carrier and is based on the operations of an existing carrier. The model incorporates traffic, cost, revenue, labor, equipment utilization, and other operating data related to the carrier's operation and reflects the types of information collected by most carriers in the course of their daily activities. This information is normally used for freight monitoring, equipment and personnel control, and report preparation. Since the model is deterministic

Figure 5.
Data-Base Information Format

Orig. Term.	Dest. Term.	Route	Inter-Lined	Break-bulked	Equip. Type	Weight Group	Total Shpmts	Total Weight	Piece Count	***	Notes
EVV	LOU	1	Yes	Yes	40ft	LTL				***	
						TL				***	
					27ft	LTL				***	
						TL				***	
				No	40ft	LTL				***	
						TL				***	
					27ft	LTL				***	
						TL				***	
			No	Yes	40ft	LTL				***	
						TL				***	
					27ft	LTL				***	
						TL				***	
				No	40ft	LTL				***	
						TL				***	
					27ft	LTL				***	
						TL				***	
		2	Yes	Yes	40ft	LTL				***	
						TL				***	
					27ft	LTL				***	
						TL				***	
				No	40ft	LTL				***	
						TL				***	
					27ft	LTL				***	
						TL				***	
			No	Yes	40ft	LTL				***	
						TL				***	
					27ft	LTL				***	
						TL				***	
				No	40ft	LTL				***	
						TL				***	
					27ft	LTL				***	
						TL				***	

(a) Concept of Data Breakdown into Smaller and Smaller Groupings as Basis for Transcription to Data Base Format

Orig. Term.	Dest. Term.	Route	Inter-Lined	Break-bulked	Equip. Type	Weight Group	Total Shpmts	Total Weight	Piece Count	***	Notes
EVV	LOU	3	No	No	40ft	1-2K	32	37821	962	***	na
CIN	CHI	31	No	No	40ft	2-5K	15	45202	721	***	na

(b) Single Data Stream Relating to a Class of Shipments in nature, it is possible to estimate the degree of error introduced as data levels are aggregated or data is removed from the system—since the results of analyses performed using "flawed" information can be compared to those developed using "perfect" information.

The model can be used to evaluate the appropriateness of various analytical methods and data levels for evaluating such areas of interest to carrier managers as traffic lane profitabilities, terminal productivities, line haul equipment utilization, pickup and delivery productivity, and terminal profitability. While the model is currently it is being used to evaluate the appropriateness of a series of costing methodologies as inputs to pricing decisions—and the effect of information availability on that appropriateness—future plans entail expanding analysis to a wide range of carrier decision making activities.

ENDNOTES

1. See Philip C. Cheng, *Accounting and Financing for Motor Carriers* (Lexington, Massachusetts: Lexington Books 1984); Garland Chow, *The Economics of the Motor Freight Industries* (Bloomington, Indiana: Division of Research, School of Business, Indiana University, 1978); David L. Shrock, "Motor Carrier Cost Analysis: the Next Step," *ICC Practitioners' Journal*, Vol. 21, No. 7, August/September 1974, pp. 11–18; David L. Shrock and Ronald V. Meeks, "Regulatory Reform and the Need for Improved Motor Carrier Costing Practices," *Proceedings: Second Transportation Workshop* (Tempe, Arizona: Arizona Transportation Research Center, November 1-3, 1984), pp. 400-413; and Charles A. Taff, *Commercial Motor Transportation*, 6th ed. (Cambridge, Maryland: Cornell Maritime press, 1980), Chapters 7, 8, 9, and 11; among many others. While the reference listed above do not in all cases specifically address the issue of information need, they do provide a variety of descriptions of information sources and uses. Additionally, a number of publications and articles have addressed carrier management needs for marketing analysis and provide additional light in this area.
2. One of the best examples of this type of study is the Interstate Commerce Commission's 51977-1978 Motor Carrier Platform Study: A Study of Direct Handling times Associated with Shipments Transferred Across Carrier Platforms (Washington, D.C.: Office of Policy and Analysis, Bureau of Accounts, Interstate Commerce Commission, Statement No. 2S1-79, July 1979).
3. See Cheng, *op. cit.*, and David L. Shrock, *Allocating the Indirect Costs of Motor Common Carrier Operation* (Bloomington, Indiana: Indiana University Graduate School of Business, 1974), Chapter 2 and Appendix A, for examples of carrier information sources and requirements, among others.
4. See *1977-1978 Motor Carrier Platform Study: A Study of Direct Handling Times Associated with Shipments Transferred Across Carrier Platforms* and *Effect of Shipment Weights on Dock Handling Labor: Volumes I and II* (A. T. Kearney and Company, Inc., 1967 and 1970, respectively) for examples of detailed studies of dock handling times and relationships to shipment characteristics.
5. See for example the supplements published by the Interstate Commerce Commission to support *Highway Form B: Simplified Procedures for Determining the Cost of Handling Freight by Motor Carriers (Statement No. 6-68)*, as revised, calculations. These supplements are issued as *Appendix A* to *Highway Form B* and define factors to be used in making specific cost allocations such as pickup and delivery speed and time factors, dock crossing likelihoods by weight class, and density adjustment factors, among other things.
6. Published sources of information for financial data adjustments included two very good American Trucking Association series titled "American Trucking Trends" and "Financial Analysis of the Motor Carrier Industry" and the Motor Vehicle Manufacturers Association's "MVMA Motor Vehicle Facts & Figures."