Patch, David, "Southern New England Dispatch," *Railpace Newsmagazine*, Vol. 12, No. 10 (October 1993), pp. 35-36.

Revis, Joseph S. and Curtis Tarnoff, *The Nation's Public Works: Report on Intermodal Transportation* (National Council on Public Works Improvement, May 1987).

Strom, Harold K. "Containerization: A Pandora's Box in Reverse?" *Transportation Journal*, Vol 12, No. 2 (Winter 1972), pp. 46-57.

Thomas, Janet M. and Scott J. Callan, "Cost Analysis of Specialized Carriers: An Investigation of Aggregation and Specialization Bias," *Logistics and Transportation Review*, Vol. 28, No. 3 (1992), pp. 217-230.

Welty, Gus, "A Wall Streeter sees 'real, absolute growth'," *Railway Age*, Vol. 194, No. 10 (October 1993a), p. 58.

Welty, Gus, "What's needed to keep intermodal growing," *Railway Age*, Vol. 194, No. 10 (October 1993b), pp. 57-62, 98-99.

ENDNOTE

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Defining Performance Measures for an Intermodal Management System

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INTRODUCTION

Based on early research efforts to develop performance measures and performance standards for use in an intermodal management system within the state of Louisiana, it became apparent that there is much confusion in the concepts of performance measures and performance standards; and that, furthermore, there is little reason to suppose that performance measures for intermodal systems would differ from geographic area to geographic area, and that even the performance standards may not differ. The focus of the research reported herein then became the development of a framework for defining comprehensive national intermodal performance measures, the definition of the nature of performance standards, and initiation of the identification of a number of candidate performance measures from application of the framework.

This paper contains a very brief summary of the literature search that was performed at the outset of the work, followed by a section on definitions, in which we distinguish between a number of terms that have been used somewhat loosely in the initial work on intermodal management systems and intermodal planning. The third section of the paper describes the framework and approach to the development of performance measures for intermodal systems and describes some initial performance measures that appear likely candidates for use in intermodal planning and intermodal management systems.

LITERATURE REVIEW

The overall intent of performance indicators, in the context of this paper, is to measure the *efficiency* of intermodal terminals. The indicators, which are expected to be the result of periodic measurements, should be compared either against a known standard, or against the results of another terminal, or against the result of the same terminal but at a different time, or under different circumstances. In short, the purpose of the measurement and related calculation of indicators is to support a qualitative judgement on the system's performance with implications for management decisions (De Monie).

Efficiency, in the context of this paper, relates to industrial systems, or systems that perform physical activities such as moving or processing concrete objects. Efficiency usually relates to the *operations* of such systems which, in turn, relates to the *operating costs*. The efficiency indicators are, in a way, proxies for the broader notion of cost which also includes

efficiency-equivalent factors, such as quality of service (e.g., frequency, reliability, damage prevention), time (e.g., processing time, delays), etc.

It should be mentioned here that the general term "performance indicators" can relate to any physical and non-physical system, and not necessarily within the context of efficiency. This paper, however, is solely interested in the measurement of the efficiency of physical, industrial-type systems, with an emphasis on intermodal terminals (Edwards).

Relevant Professional Literature

The review of professional literature in the area of efficiency measures for physical systems encompasses four areas:

- Economics, especially the so-called Allocative Economics (Intriligator);
- Industrial Engineering, especially in the areas of Industrial Design and Work and Methods Improvement;
- Passenger transportation systems, especially transit systems; and
- Port and Intermodal, especially in the areas of Terminal Operations and Capacity.

The following is a brief review of the basic concepts advocated by each discipline. A more lengthy review is provided in the final report from the research discussed in this paper (Louisiana Transportation Research Center and Louisiana Department of Transportation and Development).

ECONOMIC EFFICIENCY

In classical economic theory, producers wishing to maximize their profits, strive to minimize the cost of production.

A more relevant approach to the concepts of efficiency and, particularly, its companion *productivity* can be found in the large amount of literature specifically devoted to them. In this literature, efficiency is usually discussed in the context of the *production function* and the use of *production factors*. Productivity is viewed as a direct ratio between input and output. The most common such ratio is called *Total Factor Productivity (TFK)* (Norsworthy): the result of dividing the value of all the outputs by the value of all purchased inputs[1]. The ratio is a pure number, because both the numerator and the denominator are expressed in monetary terms ($). The unit price of the various inputs and outputs is taken from the actual market price for which the inputs were purchased and outputs sold. In fact, the TFK is very similar to the economic profitability, which is the difference between output and input (the TFK is their ratio).

This seemingly robust indicator of productivity, the TFK, has severe inherent problems, however. Altogether, the TFK has many structural problems in both definition and measurement aspects: the TFK has too much "noise" in the information it conveys because of the use of market prices; and it does not provide an insight into the production process itself, which is the overall intent of the indicators in this paper. Because the TFK is directly related to profitability, which is usually well documented and analyzed in financial reports, dealing with it in the disguise of efficiency is simply redundant. Consequently, it is proposed that neither the TFK, nor monetary values be used in the performance indicators that relate to the operational efficiency of intermodal terminals.

ENGINEERING EFFICIENCY

Industrial Engineering, like all branches of engineering, is concerned with the *design* of industrial systems. The Industrial Engineer, in his design efforts, evaluates different possible combinations of people, materials, information, equipment, and energy needed to produce a certain amount of product. While the ultimate objective of the design is economic by nature (e.g., profit maximization), the more immediate concern of the engineer relates to designing the components of the system itself, based on the performance indicators of these components. These nominal indicators can also serve as bench marks for comparing the actual utilization of the components with their rated performance (e.g., the actual tons/hour compared to the nominal one).

Again there are several serious problems with the Engineering approach, one of the more serious of which is that of multiplicity of indices. A partial solution to this issue is the use of *data envelopment analysis (Norman) (DEA)*[2]. DEA compares a given set of so-called Decision Management Units (DMU), which "use more-or-less similar inputs to produce a set of more-or-less similar outputs," in situations "where simple monetary measures are not appropriate (Land)." DEA has been applied mainly to the service industry, where the derivation of input/output relationships is especially difficult, including public institutions, such as hospitals, post offices, schools, etc. A recent application to the major U.S. and Canada railroads is described by Bookbinder and Qu (Bookbinder).

DEA is based on cross comparisons of outputs and inputs in order to identify the most efficient DMUs. The efficient DMUs are used to construct the *production frontier*, against which the remainder, the inefficient DMUs, are then compared. This comparison results in an overall efficiency score. In addition, for any one of the inefficient DMU, the program creates an efficient "image." The difference between the actual DMU and its image is in the excess of input consumed and the potential surplus of output that can be produced[3].

The use of physical input/output ratios, along with the concepts of qualitative divide and envelopment, are proposed as the overall framework for developing performance indicators for container terminals and intermodal terminals.

PASSENGER TRANSPORTATION PERFORMANCE

Systematic performance evaluation for passenger modes has been used in the past mostly in the case of public transit systems. Performance evaluation in this arena may be directed towards internal management or to state and federal funding agencies. The ability to improve transit performance, or indeed the performance of any other transportation system, relies to a great extent on the ability to measure it. Performance measurement helps to counter the

tendency to blame all performance shortcomings on factors beyond the control of management. It helps in identifying internal problems needing to be addressed and separating them from external factors.

Intermodal transportation includes the movement of both passengers and freight over a combination of modes, whereas transit systems generally include passenger movement over a single mode. Performance measures used to evaluate different transportation systems would be different. The evaluation of the performance of highway systems has been done using the level-of-service concept (Transportation Research Board). In the case of intermodal transportation, it is usually private companies that own and operate the vehicles and terminals where the transfer takes place. However, the performance of the system is still of relevance to planners because of the strategic location of intermodal terminals between public-transportation systems and also their effect on the land-use patterns in the localities in which they are situated (Ashar). Recent conferences on intermodalism have concluded that strong public and private sector relationships among those involved in transportation planning and decision making will greatly assist in achieving an effective and efficient transportation system (Roberts). An approach to planning based primarily on establishing system performance targets or goals is indicated in the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA).

Objectives of performance measurement are essentially different when looked at from different perspectives. Evaluation may be done by different groups for different reasons. The transportation provider or transit agency is interested in monitoring operations and locating sources of problems for correction. The user is interested in the quality of service and reliability of the transportation system. Certain performance measures may have been used by the transit provider to evaluate a transit system, only a few of which could be included by the transit user to evaluate the same system. The measures may even be completely different. An evaluation procedure needs to take into account different perspectives such as federal or local government, community, transit agency, citizen groups, and users. The actual performance relative to perceived goals is reflected in performance constraints. In order to respond to these constraints and to predict the impacts of proposed standards, a systematic and comprehensive structure for performance evaluation is essential. An extensive summary of the literature on transit performance evaluation is contained in the final report on this research (Louisiana Transportation Research Center).

PORTS AND INTERMODAL TERMINAL EFFICIENCY

The use of performance indicators to evaluate Intermodal terminals is similar in nature to the use of the indicators by Industrial Engineering; both apply ratios of *physical outputs to physical inputs*. In fact, the measurement of efficiency of the terminals that perform transfer is relatively easy compared to industrial systems, that are involved in production. In intermodal terminals, there is no change in form or quantity of the material involved. That is, the same number of containers or other cargo units that enters the system leaves it (eventually). Ports and intermodal terminals are conservative systems while production systems are transformative systems. This assumes that no stuffing/destuffing is performed in the terminal, which is indeed

the common situation. Measuring input/output ratios in intermodal terminals is much simpler than in production plants where raw materials are turned into products.

The overall purpose of any intermodal terminal is to perform the transfer of commodities between ships, trains, trucks, and other modes. Functionally, as already discussed at the beginning of this section, the terminal can be conceived as a stock with two flows, one related to the multi-unit transport mode — the vessel or the train — and the other to the single-unit transport mode — the truck, airplane, or pipeline. The difference between the characteristics of the two flows results in the in-between stock[4].

Before resorting to a quantitative evaluation of operational efficiency, the intermodal terminals should be *qualitatively categorized*. The grouping should be based on technology (Ro/Ro, Lo/Lo), flow pattern (typical number of containers per call), stock pattern (typical dwell times of inbound and outbound containers), and other factors deemed inherently different. Professional literature offers a wide variety of indicators to measure terminal performance (UNCTAD). The use of the indicator has two purposes: (a) as part of a management control system (Ashar); and (b) for capacity calculation (Rijsenbrij). The two issues of capacity and performance are closely related. The capacity of a terminal component is the result of the related performance indicators when the component is utilized at an optimal level.

The indicators in the professional literature are organized first by major terminal component, berth, yard, and gate. Then, for each major component there are several sets of indicators, sometimes organized in a tree-like structure (e.g., the more general indicator includes all the containers, while the more detailed one only includes the loaded containers, etc.).

The following is a short list of the most common indicators:

- **Berth Indicators** — vessel-moves/year, vessel-moves/berth, vessel-shifts/berth, cranes/vessel-shift, cranes/berth, gang-hours/crane, vessel-moves/crane-hour, vessel-moves/crane, productive crane hours/paid hours, vessel turn-around time, productive vessel hours/total hours at port, revenue moves/all moves (including re-handling and hatch-cover handling, berth occupancy (%), channel depth;
- **Yard Indicators** — total acres, total acres/berth, slots/yard-acre, yard-acres/terminal-acres, average stacking height, average dwell-time by type of container (loaded and empty), vessel-moves/yard-slot;
- **Gate Indicators** — gate-moves/vessel-moves, gate-moves/lane-hour, gate-moves/lane.

No professional literature on intermodal terminals is available yet, perhaps because the industry is relatively young. Nevertheless, there is no significant difference between the two types of intermodal terminals, except that, in general, intermodal terminals are technically less complex than container terminals.

One author (Dowed) suggests that productivity standards are "fiction." The only valid comparison is with the same terminal over time. The control a terminal has over productivity is limited, because the operation is affected by unions, carriers, and shippers, and because productivity is linked to cost. For example, vessels can be loaded or unloaded during the nights if overtime is paid. This would represent an increase in productivity, but with an associated increase in cost.

The proposed list of performance indicators in professional literature fails to differentiate clearly between inputs, outputs and the relationships between the two. As already stated, the indicators are intended to measure operational efficiency and are defined as *ratios*, or the results of dividing outputs by inputs. Consequently, only ratios should be considered as indicators and not the individual input or output items by themselves.

For example, many publications refer to the overall throughput of a terminal as an indicator (e.g. vessel-moves/year for the entire terminal). The throughput, however, is an output, and should not be considered as a performance indicator unless divided by the related input factor (e.g., vessel-moves/gang-hour).

A similar misunderstanding is often found with regard to inputs. The depth of the entrance channel to a container terminal, or the height of a bridge at the entrance to an intermodal terminal do not indicate operational efficiency. The physical characteristics of the terminal entrances certainly indicate potential for efficiency (or deficiency if not available), but they do not measure actual usage.

Another category of factors that often is considered as performance indicators includes items that are best referred to as design specifications of the terminal. In most cases of container terminals and intermodal terminals, the main user of the terminal is also the owner and the operator of them. Therefore, the facilities are designed and constructed according to specifications of the user. Thus, the number of berths, the length of the ramp, the number of cranes, the size of the yard — all are "tailored" according to the intended use of these components. They should not be considered as performance indicators. Design indicators, like the vessel or train characteristics, are not controllable by the terminal operator.

Some publications suggest that the "ultimate" performance indicator is the cost (charge) for the transfer service at the terminal (e.g., $/lift). That is, if port A charges less than port B, then port A is presumably more efficient. A similar suggestion employs vessels' turnaround time as a proxy for cost; if port A turns around a vessel in a shorter time than port B, then port A is more efficient. In the two cases, the intended measure for efficiency is the user cost[5].

Using cost as an indicator for efficiency is misleading in the case of modern container ports and intermodal terminals. First, in a competitive situation, the costs (tariff, price) are basically equal across terminals, assuming they offer similar services. Second, as was already discussed in the section on economic efficiency and TFK, costs are always case specific. Third, in the deregulation era, the actual charges are part of a package that includes many cost equivalents. That is, the service contract that defines the relationships between users and service providers includes many cost-related items such as availability of containers for pick up (e.g., gate hours), turn-around times, damage, etc. Also, the rates in the contract are usually a function of the volume. Altogether, costs serve better to indicate market and financial situations than to evaluate utilization of production factors[6].

A more practical concern is the availability of cost data. While industry people are willing to cooperate on an operational basis, they are reluctant to divulge information of commercial value. That is, previous experience suggests that many terminal operators are comfortable sharing their technical and operational experience (and data) with other terminal operators for their common benefits, while marketing people are uncomfortable releasing data on rates.

DEFINITIONS

There has been much debate about the meaning of the term "intermodal," and even as to whether there is such a word in the English language. Traditionally, the word "intermodal" has been used to refer to the transfer between modes, as derived from a strict lexicographical viewpoint in which one would note that the prefix "inter-" derives from the Latin for "between" or "among." Nevertheless, in reviewing the Intermodal Surface Transportation Efficiency Act, it is clear that the sense that Congress wished to impart through the term "intermodal" is much more inclusive than this strict interpretation. Rather, it would appear that the word "intermodal" should be regarded as substituting for the more involved used of a composite term, such as the term "intermodal/multimodal."

Networks and Focus

A transportation network is commonly defined as a collection of nodes and links (legs). The focus in the analysis of a common network (e.g., highway) is on links, where the main activity, the transportation of people or freight, takes place. The nodes of the network serve mainly as either origin and destination points (sources and sinks), or as intermediary intersections, where the direction of movement through the network changes. The nodes in the common link-node system are considered frictionless. The friction, that impedes the traffic and results in *costs*, is incurred in the links. Also, the *capacity* of a common transportation network is usually defined as a property of the links (even though it is more correctly limited by the capacity of the nodes at either end of a link).

The *intermodal* transportation network is similar in principle to a common, unimodal network (e.g., highway), except that the links are provided by different transportation modes (e.g., water, rail, highway). The intermodality of the transportation links by themselves is not a major factor, because all that is different is the specific characteristics of the links (e.g., speed, capacity, cost, and relationships between speed, volume, and capacity). The main difference is in the nature of the network nodes. In the intermodal network, some of the nodes are not mere intersections, but perform *transfers* between the connecting modes (e.g., water to rail), which is, in essence, an *industrial* type of activity. That is, unlike common networks that are dedicated purely to the transportation activity, the intermodal network is characterized by an additional industrial-type activity that takes place at certain of the network nodes. The uniqueness of the intermodal transportation network is due precisely to these transfer nodes, referred to hereafter as *intermodal terminals*.

The focus of this work on intermodal performance measures is defined as being on the nodes of the intermodal transportation system, i.e., the *intermodal terminals*. However, it needs to be understood that the node contains not only a terminal, but also the access and egress links between the terminal and the line-haul network. In defining this focus, it is also important to note that terminals may not be strictly intermodal, but may also be intramodal. The decision on whether or not to develop performance measures that operate for intramodal terminals should be considered at a subsequent stage. Because the focus is on the terminal <u>and</u> its access and

egress links, the focus includes both the terminal and portions of the network of the different transportation systems.

Performance Measure

A performance measure is strictly a measure of the efficiency of the transfer activity that takes place through a terminal. As is elaborated further in subsequent sections of this report, the purpose of performance measures of intermodal terminals is to allow comparison between different terminals (possibly between terminals offering transfers between different modes, or between terminals organized and laid out in different manners), and between an entirely unimodal path in the network and an intermodal path, e.g., as a means to assess whether the *costs* inevitably associated with a transfer between modes are offset by the decreased costs of the use of two or more modes in the line-haul movement. In short, the purpose of the measurement and related calculation of indicators is to support a qualitative judgment on the system's performance with implications for management decisions. It is expected to be an essential part of a so-called Decision Support System, in which decisions typically involve improvements in the case of low scores or, perhaps, no action (and satisfaction) in the case of high scores.

It can be argued that performance measures must, in the most general sense, be compiled as *ratios* of outputs to inputs, for example, vessel moves per gang hour. A measure such as vessel moves per year is a throughput measure, not a performance measure. Similarly, such characteristics of a port as the depth of the entrance channel, or the height of a bridge at the entrance to an intermodal yard are not indicators of performance. These are physical characteristics, which may indicate the potential for the terminal to be efficient (or deficient, if they are inadequate), but they do not measure actual use, and therefore are not measures of performance.

Performance Standards

In a similar way, performance standards can be defined as representing those levels of performance on each performance measure that are considered to represent certain levels of acceptability. The definition of highway levels of service in the Highway Capacity Manual (Transportation Research Board) provides a good example of this style of performance standard. Levels A through F define different standards by which the performance of a highway link can be assessed. It is important to note that there is no implied requirement that all highway links must perform at level-of-service A, but rather that different links in different places may be expected to operate at levels of service such as D or E at certain times of the day. Then, if such a link is found to be operating at LOS B, it is considered to be unnecessary to do anything about that link, and the transportation engineer is probably very satisfied. However, if such a link is operating at LOS F, decisions must be made on what steps can be taken (if any) to change performance to a more acceptable E or D.

The performance standards, then, flow directly from the definition of the performance measures, and represent certain levels of performance that serve to distinguish between significant ranges of performance that help to define the types of decisions that may be needed.

Design Standards and Operating Standards

The balance of what are often confused with performance measures and standards are actually design standards and operating standards. Measures of the physical characteristics of terminals, for example, are most often correctly defined as design standards. This will include bridge heights, channel depths, lengths of berths, widths of roadways, numbers of entrance gates, etc. The second type of terminal characteristic, such as the operating hours of a port, the number of stevedore gangs available, etc. are measures of the operations of the terminal. These measures result in the specification of operating standards that provide indicators of the ways in which the physical characteristics of a terminal are utilized through the definition of operating procedures and policies. In this connection, it is important to note that policies will generally not have a direct effect on the performance measures and standards, but will affect directly the design and operating standards. In fact, policies themselves are usually expressed in terms of either design measures or operating measures.

USES OF PERFORMANCE MEASURES AND STANDARDS

The primary purposes for developing performance measures and standards are to assist in the development and use of Intermodal Management Systems (IMS) and to provide part of the evaluation process that is needed within an Intermodal Transportation Plan. Performance measures and performance standards will be the main ingredients of the evaluation process for alternatives generated by the intermodal planning process. Each proposed measure must then be held up for examination against the potential of the measure to respond to alternatives in the planning process and to identify potential needs for action in the Intermodal Management System. If a measure that has been defined from the consideration of the movement of freight or passengers turns out to be one that is totally within the prerogative of the private-industry operator, and whose values should not be influenced by any action of a government entity, then such measure would be excluded from further consideration. Similarly, if a measure were found to be irrelevant to either an Intermodal Management System or to the evaluation process of intermodal planning, it would also be dropped from the final set of relevant performance measures and standards.

There are also likely to be several variables that will affect the setting of performance standards. These will include the nature of the commodity being shipped and the size and traffic patterns of the intermodal terminal. Other variables may also be defined as instrumental in defining different standards. For example, measures of cargo "sensitivity," such as time, temperature, toxicity, etc. would define different required standards, but not different performance measures.

Finally, it needs to be stated that there appears to be no reason why performance measures would vary by geographic location. Rather, performance measures should be consistent around the nation, although there may be reasons to establish different performance *standards* in different locations. Even then, most performance standards, given the variables noted in the preceding paragraph, should probably be the same across the nation, particularly when the focus is on the *transfer* activity.

APPROACH

In order to develop a set of performance measures for intermodal transfers, the structure of a transfer activity within an intermodal transfer terminal must first be defined clearly. The terminal and its functions must be understood clearly. Second, an exhaustive list of the types of intermodal transfer terminals to which performance measures would apply must be developed, so that there is a clear understanding of what takes place in an intermodal transfer between various modal pairs and in various contexts. Third, the performance measures should be defined from the customer's point of view and should be based on how a seamless intermodal transportation system would be expected to work in ideal circumstances. They should provide measures that would show the extent to which the system does or does not operate seamlessly. Fourth, the measures should be defined based on as broad a set of considerations of the operation of a transfer terminal as possible, so that they would not be based on current issues and problems alone, thereby restricting the performance measures to being reactive to current problems. Rather, a broad-based set of performance measures is required that will support reshaping of the intermodal system in the future, that will be responsive to issues that may arise in the future, and that will allow proactive strategies and policies to be identified and developed. Fifth, there needs to be a reality check of the performance measures against the issues and opportunities that exist in the intermodal system for public sector action and influence. Any proposed performance measures that are not within the sphere of influence of public sector policy or investment should be discarded. Similarly, this step should consider how the performance measures would be used, either in the intermodal plan evaluation or in an intermodal management system. Each proposed measure must be held up for examination against the potential of the measure to respond to alternatives in the planning process and to identify potential needs for action in the Intermodal Management System. If a measure is found to be irrelevant to such processes, then it should again be discarded from the final set.

The sixth step involves the assessment of the data requirements of each performance measure. Performance measures yet remaining in the candidate set following the fourth and fifth steps above, may not be feasible to measure. This, the measurement assessment step must determine whether or not measurement of this performance measure is achievable, whether modification is required to the performance measure in order for it to become achievable, or if it cannot be modified appropriately and therefore is unmeasurable. Included in this step should be an assessment of the cost of obtaining the data on the measure, the reliability of such data, and the precision with which it can be collected. Thus, there are four potential reasons that this step might exclude a measure:

- The measure is not available (measurable)
- The measure would be too expensive to collect
- The measure would be too unreliable to collect
- The measure would be too imprecise to show appropriate changes

At the end of this process, there should exist a parsimonious set of performance measures that are relevant and potentially useful for both an IMS and evaluation of intermodal plans and strategies.

TERMINAL COMPONENTS

A terminal is composed of a number of distinct elements. These elements link the terminal to the line-haul portions of the network for a consignment that moves through the terminal. Figure 1 provides a diagrammatic representation of the elements within a terminal. The "long links" represent the line-haul portion of the network, and could be any of the available modes, such as truck, barge, ocean-going ship, rail, etc. The "short links" represent the access and egress components of the network providing access into and egress out of the terminal. For example, the long link might be the interstate highway system for highway-based movements, while the short link is a local access roadway into the terminal. Although the short link has often not been considered to be part of the terminal, it is proposed here that it should be considered part of the terminal, because it possesses characteristics that can limit the operation of the terminal. For example, on the ocean, the long link may be the shipping lanes connecting one port to another, while the short link would be the movement from (or to) the shipping lane, where the vessel would normally be under the command of a pilot. Terminals may be one mode to one mode, many modes to one mode, one mode to many modes, and many modes to many modes. The additional arrows in the figure indicate that other modes could be present. Each mode has its own short links and its own entrance and exit gates.

The gate represents that portion of the terminal where entrance is gained to the terminal or exit is made from the terminal. The gate will usually involve some exchange of paperwork between each vehicle or consignment passing through the gate, and the terminal operators. Once through the entrance gate, the transfer terminal is now accessed. The transfer terminal may involve a number of operations. Most simply, it will involve off-loading the consignment from one vehicle and on-loading it to the next. In many cases, this will also require temporary storage, for example to await the arrival of the outgoing vehicle.

If storage is for the long term, e.g., in a grain silo, this is no longer considered to meet the definition of a transfer terminal. Rather, when long-term storage occurs, the terminal becomes the destination of the movement and should not be considered to be a transfer operation. Then, the next movement, from the long-term storage location, becomes the origin of the next movement of the consignment. Typically, the storage in a transfer terminal will be in transit sheds, rather than in a warehouse, silo, or other such long-term storage location. In certain instances, and for certain commodities, storage may be outside, with or without some type of protective covering against the elements. Clearly, the temporary stacking of containers

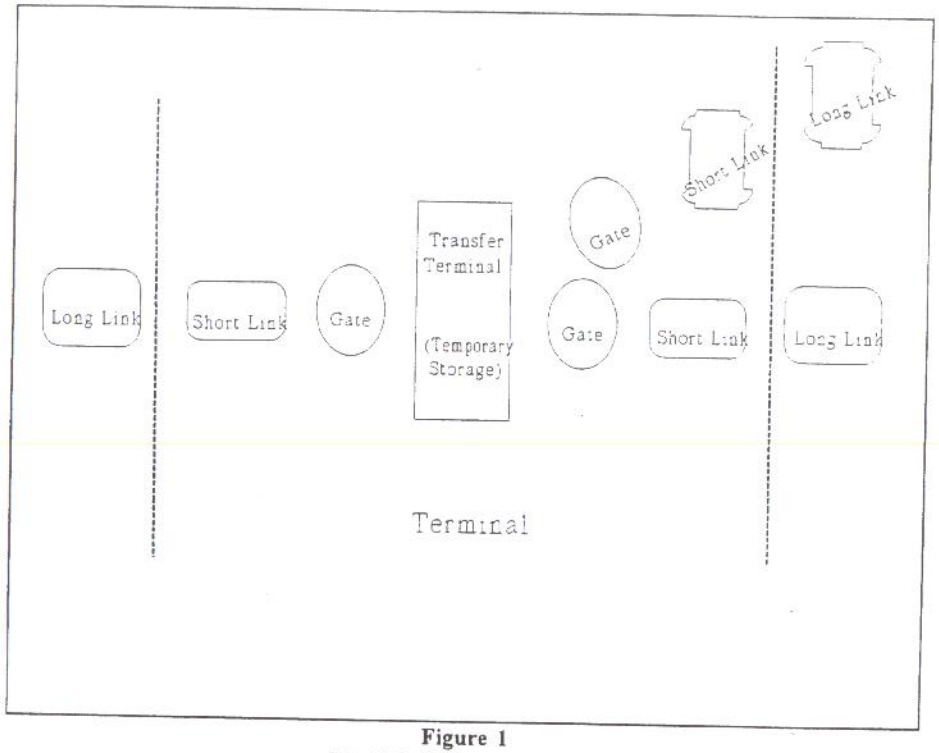

Figure 1
The "Exploded" Terminal

delivered by one vehicle and awaiting consignment onto the next vehicle would meet the definition of the transfer terminal's short-term storage.

Once the loading onto the next vehicle has taken place, the consignment moves through the appropriate exit gate and onto the short link that provides access from the transfer terminal to the line-haul network.

The above paradigm applies equally well to a passenger transfer terminal. For example, an airport can be considered to be a transfer terminal, providing many-to-one and one-to-many transfers, depending on the direction of movement (to the airplane or from the airplane). The long link for a movement to the airplane might be provided by the local freeway and arterial street system in the city where the airport is located. The short link is the airport access roadway into the terminal area. The first gate is the ticket counter or gate check in, where the passenger presents documents that indicate the travel to be undertaken and how it is being paid for. Temporary storage takes place in the gate area, while the passenger awaits the boarding

announcement. The exit gate is the departure gate for the flight, while the short link for egress from the airport is the taxiways and runway that provide access for the aircraft to the airways.

The importance of this concept of the terminal is that each of these elements of the transfer terminal — the short links, gates, and transfer terminal itself — have certain performance attributes and will be subject to the definition of performance measures and standards that are unlike those of any of the other elements of the terminal. Therefore, to develop a useful set of performance measures and standards, it is essential that each of these elements of the terminal is identified and its function understood, so that appropriate performance measures can be developed for it. In order to describe the terminal in this exploded structure, there are two primary elements that must be included:

- Physical components
- Activities

The variables affecting each of these elements must be enumerated and will help to identify the categories of performance measures.

A TYPOLOGY OF TERMINALS

Terminals can be identified on at least two dimensions: the modes operating on the long links on either side of the transfer terminal, and the types of commodities or passenger trips that can be accommodated. An initial typology, based on the modes operating into and out of the terminal, is offered herein. This typology of terminals does not include one-to-one terminals, such as those offering transfers between rail and rail or truck and truck only. However, note is made of where the terminals identified here may be used both for intermodal and unimodal transfers. Also, terminals operating inside the urban area and strictly for urban passenger trips are not included in the typology. Thus, park-and-ride lots, rail transit stations, and other similar facilities are intentionally excluded from the list, even though such terminals exist and are intermodal in nature. However, it is felt that these terminals are handled effectively by the metropolitan planning process and usually serve commuter trips primarily. Therefore, they should not be included in this methodology.

Passenger Terminal Types

Airports

Airports operate as many-to-one and one-to-many transfer terminals. The single mode on one side of the airport is air, while the other side of the terminal may include any or all of the following:

- Rail transit
- Bus/Shuttle transit

- Taxi/Limo
- Private Auto
  - Curbside
  - Parked
- Intercity bus

Intercity Rail/Commuter Rail Station

Like airports, intercity or commuter rail stations are also many-to-one and one-to-many transfer terminals. The single mode on one side of the station is intercity or commuter rail, while the other side of the terminal may include any or all of the following:

- Rail transit
- Bus/Shuttle transit
- Taxi/Limo
- Private Auto
  - Curbside
  - Parked
- Intercity bus

Intercity Bus Terminal

Also like airports, intercity bus terminals are also many-to-one and one-to-many transfer terminals. The single mode on one side of the terminal is intercity bus, while the other side of the terminal may include any or all of the following:

- Bus/Shuttle transit
- Taxi
- Private Auto
  - Curbside
  - Parked

Waterborne Terminal

Again, like airports, waterborne terminals are many-to-one and one-to-many transfer terminals. The single mode on one side of the terminal is commuter ferry, while the other side of the terminal may include any or all of the following:

- Rail transit
- Bus/Shuttle transit
- Taxi
- Private Auto
  - Curbside
  - Parked
- Intercity bus

Excluding terminals serving cruises of various types, which are not considered appropriate to include in this methodology, this covers all of the terminal types, except for the newly-emerging intermodal terminal. The intermodal terminal is therefore added here, although these are mainly in the developmental stages.

The Intermodal Passenger Terminal

The intermodal passenger terminal, as conceived so far, is a many-to-many terminal. To date, intermodal terminals have been conceived as ground transportation terminals, although often with a link to the airport, via a dedicated rail link. Movements through such a transfer terminal may provide linkages between any pair of modes, and also within-mode transfers. Therefore either side of the terminal may include any or all of the following:

- High-speed rail
- Commuter or other intercity rail
- Rail transit
- Bus/Shuttle transit
- Taxi/Limo
- Private Auto
  - Curbside
  - Parked
- Intercity bus

Typically, the airport connection for such a terminal would be provided by rail transit or by some form of high-speed or intercity rail service, depending on distance from the intermodal terminal to the airport.

Freight Terminal Types

The range of modes and types of freight terminals to date are much smaller than for passenger movements. The are primarily of the following types:

Airport

Airports function primarily as transfers between two alternative modes and for transfers within the air mode. The modes involved are simply:

- Air
- Truck

To date, airports with freight rail service are not known to exist in the U.S., although such developments may be possible in the future. Despite proximity to navigable water, there are also no known examples of airports including any type of waterborne freight transfer.

Rail Terminal

Like the airport, the rail terminal principally serves two modes, with rail-to-rail transfers being one of the possible types of movements that may take place in the terminal. The modes involved are:

- Rail
- Truck

Again, a richer variety of modes could be served, but there do not appear to be such terminals in operation in the U.S. currently.

Port

The water port is principally a few-to-many and many-to-few terminal. On the water side of the terminal, there may be two modes, comprising Deep Draft Vessels (ships) and Shallow Draft Vessels (barges). The modes on the other side of the transfer terminal are not restricted to land modes, because a port may be a point for transfer between river-going barges and ocean-going ships, and may, therefore, include any or all of the following:

- Rail
- Truck
- Pipeline
- Deep Draft Ships
- Shallow Draft Barges

Again, a richer variety of modes could be served, but there do not appear to be ports in operation that are co-located with an airport currently.

Pipeline Terminals

There are principally two types of pipeline terminal in present operation, and they represent a one-to-few and few-to-one transfer operation. So far, it does not appear that ant terminals exist that perform all of the functions described here. On the one side, the terminals comprise the pipeline, while the other side may be of one of the following two types:

- Land-based
  - Rail
  - Truck
- Land-Water
  - Deep draft ships
  - Shallow draft barges

Terminal Storage

The issue of storage within the terminal has already been alluded to. Freight stock and flow patterns within a terminal require that most consignments must be stored for some period of time, although the length of time may vary considerably. After unloading an ocean-going vessel, for example, storage may be required for a month or more before the next step in the movement takes place. This may also occur as consignments are consolidated for loading onto an ocean-going vessel, where consolidation may take place over many weeks. In these instances, the consignments may not be stored in transit sheds, but may be placed in warehouses. This raises the question as to whether the warehouse should be included as a "mode" in the above freight terminal definitions. This also raises the issue of whether or not there is a "gate" through which the consignment moves within the terminal, in order to be placed in the warehouse. Figure 2 shows the possible options that may occur within the transfer terminal itself.

Freight Typology

Although an exhaustive freight typing of terminals has not been undertaken, this section provides a beginning direction for the freight typology. First, five primary categories of freight consignment can be defined, as follows:

- Dry Bulk
- Liquid Bulk
- Neo-Bulk
- Break Bulk
- Containerized

The categories of dry bulk, liquid bulk, and containerized are in common use and require no additional explanation. The category of neo-bulk refers to large bulky objects that are not packaged for shipment. This might include large pieces of machinery, steel sheet in coils, vehicles, large pipe sections, etc. Break bulk refers to consignments in small packages, which may be transported together inside a contained or packed into a trailer for line-haul shipment, and are subsequently unloaded and consigned to multiple destinations.

Based on these definitions (which may not be exhaustive), the following typology by terminal can be suggested:

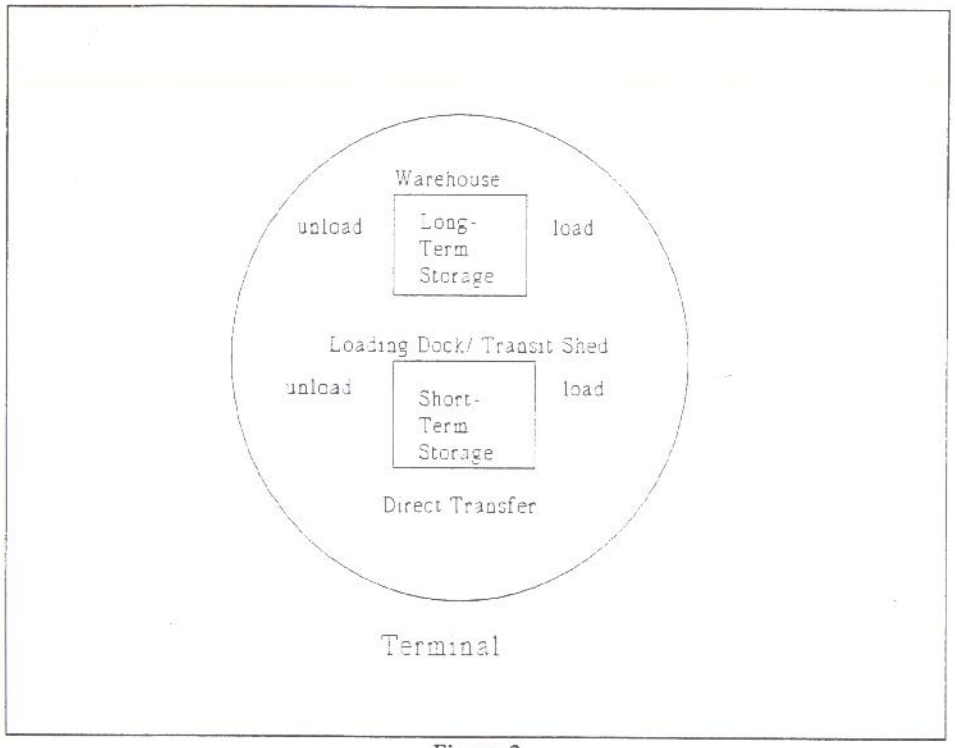

Figure 2

Options for Storage in the Transfer Terminal

- Airport: handles primarily
  - break bulk
  - limited neo-bulk
  - containerized (aircraft containers, not standard truck/rail/waterborne containers
- Rail Terminal: handles primarily
  - limited bulk liquid
  - dry bulk
  - neo-bulk
  - break bulk
  - containerized
- Port Terminal: handles primarily
  - dry bulk
  - neo-bulk
  - break bulk
  - containerized
- Pipeline Terminal: handles primarily
  - bulk liquid/gas

This provides a beginning point for the typology by type of freight and moves the process a step closer to the definition of appropriate performance measures.

NEXT STEPS

At this point, this process has defined the initial steps that must be undertaken, and has provided examples of the method that can be applied. The next steps are to refine and complete the definition of the functional breakdown of the terminal, review and complete the typology of terminals for freight and passenger movements, and complete the classification of terminals by type of consignment. Following this, it becomes possible to move into a detailed definition of performance measures, and subsequently, of performance standards, as outlined in the earlier section on Approach.

REFERENCES

De Monie, G., *Measuring and Evaluating Port Performance and Productivity*, UNCTAD, 1987.

Edwards, J. (editor), *Transportation Planning Handbook*, Institute of Transportation Engineers, Washington, D.C., 1992.

Intriligator, M., *Econometric Models, Techniques, and Applications*, Prentice Hall, 1978.

Louisiana Transportation Research Center and Louisiana Department of Transportation and Development, *Final Report on Defining Performance Measures for an Intermodal Management System*, Report to Federal Highway Administration, Washington, D.C., April 1994.

Norsworthy, J. and Jang, S., *Empirical Measurement and Analysis of Productivity and Technological Change*, North Holland Press, 1992.

Norman, M. and B. Stoker, *Data Envelopment Analysis*, John Wiley and Sons, 1991.

Land, A. and S. Powell, *Computer Programming for Data Development Analysis*, Operational Research Group, London School of Economics and Political Science, 1992.

Bookbinder, J. and W. Qu, "Comparing the Performance of Major American Railroads, *Transportation Research Forum*, 1993, Vol. 33, No. 1, pp. 70-85.

Transportation Research Board, *Highway Capacity Manual*, Transportation Research Board Special Report No. 209, Washington, D.C., 1985 (with revisions through May 1992).

Ashar, A., "Performance Indicators for Intermodal Freight Terminals." Working Paper, Louisiana State University, National Ports and Waterways Institute, Baton Rouge, LA, August 1993.

Roberts, Paul O., and Meyer, Michael D., "Highway Investment for Competitive Economies," Georgia Institute of Technology and TRANSMODE Consultants, Inc.

Louisiana Transportation Research Center, *op. cit.*

UNCTAD, *Port Development: A Handbook for Planners in Developing* Countries, Chapter VII: Performance Indicators, 1985; De Monde, G., *Measuring and Evaluating Port Performance and Productivity*, UNCTAD, 1987.

Ashar, A. "Productivity and Capacity of Container Terminals," *WWS/Worldwide Shipping*, October/November 1985, pp. 73-76.

Rijsenbrij, J., "Productivity at Selected Foreign Marine Terminals," *Improving Productivity of U.S. Marine Container Terminals*, Marine Board of the National Research Council, 1986.

Dowed, T., *Container Terminal Productivity: A Perspective*, Port Management Series, University of Washington, 1989.

Transportation Research Board, *Highway Capacity Manual*, Transportation Research Board Special Report No. 209, Washington, D.C., 1985 (with revisions through May 1992).

ENDNOTES

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1. Some researchers suggest including only the value added instead of the entire output, to trace the controllable production activity better.

2. Another solution, not discussed here, is to employ an algorithm based on Expert Systems (such as Expert Choice or the Heuristic Matrix), which are based on extrapolation of two-at-a-time comparisons made by experts (operators or users).

3. Each DMU is expressed as a linear combination of the other DMUs. The Linear Programming formulation seeks to either maximize outputs for given (constrained) inputs in its primal form; or minimize inputs for given outputs in its dual form. The actual LP formulation is devised to minimize the excess input and surplus output of the participating DMUs.

4. If the profile of the flows is the same, there is no need for stock at all. This could theoretically be the case if the intermodal yard serves single cars, each carrying one trailer which, upon arrival at the terminal, would roll down and ride straight into the road system, with no delay.

5. User costs usually combine charges against cargo, the vessel, and the opportunity cost for vessel time. An even more comprehensive cost would incorporate the costs incurred by both users and service providers to arrive at the overall, system cost. Minimizing this cost is, presumably, the goal of the port planner (in the case of a public port).

6. The relationship between cost and productivity is the subject of: "That the key to increasing productivity is whether someone is willing to pay for it." See: Thomas J. Dowed, "Productivity Standards — Fact or Fiction," Institute for Marine Studies, University of Washington, 1990.