MODELING INTERMODAL TRANSPORTATION SYSTEMS: ESTABLISHING A COMMON LANGUAGE

by

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I. Introduction

"It is the policy of the United States Government to encourage and promote development of a national intermodal transportation system in the United States to move people and goods in an energy efficient ma

The lack of common terminology arose from the lack of coordination that characterized the development and persists in the operation of the current transportation system. Each of the principal transportation modes uses an independent terminology, which militates against integrated computer models. While the independent terminologies are based in history, they confuse model developers and users in the context of an intermodal future.

According to Barnhart et al. [4], a common terminology base will ease the communication among the different entities involved in intermodal transportation and its study. This term basic to any understanding of the U.S. transportation system.

Each mode developed independently and even now a separate government agency administers each mode. This independent evolution meant a lack of coordination among the modes that still limits the efficiency of the national transportation system. The independence and lack of coordination underlie USDOT's recent emphasis on intermodal transportation and intermodalism. USDOT hopes that increased modal coordination and study will increase the efficiency and effectiveness of a transportation system [1].

Intermodalism "refers to a transportation system in which the individual modes work together or within their own niches to provide the user with the best choices of service, and in which the consequences on all modes of policies for a single mode are considered" [2]. The potential benefits of an intermodal transportation system include reduced fuel consumption, air pollution, and traffic; increased access to infrastructure through better coordination of bus, rail, and air schedules; and reduced pressure on infrastructure. To help achieve these ends, mathematical modelers will attack systems analysis and design problems like vehicle scheduling, material handling, passenger movement and queuing, resource allocation, inventory control, and maintenance planning. These types of problems exist in other industries and have been successfully addressed using computer simulation, queuing analysis, mathematical programming, probabilistic analysis, graphical analysis, and other approaches.

III. Mathematical Modeling of Intermodal Transportation: A Short Literature Review

The literature on modeling intermodal transportation emphasizes facilities over networks, and although it includes both freight and passenger intermodal facilities, the language, input requirements, and outputs of the models differ greatly even within these categories.

Ship terminal models dominate the intermodal freight literature, with work by Kondratowicz [5], Holguin-Veras and Jara-Diaz [9], Kraman et al. [10], and Park and Noh [12]. Kondratowicz [5] simulated a ship-to-rail intermodal freight terminal using a knowledge base and a set of algorithms. The knowledge base consisted of the physical elements of the terminal and the terminal operations processes–specifics about the loading and unloading of equipment, the type of vessels arriving to the terminal, the storage facilities, the type of cargo being handled, and the interactions among these elements. Kondratowicz defined the vehicle, its arrival frequency and time of first arrival, its economic cost, and its required operations. He described processes by the type of cargo transfer (storage to vehicle, vehicle to vehicle, etc), the type of cargo, a process efficiency measure, and the terminal elements required to carry out the process.

Ward [8] simulated a dockside container intermodal terminal using three sub-models

Holguin-Veras and Jara-Diaz [9] presented a linear programm personal vehicle, taxi, regional and local bus, courtesy vehicle, rail rapid transit, commuter rail, and high speed rail. The simulation represented segments or passenger interaction areas: waiting lines and areas, corridors, entry/exit areas, open spaces, concessions, restrooms, baggage claim areas, ticketing areas, bus and train platforms, taxi stands, etc. The model delivered information on passenger activity on the bus and train platforms, such as boarding and de-boarding rates and percent occupancies, in up-to-the-minute form or in a complete history of the simulation. The model also gave the average segment time for a passenger, flow rate in/out of a segment, queue lengths and waiting times for service segments, and occupancies in restroom and concession areas, demand for services and total terminal occupancy.

DiFebbraro et al [7] simulated an intermodal passenger transportation system. The model provided passengers on-line, real-time information concerning the status of the system. The system modeled three modes of transportation: buses, underground rail, and above-ground rail. The model defined nodes, macronodes, links, inner links, and events. Nodes represent a station that serves a mode of transportation. Macronodes represent a combination of nodes. Links represent the paths over which a mode of transportation can travel. Inner links refer to the path taken by a passenger to transfer between two nodes within a macronode. Events are defined as anything that may cause a change in the system. They can represent normal traff04194 Tm7 Tm590 0 12 0 and operator costs. The intermodal network consists of auto, auto-to-rail, and pure (walk to rail) rail m implementation of the system will be complicated. Bragdon [15] defines intermodal transportation to be "the safe and efficient integrated movement of people, goods, and information involving air, land, and sea in a four dimensional virtual environment." DiFebbraro et al [8] define it to be "the serial use of different modes of transport to move passengers and/or freight from one place to another." The United States Department of Transportation [16] defines it as "the convenient, rapid, efficient, and safe transfer of people or goods from one mode to another (including end-point pick-up and delivery) during a single journey to provide the highest quality and most comprehensive transportation service for its cost." These definitions cover the broad spectrum of transportation, but some definitions are limited to specific issues in transportation. Jennings and Holcomb [17] argued that these definitions apply "to containers designed and used to move goods via different modes of transportation."

In this research, intermodal transportation is defined in an attempt to incorporate all modes of transportation. Intermodal transportation is the shipment of cargo and the movement of people involving more than one mode of transportation during a single, seamless journey. An intermodal transportation system domain of operations research. Operations research can be defined as the "professional discipline that deals with the application of scientific methods of decision making, especially the allocation of resources" [3]. The primary activity in an operations research study is the formulation of a mathematical model of a system.

A system is a collection of items that act together toward the accomplishment of some end. The system is the study of the subject of interest, and the focus of this study helps to determine the system boundaries. For example, if the system in question is the operation of an airport terminal, the boundaries will be the walls of the terminal. If the system in question is the operation of a service area within the terminal (ticketing, security, baggage, etc.), the boundaries will be drawn around the area that includes the service activities (the queue area, the service center, and the servers). A model is a simplified representation of a system. There are three basic types of models: iconic, analog, and symbolic. Iconic models are scale models, and analog models use different systems with similar behavior to model the system of interest. Symbolic models are based on the logical relationships that drive system behavior. Symbolic models are often referred to as mathematical models.

A mathematical model of a system describes system behavior using only equations and logical relationships. Types of mathematical models include probabilistic models, mathematical programming models, and simulation models. In addition to the functional and logical relationships that describe system behavior, mathematical models include several other components. Decision variables are the quantities over which the decision-maker (or system manager) has control. Parameters are values over which the decision-maker has no control.

The following transportation terms are needed to complete the terminology base for modeling intermodal transportation systems. The terms in this section are essential for modeling intermodal transportation systems.

Cargo

Cargo is any commodity being transported [2]. Cargo may be handled loosely and unpacked, or it may be consolidated and loaded into containers or handled with pallets. A container is a structure into which cargo is packed. The container, therefore, may serve as the transfer unit rather than the cargo contained therein [2]. A pallet is a platform, with or without sides, on which a number of packages or pieces may be loaded to facilitate handling by a lift vehicle [2].

Passengers

A passenger is defined as a person being transported. As passengers are transported across the transportation system, some are associated with passenger cargo. Baggage is defined as the trunks, bags, luggage, etc. of a traveler, especially when packed and being used on a trip. [18]

Movement

A movement is defined as the process of transporting passengers and/or cargo from one point to another. A movement may represent a train moving along a rail line, an airplane moving through an airway, a passenger walking through a concourse, a container being moved from a ship to a chassis, etc.

Vehicles

A vehicle is any equipment used for transporting passengers and/or cargo from one location to another. Each of the different modes of transportation involves a different type of vehicle. An aircraft is a vehicle used for traveling through the air. A vessel is a vehicle used for traveling via water. A train is a vehicle used for traveling over a rail line. An automobile is a vehicle used for traveling over a road. Some types of vehicles involve a separate power source from the passenger/cargo hold. Power transports are vehicles in which the power source and the passenger and/or cargo hold are comprised by one unit. Unpowered transports are vehicles that require an external power source. Transport power sources are vehicles used to push or pull unpowered transports. A towboat is a transport power source for water transportation. A barge is an unpowered transport for water transportation. A locomotive is a transport power source for rail transportation. A railcar is an unpowered transport for rail transportation. Some railcars are power transports. Examples of these types of railcars are subway cars propelled by an electrical current. A tractor is a transport power source used for road transportation. Both chassis and trailers are unpowered transports used for road transportation. Chassis are coupled with containers to accommodate transport. Trailers have the cargo hold and wheel frame permanently

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Terminals

A terminal is any location within an intermodal transportation system where cargo and/or passengers originate, terminate, or are handled in the transportation process [2]. Terminals include facilities that accommodate a wide range of terminal processes (ticketing, inspection, maintenance, vanning/devanning, etc.) or simple loading/unloading processes (bus stops). Within terminals, a process is any activity that passengers and/or cargo may encounter. There are many different types of processes. An entrance represents the process of passengers and/or cargo arriving to the system boundaries. An exit represents the process of passengers and/or cargo leaving the system.

moved from chassis to flat car or vice versa. Load/unload represents the process of passengers and/or cargo being loaded onto and/or unloaded from a vehicle. A decision represents the process of selecting from the different routes available at the intersection and/or split of modal routes.

Infrastructure

The infrastructure of a terminal is comprised of the components and areas that accommodate the processes and movements within the terminal. There are infrastructure components related to each mode. A run encounter upon arriving to or departing from a terminal. A parking lot is a location where automobiles may be temporarily placed into storage. A warehouse is a place for the reception, delivery, consolidation, distribution, and storage of cargo [2]. Ground storage areas are places where cargo and/or containers are placed in storage, without shelter.

Material Handling Equipment

Material handling equipment represents vehicles used for cargo movement within a terminal. A conveyor is a moving belt upon which material may be placed for movement. The movement of the belt may be continuous or may be controlled by an operator. A crane is machine for lifting or moving heavy weights by m conveying people to different levels [18]. Elevators may also be used to move cargo to different levels. An escalator is a power-driven set of stairs arranged like an endless belt that ascend or descend continuously [18]. A moving sidewalk is a continuous moving, power-driven belt upon which passengers are moved. Moving sidewalks are located within walking corridors and provide an alternative to walking. People movers are power-driven vehicles that follow a defined path (usually rail) in moving passengers from one point within a terminal to another. Carts (golf carts, wheelchairs, etc.) are wheeled vehicles that provide transport for passengers unable to walk under their own power.

Personnel

An operator is a person who controls the use of any vehicle or material or passenger handling equipment. An operating crew is the group of operators required to operate a transportation vehicle. Examples of operators are airplane pilots, train engineers, truck drivers, and crane operators. A server is a person who provides the service required for a service or wait process. Examples of servers are ticketing agents, security officers, and baggage handlers.

Miscellaneous Equipment

Miscellaneous Equipment refers to all other resources beyond vehicles, material handling equipment, and passenger handling equipment that are necessary for passengers and/or cargo to complete some process. Examples of equipment are computers, maintenance tools, and fuel trucks.

Procedures and Policies

Procedures and policies are sets of rules or procedures that govern the behavior of an intermodal transportation system. Examples of procedures and/or policies are traffic regulations, hazardous materials legislation, flight schedules, and maintenance plans.

Disruptions

Disruptions are stochastic events that disrupt the normal operations of an intermodal transportation system. Examples of disruptions are weather events, equipment failures, and vehicle accidents.

IV. Conclusions

While the ultimate goal of defining a language that is broadly accepted by analysts and the intermodal industry will be difficult to achieve, the terminology base presented in this paper covers a majority of the elements and activity involved in the operation of intermodal transportation systems and provides a foundation for building models of such systems. Undoubtedly, future research will reveal additional terminology and refinements to facilitate the modeling and analysis of intermodal systems. However, an efficient national intermodal transportation system will not be realized unless real problems are defined, models of these problems are constructed, and analysis of model outputs are used to identify and implement the most efficient solutions. The terminology base presented in this paper establishes a common language from which analysts can begin this important endeavor.

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