Some Aspects of Domain Specific Conceptual Modeling for Simulation of Logistic Terminal Operations

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***Abstract*— When simulation modeling is used for performance improvement studies of complex systems such as transport terminals, domain specific conceptual modeling constructs could be used by modelers to create structured models. A two stage procedure which includes identification of the problem characteristics/cluster - 'knowledge acquisition' and identification of standard models for the problem cluster – 'model abstraction' was found to be effective in creating structured models when applied to certain logistic terminal systems. In this paper we discuss some methods and examples related the knowledge acquisition and model abstraction stages for the development of three different types of model categories of terminal systems.**

***Index Terms*— Domain Specific Conceptual Modeling, Model Classification, Logistic Terminal Systems**

I. INTRODUCTION

Ever increasing traffic of goods and passengers elsewhere has necessitated improvement of infrastructure and capacity in transportation terminal systems. An option to meet this huge demand is to expand the infrastructure; however, there are practical limitations of funding and space in such a strategy particularly for transportation systems. When it is not possible to continue expanding capacity in terms of space and facilities, then terminal managements have to think in terms of improving quality of service within the available infrastructure. Decision making in both cases above can be aided by the use of suitable mathematical or heuristics modeling approaches. Simulation modeling is a powerful quantitative tool when used for the design and performance improvement of logistic terminal systems.

This paper is intended to look into some aspects of the simulation modeling requirements and conceptual modeling related to logistic terminal systems. One of the issues related to the performance improvement studies of different terminal systems is the need for developing and using many different models of the same terminal system for solving its problems. Structured models could be developed by following Robinson's[1] two step process for domain specific conceptual modeling(DSCM) i.e. knowledge acquisition and model abstraction. In the paper we discuss a slightly modified approach to create categories of models related to three different terminal systems and discuss how these models are useful for hierarchical decisions either for performance improvement of existing systems or for the design of new systems.

We give a short introduction to conceptual modeling in the next section. DSCM concepts are introduced in section 3 Logistics and logistics decisions and operative requirements of modeling terminal systems are discussed in section 4. DSCM applied to terminal systems is described in section 5. In section 6 we briefly highlight an example of using DSCM for problem solving related an airport.

II. CONCEPTUAL MODELING

Conceptual modeling is considered to be an important step in the process of developing and using simulation models. Conceptual modeling involves abstraction of a model from a real or proposed system to a conceptual model, so that the resulting conceptual model forms the basis for the computer model to be developed. Robinson [2] defined a conceptual model as "non-software specific description of the simulation model that is to be developed, describing the objectives, inputs, outputs, content, assumptions and simplifications of the model". According to [3] the overall aim of conceptual modeling is to choose the model that will give the best outcome for the project.

Robinson [4]-[5] mentions that conceptual models consist of components that can be grouped into a problem domain and a model domain. The problem domain is closely related to the problem structuring activity. It includes the specification of objectives, outputs, inputs, model content, assumptions and simplifications. Some authors have discussed at length about problem structuring process during conceptual modeling and the linkage of this process to the model domain (see [6], [7] and [8]).

III. DOMAIN SPECIFIC CONCEPTUAL MODELING (DSCM)

Robinson [1] presents conceptual modeling as a set of artifacts between which information flows. In terms of conceptual modeling the key artifacts are:

The real world: the current or future system within which the problem situation resides.

System description: a description of the problem situation and the system in which the problem situation resides.

Conceptual model: 'the conceptual model is a non-software specific description of the computer simulation model (that will be, is or has been developed), describing the objectives, inputs, outputs, content, assumptions and simplifications of the model' [4].

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Apparently the system description and the conceptual model are not the same. The system description put together all information known about the system and hence belongs to the problem domain and it is almost certainly incomplete information. A process of knowledge acquisition extracts the information contained in the system description, during which a series of assumptions are likely to be made. The less that is known about the real system, the greater is the need to make assumptions. The conceptual model is a sub-set of the system description and expresses the content of the model and it belongs to the model domain. Again some process of model abstraction or simplification is required to obtain the information contained in the conceptual. Higher orders of abstraction imply that a greater number of simplifications have been made. It should be noted that whilst the system description and the conceptual model exist for every simulation study, they may not always be formally or explicitly expressed [4].

The description of conceptual modeling given above to all intents and purposes concentrates on generic concepts that could be applied to any modeling context. Our interest here, however, is on domain specific conceptual modeling (DSCM). As such, we wish to apply these concepts to a specific context. This should enable predefined constructs, specific to the context, to be developed and integrated into the conceptual modeling process. The aim, of course, is to enable appropriate conceptual models to be developed more quickly and more easily.

A. *The need for DSCM and hence DSCM Repositories*

According to Balci et al [9] model reuse has been very difficult or in some cases impossible in the Modeling and Simulation (M&S) discipline. They describe how reuse can be accomplished by using a conceptual model (CM) in a community of interest (COI). M&S is commonly employed and reuse is critically needed by many COIs such as air traffic control, automobile manufacturing, ballistic missile defense, business process reengineering, supply chain management, telecommunications, and transportation.

Through communities of interest (COI) built around specific problem domains, subject matter experts would develop ‘conceptual models’. Here a conceptual model is ‘a repository containing high-level conceptual constructs and knowledge for a particular COI’ [9]. We think the term community of interest (COI) is a bit confusing, as simulation as such could be applied only to specific problems or problem domains. Hence we prefer to use the term domain specific conceptual modeling (DSCM) rather COI. Literature is almost sparse on DSCM and hence there is a need for developing methodologies related to DSCM applicable in various problem domains. We develop this theme by describing conceptual model constructs for a specific problem domain, that of logistic terminal operations. A two stage process of knowledge acquisition related to problems, and problem domain and model abstraction is explained. In the next section some basics of logistic terminal operations are discussed.

IV. LOGISTICS TERMINAL OPERATIONS

A. *Logistics systems*

Logistics is concerned with the organization, movement and storage of material and people. A logistics system is made up of a set of *facilities* linked by *transportation services* [10]. Facilities are sites where materials are processed, e.g. manufactured, packaged, stored, sorted, sold or consumed. They include manufacturing and assembly centres, warehouses, distribution centres(DCs), transshipment points, transportation terminals, retail outlets, mail sorting centres, garbage incinerators, dump sites, etc.

B. *Logistics terminals*

Logistics terminals are the nodes in transport networks between suppliers and customers; they bind together transport modes with different characteristics into a transport chain in order to meet the supplier’s and the customer’s demand for frequency and capacity in the flow.

Insufficiency of capacity of infrastructure, and unpredictability of arrival and service times (such as delay in train arrival, variability in train sizes, breakdowns, etc.), reduce the level of service. There are basically two ways to face this situation: either to improve operational methods to gain small improvement in the short term, and/or to invest in new facilities to create additional capacities in the long term. The later solution is usually much more expensive, so the analysis should begin by exhausting the former option. If the desired performance is not achieved, then the investment in new facilities should be considered.

C. *Modeling of logistic terminal systems*

Logistics is an area where simulation studies have been commonly used for problem solving. This is evident from the large number of contributed papers in the sessions on Logistics, Transportation & Distribution Applications of the Winter Simulation Conferences. Modelling of transport terminals like rail yards, container terminals, airports etc have been extensively discussed in literature. Since literature is vast on different types of terminal systems, we present here only selected literature on three important types of terminal systems i.e. railway terminals, container terminals, and airport terminals. Discussions on various aspects of rail terminal models are found in [11], [12], [13], [14] and [15]. A detailed discussion and literature review on application of simulation for strategic, operational and tactical aspects of terminal management can be obtained in [16], [17] and [18]. Recent reviews on airport modeling literature can be found in [19], [20] and [21].

D. *Operative requirements of modeling terminal systems*

In literature few discussions can be found on domain specifics simulations. Valentin and Verbraeck [22] defines the requirements for domain specific simulation environments as “the expectation from a domain specific simulation environment in its use and its ability to instantiate the model construct to represent particular systems”.

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A terminal must be planned to ensure an acceptable level of service to its customers in terms of waiting times and turnaround times, and for this terminal managements have to take decisions on many issues related to long term, medium term and short term planning. Terminal operation involves interactions, for example, many container terminals- or at least the ones interested in simulation- are operating with several cranes on several ships concurrently, and probably at the same time they complete import and export operation with trucks and freight trains [23]. The simulation requirements of terminal systems have become complex due to the variety of issues the modelers have to answer. Bruzzone et al [24] mentions that the potential users of simulations can be divided in two categories: large operators and new subjects (related to multimodal container terminals).

Most of the traditional simulation packages normally support just operative short term terminal planning considering each task as a standalone procedure; like providing analysis and estimation related to a ship unloading/loading without considering interactions with other ships at the quay. Bruzzone et al [25] notes that the operative constraints for simulation models in this sector are very difficult to be satisfied by creating large full-scope simulators; so the emerging approach is to develop many different models, or to re-adapt the existing ones, that will be able to interact in a more general common framework.

V. THE PROCESS FOR GENERATING A DSCM REPOSITORY FOR LOGISTIC TERMINAL SYSTEM MODELLING

In this section we detail a two stage process of developing a DSCM for logistic terminal systems. These steps are derived from our experience in developing simulation models of three different types of terminal systems [26]. These DSCM stages are

1. DSCM-Knowledge acquisition constructs: Identify problem types in the domain of interest
2. DSCM-Modeling constructs**:** Create a set of model abstractions

More details on these stages are given below

A. DSCM-Knowledge acquisition constructs

Development of the conceptual model constructs for a specific problem domain first requires knowledge about the nature of the problems that could be addressed within that domain. For logistic terminal operations we find it helpful to classify problems as being strategic, tactical or operational (Table 1).

The second level of knowledge required is about the nature of the domain itself. This was achieved through a series of workshops with subject matter experts in which brain storming was used to identify key facilities and entities in terminal systems. Table 2 shows above for the case of an airport terminal. From this it was then possible to identify three levels of facility or entity that can be found in the airport terminal context: fixed facilities, variable facilities and transient entities (see Table 3).

TABLE 1: EXAMPLES OF DECISION PROBLEMS IN AIRPORT TERMINALS

Decision level	**Decision Problems**
Strategic level	Effect of additional flights for runway capacity expansion
	Finding the number of parking bays
Tactical level	Finding the number of x-ray baggage machines required
	Estimation of maximum occupancy of an area to determine heating/ventilation system requirements
Operational level	Rearranging schedules/passenger reporting times to level peak load
	Deciding shift timings, preparing schedules

TABLE 2: EXAMPLES OF FACILITIES/ENTITIES AND THEIR ATTRIBUTES IN AN AIRPORT TERMINAL

Facilities/Entities	**Attribute**
Runway	Length Type Number Repair/maintenance Position
Parking bays	Type Number Position Repair/maintenance
Car Parking area	Number(Capacity) Position
X-ray baggage checking equipment	Number(Capacity) Type Position
Immigration Counters	Number Position
Baggage conveyors	Speed Number Position
Flights	Number Schedules
Baggage	Number Type
Passengers	Type Number Baggage

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TABLE 3: EXAMPLES OF FIXED/VARIABLE FACILITIES AND TRANSIENTS IN AIRPORT TERMINALS

Type of facility	Airport terminal
Fixed facilities	Runway Parking Bays Terminal Space
Variable facilities	X-ray machines Check-in counters Passport Control Immigration Control Gates
Transient entities(Flow items)	Passenger Flights Baggage

B. DSCM-Modeling constructs

The DSCM constructs structured in the first phase detailed above can be further expanded to modeling constructs (while still remaining in CM phase). A repository of knowledge about the nature of the problems and the nature of the domain for logistic terminal operations is developed above. This repository can then be used to aid the identification of the appropriate conceptual model when a modeler is faced with a specific modeling problem. This can be achieved by identifying the nature of the problem and then using this as a basis for choosing the level of granularity at which to model the various facilities. It may be noted that there can be several configurations of each type models depending upon the type of specific problem under study and the level of details that can be included. CM tools such as include/exclude technique [2] can be used at this stage. Table 4 shows sample case for a component in airport model. We have developed three types of models (named FFF, VFF and TEF) based on the modeling constructs described above.

Strategic Focus = Fixed Facility Focus (FFF) Model

The FFF Models were used to study problems of strategic nature; and when using such models for experimentation, all the entities i.e. fixed, variable and transient, were allowed to be changed in number.

Tactical Focus=Variable Facility Focus (VFF) Model

In VFF Models, some restrictions were imposed for changing number and position of fixed facilities and only variable and transient entities were allowed to be changed in its number for experimentation. This resulted in models that were useful for the study of tactical decisions, such as that of varying the number of variable facility and changes in flow routes.

Operational Focus = Transient Entity Focus (TEF) Models

The TEF models most accurately represented the actual system configuration and such models were used for studies related to changes in operational schedules.

TABLE 4: AN EXAMPLE OF INCLUDE/EXCLUDE TECHNIQUES

Facility/ Component	Characteristic	INCLUDE/EXCLUDE		
		FFF	**VFF**	**TEF**
Runway	Number	Include	Exclude	Exclude
	Repair/maintenance	Exclude	Exclude	Include

For the strategic decisions related to augmenting the fixed facilities, the tactical and operational issues resulting from corresponding changes in the configurations of the variable facilities and the time schedules of the transients needs to be addressed. Performance improvement of the existing system can be done by optimizing operational methods and schedules without changing fixed and variable facility configurations. But whenever the fixed and variable facility configurations require changes, the schedules of transient entities need to be reworked. FFF,VFF and TEF modeling constructs created during conceptual modeling are found to be useful in analyzing many actual problems mentioned in [27].

VI. CONCLUSIONS

This paper illustrates a useful framework for developing flexible simulations models solving different categories of problems in a problem domain. A two stage process for domain specific conceptual modeling (here for logistic terminals) i.e. knowledge acquisition constructs, domain knowledge constructs and model abstraction process is described in detail. Brainstorming combined with affinity diagrams are used to categorize problems and model elements; and CM tools such as include/exclude technique are used during conceptual modeling to develop three types of simulation models designated as Fixed Facility Focus models, Variable Facility Focus models and Transient Entity Focus models and mentioned how they are helpful to solve problems of strategic nature related to fixed facility, tactical issues related to variable facility and operational problems related to transients. Further research is required to extend the conceptual framework suggested for creating model categories to more cases in the field of Logistics and Manufacturing. It is also possible to find out and develop better tools for domain specific conceptual modeling.

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