More than just Piers: A multi-agent systems in defining organization in a seaport terminal management system

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Abstract

In Rudyard Kipling's novel, "As Easy as ABC" (1912), he may have been referring to seaports in his futuristic story about the year 2065 when the world's governing body, the Aerial Board of Control, invokes the motto that "Transportation is Civilisation". The theory behind the motto is that man can do as he pleases, so long as he does do not interfere with the traffic and all it implies. Today, modern seaport systems are experiencing the adverse effects from the growth of globalisation, i.e. large ships carrying thousands of containers, roadway and port congestion, physical bottlenecks, and increasing customer demands (supply chain, J-I-T). Thus, the "Sustainable Mobility" policy of the European Union is increasingly under sharp attack from many areas in freight transport. Perhaps, this is contributed by the complex dynamics of container logistics in seaports.

The seaports are the main nodes in transportation and logistics systems. Over 90% of the general cargo is shipped in containers that are loaded or unloaded at seaports. In turn, the containers are loaded or unloaded from other transportation modes, such as lorries, rail, and barge. The aim of this paper is to propose first, that seaports are an organisational system that has been traditional managed from traditional theories of systems thinking, and organizational theory. The seaport terminal systems are centrally managed in what are considered to be "virtual networks". The use of systems and networks as a metaphor has been used widely in scientific literature to describe the processes, activities, and relationships in ports and terminals.

Ludwig von Bertanlanffy observed that science is focused on finding order from the complexity in nature. The theory on systems is based on the problems of organisation in systems and that the most general science is the science of organisation, the basis for general systems theory. The society or community view of a port or terminal provides an additional abstraction that may yield a richer detail of the structures and provide insight to the incorporeal relationships between actors. Second, a seaport terminal community is a complex system that requires better understanding of the dynamic interactions that occur between the various entities in the system(s). In modelling and simulating a seaport terminal management system, a prototype based on multi-agent technology is currently being developed and the design of the conceptual model is presented. The seaport terminal management will simulate strategic and operational polices used in the coordination of seaport resources. The multi-agent paradigm has been successful in modelling other societies or communities in varying fields of scientific research.

Keyword: Seaports; Seaport Terminal Management; General System Theory; Complexity; Multi-Agent Systems

INTRODUCTION

Most of the literature on seaports, ports, container terminals and intermodal terminals has been focused on the optimising the objects and resources that handle the cargo and cater to the ships. The use of the metaphor of network and systems has been used to describe and explain the functions or the processes. The handling of containers has been traditionally thought through as networks. Where Ports are the nodes and the various transport means are the modes. In this paper we view ports, container terminals especially to be systems. A network can be defined as nothing more (or less) than a system (Casti 1995): Network= objects + connections=system Thus we deduct from the above statement and view the container system as: *S*ystem= objects + connections=network.

In first looking at a seaport it is deemed important that it interacts with other systems such as the hinterland system and the shipping system. The hinterland can be seen as the network of rail and roadways that connect the cargo centres to the seaport. The shipping system is either asynchronous system when referring to tramp ships or a synchronous when referring to liner shipping, i.e. container ships. The focus of the paper will be on container terminals and the managers that manage the system. The attempt to model and define the management organization and the members who make up the managing organization in a container terminal is seen as an important element to simulating a container terminal. Container shipping is considered to be a system, a group of interacting, interrelated, or interdependent elements forming a complex whole. Within this system of container shipping is the important node, known as a seaport or more specifically a container terminal. The management of container terminal systems is a decentralised, poorly structured, complex, and changeable problem domain. Ports and container terminals are demand driven by many customers, and users. To satisfy all actors is very difficult. Often actors have *conflicting* interests. Sometimes an actor can even become dominant and his demands can take excessive importance. Complex management problem to solve because performance is determined by a variety of inputs, outputs, actors, intrinsic characteristics and external influences. Therefore we propose that a MAS approach would offer port or terminal actors a suitable means of control, coordination, and management in the organisation of container terminal.

The use of multi agent systems (MAS) offers many possibilities in modelling and simulating systems, especially social systems. The concept of sociality in MAS has been proposed by (Panzarasa and Jennings (2001) in *'The Organization of Sociality: A Manifesto for a New Science of MAS'*, supplemented by traditional theories such as organizational theory, systems theory, and general systems theory. In synthesizing the various schools of thought on sociality and strengthening the model of MAS by using the tools provided by organization theory (Panzarasa and Jennings (2001), a MAS model of a management system can be developed. The use of multi agents assisting managers offers possibilities on efficient management of a seaport, more specifically a container terminal. Through grounding on the principles of general system theory and MAS, a computer management simulator of a container terminal is being developed. The use of the MAS management simulator will interact with a simulated model of a societal view of a container terminal in order to define what are proper strategies and policies and why. The results of the simulation would not yield an optimum policy solution, instead it would offer decision makers the ability to view the structure of a port system and the functions that the various actors in the container terminal community have under various "what if" analyses.

PROBLEMS IN THE ORGANISATION IN CONTAINER TERMINALS

Seaports and terminals have not kept with the pace that economic development has been growing. There exist many bottlenecks in terms of information and physical status or flow of the cargo. Information refers to the content of, and means and procedures for communication, inside the port as well with the external actors (EUROBORDER p13.) Congestion and increasing cargo dwell times is a common scene in many of the world's ports. The container terminal industry is redefining itself due to the previous borders between the port users and the port operators are beginning to blur and merge. There lacks high-level information system architecture with the freight systems. Competitive pressures, uncertainty about technology, and the sheer complexity of the industry holds development of an architecture and data interchange standards that define how and with whom information is shared back. The industry has relied on a patchwork of standards imposed (often ad hoc) by shippers, brokers, individual carriers, customs, etc. The result is "islands of information".

The first problem when one attempts to study or consider modelling a container terminal is that no two container terminals are alike. The various types of organisational structures have an important effect on how the work is organised and which organisation is to handle a specific task. Many seaports and container terminal operators have decided to develop technology in-house due to the problem in finding off-the-self solutions. This problem has in fact led many ports and container terminal operators to spawn–off software and consulting companies, i.e. HHLA (port of Hamburg), APEC (port of Antwerp), COSMOS (Hessenatie container operator), and Portnet (Port of Singapore), etc.

Container handling activities are shown to be dependent on related subsystems, i.e. the discharging of containers at a fast rate may lead to sub-optimal conditions for the stacking and positioning of containers in the yard. The managers involved are generally referred to as terminal managers, ship planners, yard planners, ship line agents, resource planners, and various third parties representing the cargo or ship. However, more importantly is the situation of the landside interface, if the customs procedures take time, than the dwell time for the container rises and will have an impact on the capacity of the terminal. For example, it may take 10 days for a container to depart from New York to Rotterdam, however if the Dutch customs require 5 days to customs clear the cargo, than the speed of physically shipping and handling the container has lead to no benefit to the system.

MAS BASED MANAGEMENT MODEL OF A CONTAINER TERMINAL

In most social science research, simplified representations of the phenomena are needed for better understanding. There exist three types of 'symbol system' that can be applied to representations: verbal, mathematical, and computer simulation (Ostrom, 1988). The logic for simulating is to better understand the domain, as in the case of a seaport and container terminal. The principal value of social simulation is for the development of theories than in prediction (Gilbert and Terna, 1999). The modelling of various agents in a system provides a unique method in solving problems from a decentralized or distributed structure. By dividing tasks according to the agents representing artefacts, objects, and people, this combination of agents forming a society would offer another means of finding a solution. Agents are often modelled as with human characteristics, for example the Belief-Desire-Intent architecture captures some of the characteristics of an individual. Following

In this paper, we consider the port terminal domain to be a complex system and difficult to be structured quantitatively. The fundamental properties of such complex systems according to (Gosh and Lee 2000, page 19: consist as follows:

1. Entity: characterized in the CT domain as resources, such as ship planners, yard planners, stevedore, and having consistent behaviour that does not deviate, i.e. yard planner will not change roles with ship planner.
2. Asynchronous behaviour of the entities: various entities on the CT, such as port captain, ship planners, and ship agents are encapsulated with unique behaviour described by functionality and timing.
3. Asynchronous interactions between the entities: not all the managers in the container terminal have the knowledge to execute a task, thus the sharing of information is necessary to carry out jobs,
4. Concurrent execution of the entities: simultaneous decisions are made by managers that have an effect in their subsystem which in turn has an effect on the "global" container terminal
5. Connectivity between the entities: the sharing of data, information amongst the managers and planners in the container terminal constitutes connectivity.

In (Skyttner 2001), he places emphasis that on focusing on problems of complexity, system thinking applied as system science offers a more robust means of modelling. The application of the systems approach in implementing a MAS is seen as a rational manner in order to look at the system from a top-down approach. The need to provide holistic thinking supports a holistic model of the container terminal, in that the subsystems of the system can be better explained when seen as a whole. The MAS based container terminal management model will provide a tool in simulating how the planners or managers make decisions and concurrently on the decisions affect other planners and managers in the system.

Multi-agent based simulation is one type of complexity system model that may prove useful. The model of the port community will utilise multi-agent technology, where software agents represent the physical stakeholders. By having more than one agent, the model becomes a multi-agent system, which leads to more complex issue, such as how are the agents to communicate or work together in order to fulfil task(s) or goal(s). The main characteristics of agents are autonomy, pro-activity, coordination, and communication. This approach allows for a distributed model and distribution of the processes and tasks that are carried out by agents. The use of MAS as a metaphor in container and/or intermodal terminals is valid and is supported by previous research. (Henesey, 2002). The result from the MABS may result in interesting behaviour or patterns that are interesting for analysis. This resulting or emerging behaviour of the various agents modelled at a micro level and than simulated on a macro level would facilitate in better understanding of the complex interactions of the modelled agents. There do exist other micro modelling simulating strategies, however these strategies only model the entity at the micro level only, where as MABS allows the entities to interact and allow researchers to observe the behaviour under complex conditions.

A CONTAINER TERMINAL SIMULATOR

During port visits we paid special attention to the management operations of the port, the processes and how decisions were made in order to carry out functions. The main function of a terminal can be explained as place where the flow of cargo moves through the terminal, ensures that the cargo all goes to the right places and that the cargo movements are handled in the most efficient manner. The initial hypothesis stated that information handling and knowledge are fragmented, thus leading to low productivity. The research at the port has produced results that are support to what was initially believed to be true.

In Figure 1, the four main subsystems/operations in a container terminal system are illustrated; (1) ship-to-shore, (2) transfer cycle, (3) storage, and (4) delivery/receipt. The two subsystems that are constantly plagued with congestion and bottlenecks are the (2) transfer cycle and the (4) delivery and receipt area (also known as the "gate").

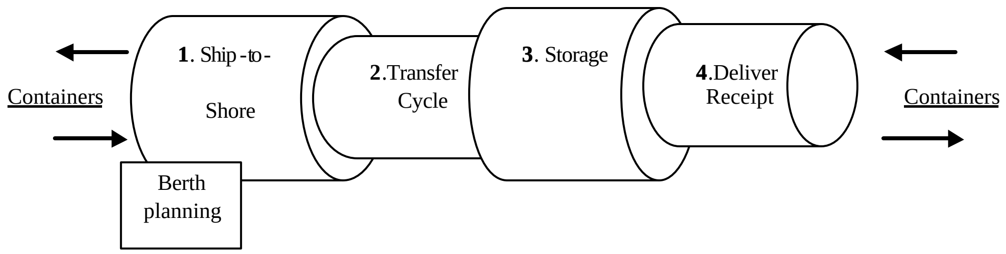

Figure 1 Container Terminal Diagram of Four Sub-systems

The decision to build a simulation prototype for domain experts in a container terminal presents many challenges. The choice of the 'soft' systems methodology has been motivated by (Checkland 1981), in that the methodology allows completely unexpected answers to emerge at later stages (Checkland 1981 page 191). Many in the MAS community have embraced the notion of 'emergence', where the interaction of two of more agents leads to an action that was not initially predicted or designed. In the MAS based container terminal, the decisions made by the various managers via interaction with other agents (communication, negotiation, and inferencing).

There exist various methods in modelling the management of an organisation. In modelling the container terminal management as an artificial closed society is viewed as robust notion when referring to the organisations structure. In (Davidsson 2001), the concept of closed agent society provides the advantage to possibly better engineer the society, e.g. which agent is to handle a certain task. According to (Davidsson 2001), the use of closed agent societies has been the major type of MAS developed in solving problems that are distributed between agents in MAS. The management in a container terminal can be viewed as a closed society containing four subsystems within the concept of an artificial society. The diagram of the MAS based container terminal is presented in figure 2 best describes the various subsystems found within the system. The managers of the container terminal simulator that inhabit the system are the ship planner, port captain, yard planner, and stevedore. They will make decisions that will have effects on the container terminal simulator and in turn these decisions will effect further decisions made by other managers. The tasks or roles of the various planners are listed below

?? *Ship planner's* main task is to correctly load and unload a ship. The planner may request equipment.

?? *Port Captain* is concerned with optimal allocation of fixed capital, such as the berth and cranes to the customer (ships and cargo).

?? *Yard planner* manages the physical stacks of cranes according to various policies.

?? *Stevedore* is focused on the physical handling and providing the service as demanded by the ship agent.

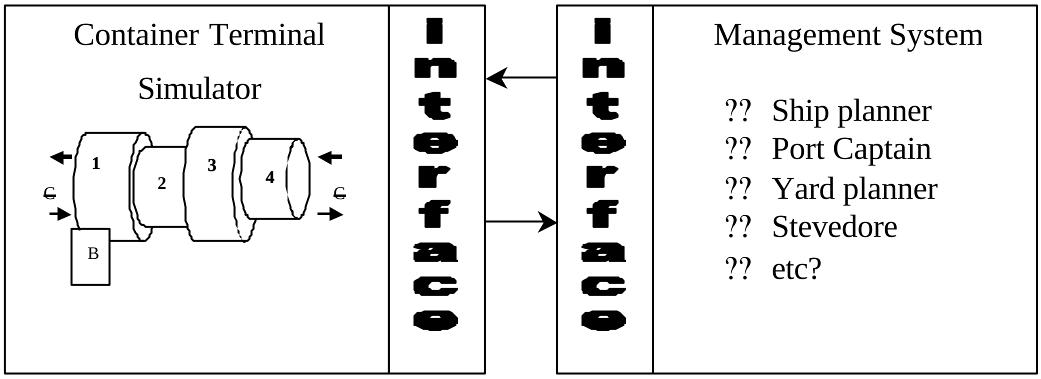

Figure 2. Diagram of the MAS based container terminal and management system

MAS-COMMONKADS

The modelling of the various managers that are employed in organising and managing the container terminal presents many problems in adequately representing the roles and tasks that each planner or manager takes in a work decision. The need to model the knowledge of the managers in the container terminal prompted the use of CommonKADS, a methodology in collecting knowledge in a series of structured work sheets. The choice in using CommonKADS was motivated by a previous work at Karlshamn Port in Southern Sweden. The models employed for the container management system are the organisation, agent, and the communication. The diagram in figure 3 provides a detailed structure of the CommonKADS.

Many methodologies exist in building a solid foundation for MAS; please see (Weiss 1999), for a short survey and description on formal frameworks for MAS analysis and design. In multi agent systems modelling, CommonKADS is used in designing agents. The CommonKADS is a European Community ESPRIT funded program. The development of knowledge based systems (KBS) and designing software to build such systems lead to a formal methodology known as Common-KADS. The Common KADS methodology incorporates models that assist in eliciting tacit knowledge. The models number seven and each model consists entities to be modelled and relationships between the entities. The models that have been used are the communication, agent, and organisation in Common-KADS. The need for a methodology, which assists in obtaining the systems requirements and specifications of MAS, has largely been influence by software engineering and AI. By using a formal approach to modelling, it allows the implementation of a system to be built more robustly. The major steps in developing an approach are

- viewing the system as a network or society defined by common rules, relationships and goal(s).
- assigning the agents to roles based on design criteria
- internal architectural design of the agents

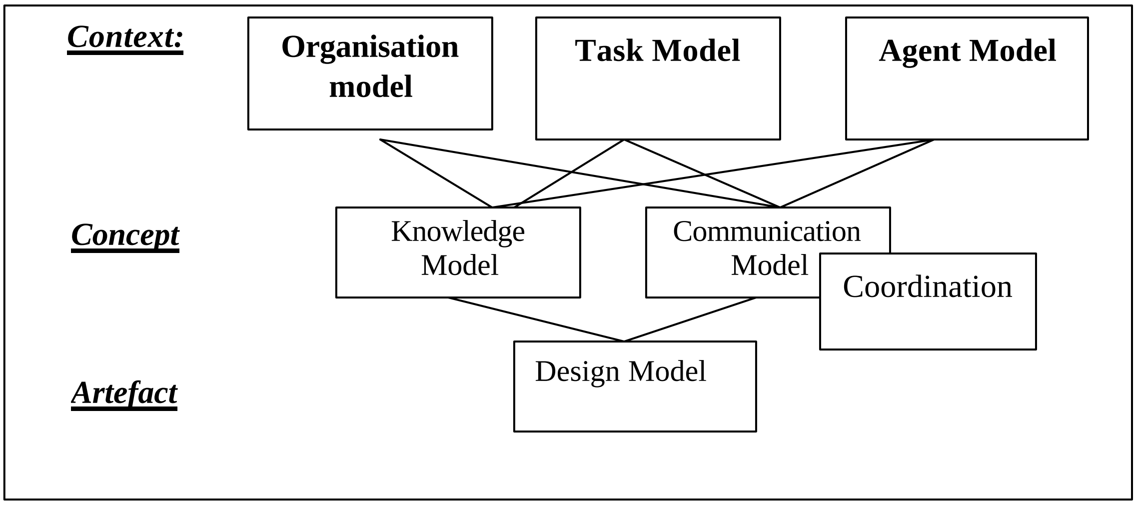

Figure 3. The CommonKADS model suite [Schreiber et al. p.18]

From the figure 3 the study of ports was based on a contextual basis. We wanted to understand the wider organisation and factors necessary for success in a knowledge system. The organisation model was the best tool and by filling-in the five worksheets we were able to generate some interesting results. The task model helped to identify any bottlenecks, and analyse the inputs and outputs for each individual task. The agent model worksheets and interviews, assisted in painting a clearer picture of the individuals working at the port and identifying their characteristics. The expertise held by some individuals (*managers/planners*) had a direct influence on the operation and function of the whole port.

The system requirements for building computer models of real world systems is achieved by using various methods, i.e. UML Unified Modelling Language or OMT Object Modelling Language. The building of a multi-agent system also requires the need to define the system requirements. An agent is defined as any entity – human or software – capable of carrying out an activity. The identification of agents was based on the use cases diagrams generated in the conceptualisation. Such identification could be augmented in the task model. Using the work sheets carries out the mapping of the physical actors with agents and templates found in the CommonKADS methodology. Agent based modelling of society has been used in assisting planners in policy development, one such example is Robert Bernard's work in modelling and simulating rent control (Bernard 1999). More detailed information on the agent research area can be found in (Geiss 1999).

DISCUSSION AND FUTURE WORK

Davidsson writes, "An emerging view of distributed software systems is that of information ecosystems. These are populated by info-habitants" (Davidsson, 200). The application of agents to help in defining the system as a multi-agent system or an artificial society provides a rich abstraction to model and simulate. Polices and strategies can be better understood. The container terminal simulator is being built and partially running, the prototype will be tested with real data. To test the simulator with the actual domain experts offers many tantalizing ideas. One possibility is that the knowledge of the domain experts could be captured and stored by the various agents. As a tool for training, e.g. many container terminals in Sweden are managed by planners who will be retiring in the next few years; the simulator could let young managers develop the experience and knowledge in order to successfully operate a container terminal. The building of the simulator has demanded hundreds of man-hours in ascertaining the rules, functions, and processes in order to develop a systems design of the area. The tools used by software engineers, such as Rational Rose® assisted in the design and building of the system, especially in modelling the managers.

CONCLUSION

Modern ports are no longer passive points of interface between sea and land transport, used by ships and cargo as the natural point of intermodal interchange. They have become logistic centres acting as 'nodal points' in a global transport system. The importance of seaports to the economic and social dimensions of a community, nation, or region is significant, if not great. Seaports have been modelled and managed according to the traditional theories of organizational theory and systems theory. The coordination of information and the physical flows of cargo in seaports has long been a problem due to the various parties involved (i.e. customs, freight forwarders, ship agents, stevedores, and port authorities). The managing of ports is quite complex and crucial to the efficient and effective operations that are increasingly demanded. It is in this decentralized problem solving area that gives rise to the idea or approach to the MAS approach to the shipping of containers, allows each agent to communicate through the array of networks and systems that make up the container terminal system. To date, the majority of scientific literature has been focused on port optimisation and efficiency. However, seaports are complex systems where various organizations and actors that can interact and be modelled as agents in MAS.

In developing a computer model of a container terminal in order to conduct simulation, the management of the system has been considered to be a part of the model via the use of multi agents in mapping the various planners and managers.

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