

Enemy at the gates: introduction of Multi-Agents in a terminal information community

L. Henesey & J Törnquist

*Department of Software Engineering and Computer Science
Blekinge Institute of Technology, Sweden*

Abstract

Container terminals in Europe play a significant role as nodes within logistics chains. The management of container transportation system is a decentralized, often poorly structured, complex, and changeable problem domain. Therefore we propose that a Multi-Agent System (MAS) approach would offer port and terminal actors (e.g. rail operators), a suitable means of control, coordination, and management in the container terminal domain. Ports, as nodes, accept and deliver freight from various modes of transport and offer services that add value to the freight. In order to plan the activities in the terminals, continuous and reliable information on the cargos' physical status (e.g. position, condition) is paramount to other activities. Integrating the information flows from the various transport providers and actors would improve the planning for the terminals and benefit planning and scheduling for the others in the chain. Through the introduction of "information society" to a logistics chain, transport providers and actors can improve individual performance and service by sharing information with each other. In the suggested MAS approach, the actors involved in the physical and information flows will be mapped with agents that will have the abilities to search, coordinate, communicate, and negotiate with other agents in order to complete their specified goal(s). Information society members could benefit from information sharing with the use of Multi-Agents, especially in cases of deviations or other kinds of problems. Knowing problems at an early stage can increase the ability to limit negative impacts. Thus, this approach may serve as the basis for a decision support system (DSS).

1 Introduction

There exist many bottlenecks in terms of information and flow of cargo in container terminals. Information refers to the content of, and means and procedures for communication, inside the port and information possessed by external actors [13]. Congestion and increasing cargo dwell times is a common scene in many of the world's ports as well as in the road and railway networks and at airports in Europe [5]. In order to avoid further bottlenecks, especially due to increasing road transports, the European Union has stated their aim of "turning intermodality into reality" [5]. This will be achieved by technical harmonization and interoperability between systems [5]. Intermodal transportation can be defined as "movement of goods in one and the same loading unit or vehicle that uses successively several modes of transport without handling of the goods themselves in changing modes" according to the definition of The European Conference of Ministers of Transport provided in [15]. In the White Paper [5], the EU policy of delimiting the predicted increase in road transport by increasing use of intermodal transportation, is intended to be achieved by shifting the balance between transport modes, i. e. substituting road transports with transports by short sea shipping, rail and inland waterway when possible [22]. An intermodal transports chain can be characterized by using railway and/or shipping for long distance transfer of goods between two points and road transport for collection and distribution of goods. In some relations this has been achieved by devoted intermodal corridors, but not to the same extent as expected. Not only transportation itself is important, but also the activities occurring in the transport chain, such as cross-docking. Intermodal transports are often joined with high costs in comparison with unimodal transports due to the need of terminal operations in the process of changing transport mode, and terminal operations constitute a large part of the total intermodal cost [3]. Another obstacle is the dependency on a large number of actors in the chain and the critical integration between them [11]. Integration can be, and is in this context, the need of sharing important information that may have an influence on the daily planning. This paper will focus on the importance of collaboration between different parties improving intermodal transportation, and in particular the rail-port interface since it affects the overall performance of the total transport chain. The paper will first briefly discuss the measurements and driving forces in transportation, then present a MAS approach for rail traffic, a container terminal and their interface. The MAS approach will be presented as an alternative method for improving the container terminal interface system.

2 Performance measures

The measurements of performance used in transport chains vary greatly as well as the definitions of performance [6]. However, one performance indicator often

used is accuracy in time of delivery (ToD). Through measuring the accuracy in ToD for different transport modes, the degree of reliability of the transport mode can be viewed. In this context reliability refers to trustworthiness, i. e. if the requirements of a transport are fulfilled to a certain established level. Reliability is one of the key factors when choosing transport mode as well as lead-time and price [17]. In the final report of the project *Intermodal Quality* (IQ) [3] the decisive factors in the modal choice between intermodal and road transports are addressed. The project has identified that first price is determinant and second the match to the individual logistics requirements, closely followed by degree of flexibility. However, as stated in the same report, there are relations between quality and price, which together determine the attractiveness of a specific transport mode or combination of transport modes.

3 Intermodal transport

There are socio-environmental impacts that affect transportation to a varying extent such as the surrounding traffic flow. The sensitivity differs between the four basic kinds of transport modes; road, rail, sea and air. Sensitivity refers to how much of an impact the surrounding traffic has on the transport mode. The infrastructure, for instance, used in railway transportation is limited which make it more dependant of the surrounding traffic, while road transports are not affected to the same extent. The varying complexity in different unimodal transports is thus obvious. Combinations of transport modes are even more complex due to the additional critical integration on different levels (e.g. documentation, information, required facilities). As illustrated in figure 1., a transport chain consists of four main layers. The illustration is a result from reviews of related beliefs such as the five-layer model of a road transport presented in [7] and empirical studies in the field. The figure is hierarchical ordered, illustrating that the infrastructure is the basic means for transportation; there is a traffic flow of which each transport is a part. The flow of goods is the core of transportation and the information flow placed above refers to that it is not a necessity, but critical for the performance of the transports. Furthermore, each layer is divided into parts. The infrastructure contains rail network, roads, terminals, etc. Traffic flow can be divided into different traffic systems for and within each transport mode and the devoted flows of transports. The flow of goods can be divided into type of goods, type of transport unit used, etc. Finally, the information flow can be divided into technology, systems, format, accuracy, etc. Economic flows are not considered.

26 Maritime Engineering & Ports III

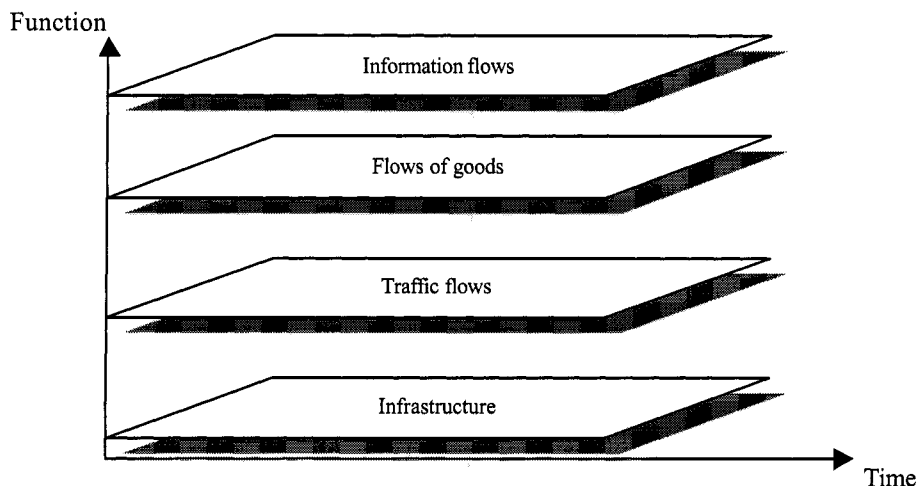


Figure 1. The four main layers of a transport chain.

4 The problem description

Currently, there exist an estimated 15 million containers and this figure is projected to continue increasing for the next 10 years at 8.5% [16]. Ship lines are aware of this growth as can be seen by the huge investments in yard construction of container ships that can transverse the oceans at 25 knots, whilst laden with 8000 or more containers (known in the industry as TEU, twenty foot equivalent unit). The planned container terminal investment in Europe (1999-2001) is approximately 208 million Euros [20]. Container handling systems in in-land and marine container terminals have a substantial impact on waiting time of incoming trucks and trains. Additional waiting time at these terminals directly translates to larger fleet size requirements for ground container transportation, which contributes to traffic intensity, and increased ground transportation capital investment and operating costs. Ship lines are unconcerned if there is a poor terminal productivity, as long as their vessel sails on time. Terminal operators are trying to reduce or stabilize the cost per ton/teu handled and thus maximize profit. Their aim is to efficiently use the resources available during the operating time that the vessel is occupying the berth.

5 Methodology

An intensive literature survey of articles published in journals was conducted. The European projects: IQ, COST330, EUROBORDER, and INFOLOG were analysed. A survey and interviews were designed for 30 port users and port

providers of ports in Sweden and in Belgium, in order to establish if the situation of congestion has been resolved. The results from our data collection have shown that the bottlenecks do exist. The results of the survey validate that if port actors can share information with each other through a portal, than they can achieve individual benefits within their business functions. For coordination of information within terminals, portals are considered detrimental to their work. The use of the multi-agent approach in the interface between port terminals and port users is supported from other MAS applications and research [9][4]. The goal is to conceptualise a simulation tool by using a MAS, fed with real data.

6 Multi-Agents System Simulation

There exist several definitions of what agents are and many of them are debatable. In this paper, we use the definition from Davidsson; "an agent can be viewed as an autonomous program that can modify its behaviour based on experiences and is capable of interacting independently and effectively in its environment" [8]. The agent can be alone or embodied, such as in the case of a "Mars Rover." The agent-like technology applications that most are familiar with are web-crawlers, software programs that scan the Internet for information.

A MAS is a collection of agents co-operating with each other in order to fulfill common and/or individual goals [9]. In a MAS, different agents may have different roles and individual goals. The actors or elements in the container transportation system can be viewed and modeled as an information society, where communication, negotiation, and collaboration occur. Agent communication is possible with computer languages such as KQML (Knowledge Query Manipulation Language). The agents are often created by using agent programming, an extension of object-oriented programming. The abstraction level is high in agent programming and facilitates the ability of agents to act in a goal-oriented fashion. The various actors in a system, such as the container transportation system, would be identified and modeled according to their function or behavior. By performing simulations in the agent-based model, patterns and behaviours can be analysed. Through analysis of the complex behaviour of agents representing different parts of the problem domain, (e.g. schedules, operations, and tasks), would provide an opportunity to optimise the resources in the whole terminal interface process.

The MAS simulation of a container terminal interface with a railroad operator is considered feasible since similar use of MAS has been applied (c.f. work by John L. Casti and OASIS air traffic management project at Sydney airport). John L. Casti, a researcher at the Santa Fe Institute simulated the transport system of Albuquerque, New Mexico with the use of agents [4]. A MAS simulation between the actors is helpful in gaining insightful information about a system. An example of a MAS simulation could be a distributed organization of a container transport system.

7 The Railway-Port interface

The interface to other modes of transport lies in this system. The management of the gate consists of obtaining information on containers entering the terminal, leading to the proper physical handling. Controlling the gate to the terminal is important since it affects other parts of the container terminal system. The data that is collected; container number, weight, port of destination, hazmat, reefer, shipper, ship line, and seal number is used when deciding where to place containers for storage and later for loading. The interface also serves the rail operators, as well as other modes of transport with information such as waybills, arrival notices, and dispatches. The rail operators are able to plan and schedule accordingly to the information received from the shipper via a terminal portal.

8 Railway status

As mentioned, the European Commission states its aim of increasing intermodality in order to avoid an increase in road transports and the related problem with congestion and pollution, in the White paper [5]. As many have pointed out, for example in [1], an increase in railway transportation requires an increase in capacity since there are capacity problems already today. In the infrastructure proposition provided by the Swedish government [23] the following is written: *Without efforts for increasing the railway capacity, the transition to environmentally friendly transport modes, which could happen today, will be delayed. The adjustment to a long term sustainable transport system will thus also be delayed* (translation from Swedish). Capacity problems do not only prevent new actors to establish themselves in the transport market for railway traffic, but they also generate bottlenecks, which in turn cause delays in the traffic flow. As described earlier, one deviating train may cause severe disturbances in the whole network depending on how the disturbances are propagating. Problems due to delays in railway traffic in Sweden have been partly studied in a R&D project, *Baninfo*, financed by Banverket, the Swedish National Rail Administrator. The project aimed at identify ways how to increase customer satisfaction at Banverket regarding accessibility to traffic related information, by interviewing several customers on different levels. The results showed that not only punctuality is of interest, but information on deviations and their consequences, i.e. changes in Estimated Time of Arrival (ETA), is also important for the planning of transports. Today, there is no system that has the ability to predict the outcome of changes in the Swedish railway traffic flow. However, as pointed out, the results from the project Baninfo argues for a need of this kind of information at an early stage. Several of the interviewed companies stated the importance of knowing about changes in time, since it is a prerequisite for effective rescheduling.

Prediction of the consequences of a deviation in railway traffic is a complex process, and the factors that affect the final outcome are many. One approach is to simulate the traffic flow in real time and use a distributed system where agents represent the train dispatchers and the transport operators. The *train dispatching agents* are the operative decision makers when handling a disturbance in the train traffic flow, and the decisive measures they take in different situations have to be mapped. The *transport operator agents* also have an influence since when there is a conflict between two trains operated by one and the same company, the company can choose which train the company prioritize. This approach is under development by a group at Blekinge Institute of Technology. For further information, see [19].

This agent-based approach is primarily aiming at increasing the performance in the Swedish train traffic and, further on, the attractiveness of intermodal railway transportation by an increasing punctuality and reliability. The benefits of this approach are dual. Firstly, the simulation will provide a decision-support tool for the train dispatchers to evaluate different counter measures and actions taken when handling disturbances in the railway traffic both in real time and for strategic purposes. Secondly, and most interesting in this context, the simulation will provide all concerned with information on changes in the transports' plans that will affect their business. This information will serve partly as input for ad hoc planning and coordination of resources in terminals such as the ports described below.

9 Port status

The MAS approach is to be considered as a suitable tool in container terminal management due to the complexity, terminals are determined by a variety of inputs, outputs, actors, intrinsic characteristics and external influences. The allocation of resources and scheduling of operations is conducted by several distributed decisions makers. By using agents to optimally schedule and allocate resources to the terminal interface, the rail may be better served and the performance of the container terminal system as a whole may improve. Using the metaphor of an information society, the actors that work through networks and make decisions effecting the daily operations of the port can be properly represented by agents. The use of agents to represent the various actors in a simulation would permit management to better control and coordinate the terminal activities. Ports are demand driven by many customers, and users. Satisfying all actors is very difficult since actors often have *conflicting* interests. Sometimes an actor can even become dominant and his demands can take excessive importance. For the vessel owners it is paramount that the vessel is quickly "turn-around", meaning loaded and discharged as fast as possible. An average container liner spends 60% of its time in port and has a cost of \$1000 per hour or more [21]. To shorten the time spent by vessels, terminal operators need to spend special emphasis in resource allocation, receipt of information before vessel berths in order to reduce the \$45000 stay of a third generation containership or \$65000 of large vessel at port [16]. The terminal operators are

30 Maritime Engineering & Ports III

providing services that involve much more than loading a ship. Various actors with intrinsic goals, that are often in conflict, in combination with complex coordination of several services, is a decentralized problem area that gives rise to the idea or approach of a MAS.

The MAS approach to the container terminal interface, would allow the terminal interface to be modelled as a *gate agent*. The *gate agent* would receive information of arriving export cargo from a *rail agent*. The information of containers entering the terminal would be communicated to a “yard planner” and “ship planner”, which in turn may be modelled as a *yard planner agent* and *ship planner agent*. The *yard planner agent* instructs the *gate agent* to advise the lorry which terminal area to park for loading or unloading. The *gate agent* communicates with other actor agents (i.e. rail agent or lorry agent) in dispatching containers. The *yard planner agent* would “wrap” an existing software program to optimise the capacity of the yard while minimizing the use of resources. The basic idea is to place wrapping software around legacy code in order for it to appear normal to other agents ~ agentify [9]. The *ship planner agent* is a modelled agent that would “wrap” around an existing ship planning software program. It would allow the ship planner to have decision-making ability and communicate with other agents in order to complete its goal, to load the vessel according to the established scheme. In reversed order, the vessel (modelled as a vessel agent) may communicate via the *yard* and *gate agents* to the rail operator (modelled as a rail agent) the time of arrival and number of containers to be discharged. The information may also include weight, description of cargo, destination, and other data deemed relevant by the *rail agents* in order to optimise and increase the performance of the rail operations. The premise for the agents in the simulation is to identify the relationships between the various elements by mapping them as agents [12]. The use of agents would assist containers or cargo in finding their destinations through the array of networks and systems that make up the container terminal simulation. The simulation tool would be the basis of a DSS.

10 Discussion

According to Parunak, “the use of agent based modeling thrives in situations characterized by a high degree of localization and distribution and dominated by discrete decisions” [18]. Many problems can still be solved using existing methods and the availability of software that has been developed for such tasks (e.g. routing software, stacking algorithms, discrete event simulation). However, in choosing the MAS approach to model the port interface, the actions and functions of the various actors can better analysed than with existing techniques. A holistic model does not exist that analyses the various subsystems, and actors in the container terminal transportation domain. The MAS approach enables the simulation of the various individual actors, processes, and elements to be individually modeled. The simulation allows observation of the behaviours, plans, and co-ordinations between the agents in order to solve a problem. The interesting fact is that before a simulation is conducted, the result is difficult to predict. The simulation of the elements is the basis for an intelligent decision

support system, enabling the various actors to plan, schedule and coordinate optimally. Better planning is obtainable with real time data being available for the various agents to analyse and make decisions upon. Technology such as agents may be able to assist terminals by increasing capacity and performance without spending large investments on terminal expansion and equipment. The 'software' rather than the 'hardware' of port development will be the determining factor in future trends in port competition vis-à-vis terminal management [21].

11 Acknowledgments

Due appreciation is given to Prof. Dr. Paul Davidsson at Blekinge Institute of Technology and Prof. Dr. Peter Värbrand at Linköping University.

12 References

1. Aktuell om Logistik, No. 4, provided by Sveriges transportindustriförbund (in Swedish), 2001.
2. Arlbjorn, J. S., *Logistics knowledge creation: reflection on content, context and processes*, International Journal of Physical Distribution & Logistics Management, Vol. 32, No. 1, 2002.
3. Cardebring et. al., *Summary report of the IQ project*, 2002, TFK Transportforschung GmbH and INRETS for further information or <http://www.tfk-hamburg.com/>
4. Casti, J.L. *Would be Worlds: How Simulation is changing the Frontiers of Science*. John Wiley & Sons, New York, 1987.
5. Commission of the European Communities, White paper, *European transport policy for 2010: time to decide*. Brussels, 2001.
6. Chow, G., Heaven, T. D., Henriksson, L. E., *Logistics Performance: Definition and Measurement*, International Journal of Physical Distribution & Logistics Management, Vol. 24, No. 1, 1994.
7. D'Este, G., *An event-based approach to modelling intermodal freight systems*, International Journal of Physical Distribution & Logistics Management, Vol. 26, No. 6, 1996.
8. Davidsson, P. *Autonomous Agents and the Concept of Concepts*. PhD. Thesis, Lund University, Lund, Sweden, 1996.
9. Davidsson, P. and Wernstedt F., *Software Agents for Bioprocess Monitoring and Control*, Journal of Chemical Technology and Biotechnology, Vol. 77, 2002.
10. Gustafsson, I., Törnquist, J., Källström, L., *Förbättrat informationsutbyte mellan Banverket och dess kunder*, Final report of R&D project financed by Banverket (in Swedish), 2002.

32 Maritime Engineering & Ports III

11. Heller, C., *Tracking & tracing in combined road/rail freight transport*, IPTS Technical Report Series, Institute of Prospective Technological Studies, Seville, EUR 18716 EN, March 1999.
12. Henesey, L. Wernstedt F, Davidsson, P., *Market Based Approach to Container Terminal Management*, Agent Technologies in Logistics workshop. The 15th European Conference on Artificial Intelligence, Lyon, France, 2002.
13. Hultén L *EUROBORDER*. European Commission DGVII R&D project-Transport contract no. WA-95-SC.153. Brussels, 1999.
14. Hultén, L., Bolin, H., *Information Exchange and Controllability* (2002), TFK – Transport Research Institute, for further information www.tfk.se
15. Kallstöm L. *Infolog*, European Commission under the Transport RTD Programme of the 4th framework, 2000.
16. Kia, M., Shayan, E., & Ghotb, F., *The importance of information technology in port terminal operation*, International Journal of Physical Distribution & Logistics Management, Vol. 30, No. 3/4, 2000
17. Lumsden, K., *Logistikens grunder*, Studentlitteratur, (in Swedish), 1998.
18. Parunak, H., Savit, R., & Riolo, R., *Agent-Based Modelling vs. Equation-Based Modelling: A Case Study and Users' Guide*. Proc. of Multi-Agent systems and Agent-based Simulation, Springer-Verlag: Berlin and New York, pp. 10-25, 1998.
19. Törnquist, J. and Davidsson, P., *A Multi-Agent System Approach to Train Delay Handling*, Agent Technologies in Logistics workshop. The 15th European Conference on Artificial Intelligence, Lyon, 2002.
20. Wiegman, B.W., Ubbels, B., Rietveld, P., & Nijkamp, P. *Investments in Container Terminals: Public Private Partnerships in Europe*: International Journal of Maritime Economics Vol. 4 no.1, pp.1-19.2002.
21. Winklemans, W., (ed.). *Port Competitiveness*. De Boeck Ltd, Antwerp, Belgium. 2002.
22. http://europa.eu.int/comm/transport/library/marco_polo_summary.pdf Summary of the proposal of Marco Polo project (visited 2002-04-30)
23. <http://naring.regeringen.se/fragor/transport/infrastrukturprop2001/bakgrund.htm#jarnvag>, Infrastructure proposition 2001 by the Swedish government (in Swedish), 2001.