The design of logistic control for intermodal transport chains of the 21st century

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Contents

Abstract

This paper is a short overview of the author's Ph.D.-research project. The research focuses on designing logistic control structures for intermodal transport chains of the 21st century. We distinguish research questions on two levels. The upper level focuses on the *development* of a method to design logistic control structures. The lower level focuses on the *application* of the method to actually design logistic control structures. The inductive-hypothetical research strategy will be applied to reach the research objective. Case study research is very suitable within the inductive-hypothetical research strategy. This paper ends with a short introduction in the first inductive case study, the Underground Logistic System (OLS).

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1 Introduction

The intermodal transport chains of the 21st century will differ largely from the chains used today. The freight flows will have a larger scale and more reliability, faster throughput times, higher service levels, and more flexibility are needed [Celen, et al. 1997 and Evers 1998]. These increasing requirements ask for new logistical control structures. The research described in this paper focuses on the development of a design approach to support the design of new logistical control structures, which can be used within intermodal transport chains of the 21st century.

1.1 Research program FTAM

This Ph.D.-research project is placed in the research program FTAM. The research program FTAM (Freight Transport Automation and Multimodality) was started in 1997 to design intermodal freight transport services for the 21st century. The research program is aimed at reaching a breakthrough in the technological and organisational conditions for competitive and sustainable multimodal freight transport. The central objective can be formulated as follows:

> '*Design and develop technologies and organisational structures for an integrated, highly automated freight transport system for inland intermodal transport. This includes an advanced integrated control system, automated vehicles, transshipments facilities, and a dedicated infrastructure.*'

The program is divided into two project clusters: Intermodality and Organisation (I&O) and Vehicle and Operations (V&O). The cluster I&O is focused on the organisational aspects of intermodal freight transport. The cluster V&O is focused on the development of multifunctional smart vehicles for freight transport. Each of the two clusters contains a number of projects:

Intermodality and Organisation	Vehicle and Operations
1. Intermodal networks and new terminals	5. Vehicles mechanics and mechatronics
2. New urban freight transport	6. New traffic control
3. Lanes for automated freight transport	7. Diagnostics and incident handling
4. Interorganisational co-ordination of transport processes	

Table 1: Different projects within the FTAM-research program

The Ph.D.-research program of the author is placed in the fourth project, interorganisational co-ordination of transport processes.

1.2 Motivation

Freight transport is of major importance to society, especially for the Dutch society. Due to its favourable position in Europe the Netherlands has always been one of the major gateways to the European hinterland. Besides the favourable position the Netherlands has got an accessible economy, a highly educated workforce, and a good infrastructure. These characteristics have led to an enormous growth of the transport sector, the total added value the transport sector rose from 32.2 billion guilders in 1990 to 36,8 billion guilders in 1992 [Centraal Bureau voor de Statistiek 1995].

Besides the benefits for the Dutch economy, this growth, however, has negative consequences as well. The majority of freight is transported by truck. Because of the large number of trucks (and cars) the congestion of the road network is constantly growing. This makes the Dutch economic centers difficult to reach. Furthermore, freight transport by truck is one of the major perpetrators of “green house” gases, like CO_2. Trucks make a lot of noise, cause a lot of accidents, etc [see Venemans 1994]. In future the transport sector will continue to grow strongly. The policy of Dutch and European government is to reduce the negative effects of transport. There are several strategies to reach this goal. One of the strategies is to replace pure road transport by intermodal transport.

The social relevance of the FTAM research project is aimed at improving the conditions for intermodal transport and thus helping to make intermodal transport a more attractive alternative for road transport. This helps in achieving a considerable shift in the modal split of freight transport in favour of intermodal transport.

The specific relevance of this Ph.D. research project is its contribution to the interorganisational aspects of intermodal transport. Most of the efforts in the FTAM research project are focused on the technical or the organisational side of transport. In intermodal transport chains many different organisations have to work together. For example the number of organisations involved in the transshipment of cargo from a shipper in Frankfurt to a consignee in Vancouver can involve up to 40 different organisations [Streng 1993]. To improve conditions for multimodal transport we have to look further than technological and organisational aspects alone. This research focuses on the (inter)organisational co-ordination between the different parties involved in intermodal transport chains.

1.3 Outline of the paper

After this short introduction, where the position of the Ph.D.-project and it’s motivation are discussed, chapter 2 focuses on the research area of logistics. Chapter 3 discusses the research scope and focuses especially on the research approach that will be used within this research, the inductive-hypothetical research strategy. This paper ends with an case study within the Ph.D.-research project, the Underground Logistic System (OLS) near Amsterdam Airport Schiphol.

2 Logistic control structures

This chapter provides a short introduction into logistics and control structures.

2.1 Logistics

The term logistics originates from the military field. Originally logistics are the preparations and activities that are necessary to let the army fight under optimal conditions. This means that logistics is more than just transport and storage. In the Second World War logistics got more and more professional. After the war logistics also developed in civil organisations. With this the scientific interest in the field of logistics also grew.

In this research attention is given to transport, inventory and related subjects. Production logistics are not taken into account. Logistics in this research is defined as follows [Ballou 1992]:

> "*The mission of logistics is to get the right goods or services to the right place, at the right time, and in the desired conditions, while making the greatest contribution to the organisation*."

This definition shows that logistics not only handles physical good flows, but also deals with:

- Flow of people,
- Flow of vehicles,
- Flow of information (or data).

2.2 Logistic chains

In the last decade there has been a shift in logistics from studying single links towards studying chains. Organisations work more and more together in logistics, and form a chain of organisations. In literature logistic chains are studied from different perspectives.

The macro perspective on logistics has not received as much attention as the meso perspective in literature. The last decade interorganisational logistics has received more and more attention. One of thoughts behind this is that logistics crosses the organisational boundaries.

This means that when improving the overall performance of logistics attention should be paid to the co-ordination between the different organisations. Babeliowsky uses the term interorganisational logistic network. This is a logistics system of which the processes are carried out by actors from two or more organisations having no joint executive [Babeliowsky 1997]. To have an optimal control of the flow of items within the logistics system, adequate co-ordination and co-operation between the individual organisations are essential. Babeliowsky sees the designing of a logistics system as the structuring of actors and processes in order to achieve a certain logistic performance [Babeliowsky 1997].

2.3 Logistic control structures

A control structure is a mechanism used to regulate or guide the operation of a machine, apparatus or system [The New Penguin English Dictionary]. Logistic control structures are defined as:

> "*A logistic concept in which the flow of goods (or passengers) is integrally controlled through the entire chain, fulfilling demands of the final customers as much as possible*."

The logistical control structure should give answers how resources should function. The questions to be answered are:

- *Which* resource should do,
- *What* tasks,
- *Where* should the tasks be performed,
- *When* should they be performed.
- *How* should these tasks be performed

TNO Inro uses the term logistic concept. A logistic concept is the whole of coherent activities, means and information aimed at an efficient manner to transport goods from origin to destination [Brugge 1997].

3 Research scope

In this chapter the research objective and questions are introduced. After this the research approach that is used in this research is discussed. This chapter ends with showing the two different levels of research that can be distinguished.

3.1 Research objective and questions

The objective of this research project is *to improve the performance of intermodal transport by designing new logistic control structures for intermodal transport chains of the 21st century.*

To reach the research objective several research questions must be answered:

1. What are the important developments in (intermodal freight) transport and in controlling transport?
2. What logistic control structures are used in general in the intermodal transport chains of today?
   - What methods or processes are used to develop them?
   - How can we improve this process?
   - What would be a good framework be to compare logistic control structures?
3. What supporting tools (in particular simulation tools) can be used to improve the process of designing and evaluating logistic control structures?

3.2 Research approach

A research strategy provides an outline of the plan, which must be carried out to conduct the study to meet the research objective. The choice for the research strategy is based on the nature of the research problem, and on the status of theory development in the research field. The research strategy used in this research is the inductive-hypothetical research strategy [Sol 1982]. The inductive-hypothetical research strategy has a number of advantages, that make it very useful for new and emerging research fields:

- it emphasises the activities of conceptualisation and problem specification, underlining the specification and testing of premises in an inductive way;
- it opens up possibilities for interdisciplinary problem specification;

- it enables the generation of more than one solution, starting with an analysis of the existing situation;
- it regards the phases of analysis and synthesis in solution finding as interdependent;
- it is very suitable to solve problems from the organisational practice;
- it is very useful when there is a lack of usable theory or methodological support before the research starts.

The inductive-hypothetical research strategy is very useful when studying co-ordination of intermodal transport processes. First of all, intermodal transport is more than just a technology. Organisational, economical, juridical aspects play an evenly important role. This asks for an interdisciplinary problem approach. Secondly, there is a lack of generally supported theory or methodology in the research area of intermodal transport. Furthermore, problems in intermodal transport do not have one optimal solution, but multiple possible solutions.

The inductive-hypothetical model cycle consists out of five steps, in which four different models are constructed:

1. In the first step a number of theories about control of logistics are identified. Using these theories a number of empirical situations are investigated. This step ends with the construction of one or more descriptive empirical models of the control of intermodal transport chains. The first step is primarily used to get a detailed understanding of the research area on the basis of a number of relevant cases in the research area;
2. In the second step an abstraction is made of the essential parts of the field of interest. Perceived problems are translated into a single descriptive conceptual model. The descriptive conceptual model is used to represent the essential and generic elements of the problematic situations that are studied;
3. In the third step a theory (or an approach, a tool, etc.) is constructed to solve (or partially solve) the observed problems. This theory is translated into a prescriptive conceptual model for a number of relevant cases in the research area;
4. In the fourth step the prescriptive conceptual model is implemented into one or more prescriptive empirical model(s);

5. In the last step the results of the prescriptive empirical model are evaluated by comparing them with the results of the descriptive empirical models. Based on this evaluation the prescriptive conceptual model can be improved or a new inductive-hypothetical research cycle can be started.

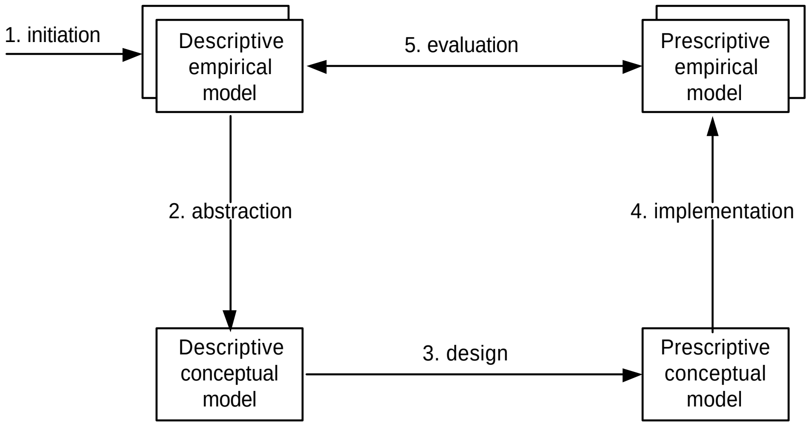

Figure 1: The inductive-hypothetical research strategy

As stated above different models are used in the inductive-hypothetical research strategy. A distinction is made between models of current situation (descriptive or as-is models) and models of the possible future situation (prescriptive or to-be models). Further distinction is made between conceptual models (which define the problem structure) and empirical models (which enable analysis and diagnosis of the problem or possible solutions) [Vreede and Verbraeck 1996]. Others have also successfully used this approach in a series of organisational studies:

Researcher	Year	Subject (or title dissertation)
Meel	1994	The dynamics of Business Engineering
Vreede	1995	Facilitating Organisational Change
Eijck	1996	Designing Organisational Co-ordination
Uijlenbroek	1997	Designing Electronic Document Infrastructures
Babeliowsky	1997	Designing interorganisational Logistic Networks
Meinsma	1997	Decision Support in Business Environments
Herik	1998	Group Support for Policy Making
Hengst	1999	interorganisational Co-ordination in the Container Transport Sector

Table 2: Overview of studies following the inductive-hypothetical research strategy

3.3 Research instruments

The inductive-hypothetical research strategy gives no indication of the research instruments that are to be used to conduct a research. The choice of research instruments depends on three conditions, type of research question, control over the actual behaviour of the phenomenon, and the time focus. Case studies are especially suitable when “how” or “why” questions are being posed, the investigator has little control over events and the focus is on a contemporary phenomenon within some real-life context [Yin 1994]. Case based research and action based research are the most suitable instruments within the proposed inductive-hypothetical research strategy [Sol 1982]. A case study combines several data collection methods such as interviews, questionnaires, and observations.

It is, however, difficult to obtain suitable cases. The choice of a case is often based on opportunism, rather than rational grounds [Yin 1994]. Some thought should therefore be given to the criteria for selecting cases in this research:

- Cases should entail problems in the (intermodal) transport sector;
- Cases should involve problems that cross the organisational boundaries and involve a chain of organisations;
- Cases should involve organisations that are willing to introduce new logistics control structures, new technologies for transport or transshipments or new ICT possibilities.

At the beginning of this PhD-research a number of possible case studies were identified. The first case study is the Underground Logistical System (OLS). This is an underground freight transport system. The OLS uses new transport technologies like automatic guided vehicles (AGV’s), automated transshipment facilities and an automated control system for the conflicting use of infrastructure. Different parties are involved the OLS to transport goods between Amsterdam Airport Schiphol, Flower Action Aalsmeer and Railterminal Hoofddorp. For example shippers, transport companies, airline companies, customs are involved. The disadvantage of this case is that one transport mode is used and only a part of an intermodal transport chain are studied.

3.4 Two levels of research

In this research two different levels can be distinguished, an upper and a lower level. At the upper level a design approach is developed to design logistic control structures. At the lower level the design approach from upper level is applied to design logistic control structures. This two-level approach has also been used to facilitate organisational change [Vreede 1995] and to design organisational co-ordination in the insurance industry [Eijck 1996], making it highly relevant for designing co-ordination of intermodal transport processes.

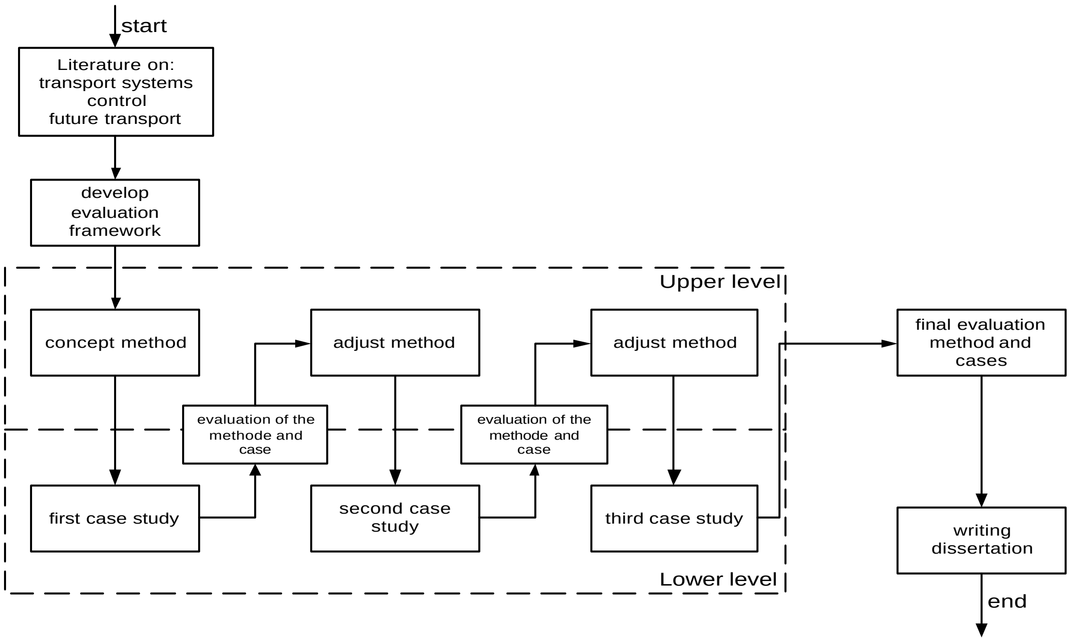

Figure 2: Two levels of research

This research started with an literature study on transport systems that are used today and what logistic control structures that are used to control these systems. Furthermore, literature on future transport systems has been studied. After the literature study the development of the evaluation framework and the design approach was started.

After every case study the design approach and the case have to be evaluated. Both will be evaluated according to different criteria. Common criteria for evaluating the method are throughput time and completeness. Criteria evaluating the case study are logistic performance indicators, like costs throughput time, reliability, etc.

The arrows in the figure are pointing in one direction, in reality however the process is much more iterative. Especially between the literature study, the development of the method and the evaluation framework several iterations will be made.

4 Case study: Underground Logistic System

One of the case studies within this research is the Underground Logistic System (OLS). Within these case study the different phases of the design approach will be developed and tested. The Underground Logistic System is an underground freight transport system for time critical goods, e.g. flowers and computer parts. The goods will be transported between Amsterdam Airport Schiphol, Flower Auction Aalsmeer and Railterminal Hoofddorp.

The goals of the OLS project are broader than only the efficient transport of goods:

- guarantee good accessibility of Amsterdam Airport Schiphol (AAS) and the Flower Auction Aalsmeer (VBA),
- reduce the environmental impact of transport,
- reduce the congestion on the roads located around Schiphol and Aalsmeer,
- stimulate the use of trains in intermodal transport chains,
- gain more knowledge on underground building and great scale automated transport systems.

The OLS consists of a number of systems and subsystems. The most important are mentioned below. Within the OLS three area's are connected: Flower Auction Aalsmeer (VBA), Amsterdam Airport Schiphol (AAS) and Railterminal Hoofddorp (RTH). The area's are the physical origins and destinations from where and to where cargo is transported. Each area consists out of a number of terminals; Amsterdam Airport Schiphol consists of 2 to 5 terminals, Flower Auction Aalsmeer consists of 1 to 3 terminals, Railterminal Hoofddorp is a single terminal. The terminal is the place where customers and OLS come together. On one side of the terminal customers deliver and receive their goods, on the other side the OLS-vehicles take care of transport. Furthermore, terminals have a buffer function to temporally store goods. The terminals are connected by tunnel segments. The tunnel segments have a diameter of 5 meter and are located at a depth ranging from 0 to 20 meters underground. The tunnels are drilled and can be one-directional or two-directional. The terminals are located at ground level to reduce building costs. Within the OLS Automatic Guided Vehicles (AGV's) are used to transport cargo between the terminals.

The use of AGV's has certain advantages: less personal is needed which leads to lower transport costs, less chance of human errors which improves the reliability of the system, less strict demands to the tunnel segments (safety exits, ventilation, etc.).

A logistic control structure for the OLS is hard to design. Several hundreds of autonomous AGV's, that can be kilometer apart, semi-autonomous terminals, late orders, demands for high speed and great reliability ask for a flexible decentralised logistic control structure. In logistic control structure for the OLS a distinction is made between the physical layer and a control layer. The physical layer consists out of the physical aspects of the system, like AGV's, terminals and docks. The control layer consists of the components that control the physical aspects, like terminal manager and empty car manager. Part of the control layer is the external co-ordination. Here the activities of the OLS and the customers are connected.

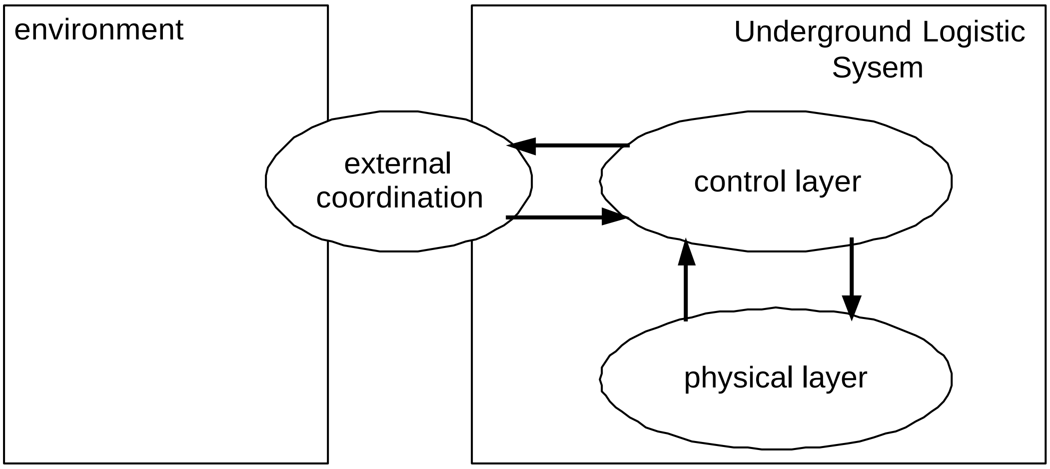

Figure 3: Different components of the OLS

Transport systems of a great scale or with a high level of automation often have one organisation that is responsible for the exploitation of the transport system. Different organisations make use of the system, most of them use the transport means that are offered by the exploitation organisation. Bigger users, however, often want to use their own vehicles.

The goal of this case study is to design a logistic control structure for the OLS when organisations that want to use their own vehicles. The major problem in this case is that many organisations want to use the OLS at the same moment and the OLS only has a limited capacity. In other words: how can the OLS maximise the use of its limited capacity when different organisations make conflicting use of the infrastructure.

Some examples of possible logistic control structures are:

- *Priority mechanisms*. Special customer (e.g. who transport a large volume of goods) get priority over normal customers, when they announce their cargo for transport;
- *Transport brokers*. A broker sells pieces of capacity to the highest bidders;
- *Capacity slots*. Like the holiday travel industry, the exploitation organisations offers a slot of capacity to the customer (far) in advance.

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