Architecture of Intelligent Intermodal Logistics Centres

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Abstract: The purpose of this research and development project is to construct the foundations of a logistics IT centre with a universal and intermodal character, i.e., covering all modes of transportation and corresponding central functions related to warehouses and container terminals. Through its modular structure it is applicable to arbitrary concrete site dependent needs. It also contains intelligent elements, which offer sub-optimal solutions to certain classic mathematical optimization problems connected to logistics, acceptable from a practical point of view and tractable in the computer science sense. In order to realise and implement this system, several basic research tasks both in logistics and IT will be solved.

Keywords: intermodal traffic systems, logistics chains, intelligent systems, telematics, logistics centre, fuzzy theory

1 Introduction

In this paper we present a development project containing both base and applied research, aiming to construct the foundations of a multicentral logistics IT centre with a universal and intermodal character, i.e., covering all modes of transportation and corresponding central functions related to warehouses and container terminals. Through its modular structure it is applicable to arbitrary concrete site dependent needs. It also contains intelligent elements, which offer sub-optimal solutions to certain classic mathematical optimization problems connected to logistics, acceptable from a practical point of view and tractable in the computer science sense.

2 Basic Models and Procedures

The task of the research-development project is to set up the basics of a universal and intermodal logistics information centre, which can be used with different place-specified demands, and contains intelligent elements, which provide a practical sub-optimal solution of classical mathematical optimising problems applicable in terms of computer technology.

To achieve this, we worked out different logistics and informatics research tasks.

2.1 Multi-Central Model of Logistics Centres

The most important and international acknowledged result of our study is the set-up of the multi-centre architecture of logistics service suppliers, and the creation of its establishment-methods. The substance of this multi-centre architecture is that we defined the possibility of using decentralized regional resources, instead of the only-known geographical centralized model[1].

A complex model has been elaborated that proposes an algorithm, by which the formation of logistics centres can be supported involving small and medium sized companies. The initial input of the model is based on a survey exploring the existing regional logistics capacity, transport infrastructure and demand. Comparing supply and demand deficit a possible development concept can be determined.

Relevant actors of regional economic and social life must be involved in the elaboration of development concept. The intended range of services must be outlined, regional effects are to be predicted and financial calculations and studies must be carried out. Survey on willingness for co-operation is an important element of the concept since the virtual centre is based on close collaboration of different organisations[2].

Financial verification of the project is carried out in the last phase, information about the possible sources is used as an input, and the final feasibility study is the output of the model.

Application of the model, conditions and approaches

Role of the government

The methodology does not count on direct central, governmental investment. The role of the state should be based on tendering processes in which the government can support the activity of local, regional actors in projects that match the national economic targets.

Regional tasks

The model represents regional approach so the importance of collaboration with local authorities, city councils and civil organisations cannot be overemphasised since these institutions are eager and ready for regional development.

Using of existing capacities

The model pays attention to the existing logistics capacities and compares the regional supply and demand. The concept of the model is that the most effective way of covering the deficit in regional logistics capacities does not necessarily mean new investments that can increase the competition between small and medium sized businesses. Instead of that the actors of the supply side have to be specialised for given services and a joint appearance on the market makes them able to provide complex, high level logistics service.

From the point of view of physical facilities the solution does not mean concentration, so the so-called multi-central model has to be applied.

IT tools

The IT based system is able to build up and operate logistics chains that can meet the actual needs[3]. In the first step the informatics system set the model of logistics chain, and that chain is operated by the allied companies as a project. The offered "product" is the logistics chain, the customer buys the service of the logistics centre that operates as a virtual company. The "virtual company" uses the information system of the logistics centre and the resources of allied companies. After finishing the job the virtual company is dissolved and a new one is established for the next task[4].

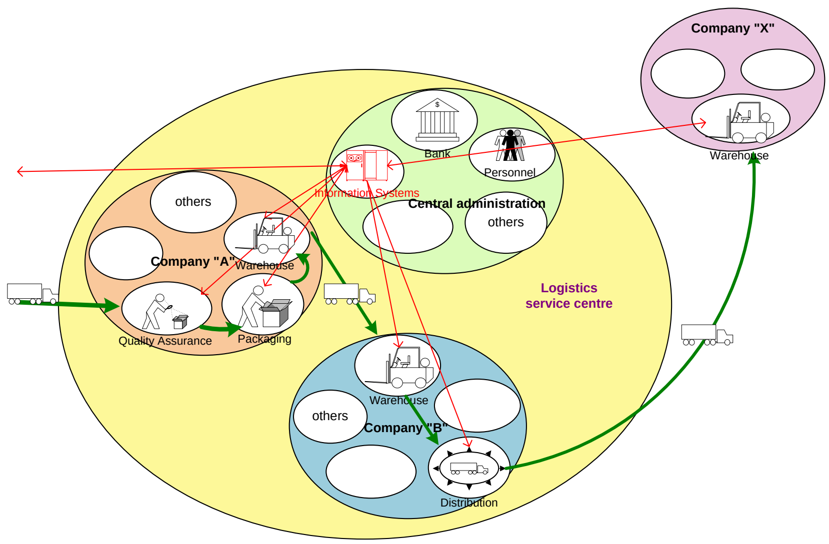

Figure 1
The virtual logistics chain

2.2 Fuzzy Logic and Computational Calculative Intelligence

Decisions based on intuition are often of great efficiency even if there is not enough information available, certain conditions are not exactly determined or the goal function of decisions is not specified. For decisions and conclusions made under uncertain conditions the most appropriate formal method is a rule based (or maybe hierarchical) decision-making algorithm based on fuzzy logic (or any other sub-symbolic technique). After some consideration we have selected the fuzzy logic rule based system/algorithm to create the intelligent functions[5].

The most critical point of the approach based on fuzzy rules is the computational complexity of the applied models. It is well-known that the questions concerning transportation optimisation, being the central topic of the project, can be attributed to NP complete and other non-polynomial procedures which are not tractable in the sense of computer science[6]. Considering that the logistics and informatics system, to be carried out according to the purposes of the project, manages a great number of goods to be transported, transport vehicles, dates and routes at the same time, it is necessary to apply complexity reduction methods even by quasi-optimal formal approaches[7],[8].

The appropriateness of the method is obvious as the logistics centre manages several alternative transportation methods and facilities, exceptional events (breakdown of vehicles, delays of loading etc.) and partially contradictory goals at the same time and it realises communication through human operators if necessary. The basic task is a combined optimisation task we have already referred to[9].

The referred system applies a hierarchical (two-level) structure which can fit to the hierarchical rule-base system we have developed earlier. The applied linguistic fuzzy model is identical with the basic methods of TMIT BUTE achievements[10],[11]. Locality in the planned system is not only used in geographic but also in organisational and functional terms. An important element is the separation of predictive and reactive task management within intelligent decision-making functions. Predictive management means a basic starting decision, distribution, selecting routes and making schedules. Reactive task management means the intelligent blocks resulting from the interaction of the system elements with delayed reaction and the blocks making dynamic decision-changes as an outcome of unpredictable results.

At this point we have to describe the task-system of co-operation and communication with other similar systems and sub-systems. We referred to the study[12] dealing with logistics management of certain industrial areas but its principles can be made general and extended to a communication and co-operation mechanism of national or international networks of logistics informatics centres. The main point of this solution is an agent-like distributed management system supposing intelligence without a distributed and common supervision system. The terms ‘u-space’ and ‘u-area’ created at TMIT BUTE and based on the fusion of ‘ubiquitous computing’ and ‘intelligent space’ apply the above described approach. It is worth mentioning that the agent-based co-operation principle has been used successfully for traffic control[5].

The necessity of simultaneous managing of the so called hard and soft conditions and the advantages of realisation by fuzzy intelligence have to be emphasised. As hard conditions the following can be mentioned: non-fuzzy transport restrictions because of the physical condition of the goods, and special ways of handling (e.g. dangerous goods) requested by law. Soft conditions: preferred transportation deadline, where some deviation can be of cost-optimising effects and as a result there emerges some penalty-like loss when it results in savings from groupings at the same time.

2.3 The Model of the Intelligent Logistical Information System

The IT system manages information - the primary resource of the logistics centre. It effectively shares and organizes information between the individual participants, bridging the geographic distance between them, substituting this way the need for physical proximity[13].

The IT system provides an interface for all participants of the logistics chain, including internal parties (members of the logistics centre) and external parties (cooperating, non-formal members of the centre).

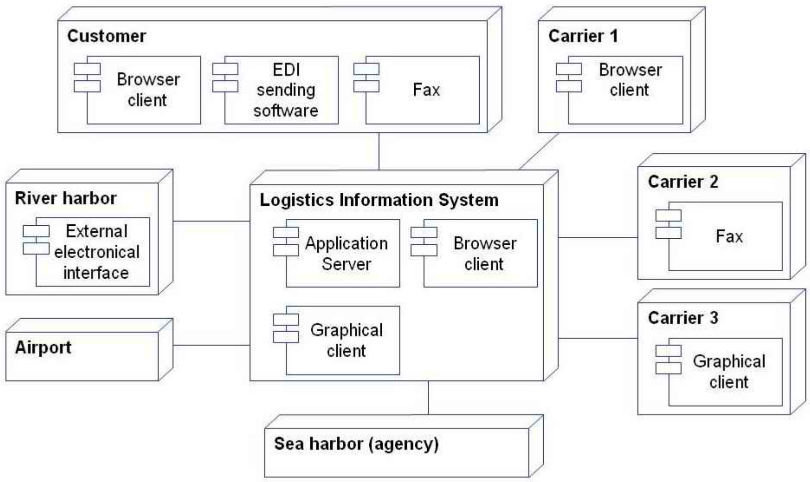

Figure 2
Deployment diagram

The difficulty of concentrating information is caused by the large number of service providers utilizing different transportation modes. The information is owned by the service providers. Because of the lack of a universally accepted, specific and complete communication standard it is not possible to implement automated computer to computer communication between each of these providers. An IT architecture must be created which can integrate as many providers as possible, because this - along with several intelligent elements - is the foundation for the competitiveness of a logistics centre.

3 Steps of the Development

The development is of modular structure which supports project management. The following figure shows the most important steps of development:

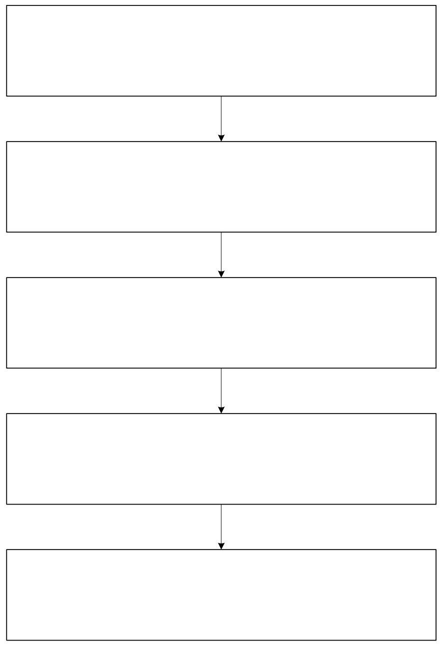

Figure 3
Steps of the development

In the following we give a brief summary of the goals and means of the single development phases. (Detailed description is not possible because of space restrictions.)

1 Intelligent Resource-Planning

The industrial resources are limited. The optimal use of these resources is essential for the successful operation. The task of the main research is to define the value of information, as an industrial resource, and to set up models, which lets outline the information, as a substitutional resource.

2 Logistical Performance Modelling

2.1 Defining the logistical quality and performance

For the use of the theoretical models outlined before, the analysis of logistical performance and quality measurement problem is essential. We define the range of other necessary logistics measures and qualification parameters, and define the measurement principles.

2.2 Task Scheduling and the Developing of Multi-Criteria Decision-Making Algorithms and Procedures, Outlining of Intelligent Quasi-Optimal Methods

The selected algorithms are applied to carry out the scheduling and multi-criteria decision-making tasks of the logistics model. The procedures are specified so that they can be implemented in the applied research tasks.

Mathematical algorithms and procedures are also prepared when considering computational complexity, applicability and characteristics of approximation algorithms suitable for quasi-optimal solution, and are specified according to the concrete implementation.

2.3 Performance Management Module

The main goal of the task is the preparation of algorithms and procedures for the use in intermodal logistics centres, and the further development of the demonstration software.

3 The Modelling of System Connections

3.1 The Map of Logistics System Connections, and the Outline of Decision Criteria

The integrated information connection model of intermodal logistics system connections was worked out and its dynamic structure was defined. We identify the logistics decision-making criteria for decision-making algorithms and define their system and importance-values. We give definitions to the identified criteria by the application of mathematical procedures.

3.2 The Analysis and Development of Hierarchically Controlled Scheduling and Decision-Making Techniques

We examine the issues of specific applicability of fuzzy models and algorithms with general purpose and based on hierarchical (maybe interpolative) rules in the actual tasks, and the characteristics of adapting the supervising system and algorithm developed earlier in this project.

According to the results we develop the management model with hierarchical supervision, which is considered to be the most appropriate model for high-level managing of the information system to be carried out in the project, consisting of co-operating components.

4 System Integration

4.1 The Adaptation of Agent-like Systems by the Multiple Component Scheduling and Decision-Making Tasks

We examine the application results of agent-like distributed intelligence solutions being the co-operation alternative with distributed management of intelligent logistics systems consisting of several components and locations with special regard on the solutions of scheduling and decision-making problems of co-operation of several independent logistics informatics centres. On the basis of the results we develop the agent-like co-operation/managing model, which is considered to be the most appropriate model to manage the logistics informatics systems to be carried out in the project and consisting of loose components.

4.2 Integration Module

At this point integration of different transportation methods (roads, railway, river boats, storage as quasi transportation, air transport) gets realised and further intelligent functions are added. Beside this the task it is necessary to prepare the defined algorithms and procedures for using them in intermodal logistics centres.

5 Macro Economical Modelling

5.1 Defining and Modelling of the Metaregional System-Connections, the Optimalisation of Flows

Based on previous research results we plan to work out mathematical models appropriate for showing the external effects of single transportation methods by goods-streams in big areas. Our most important purpose is to depict the relevant microeconomic changes interpretable for the criteria-system of company profitability. In the model we intend to emphasise the complex quality parameters as opposed to the general one-parameter (nominal cost) models and the external effects.[14]

5.2 The Developing of the Procedures of Grouping and Optimal Geometrical Arrangement for Transport Methods, Intermodal Decisions

Forwarders often make their transportation capacities in a construction available which cannot provide optimal capacity utilisation for individual orders, what is more, utilisation is poor. The optimal solution of the problem lies in a theoretically intractable mathematical model (NP complete problem), that is why it is of great importance to find algorithms which can provide an optimal-like solution for the so called packing problem. We intend to develop a procedure for this on the basis of own results and results from the relevant literature.

4 Utilisation

After realising the project the advantages can be seen in wide scale, in both short and long terms. A brief summary:

- on the region and the environment:
  - increase of economical potency due to the larger competitiveness,
  - decrease of the negative externals of transport,

  - improvement of the employment situation even in short-turn,
  - improvement of life quality
- on the transport:
  - the better utilization of the existing transport infrastructure,
  - better division of labour between transport methods, considered to the energy consumption,
  - strengthening of vertical cooperation due to the set-up of adequate information connections,
- on the customer:
  - fast, exact, reliable, elastic transport supply,
  - helps to get into new markets,
  - increase of company performance and competitiveness,
- on the carriers:
  - advantageous cooperation among different carriers, due to the common infrastructure, information and communication system,
  - better utilizable transport capacities,
  - the possibility for small and medium sized companies to join the integrated supply chain, and with that
  - the strengthening of competitiveness of small and medium sized companies in the region

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