# Chain Management in Container Transport: A Practical Application

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## Abstract

In the container transport industry, ICT is currently only used to support existing processes at an operational level. At a more strategic level, at which organizations negotiate with each other to come to agreements, ICT support is hardly used at all. Yet, at this strategic level, major impacts of ICT are expected: electronic auctions, e-commerce, electronic markets, negotiation support systems. To gain advantages of the use of ICT, a decision support system for chain management is designed.

The decision support system consists of a database and a 'model' base. The database has been designed to make information available in an electronic matter. Great challenge in this was to find a good database structure for storing information with a different nature: trains follow a time schedule, trucks can drive at any moment in time, terminals have opening hours, tariffs depend on the type and weight of the container and the weight of goods, and so on. Even more challenging was to find algorithms for the model base to analyse the data. A multimodal and multi-criteria search algorithm has been developed for searching for the best route through the network of transport services, given certain criteria such as time, costs, environmental effect and reliability.

The decision support system has been evaluated successfully in a laboratory setting. But since the proof of the pudding is in the eating, it has recently been applied to an organization in the port of Rotterdam. This organization plays a forwarding role for about 60.000 containers per year. Although the database and the model base were designed in such a way that most situations could be handled, practice showed that even more detail was required. Practice furthermore showed that – although using ICT as designed has many potentials – it takes many smaller steps to reach the ultimate goals.

**Keywords**: chain management, ICT, inter-organizational coordination, container transport

### *Introduction*

In the New Economy, organizations must continuously change due to ongoing changes in the environment [Donaldson 1996]. In trying to improve the performance of the organization, the focus has shifted over the past years from the organizational level towards the interorganizational level [Malone and Rockart 1991, McGrath and Hollingshead 1994]. Developments in ICT such as the World Wide Web, Electronic Data Interchange, and electronic mail can be seen as enablers to cross organizational boundaries more easily when dealing with information intensive processes. In the beginning, the focus was on supporting existing interorganizational processes, for example the exchange of documents between organizations. One rapidly growing trend today is the emergence of new ways to do business, replacing the current business. Examples of this are the introduction of elecrtonic trading markets, electronic auctions, and electronic bookstores. This shows that ICT developed from a minor force supporting the interorganizational processes into a dominant force for changing them [Buxmann and Gebauer 1998].

Chain management as a special form of interorganizational coordination is about to change as well with the ongoing developments in the ICT. This is true for many different areas. In this article we focus on the container transport industry. In the next section, the current situation in the container transport industry is presented. From this it can be concluded that chain management in container transport can gain advantage of the use of ICT. To realize this, a decision support system for chain management has been designed [Hengst 1999] and described in the third section. Since the proof of the pudding is in the eating, the system designed has recently been applied in real life for a forwarder in the port of Rotterdam, the results of which are presented in the fourth section. This article ends with the major conclusions and recommendations.

### *Container Transport: current situation*

The chain manager fulfills an important role in the coordination of container transport. During the operational coordination level, the chain manager, on behalf of the transport requester, takes care of the documents and formalities that are required for different activities in the container transport chain. ICT based systems have been, and still are being introduced to improve the information exchange: less errors, faster exchange, and in time delivery.

During the strategic level, however, little ICT support is used. The chain manager supports the transport requester during the strategic coordination phase in selecting those transport services that have the best fit with the requirements of the requesters. The chain manager must, therefore, know the possibilities and follow the latest developments in the transport network. Close contact with transport providers is a prerequisite. Information and communication are important in this. Conventional technologies such as fax and phone are used to support coordination. This limits the strategic coordination processes in several ways:

- Information is scarcely available and mainly on paper only.
- The amount of information used is limited since processing this information by hand is time consuming.
- The tariff is the most important factor taken into account, whereas other factors that are important for the container transport are not taken into account.
- Decisions about with whom to do business are made by head.
- Subjective preferences of the persons in charge dominate the choice of business partners.

It is believed that the situation described above is not adequate anymore as a result of today's developments. First, it is getting more difficult to make the right selection of transport services offered, because the container transport network is getting wider and more dynamic: information about the network today is outdated tomorrow. Second, transport requesters ask for cheaper transport and more possibilities to choose from, but still with a high level of reliability. It becomes increasingly important to process the increasing amount of information and to settle sharp agreements with the partners. Regardless of the potential for the use of ICT, there are hardly any initiatives taking place to support strategic coordination. In the rest of this article, therefore, attention is paid to introducing an ICT based system for the strategic coordination level.

***Decision support for chain management***

It is widely believed that the use of ICT may lead to an overall shift towards smaller firms and propotionally extra use of markets instead of hierarchies [Malone et al. 1987]. Outsourcing can be identified and at the same time the use of ICT can facilitate an increase in the number of organizations involved. Although the use of ICT facilitates interorganizational coordination, it also increases the complexity of coordination: more coordination processes are used and more organizations are involved resulting in more communication activities and in more information to be taken into account when making a decision. Several authors [Bakos 1998, Chircu and Kauffman 2000, Kornelius and Ekering 1994, Malone and Rockart 1991, Moore 1996] believe that introducing an intermediary to deal with the complexity can satisfy the need for coordination, or as it is sometimes called chain manager, broker, network director, infomediairy, consolidator, or specialist. Based on these expectations, it is assumed that in container transport a chain manager will carry out strategic coordination processes between transport requesters and transport providers. This section will focus on ICT based decision support for this chain manager consisting of processes to carry out chain management, an information structure in the form of a database and a model base used for analysis of the information and supporting the processes to be carried out.

**Processes**

Strategic coordination is divided into three smaller steps, based on Guttman and Maes [1998]: the information step, the preparation step, and the negotation step. The information step is mainly about information collection about competitors, transport providers, transport requesters, and environmental changes. The availability of this information is considered to be a necessary precondition to lower the degree of uncertainty and to start negotiations. In contrast to the current situation, detailed information about the inland container transport chain should be collected by the chain manager. An information structure is designed to support this (see below).

During the preparation step, negotiations are prepared for by defining requirements to specify what it is that is wanted and by selecting possible participants than can meet these requirements. The number of factors or requirements taken into account should not be restricted: the more factors there are under consideration, the more a better comparison between alternatives is enabled and the more the outcome of the negotiation is improved [Roloff and Jordan 1992, Schermer 1997]. A number of factors was defined for inland container transport which together form a complete set of requirements for transport requests [Bowersox and Closs 1996, Mennega 1993, Ribbers and Verstegen 1992]. Some factors are transport related: costs, time, environmental effect, physical complexity, administrative complexity, and extra service. Other factors are participant related: quality, reliability, personal relationship, and after-sales service. The factors are used in a multicriteria method to evaluate the degree to which a transport solution meets with the requirements of a transport request. An algorithm is designed to support this and is described under the model base. The transport solutions that result from the algorithm are used as input for the negotiation step.

During negotiation, one tries to reach an agreement with one or more of the participants selected. Negotiation can be seen as a sequential process, which is manifest by the iterative communication of offers and counteroffers. The negotiation process terminates when a consensus is reached or a willingness to negotiate vanishes. A detailed description of the negotiation step can not be given since this depends strongly on the characteristics of the person involved. However, a cooperative approach is preferred over a hostile one for the inland container transport chain, because of the importance of trust [Guttman and Maes 1998, Mumpower 1991, Schenker 1997]

**Information structure**

Information must be collected about the inland container transport network. Great challenge in this was to find a good structure for storing information about different element of the container transport system: trains follow a time schedule, trucks can drive at any moment in time, tariffs depend on the type and weight of the container and the weight of the good, tariffs for transshipment depend on the time in the day, and so on. The information structure is presented in Figure 1 and stores information on three main elements: transport providers, transport requesters, and competitors.

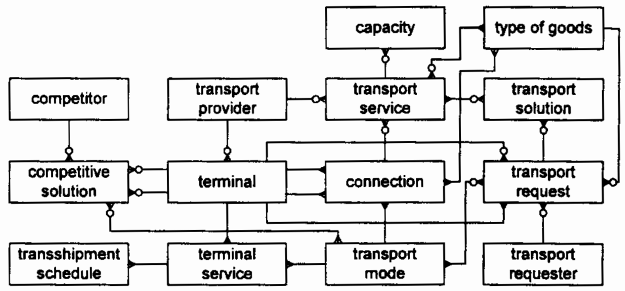


**Figure 1: Information structure**

First, information about transport providers is stored. Two types of providers are of importance: carriers and terminal operators. A terminal operator operates at one or more terminals. Two services are carried out at a terminal: transshipment and storage. The storage of a container costs a certain amount of money. The transshipment of a container also costs a certain amount of money, but this amount depends on the transport mode and on the time transportshipment takes place. For example, during weekends or at nights it could be more expensive or not be possible. The carrier is the other type of transport provider, which operates a transport service on a connection between two terminals. A connection has a certain distance, which can be crossed using a specific transport mode. A transport mode causes some environmental costs when used, for example air pollution. A list of the types of goods that are allowed on this connection is added to the information structure. The transport of highly explosive goods, for example, is prohibited on certain connections. Furthermore, a connection has a start time and an end time. The reason for this is that transport may not take place at every time of the day or week, for example during nights or weekends it might be prohibited. A transport service starts at a certain moment in time, has a certain frequency such as daily or weekly, and takes a certain time to completion. In case of a truck service which does not follow a schedule the duration is sufficient. Furthermore, the transport of a cointainer costs a certain amount of money. Finally, a list of the types of goods that are allowed to be transported with this transport service is added to the information structure: for the transport of some type of goods, a qualification is required and not every transport providers has the right qualifications.

The second element concerns transport requesters. A transport requester can have one or more transport requests. A transport request contains information about the number of containers which the transport requester wishes to transport, the type of goods in the containers, the origin and destinations of the containers, the total transport time allowed, and the allowed transport modes in the case of a preference. Furthermore, a request comes with certain criteria that must be met, for example, concerning costs, transport time, physical and administrative complexity, environmental effect, reliability, safety, after-sales service, and quality. When a transport request is already linked to a transport service, there is a transport solution. A transport solution is constructed out of one or more transport services, for example when train and truck are used to transport a container.

The third element is about competitors. They provide transport solutions between two terminals. A competitive solution has a certain tariff, starts at a certain moment in time, takes a certain time to completion, uses one or more transport modes, and has possibly extra services that come with the transport solution.

**Model base**

The model base mainly consists of an algorithm to deal with multiple criteria as mentioned under the preparation step [Hengst and Sol 2000]. Many different methods have been described in the literature for comparing alternatives on several, sometimes conflicting, criteria [Zeleny 1982, Patton and Sawicki 1986], for example: the multi-attribute utility theory, goal programming, multi-objective programming, compromise programming, linear multi-objective programming, paired comparison, lexicographic ordering, the Goeller scorecard, and the alternative-consequence matrix. There, however, is no one best method. One aspect on which the methods can be compared concerns the outcome of the method; some methods produce a single value and other methods use several values. Patton and Sawicki [1986] say that methods producing a single value are useful in helping individuals or small groups with similar preferences to select among alternatives. The other methods are more useful for public-sector problems where different groups hold different values. With the construction of transport solutions, the preferences of only one actor, the transport requester, are important. A multiple criteria method producing a single value can, therefore, be used for the construction of a transport solution.

Using a multiple criteria method, however, is not sufficient for the construction of transport solutions. Multiple criteria methods can compare explicit alternatives. If alternatives are available explicitly, the value for criteria can be achieved in a direct manner. A transport service, for example, is an explicit alternative. Implicit alternatives are alternatives that must be constructed out of a set of 'sub-alternatives'. The values for the sub-alternatives are available, but the values for the alternative depend on the construction out of the sub-alternatives. Transport solutions are implicit alternatives; they are constructed out of transport services, such as transport by train, transshipment and transport by truck. The solutions must be constructed before the values can be obtained and a multiple criteria method can be used. The transport services, however, describe a complex network of transport routes, which can be combined into many different transport solutions. Most of these solutions are not relevant to the request asked for. It would be too time consuming to construct all possible transport solutions and to compare them [Buis 1996, Jurgens 1992, Rosmuller et al. 1997]. Therefore, an algorithm should be used that supports optimization of implicit alternatives. The algorithm should deal with large networks, but should still calculate a transport solution within reasonable time.

Several algorithms exist that support the optimization of implicit alternatives, see table 1. Some algorithms were especially designed to be used in transport: the algorithms designed by Tulp,

| Algorithm | Multiple modes | Multiple time aspects | Multiple criteria |
|---|---|---|---|
| Algorithm Dijkstra [1959] | one mode | throughput time | one criterion |
| Algorithm Floyd [1962] | one mode | throughput time | one criterion |
| Algorithm Jurgens [1992] | one mode | throughput time | one criterion |
| Algorithm Tulp [1991] | one mode: train | time schedules | one criterion: time |
| Algorithm Buis [1996] | multiple modes | throughput time, time schedules, and time windows | one criterion: time |
| Algorithm used in road systems (Route66, AutoRoute, AutoLease) | one mode: road | throughput time | one criterion: time or distance |
| Algorithm used in air reservation systems (Galileo, Sabre, Apollo, Amadeus) | one mode: air | time schedules | one criterion: time |

**table 1: Algorithms matched with the requirements for inland container transport**

Buis, road systems, and air reservation systems. Other algorithms have a more general application area: the algorithms designed by Dijkstra, Floyd, and Jurgens. Unfortunately, most algorithms lack some aspects required for use in inland container transport. The requirements that the algorithm must meet are presented below.

- *Multiple transport modes*. Inland container transport is characterized by intermodality, meaning that more than one transport mode can be used for the transport of containers. The current algorithms are often oriented towards only one transport mode. The algorithm must work with trains, trucks, barges, and coastal vessels.
- *Multiple time aspects*. The algorithm should deal simultaneously with three different time aspects. The first aspect is the throughput time of transport services without taking into account some schedule. Trucks that can travel at any time are an example of this. The second time aspect takes into account time schedules according to which a transport service is carried out, for example in the case of trains. The third time aspect concerns time windows in which no transport is allowed, for example a driving ban during weekends for trucks or tides in the case of coastal vessels. Most algorithms can deal with one time aspect only, being throughput time or time schedules.
- *Multiple criteria*. As mentioned above, it is important to take into account multiple criteria for the construction of a transport solution. Most algorithms take into account only one criterion, for example time or distance. The algorithm to be used for the construction of transport solutions should take into account several criteria.

Buis's algorithm meets best with the requirements and is used as starting point for the algorithm. The requirement for using multiple criteria is not met by his algorithm and this needs to be adapted in the algorithm. The algorithm is based on the shortest path algorithm described in Dijkstra [1959] and elaborated in Buis [1996]. Dijkstra's algorithm is often considered to be the best algorithm to search a finite, directed graph whose links have non-negative lengths. Dijkstra's algorithm can be shown to find an optimal path, when available, from one node in the graph to another node in the graph. The algorithm described in this paper searches transport solutions through a graph. The construction of the graph was adapted to the situation of inland container transport. Graphs are constructed based on the information available in the information structure.

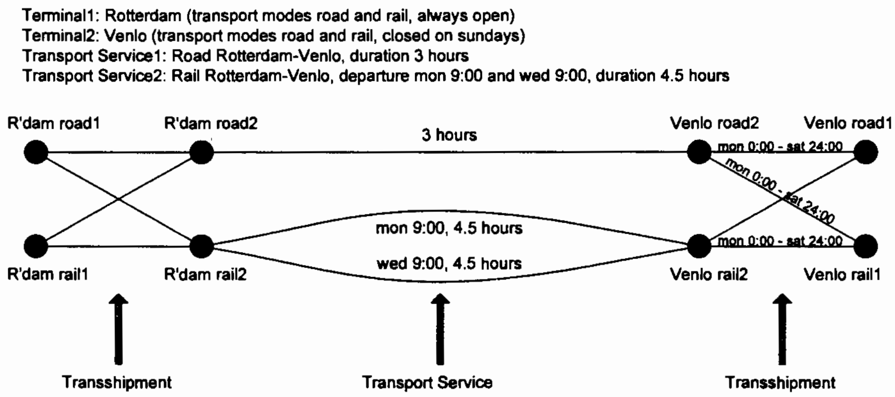


**Figure 2: Graph notation**

A graph consists of nodes connected by links. The nodes represent terminals, whereas the links represent transport services. Since more transport services are possible between two terminals, for example a service during the morning and a service during the evening, more links are possible between two nodes. Whereas in most graphs a link contains only one value, in the graph used in this research each link contains several values for tariff, throughput time, time schedules, time windows, environmental effect, administrative complexity, physical complexity, reliability and so on. These values are calculated into a single total value using a multiple criteria method. To represent terminal services, each node was divided into subnodes, eight at most: an incoming and an outgoing subnode for each transport mode. In contrast to traditional graphs, each node has an attribute containing the transport mode. The terminal services with their time schedules and tariffs are then represented as links between the sub-nodes.

Using this graph notation, the algorithm can search for the optimal route between two nodes, given certain restrictions, for example with regard to transport modes or departure and arrival times. These restrictions are expressed in the transport request and can be used in the graph since the links and nodes contain values for each of these elements. A simple example of the graph notation is given in figure 3.

***Prototype***

An information system was developed as first prototype to support the steps described above. The information structure is translated to a database which supports the storing and processing of the information. During the preparation step, this information is processed using the algorithm in the model base. Transport solutions are presented in an ordered manner to the user. No ICT support as yet is prescribed for the negotiation step. Although ICT could be used to support communication, face-to-face meetings are considered to be too important to be replaced.

The first prototype is presented in Figure 3. The box at the top of the screen shows the transport request for which the chain manager must find a transport solution. The information system searches for transport solutions and the results of this are presented in the lower half of the user interface. A map is presented on which the terminals are located and on which routes are drawn. A textual output box is available in which detailed information about the transport solution can be found. A histogram is used for a graphical comparison of the transport solutions and is presented at the bottom of the user interface. The transport solutions are ranked according to the total value, based on the values for the individual factors. The reason for presenting the individual values is that transparency of an algorithm increases acceptance by decision makers [Kersten 1988, Zeleny 1982].

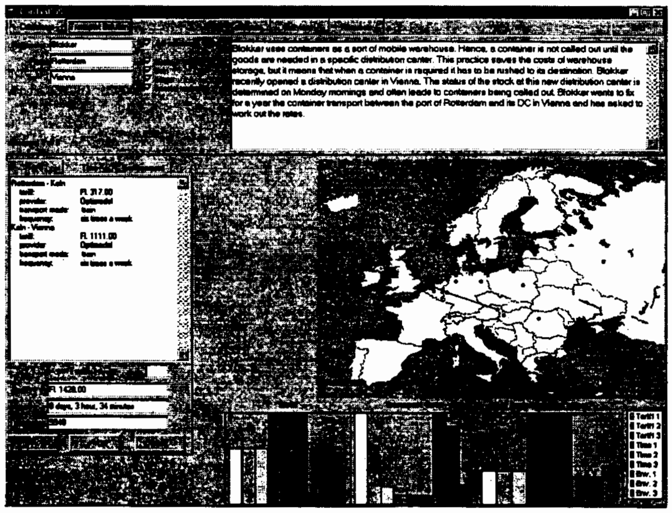

**Figure 3: Screendump of first prototype**

Nine experts from the container practice were invited to analyze the prototype and the prescribed processes of the chain manager. All experts were enthousiastic about the prescribed situation and were convinced that such a situation will occur eventually in the port of Rotterdam. Furthermore all experts were enthousiastic with regard to the prototype. None exclusive asked for the availability of a commercial version of the prototype. Main advantages of the system mentioned by the experts: having such an amount of detailed information available right at hand, and searching through this information using several factors. Main question that was left unanswered is: who will play the role of chain manager. Forwarders are yet too much focused on the operational processes, and it is not the core business of shipping agents and inland carriers. Furthermore, most forwarders are too small to invest large amounts of money in developments as mentioned above.

***Practical Application***

LEHNKERING Logistics B.V. is a forwarder operating in the port of Rotterdam amongst others. The department Container Logistics takes care of the container transport through the port of Rotterdam. This department plays a forwarding role for about 60.000 containers per year for three main clients and some more smaller clients. Most containers are export containers with their origin in Germany and their destination somewhere oversea.

Until some years ago, LEHNKERING Logistics B.V. arranged all aspects of the inland container transport. Most of these activities now have been taken over: shipping agents more and more want to arrange the inland container transport themselves. Currently, shipping agents settle agreements with shippers about the inland container transport and the shipping agents take care of this inland transport. In this case, LEHNKERING Logistics B.V. only functions as an 'administrative' link in the process: they take care of the flow of documents and control the flow of containers. With the ongoing developments in ICT, however, these tasks also are due to disappear.

It can be stated that LEHNKERING Logistics B.V. mostly carries out operational coordination processes, while these have the potential to be automated by ICT. The strategic coordination processes are mainly carried out by shipping agents. In order to stay competitive, LEHNKERING Logistics B.V. wants to change its business processes from the operarional coordination level more towards the strategic coordination level. To start this process of change, the decision support system for chain management in the container transport industry presented in the previous section was used as starting point. The rest of this section pays attention to the changes that were required to implement the system designed in a real life situation and the challenges that were faced during this process.

**User Interface**

When looking at the screendumps (Figures 4 - 6) some major changes concerning the user interface can be identified. First, the transport request is elaborated into great detail. Besides asking for the origin and destination as well as the preferred transport modes, elements like the type of container, type of goods, and time preferences have been added (on the left side of the screen). On the right side of the screen, the factors for the transport request can be set to a value. For the factor tariff, for example, a limit is asked for as well as a desired value. Furthermore the importance of the tariff is asked for for each transport request. In the first prototype, it was assumed that this was a one time excersise, but it showed that each transport request has its own characteristics.

Also with regard to displaying the transport solution a change can be spotted. In the first prototype a graphical presentation of the transport solution was added, but it seemed that this has hardly any added value. Furthermore, the prototype showed several transport solutions ranked according to their total value. This was quite disturbing for the chain manager, especially when it seemed that the best solution is always used as a starting point. Therefore, just one transport solution is presented on a global level. Besides this global level, a more detailed level of the transport solution in which more information is presented can also be shown as is presented in the last screendump. If the best solution shown is not chosen, one can search for the next best solution

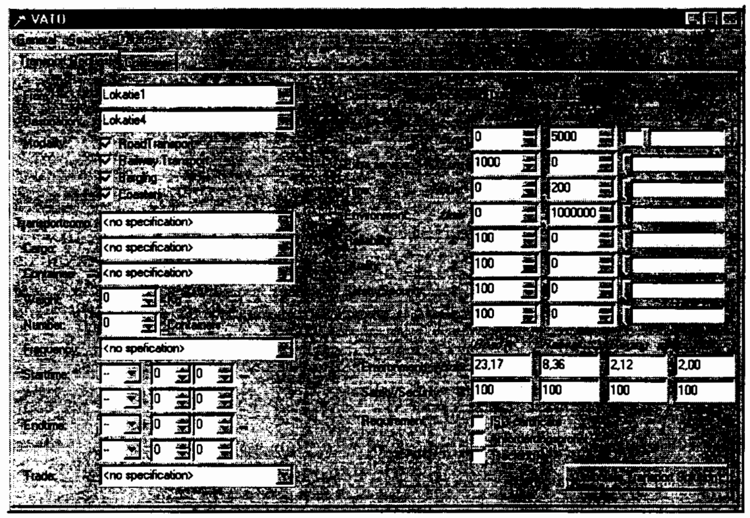


Figure 4: Screendump of transport request

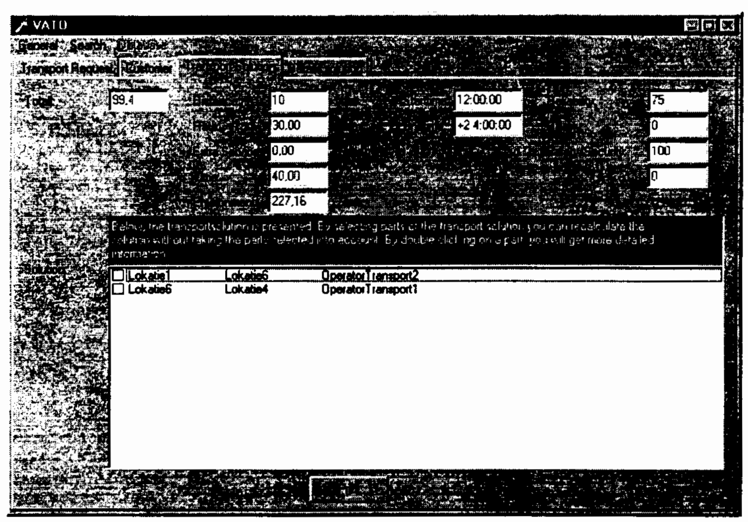


Figure 5: Screendump of transport solution

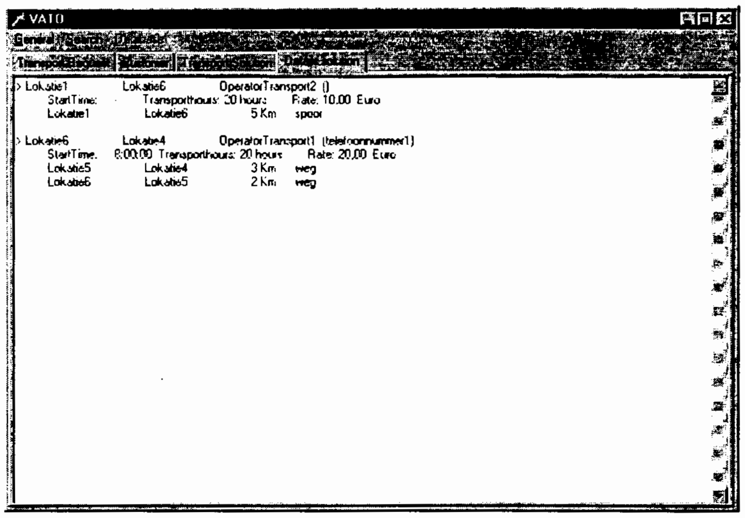


**Figure 6: Screendump of detailed transport solution**

**Information structure**

The information structure designed for the first prototype was set up in such a way that it could deal with the many different elements of the container transport industry. Yet, during implementation at LEHNKERING Logistics B.V. it showed that much more level of detail would be required to take into consideration all situations possible. The tariff for transshipments, for example, doesn't only depend on the time in the week, but also on the overseas destination of origin of the container. During implementation it became clear that a trade off had to be made between the required level of detail and the time it would cost to fill the database with information. The more detail required, the more information needs to be filled in. Deciding on this trade off was a difficult exercise taking up much time for several reasons. The persons filling the database are not the same persons as using the information in the database and discrepancy exists between these two.

Furthermore, it showed that filling the database with the right information is a time consuming activitiy. First, because most of the information is available on paper at this moment. Second, because some information elements are not known in the current situation and must be collected explicitely. Although this activity is considered time consuming, it is expected that most of this information will be made avalailble in an electronic format in time. The use of internet and software agenst then can take over great part of the work now done by human beings.

**Model base**

With regard to the model base, hardly any changes were required. Several techniques were added to reduce the search time of the algorithm:

- *Use heuristics*, for example by starting with the links with the highest total value or by starting with nodes that are located in the close neighborhood of the origin node or destination node.
- *Reduce the number of links*, for example by removing the links with the lowest total value if more than one link exist between two nodes or by removing the links that do not meet the restrictions with regard to transport modes or departure and arrival times requested for.
- *Reduce the number of nodes*, for example by removing the nodes that are located between only two other nodes or by removing the nodes that do not meet the restriction with regard transport modes requested.

### Conclusions

ICT is offering great opportunities for changing and supporting inter-organizational coordination and more specifically for changing and supporting chain management. A decision support system has been designed for supporting chain management in container transport. A first prototype has been used successfully in a laboratory setting. But since the proof of the pudding is in the eating, is has also been applied to a real life situation, offered by LEHNKERING Logistics B.V. Several things can be concluded from this.

First, the database could handle a great level of detail, but this appeared to be insufficient to deal with all special situation in practice. Deciding on the exact level of detail to be incorporated in the database appeared to be an ongoing discussion between the persons entering data into the database and the persons using the data. Second, the system is being used during negotiations and not during the preparation step that precedes the negotiations. This requires a fast algorithm. Modifications have been made to reduce the search time of the algorithm. Furthermore, filling in the database is a time consuming activity, especially at this moment since hardly any information is available electronically. It is advised to have one person available to keep the database up to date. Finally, implementing the system described in this paper is just one step towards carrying out chain management. Inter-organizational processes and structures must change accordingly to gain maximum advantage of the usage of ICT for inter-organizational chain management. By implementing the system, the first step is taken, but it takes many more steps to reach the ultimate goals.

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