MASTER

Smart bargaining
intelligent software agents in the outsourcing processes of Vos Logistics Organizing

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Smart Bargaining

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Appendices

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A Stages of ICT architectures

Figure 23 depicts the various stages of automation that information systems have gone through or can go through. What can be seen is that in the first stage, 'islands of automation' exist. In the second stage, the focus is on organization-wide integration of these islands, for example by implementing ERP modules. The third stage, chain integration, focuses on cross-organizational integration with a fixed set of supply chain partners, e.g. through EDI connections. In the fourth stage, the set of partners is much larger and more flexible. The companies in such a configuration are sometimes referred to as forming a 'virtual enterprise', as linkages between the network partners are very dynamic and sometimes live for a short time only, e.g. coalitions of partners are formed on a per project basis.

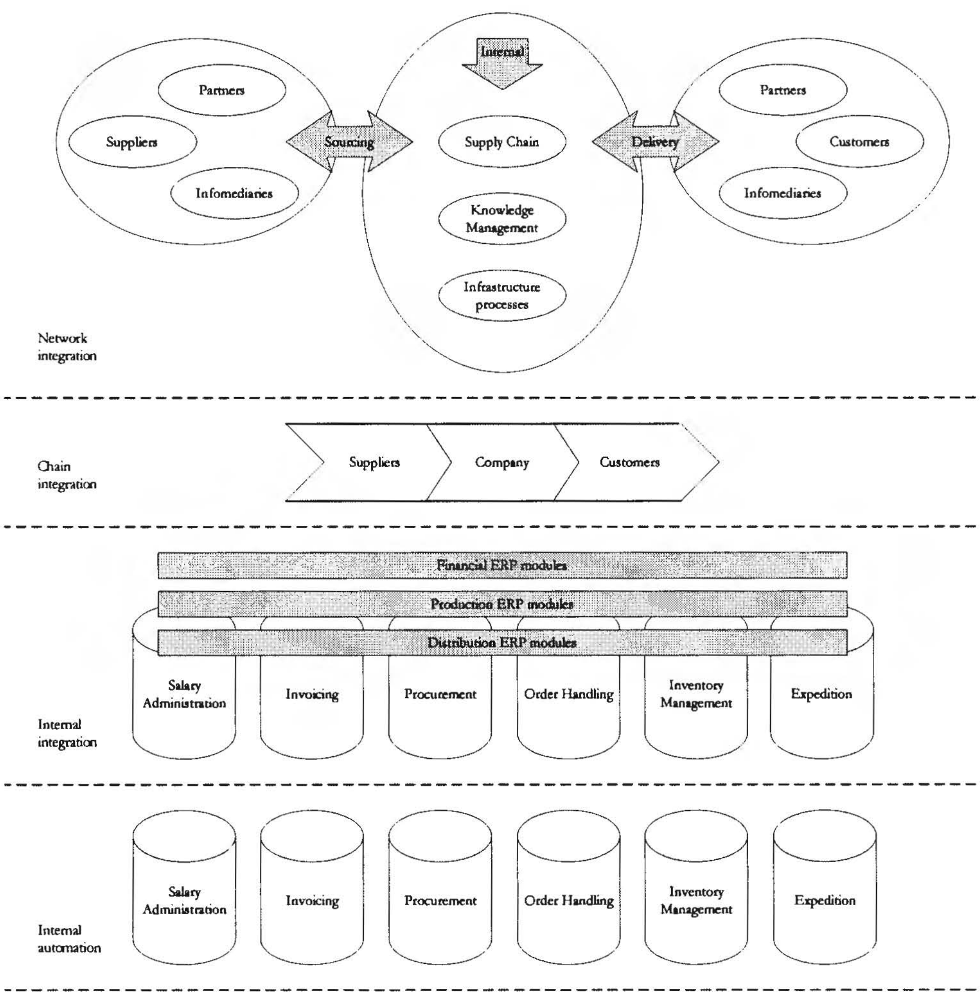

Figure 23: Stages of ICT architectures

B Agent types

Papazouglou [44] has recognized the importance of organizing agents in a multi-agent environment into different categories, depending on their functionality and competencies. He defines four categories:

- application agents
- personal agents
- general business activity agents
- system-level support agents

This categorization has been simplified by Verduijn et al. [65], based on the vague distinction between application agents and general business activity agents. The two categories have been merged, and along with some other minor changes, this has led to the classification depicted in Figure 24.

Figure 24: Classification of agent types

The three main categories will be described here briefly to illustrate some of the concepts and capabilities of agents.

General business activity

General business agents perform a large number of general commerce support activities that can be customized to address the needs of a particular business organization. In the new classification from Verduijn et al., this category also includes application agents. According to Papazouglou, an application agent is specialized to a single area of expertise and provides access to the available information and knowledge sources in that domain and works co-operatively with other agents to solve a complex problem in that vertical domain. However, the difference as to whether an agent relates to a specific value-adding area or whether it is related to a general activity area is a bit vague, and for this reason they were merged in the new classification.

Examples of agents in this category with respect to VLO would be those that monitor incoming orders (e.g. for completeness and validity), create bundles out of these orders or negotiate with other (human or software) agents on the settlement of these orders.

System-level agents

System-level agents exist on top of the distributed objects infrastructure, which provides objects with transparent access not only to other application objects, but also to such facilities as transaction processing, permanent object storage, event services and the like [44].

With respect to VLO, an example of an agent in this category would be interoperation agents that support e-business transactions by linking new or extended information systems with other systems (e.g. legacy Transport Management Systems).

Personal agents

Personal agents are those agents that work directly with users to help the user with a specific request (presentation, information collection, etc.). A personal agent gives its user easy and effective access to profile related specified services and information widely distributed for example on the Internet [44].

For VLO, one could think of an agent presenting the results of a negotiation to support the user in making the final decision (e.g. when the decision would involve too many factors to completely automate the process). Another example would be an agent that would actively search the Internet for carriers with a certain specialism (which is entered by the user) and ranks them based on the criteria relevant to VLO (price, number of trucks, ISO qualification, etc.).

C Agent applications

Chapter 2 mentions a classification of application areas for agents in transportation and logistics. This classification is repeated below in Figure 25, for easy referencing. Each of the seven types depicted in this figure will be discussed in more detail below.

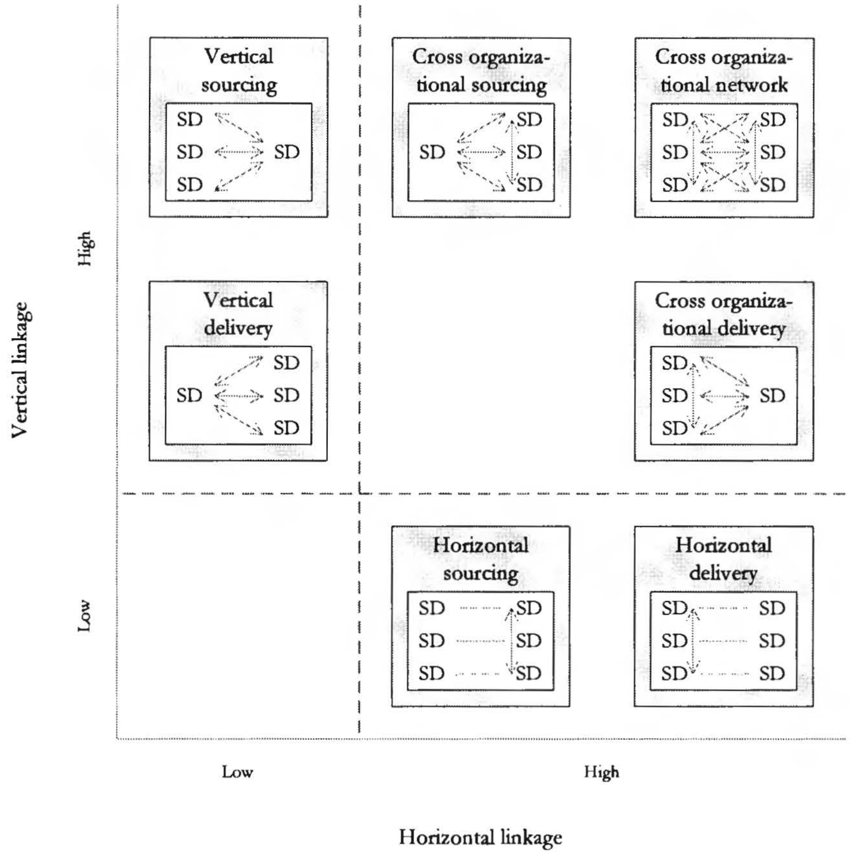

Figure 25: Classification of agent-based collaboration structures (repeated)

Horizontal sourcing

In horizontal sourcing several parties that perform similar activities and/or services form a collective buyers group. Together they can achieve cost reductions because of a larger demand, which they could not have realized by themselves. Agents can search which partners would want to join in a collective purchasing order, they can negotiate on and agree to the terms (minimum quality, maximum price) and they can choose a broker to interact with the supplier on behalf of the customers [65].

Horizontal delivery

Horizontal delivery concerns opportunities for consolidation based on the coordination of deliveries. Carriers might exchange shipments to achieve loading percentages closer to FTL and/or to create more efficient routes (e.g. less empty kilometers). Coordination between competitors can be efficiently handled by means of negotiation between the agents in a multi-agent system [65].

Vertical sourcing

In vertical sourcing, a buyer identifies potential suppliers and negotiates product price, service and quality elements. Next, the buyer selects a supplier through setting (weighed) priorities and comparing the offerings [65].

The capabilities of agents to autonomously move across and search the network for supplier information allow them to support in the identification of parties in the bidding process. Autonomous agents can also be used to negotiate with each other, taking their own goals into account. Agents can jointly explore possible contract combinations, including the possibilities of negotiating over bundles of inter-related orders. Finally, the buyer agent can assist the buying party in winner determination and contract awarding.

By taking away the manual steps and the waiting times that go along with it, agent technology can help to shorten sourcing cycles. Furthermore, much more alternatives can be evaluated and, as a result, there is an increased chance of coming to a better decision.

Vertical delivery

Vertical delivery concerns the coordination of deliveries of one supplier in accordance with the requirements of its customers. Although traditional IT can manage these interdependencies of the supplier and its customers for stable supply chains, agile supply chains require more flexible, adaptive agent-based systems, in order to deal with dynamic coalition formation [65].

Cross organizational sourcing

Cross-organizational sourcing involves inter-organizational vertical coordination of deliveries and customer requirements in combination with inter-organizational horizontal coordination of demand. This type of sourcing might prove beneficial if the customers are confronted with scarcity at the delivery side. Customers can coordinate demand in terms of quantity and timing at the sourcing side to improve chain-wide performance [65].

Cross organizational delivery

In this case, the customer's order is so particular that several suppliers need to work together to fulfill the order. As a result, the suppliers need to (horizontally) coordinate the delivery activities. Suppliers may need to coordinate their final deliveries with the customer concerning location and time [65].

Cross organizational network

In an agent based cross organizational network many actors have to plan their activities simultaneously. These interdependencies include both vertical and horizontal collaboration between the parties. This leads to the need for extensive planning and coordination that is in accordance with the interests and characteristics of all actors. The benefits discussed in the previous categories are combined in this form of network collaboration [65].

D Negotiation research areas

The variety and diversity of roles of negotiators and negotiation situations challenge researchers from many disciplines. Although problems arise from this variety of involved disciplines (e.g. the introduction of different terminologies, definitions, notations, etc.), interdisciplinary approaches provide richer and more comprehensive models of negotiators and negotiations [5]. It is therefore important to understand the areas of studies concerned, their results and key influences. These areas and the relationships between them are depicted in Figure 26, which was adopted from Bichler et al. [5].

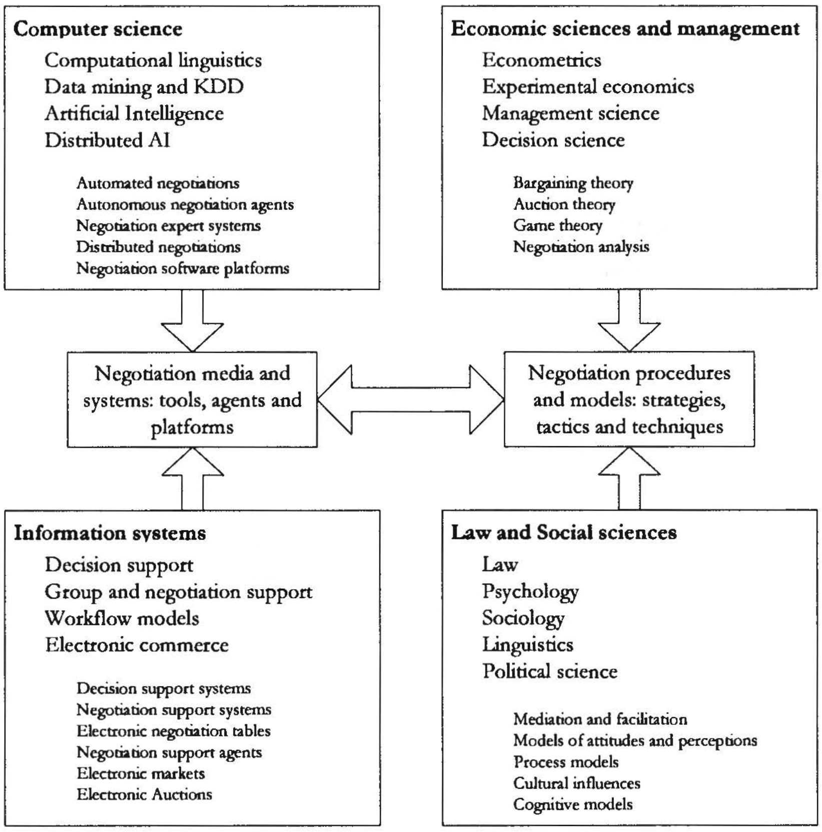

Figure 26: Negotiation research areas, their results and key influences

E Quotation process

In Figure 27, the process of quotation handling has been represented using UML activity diagram notation. This process involves providing quotes to VLO's customers for some of the smaller contracts. The quotation process for smaller contracts is described here as it illustrates how prices are constructed. Furthermore, at times carriers are involved in this process to come up with well-funded prices. Finally, this process is relevant as VLO currently works more often than not with fixed prices and uses the prices provided by the carriers in this process.

Larger and/or long-term contracts are strategically sourced. This process has not been considered in detail here due to its ambiguity, complexity and the implications it has on relationships with carriers. In paragraph 2.3.2, it has been explained why software agents would not be suited to deal with these kinds of situations.

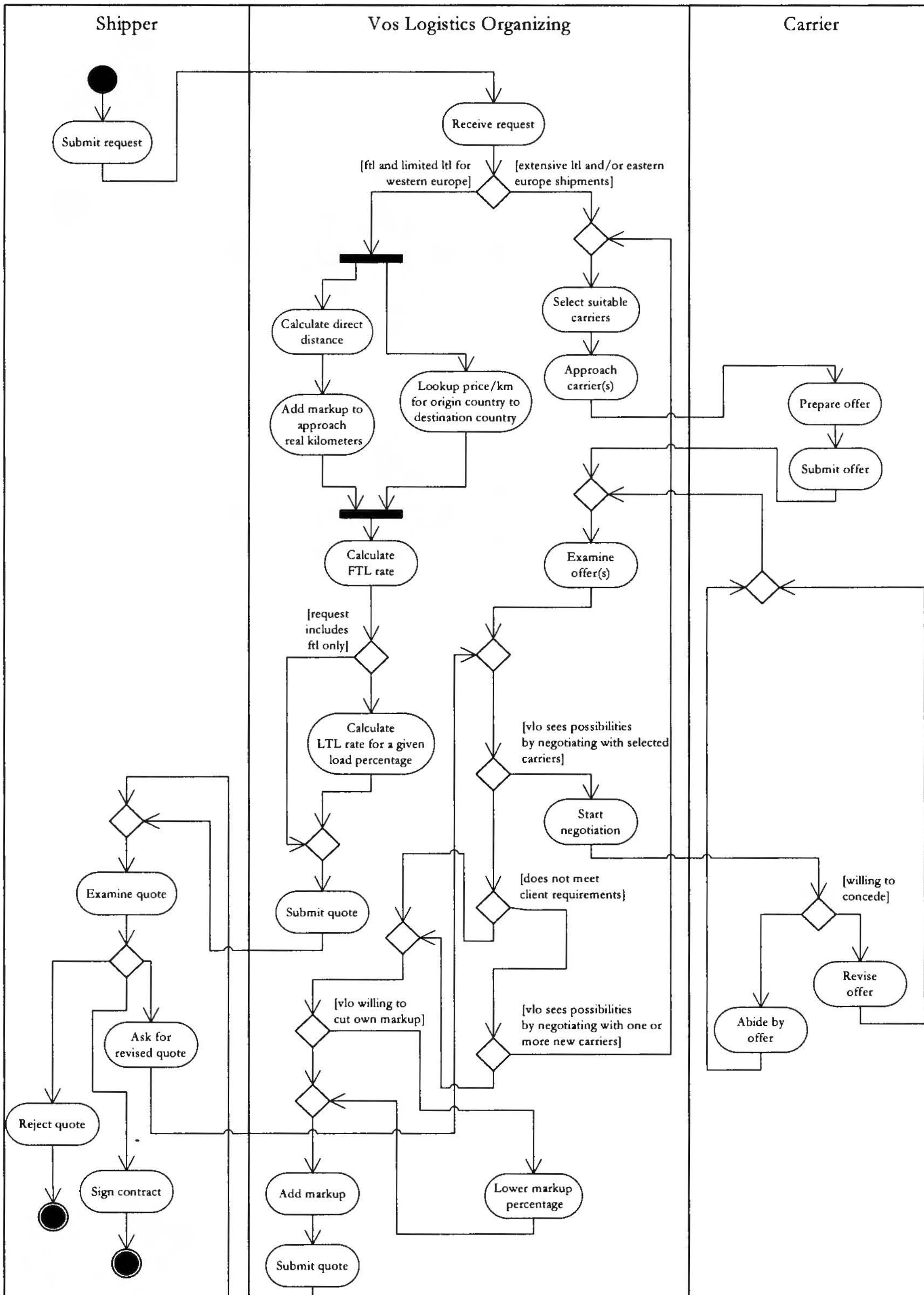

Figure 27: Quotation process

The important and non-obvious steps will be described below.

Examine request

When requests for quotations are received, through email, telephone or fax, a first check is made to check the country of origin, the country of destination and to see if it involves LTL (less than a full truckload) shipments.

Calculate direct distance/add markup to approach real kilometers

If the shipments mainly consist of FTL (full truckload) shipments and are located in Western Europe, Vos Logistics Organizing (VLO) determines the prices themselves. Using a route planner, the distance of the shipment is calculated and a small percentage is added to approach a more realistic distance. Usually this is 5% to account for issues such as detours due to road maintenance or traffic jams.

Lookup price/km for origin country to destination country

A certain price/km value is used for a 'country of origin' to 'country of destination' combination. Different values are used for each combination, e.g. for a shipment from France to the Netherlands a lower value is used than for shipments from the Netherlands to France. This has to do with the amount of return freights generally available in the country of destination.

If a truck coming from France has to deliver something in the Netherlands, chances are high that there is a freight waiting to get from the Netherlands to France. It is different the other way round. If a truck is empty in France there is a much smaller chance that there are freights waiting to get from France to the Netherlands and as a result there is a higher chance that the truck has to return empty. To illustrate, rates from France to the Netherlands are about € 0,60 to € 0,80 per kilometer, whereas prices from the Netherlands to France range from € 1,25 to € 1,50 per kilometer.

Calculate LTL rate for a given load percentage

If the request includes some LTL shipments also, a price is calculated for each loading percentage using a logarithmic-like function. A quarter of a truckload is roughly 50% of the FTL price for example, whereas half of a truckload equals approximately 70% of the FTL price. The quote is then sent back to the shipper, again through e-mail, telephone or fax.

Select suitable carriers/Approach carrier(s)

If a shipment involves extensive LTL shipments or involves destinations in Eastern Europe, VLO approaches carriers to get an indication of the costs. The main reason is that prices fluctuate too heavily in the Eastern European area for VLO to use simple rules of thumb such as a price/km from one country to another. With respect to LTL shipments, VLO doesn't have enough expertise to come up with well-estimated prices. Several carriers, who VLO believes to be interested in taking on the job, are approached.

Examine offer/Start negotiation/Add markup/Submit quote

Bids are received from one or more of the carriers. These bids are examined and if VLO thinks prices are too high a negotiation process is started already in this phase. If VLO thinks there is no more room for negotiation, a markup percentage of around 10%-15% is added and the final quote is submitted to the shipper.

Examine quote/Reject quote/Accept Quote/Ask for revised quote
The shipper chooses from three courses of actions. First, the quote can be rejected and the process is aborted. Second, the quote can be accepted directly, after which the contract is signed. The third option is that the shipper might ask for a revised quote.

(Re)Start negotiation/(Re)Select suitable carriers/Lower markup percentage
When a client asks for a revised quote, VLO starts negotiating with the carriers that were already approached for this quote. If they do not concede and VLO thinks there is a chance for better offers by approaching one or more new carriers, the process of selecting suitable carriers is restarted. If the quote still does not meet the client's requirements but VLO sees no more room for negotiation, VLO might decide to lower it's own markup percentage if a high volume is involved or if the client's (future) business is desired by VLO. The quote is then resubmitted.

F Order tracking process

VLO does not actively monitor the loading/unloading of the transport itself. However, when exceptions arise, VLO is notified and participates in finding a solution. This process is displayed in Figure 28.

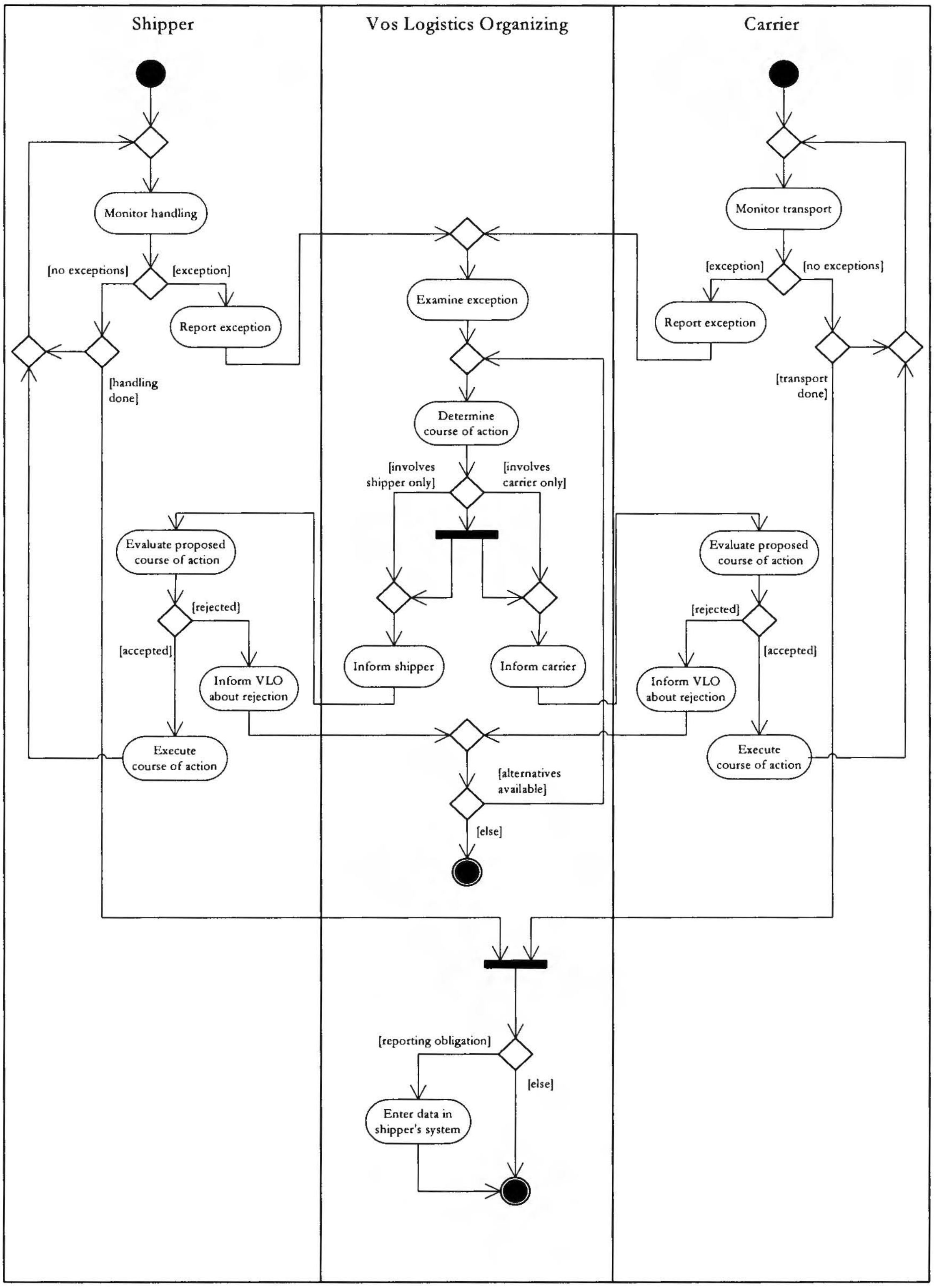

Figure 28: Order tracking process

Monitor handling/Monitor transport/Report exception
Either the carrier or the shipper notifies VLO of exceptions. With respect to the shipper, this could be things like damaged goods, exceeding of the loading/unloading time slots, a driver which was unsatisfactory, e.g. he did not speak the language or smelled like alcohol, or a truck that was unsatisfactory, e.g. one with worn-out tires. A carrier in its turn reports when a truck is running late due to traffic jams for example. The cancellation of transport by a carrier is also considered an exception here.

Examine exception/Determine course of action/Inform shipper/Inform carrier
In all cases, VLO receives and examines the exceptions. After examination, a course of action is determined and this action is discussed with the shipper, the carrier or both.

Evaluate proposed course of action/Execute course of action/Inform VLO about rejection
If the proposed course of action is accepted, it is executed according to plan. If it is rejected, VLO looks for alternatives and proposes these. Such alternatives could include finding a new carrier if the original carrier has cancelled. If there are no viable alternatives, the order is cancelled and the process is terminated. To illustrate the process of exception handling, consider the following example that happened during the participatory observation. The shipper of the goods called VLO that the goods that are in transport are not suited for retail and need to be returned to the factory. The truck responsible was at that time almost at the destination and could not return due to tight planning for the rest of the day. After some deliberation, VLO, the shipper and carrier agree to drop off the goods at a warehouse close to the truck's current location and agree that a new carrier is to be sought for bringing the goods from this location back to the point of origin.

Enter data in shippers system
If no exceptions occur or if all exceptions have been handled, VLO enters the data in the shipper's system if the shipper has requested to do so. An example of such a platform is AX4, which is in use by BASF, one of VLO's larger clients. If there is no external reporting obligation, this step is skipped.

G Teleroute tariffs

In Table 13 the tariffs charged by Teleroute for usage of their services are displayed, which were retrieved from http://www.teleroute.nl at May 10th, 2005.

SERVICE	UNIT	PRICE
Subscription	Month	€ 50,00
Supply		
Freight/truck	Offer	€ 1,75
Refresh (top of list)	Offer	€ 1,75
Demand		
Freight/truck	Offer	€ 0,28
Extra services		
SMS	Message	€ 0,15
Routeplanning and distance calculation	Calculation	Free

Table 13: Tariffs from teleroute

H Comparison of criteria

This step of the full analytical criteria method involves weighing the criteria against each other. Reading across from the vertical axis, each criterion is compared to those on the horizontal axis. Each time a weight is recorded in a row cell (e.g. 1, 5, 10), it's reciprocal value (e.g. 1/5, /10) must be recorded in the corresponding column cell. Each horizontal row is totaled and converted to a relative decimal value through dividing it by the grand total. This has been done in Table 14 for the criteria that were identified in Chapter 5.

Criteria	Business impact	Research interest	Feasibility	Row total	Relative Decimal Value
Business impact		1	1	2,00	0,33
Research interest	1		1	2,00	0,33
Feasibility	1	1		2,00	0,33
			Grand total	6,00	

1 = Equally important
5 = More important
10 = Much more important
1/5 = Less important
1/10 = Much less important

Table 14: L-shaped matrix for weighing criteria

I Business impact criterion

Table 15 depicts the nine alternatives compared with each other on the criterion of business impact. Comparison is done in the same way as for the criteria weighing process. To illustrate, consider the bundling of (subsequent or return) FTL shipments, which is expected to have more impact than the bundling of multiple part loads. As a result, a value of 5 has been given in the appropriate row cell of Table 15 and a value of 1/5 has been noted in the appropriate column cell.

Scores have been attributed based on interviews with experts at VLO as well as through analysis of the historical dataset over the year 2004.

Business Impact	Bundle-Part-Ship	Bundle-Full-Ship	Offer-Cap-Carrier	Offer-Cap-Tele	Search-Part-Tele	Search-Full-Tele	Neg-Price	Neg-Time-Window	Neg-Equip-Type	Row Total	Relative Decimal Value
Bundle-Part-Ship		1/5	10	10	1/5	1/10	1/5	1	10	31,70	0,12
Bundle-Full-Ship	5		10	10	1	1/5	1/5	5	10	41,40	0,16
Offer-Cap-Carrier	1/10	1/10		1/5	1/10	1/10	1/10	1/10	1/5	1,00	0,00
Offer-Cap-Tele	1/10	1/10	5		1/10	1/10	1/10	1/10	1	6,60	0,03
Search-Part-Tele	5	1	10	10		1/5	1/5	1	10	37,40	0,14
Search-Full-Tele	10	5	10	10	5		1/5	1	10	51,20	0,20
Neg-Price	5	5	10	10	5	5		5	10	55,00	0,21
Neg-Time-Window	1	1/5	10	10	1	1	1/5		5	28,40	0,11
Neg-Equip-Type	1/10	1/10	5	1	1/10	1/10	1/10	1/5		6,70	0,03
									Grand total:	259,40	

1 = Equal impact
5 = More impact
10 = Much more impact
1/5 = Less impact
1/10 = Much less impact

Table 15: L-shaped matrix for comparing options relative to 'business impact' criterion

Bundle LTL shipments (order set), referred to as Bundle-Part-Load
To estimate the potential of bundling part loads, a query was run to check for all shipments if their delivery location and delivery date matched with the delivery location

and delivery date of any of the other shipments. Date matching was based on the same day, whereas locations were matched based on 2-digit postal code areas. Combinations found needed to fulfill the constraint that the part loads together should not exceed the maximum load capacity.

A query on all 6216 shipments handled by the Forwarding desk in 2004 returned 168 results. After removing duplicate combinations (as the result set contained both {a,b} and {b,a}), 84 results remained.

The fact that only such a small number resides (given the large number of shipments) is explained by the shipment profile, depicted in Figure 29. A significant part of VLO's orders consists of full truckloads and as a result there is less potential for bundling due to capacity constraints that are exceeded.

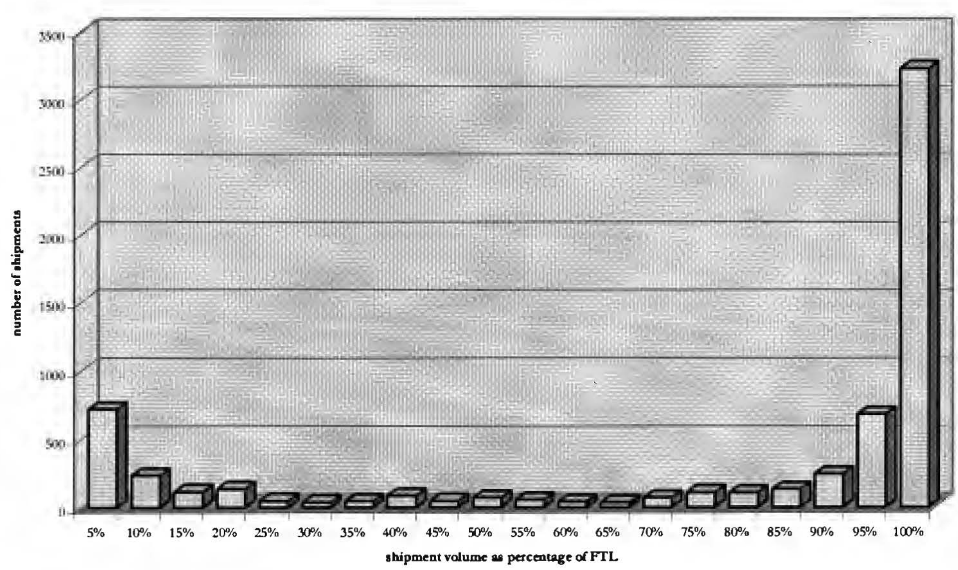

Figure 29: Shipment profile for 2004 orders handled by Forwarding desk

A manual check was done to remove mutually exclusive combinations (e.g. with combinations {a,b}, {a,c} and (TotalLoad(a+b+c) >100%), the occurrence {a,b} was kept and {a,c} was removed). Combinations that weren't mutually exclusive were bundled manually (e.g. with bundles {d,e}, {d,f} and (TotalLoad(d+e+f) <= 100%) a bundle {d,e,f} was created).

This led to a total of 101 shipments consolidated into 47 bundles. To determine savings, the average load of the situation for shipments with bundled orders was calculated. This turned out to be 38,60%, whereas the average load for the original situation was only 18,33%. Actual carrier data was used to calculate the difference in price paid for these two load percentages. This resulted in a price which was 19% lower per load unit (e.g. pallet, kilo).

With a total value of € 32201,83 for this subset of orders, savings of 19% would result in total savings of around € 6.000,00. It should be noted here that in the scoring/comparison of options, it has been taken into account that VLO expects the number of part loads to increase in the future, and business impact of this option is therefore expected to increase as well.

Bundle subsequent/return shipments (order set), referred to as Bundle-Full-Load

In order to make bundles of return or subsequent shipments, delivery and pickup locations should be close (to minimize empty kilometers) as well as delivery and pickup time windows (to minimize waiting hours costs). In order to examine the potential for this type of bundling, a query was run to check for all shipments if their delivery location and delivery date matched with the pickup location and pickup date of any of the other shipments. This query was run on all 6000+ shipments handled by the Forwarding desk in 2004.

The result set included approximately 3200 combinations. However, it included mutually exclusive combinations. Consider the result set from Table 16.

First-ID	Second-ID	First-Delivery-Date	Second-Pickup-Date	First-Delivery-Location	Second-Pickup-Location
1	2	11-05-2004	11-05-2004	34	34
1	3	11-05-2004	11-05-2004	34	34

Table 16: Sample shipment set with duplicate first shipment

Obviously, shipment 1 could be combined with shipment 2 or shipment 3, but not with both[29]. Given the large result set, a simple rule was used where the first occurrence was kept and all other combinations were removed.

A similar thing happened when there was only one shipment waiting. In this case, the query would also return mutually exclusive combinations as can be seen from Table 17.

First-ID	Second-ID	First-Delivery-Date	Second-Pickup-Date	First-Delivery-Location	Second-Pickup-Location
4	6	13-05-2004	13-05-2004	45	45
5	6	13-05-2004	13-05-2004	45	45

Table 17: Sample shipment set with duplicate second shipment

Again, the first occurrence {4,6} was kept and the other combinations were removed.

This simple heuristic can lead to a loss of interesting bundles though. Consider the starting result set {a,b}, {a,c}, {d,b} and {d,c}. After the removal of duplicate bundles that use the same first load, the bundles {a,b} and {d,b} remain. However, they both use shipment b to make a bundle. After the removal of duplicate bundles with the same second load, the result set contains {a,b} only. The combination {d,c}, which is valid in this case, has been lost in the process.

[29] Unless shipments 2 and 3 could be bundled together in the same truck without exceeding maximum load capacity. This has not been examined here, due to its added complexity and the close-to-FTL nature of most of VLO's shipments.

However, due to the more qualitative nature of this specific data collection, this simple approach was still favored over a more optimal, but considerably more complex approach.

In the end, a total of 760 shipments were found. Total savings can be calculated by multiplying this number with the average shipment value of € 670,00[30] and the 10% discount expected from carriers. This results in total savings of around € 50.000,00.

Offer truck capacity (carrier), referred to as Offer-Cap-Carrier

The idea behind this improvement, is that if VLO has a load consuming half a truck's capacity, it could offer the remaining capacity to its carriers. By doing so, it might attract a load from Carrier A. VLO might ask 75% of the FTL price for both of the loads (as prices are not linear) and charter a full truck at 100% of the FTL price from, say, Carrier B. However, if the transportation job of VLO is negotiated about by a group of carriers, this impact would not be significant. If VLO was to offer its freight to Carrier A and Carrier B in a competitive fashion, Carrier A is very likely to offer a very low price, as he would then have a full truckload and only needs about 25% of the FTL price to cover his expenses. Although it is likely that the carrier would ask somewhat more (unless he is very risk-averse), VLO can still get considerable savings this way. It has been assumed that the extra costs incurred from finding a freight itself minus the extra benefits gained are negligible. This option is therefore not considered to be very attractive with respect to business impact.

Offer truck capacity (Teleroute), referred to as Offer-Cap-Tele

For offering truck capacity on Teleroute the problem mentioned above also plays a role. By simply offering freight on Teleroute, VLO can already get good tariffs from carriers who are looking for such a freight to fill their truck. However, Teleroute offers much more potential for improving margins, as it is also occupied by shippers. Whereas carriers would offer favorable prices if they have a matching load to attract VLO's load, this does not hold true for shippers offering their freight on Teleroute. If VLO was to attract this matching load (by offering capacity) and offer it as a bundle (either to a carrier from their own closed group or by placing it on Teleroute), VLO can significantly increase their margin. However, offering capacity does not differ much from searching for freight. If VLO can continuously look for freight using an agent, this will lead to the same results as offering capacity and this option is therefore not discussed further.

Search for LTL shipments (Teleroute), referred to as Search-Part-Tele

Teleroute can be used by VLO to actively search for freight to create bundles with. It should be noted here that most of the parties on Teleroute involve external parties from an open group, and are unknown to VLO. As such, if VLO was to make a deal with them, they would run the risk of dealing with an unknown party and would probably have to verify them first (e.g. asking for and checking up on references). Furthermore, all new contacts have to be entered in VLO's financial system CODA, which takes up valuable time. The business impact is nevertheless expected to be high, due to Teleroute's very

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[30] This value differs from the one provided in 3.1.1, as only those orders handled by the Forwarding desk are taken into account here.

large order set (70.000+ orders/day[31]). Due to this large order base, the business impact is expected to be higher than creating bundles from multiple part loads from VLO's own order set. However, given the FTL nature of most of the shipments, impact is expected to be lower than bundling return or subsequent shipments from the own order set.

Search for subsequent/return shipments (Teleroute), referred to as Search-Full-Tele
For creating bundles with subsequent or return shipments, VLO can also make use of Teleroute's daily order set of 70000+ orders. The own order set has already proved that substantial gains in margins can be achieved. Using a much larger order set (in the order of thousands of times larger) significantly improves the chances of creating efficient bundles. Business impact can therefore be expected to be very high.

Negotiate on price (carriers), referred to as Neg-Price
To estimate the impact negotiation on price might have, as opposed to working with fixed prices, the commercial manager at the Breukelen office of Vos Logistics was asked on their experiences with Transporeon TiCap[32]. Their estimation was that this application, in which tariffs are renegotiated for each shipment, pushed prices down by as much as 20%. Therefore, this option is judged as having a high business impact.

Negotiate on time window (carriers), referred to as Neg-Time-Window
This option proved one of the most challenging options to estimate. Negotiation on time windows does not occur at this moment and it involves many interacting factors, as explained in paragraph 4.3. The many situations where potential savings might be generated and the positive judgment and enthusiasm from experts at VLO were reasons to consider this improvement as having a high business impact.

Negotiate on equipment (carriers), referred to as Neg-Equip-Type
The business impact of negotiation on equipment type was estimated to be close to zero. Not many shippers would want to use the way of working needed for this option, as it would involve waiting till the last minute to get the number of pallets to prepare for shipment. Furthermore, since agent technology will probably not be implemented at carriers for some time to come, evaluation of opportunities would have to be done by humans and would prove to be too costly, if possible at all.

[31] Source: http://www.teleroute.nl

[32] See http://www.transporeon.com/english/products_ticap.shtml for product details.

J Research interest criterion

In Table 18, the alternatives have been compared on the criterion of research interest. Research interest has been judged in collaboration with experts at CWI.

Research Interest	Bundle-Part-Ship	Bundle-Full-Ship	Offer-Cap-Carrier	Offer-Cap-Tele	Search-Part-Tele	Search-Full-Tele	Neg-Price	Neg-Time-Window	Neg-Equip-Type	Row Total	Relative Decimal Value
Bundle-Part-Ship		1	5	5	1	1	1/5	1/5	1/5	13,60	0,07
Bundle-Full-Ship	1		5	5	1	1	1/5	1/5	1/5	13,60	0,07
Offer-Cap-Carrier	1/5	1/5		1	1/5	1/5	1/10	1/10	1/10	2,10	0,01
Offer-Cap-Tele	1/5	1/5	1		1/5	1/5	1/10	1/10	1/10	2,10	0,01
Search-Part-Tele	1	1	5	5		1	1/5	1/5	1/5	13,60	0,07
Search-Full-Tele	1	1	5	5	1		1/5	1/5	1/5	13,60	0,07
Neg-Price	5	5	10	10	5	5		1/5	1/5	40,40	0,21
Neg-Time-Window	5	5	10	10	5	5	5		1	46,00	0,24
Neg-Equip-Type	5	5	10	10	5	5	5	1		46,00	0,24
									Grand total:	191,00	

1 = Equally interesting
5 = More interesting
10 = Much more interesting
1/5 = Less interesting
1/10 = Much less interesting

Table 18: L-shaped matrix for comparing options relative to 'research interest' criterion

Bundle LTL shipments (order set), referred to as Bundle-Part-Load

Agent technology is very suited to deal with the creation and handling of bundles. It is a challenging area with much potential for real results. The autonomous behavior of agents for example allows them to rearrange the order set into a new, efficient set of bundles upon arrival of each new order. The CWI has already participated in projects where value is added through the creation of bundles [58]. It has therefore been considered to be of interest to research.

Bundle subsequent/return shipments (order set), referred to as Bundle-Full-Load

Please refer to the explanation above.

Offer truck capacity (carriers), referred to as Offer-Cap-Carrier

Offering remaining capacity is a relatively simple undertaking. It has therefore not been considered to be of particular research interest.

Offer truck capacity (Teleroute), referred to as Offer-Cap-Tele

Please refer to the explanation above.

Search for LTL shipments (Teleroute), referred to as Search-Part-Tele

For a large part, the same points that were mentioned for bundling within the own order set are valid here as well. It has therefore been considered of equal interest to bundling within the own order set.

Search for subsequent/return shipments (Teleroute), referred to as Search-Full-Tele

Please refer to the explanation above.

Negotiate on price (carriers), referred to as Neg-Price

One of the main research areas at CWI is the design and implementation of market mechanisms. Negotiation on price can be implemented in many ways using many different protocols (e.g. auctions, concurrent bilateral or simultaneous one-to-many negotiation). Each of these options has a varying impact and it is considered to be a challenging undertaking to research those impacts.

Negotiate on time window (carriers), referred to as Neg-Time-Window

Negotiations on time window offer many opportunities for optimization, such as those discussed in paragraph 4.3. As a research area it is therefore promising to look into issues such as discrete vs. continuous time intervals and deciding on how to implement penalties for violating time windows. Furthermore, agent technology is very suited to deal with a complex and dynamic problem such as this one and is able to evaluate and choose from a large number of options. It has considered to be even more interesting than negotiating on price, due to it's novelty.

Negotiate on equipment (carriers), referred to as Neg-Equip-Type

Negotiation on equipment type provides another interesting research topic. Optimizing shipment sizes based on expectations or indications of available capacity (e.g. mega trailers) is a non-trivial problem. Research interest is therefore considered to be high for this option.

K Feasibility criterion

In Table 19, the alternatives have been compared on the criterion of feasibility. Feasibility has been determined in collaboration with experts from CWI and VLO.

Feasibility	Bundle-Part-Ship	Bundle-Full-Ship	Offer-Cap-Carrier	Offer-Cap-Tele	Search-Part-Tele	Search-Full-Tele	Neg-Price	Neg-Time-Window	Neg-Equip-Type	Row Total	Relative Decimal Value
Bundle-Part-Ship		1	1/5	1/5	5	5	5	5	10	31,40	0,13
Bundle-Full-Ship	1		1/5	1/5	5	5	5	5	10	31,40	0,13
Offer-Cap-Carrier	5	5		1	10	10	10	10	10	61,00	0,25
Offer-Cap-Tele	5	5	1		10	10	10	10	10	61,00	0,25
Search-Part-Tele	1/5	1/5	1/10	1/10		1	5	5	10	21,60	0,09
Search-Full-Tele	1/5	1/5	1/10	1/10	1		5	5	10	21,60	0,09
Neg-Price	1/5	1/5	1/10	1/10	1/5	1/5		5	5	11,00	0,04
Neg-Time-Window	1/5	1/5	1/10	1/10	1/5	1/5	1/5		5	6,20	0,03
Neg-Equip-Type	1/10	1/10	1/10	1/10	1/10	1/10	1/5	1/5		1,00	0,00
									Grand total:	246,20	

1 = Equally feasible
5 = More feasible
10 = Much more feasible
1/5 = Less feasible
1/10 = Much less feasible

Table 19: L-shaped matrix for comparing options relative to 'feasibility' criterion

Bundle LTL shipments (order set), referred to as Bundle-Part-Load
Bundling from within the own order set poses no real problems with respect to feasibility. A lot of shipment data is readily available at VLO and similar logarithms/solutions have been designed in the past.

Bundle subsequent/return shipments (order set), referred to as Bundle-Full-Load
Please refer to the explanation above.

Offer truck capacity (carriers), referred to as Offer-Cap-Carrier
Offering truck capacity is a relatively simple undertaking. It has therefore been judged as more feasible than the other options.

Offer truck capacity (Teleroute), referred to as Offer-Cap-Tele
Please refer to the explanation above.

Search for LTL shipments (Teleroute), referred to as Search-Part-Tele
Using Teleroute to create bundles adds a level of complexity on top of the 'regular' bundling proces. For this option it should be able to automatically query Teleroute (e.g. using their API[33]). Furthermore, estimated guesses need to be made with respect to the costs incurred by checking up on, and making deals with previously unknown parties. It has therefore been considered to be less feasible compared to bundling using the own order set.

Search for subsequent/return shipments (Teleroute), referred to as Search-Full-Tele
Please refer to the explanation above.

Negotiate on price (carriers), referred to as Neg-Price
For negotiating on price the support of carriers is needed. However, VLO has a considerable amount of power over their carriers, as there is a significant overcapacity in the market. The fact that systems such as Transporeon[34], Ariba[35], FreightTraders[36] and many others are widely deployed in shipper-carrier relationships, despite carriers' reluctance against these systems, supports this assumption.

However, these kinds of systems are usually not used on a per-order basis but for large tenders instead. If VLO is to deploy them at a per order basis (with significantly lower absolute margins) it should take care in making sure that it is still attractive for carriers to use. This means for example, that given the expectation that agent technology will not be deployed for some time at carriers, offers should not be sent to a limited amount of carriers. This makes sure that carriers have reasonable chances of winning the order compared to the effort they have to put into responding to these requests. In a similar fashion, the number of rounds to come to a deal (e.g. in the case of using alternating offers) should be minimized as costly human effort is used on the carrier side.

Negotiate on time window (carriers), referred to as Neg-Time-Window
For negotiation on time windows the support for carriers is needed, as well as that of shippers. As agent technology might be implemented only at VLO's side, the same limitations apply that were mentioned above. Furthermore, in contrast to negotiating on price, it is a concept carriers and shippers are unfamiliar with (at least on a per-order basis). Therefore, more time is needed for issues such as establishing requirements and it has therefore been considered to be less feasible than negotiating on price.

Negotiate on equipment (carriers), referred to as Neg-Equip-Type
Negotiation on equipment type has been considered the least feasible, as it is a very abstract concept. Getting datasets or expectations about predicted behavior or results

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[33] Application Programming Interface. The interface (i.e. calling conventions) by which an application program might access other application programs, operating systems or other services.
[34] See http://www.transporeon.com/english/products_tisys.shtml for details
[35] See http://www.ariba.com/ for details
[36] See http://www.freighttraders.com/ for details

would therefore be more difficult, as shippers would be having difficulty understanding the concept. Furthermore, as explained under the heading of business impact, potential is judged to be limited, which would even further reduce the willingness of shippers and carriers to cooperate.

L Common auction types

English auction

The English auction is an ascending price, open-cry auction in which the price rises successively. The auctioneer seeks to find the market price of a good or service by initially proposing a price below that of the supposed market value and then gradually raising the price. Each time the price is announced, the auctioneer waits to see if any buyers will signal their willingness to pay the proposed price. As soon as one buyer indicates that it will accept the price, the auctioneer issues a new call for bids with an incremented price. The auction continues until no buyers are prepared to pay the proposed price, at which point the auction ends. If the last price that was accepted by a buyer exceeds the auctioneer's (privately known) reservation price, the good is sold to that buyer for the agreed price. If the last accepted price is less than the reservation price, the good is not sold.

Dutch auction

In contrast to the English auction, the Dutch auction is a descending price auction. The auctioneer attempts to find the market price for a good by starting bidding at a price much higher than the expected market value, then progressively reducing the price until one of the buyers accepts the price. The rate of reduction of the price is up to the auctioneer and there is usually a reserve price below which not to go. If the auction reduces the price to the reserve price with no buyers, then the auction terminates.

First price, sealed bid auction

In this type of auction, the sealed bids are collected until a certain closing date. At this date, all bids are opened, and the bidder with the highest bid wins and has to pay his bid.

Second price, sealed bid or Vickrey auction

As in the first price auction, every bidder submits a sealed bid and the winner is the bidder with the highest bid. However, only the second highest price needs to be paid. This type of auction is not frequently used in practice, but has some attractive characteristics. This type of auction is an example of an incentive-compatible mechanism [20]. This means that the mechanism gives agents a compelling incentive to be honest to the opponent. As preferences are truthfully revealed, the goods will be efficiently allocated.

M Protocols

InformForOrder

Details of this protocol are given in Table 20.

InformForOrder		
Initiator:	Partner:	Input:
OrderHandler	BidCatcher	Orders
Description:		Output:
Orders that are suited to be handled by the system, are passed on to the BidCatcher		OrderInfo

Table 20: The InformForOrder protocol definition

InformForBidRequest

Details of this protocol are given in Table 21.

InformForBidRequest		
Initiator:	Partner:	Input:
BidCatcher	Bidder(s)	OrderInfo
Description:		Output:
Carriers that are invited by the BidCatcher to place bids, receive the order information through this protocol.		BidRequest

Table 21: The InformForBidRequest protocol definition

InformForBid

Details of this protocol are given in Table 22.

InformForBid		
Initiator:	Partner:	Input:
BidWatcher	BidCollector	BidRequest
Description:		Output:
If a carrier decides to bid on a job, a BidWatcher is created, which sends its bid(s) to the BidCollector		Bid

Table 22: The InformForBid protocol definition

InformForRank

Details of this protocol are given in Table 23.

InformForRank		
Initiator:	Partner:	Input:
BidCollector	BidWatcher	Bids
Description:		Output:
If the BidCollector receives a bid, it is ranked and the BidCollector notifies all bidders on this order about their ranks, which might have been changed.		Rank

Table 23: The InformForRank protocol definition

InformForDeadline

Details of this protocol are given in Table 24.

InformForDeadline		
Initiator:	Partner:	Input:
BidCollector	Winner-Determinator	-
Description:		Output:
The BidCollector issues this protocol if bids are due to expire or the deadline of the auction has been reached.		-

Table 24: The InformForDeadline protocol definition

InformForOutcome

Details of this protocol are given in Table 25.

InformForOutcome		
Initiator:	Partner:	Input:
Winner-Determinator	BidWatcher	Bids
Description:		Output:
There is at least one moment when the WinnerDeterminator has to decide on the outcome. But if carriers place bids with expiration times before the order deadline, it has to evaluate these bids right before they expire and notify all bidders on this order about the outcome.		FINISHED, a carrier has been awarded the contract and the bidding process is terminated. Or CONTINUED, the carrier was not awarded the contract and the bidding process continues.

Table 25: The InformForOutcome protocol definition

N Paper proposal AAMAS 2006

A paper proposal, largely based on the work performed in the context of this thesis, has been written for and submitted to the industry track of the Fifth International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS 2006).

According to the AAMAS website[37], the AAMAS conferences aim to bring together the world's researchers active in the important, vibrant, and rapidly growing field of agents and multi-agent systems. The AAMAS conference series was initiated in 2002 as a merger of three highly successful related events:

- AGENTS (International Conference on Autonomous Agents)
- ICMAS (International Conference on Multi-Agent Systems)
- ATAL (International Workshop on Agent Theories, Architectures and Languages)

The aim of the joint conference is to provide a single, high-profile, internationally renowned forum for research in the theory and practice of autonomous agents and multi-agent systems. The AAMAS industry track is a special track at the AAMAS conference that runs in parallel with the regular AAMAS scientific track. The track is dedicated to fostering commercial, or real world, impact for agent technologies. The industry track aims to foster mutually beneficial links between those engaged in foundational scientific research and those working to make autonomous agents and multi-agent systems a commercial reality.

The paper proposal, as it has been submitted on December 1st of 2005, is given below.

[37] http://www.fun.ac.jp/aamas2006/

Automating Supply Chain Negotiations using Autonomous Agents: a Case Study in Transportation Logistics

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ABSTRACT

This paper presents a case study for the application of agent-mediated negotiation techniques in transportation logistics. More specifically, we consider the interaction between several logistics service providers negotiating over the allocation of transportation orders. In this context, we show that automated negotiation techniques (especially multi-issue or multi-item negotiation) can bring significant advantages, by allowing parties to discover jointly profitable bundles (allocations) of orders. The model, evaluations and results reported in this paper concern the business processes of Vos Logistics, one of the largest European transportation logistic providers.

Categories and Subject Descriptors

I.2.11 [**Distributed Artificial Intelligence**]: Intelligent agents
H.4.2 [**Information Systems Applications**]: Logistics

General Terms

Management, Performance, Design, Measurement.

Keywords

Automated negotiation, multi-agent systems, transportation logistics, supply chain management.

AAMAS'06, May 8-12, 2006, Hakodate, Hokkaido, Japan.

1. INTRODUCTION

Negotiation represents a key form of interaction in agent-mediated electronic markets that transcend the sale of uniform goods. Through negotiation, suppliers and consumers can reach complex agreements in an iterative way, which better match the needs and capabilities of different parties. Recent research work has led to a variety of new, increasingly complex algorithms to deal with application of automated negotiation (especially multi-issue or multi-item negotiation) in a variety of settings [4, 9, 11].

Transportation logistics and supply chain management represents a challenging, but potentially very fruitful area for application of automated negotiation. In this setting, it is often possible for all parties in a supply chain to obtain joint savings through more efficient, fine-grained matching of their requirements and capabilities (i.e. orders and transport capacity). The increasing complexity of modern supply chains, as well as increasing competitive pressures in this market has led to an increasing demand and interest for such distributed optimization techniques.

The practical impact of improved allocation which can be achieved through such techniques can be significant. For example, in the Netherlands, the average transport performance is between 40% and 60%[1]. [2]. Improving this utilization rate is also the goal of the DEAL (Distributed Engine for Advanced Logistics) project, which groups together several universities and large logistics service providers in the Netherlands. The work reported here is also carried out in the framework of this project, involving the CWI and Vos Logistics.

The paper describes a case study application of automated negotiation to the logistics domain. It is important to stress that, in this paper, we do not aim to propose a new algorithm or analyze

[1] Defined a defined as the extent to which transportation units are utilized as percentage of total capacity, usually given in ton-kilometer. Thus, a truck that is driving with only half its capacity has a transport performance of 50%.

fundamental aspects of agent-mediated negotiation techniques as such (this has already been done elsewhere, in papers by the same authors at the research track of AAMAS and AMEC [4, 9, 6]. Our goal is to focus more on the specifics of the application domain and to describe our experience with agent-mediated negotiation techniques in the real-life case of the organizing branch of Vos Logistics. The paper is largely based on the Master Thesis work of the first author, performed jointly at Vos Logistics and CWI [13].

The remainder of the paper is organized as follows. In Section 2 we describe the logistics of the transportation domain and briefly outline the profile of Vos Logistics as well as the transportation market in which it operates. Section 3 goes more in depth, by providing a more detailed analysis on how the order allocation and negotiation processes are actually conducted at the Vos Logistics Organizing branch in Nijmegen. Section 4 briefly outlines the potential of existing techniques from agent-mediated negotiation and discusses to what degree and how they are relevant or applicable to this domain. Section 5 describes our proposed multi-issue negotiation solution and how it can be used to discover more efficient allocations (or bundles) of orders during trading. Section 6 presents an analysis of the gains which can be actually achieved by bundling of transportation orders, based on the real order set of Vos Logistics Organizing. Section 7 provides a discussion of how our approach compares to other approaches to this problem (both from the theoretical literature and industrial-grade solutions). We conclude the paper by pointing out some of the challenges which can be encountered in the application of a pilot project on automated negotiation at a company such as Vos Logistics.

2. THE TRANSPORTATION LOGISTICS DOMAIN

Several trends have recently produced a significant impact on the area of transportation logistics. One of these is an increase in competition, with the continual entry of new carriers in the market pushing down expected profit margins. Another one is the increasing complexity and sophistication of modern supply chains. In fact, due to increasing and shifting trade patterns, not only the complexity of transportation chains has increased, but also their variability and dynamics. These challenges require increasingly sophisticated optimization solutions, that exploit all the niches in the supply chains involving different companies.

We note that his optimization has to occur both intra-company (where a company optimizes its own activity), but increasingly also inter-company, between different actors that do not necessarily share the same goals. Inter-company optimization poses considerable extra challenges, since the parties forming the supply chain can be self-interested, so they may be unwilling to share private planning information and strategic concerns make the problem considerably harder than cooperative case. The solutions proposed in this paper specifically address this case of inter-company optimization of the logistic chain.

The transportation management literature [12] identifies two main types of orchestrator companies for transportation logistic chains:

- Third Party Logistics service providers (3PL), which orchestrate the logistic processes and assures they are well executed according to a current logistic concept
- Fourth Party Logistic service providers (4PL), which orchestrate the supply chain and are responsible for the design of the logistic concepts.

There is, however, considerable disagreement about the exact meaning of these terms, both in existing literature and in practice. In our approach (and the remainder of this paper) we use the term 3PL provider companies to denote those that have their own transport capacity (i.e. truck fleet) and plan (or orchestrate) their movement, based on a set of orders from shippers and other companies. Fourth Party Logistic companies (4PL) have recently emerged as a result of the increasing complexity of supply chains and mostly have a role of coordinating these chains. In this paper we denote as 4PL companies those that do not have their own transport capacity: they receive large transport orders from shippers and then distribute them among a set of 3PL companies or independent carriers. This process involves direct negotiation with 3PL companies and often entails breaking up large orders or bundling orders for partial loads, in order to increase efficiency. The remainder of this section describes in more detail the company which forms the object of our solution, as well as the market in which it operates.

2.1 Company profile

Founded in 1944 as a one-truck company, transporting loads between Oss and Nijmegen in The Netherlands, Vos Logistics has grown into one of the larger logistics service providers in Europe. It has over 3000 trucks, 10000 trailers and containers, 350000 square meters of warehousing sites, 325 storage silos and 2 rail service centers. Vos employs 5000 people working at more than 45 locations throughout Europe. Annual turnover is around 800 million euro.

The increasing complexity of transportation chains has determined Vos to offer new solutions to its large corporate customers (shippers), which can now outsource all of their transportation activities to Vos. This lets them avoid the problem of finding and negotiating with individual suppliers, billing, following up orders etc. Another advantage of using this outsourcing service for large shippers is that Vos Logistics has a much better knowledge of the transportation market, so it is better positioned to find suitable sub-contractors.

Vos Logistics Organizing from Nijmegen (henceforth abbreviated VLO in this paper) is a subsidiary of Vos Logistics B.V. that was set up in order to handle such complex supply chain orchestration activities. Based on the taxonomy above, VLO (the subsidiary) can be seen as a 4PL company, though its parent company, Vos Logistics performs mainly 3PL activities. Hence, VLO acts as an intermediary company that acquires large (sets of) orders from suppliers and negotiates the allocation of the orders, the terms of transportation (i.e. delivery deadlines, destination) as well as the price with which 3PL companies that subcontract these orders.

2.2 Market organization. Closed vs. open group negotiations

This section describes the operation of a 4PL logistic company, which simultaneously interacts with customers (shippers), a set of 3PL companies (with actual carrying capacity) and the open market. For the purpose of this paper we identify this 4PL company with Vos Organizing (VLO), but the model should be a general enough to be applied to other companies in the same field.

Figure 1 presents a graphical model of this interaction.As depicted in Figure 1, there are two main mechanisms for allocating orders received from shippers:

- **Closed group negotiation.** Most of the orders (i.e. around 80%) received by the 4PL company are currently not auctioned off to an outside market, but are allocated among a small group of trusted 3PL carriers. The size of this group is around 5-10 companies. The composition of this "closed group" of trusted companies is based on trust and a history of good business relationships – in fact for each shipper there may be a customer specific list of companies with which the negotiation takes place. In current practice, the protocol for conducting negotiations is usually bilateral and sequential.
- **Open market.** A small subsets of orders (around 20%) is offered on the "open market". Usually this means offering the loads through transportation matching sites such as Teleroute [15]. The important point here is that there are no barriers of entry or "admission rules" on these sites (i.e. any company or individual carrier in the Netherlands or in the whole of Europe can make offers by phone for these orders)

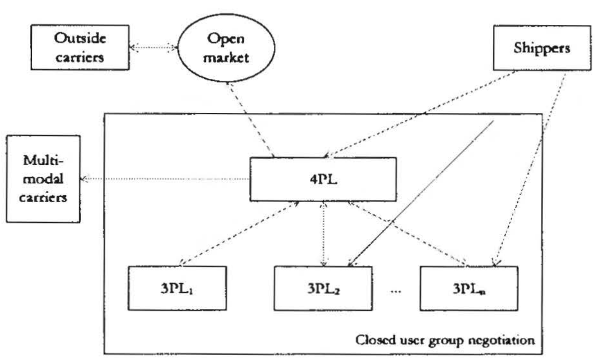

Figure 1: Interactions between parties in a multi-party logistics setting

We argue that both types of mechanisms can benefit from agent-based automation, though they may require different mechanisms. For the open group negotiation, auction protocols would probably be the most suitable, since here all agents are strictly competitive and there are no barriers of entry.

However, in our approach we concentrate more on the first set-up, the closed negotiation, chiefly because it is more applicable for our particular setting, i.e. it has a higher business impact and 80% of the orders are allocated in this way. For this set-up we considered two types of choices. The first one is automated negotiation, especially multi-issue and multi-item negotiation models that enable parties to reach mutually profitable (Pareto-efficient deals [8]) that go beyond strictly price competition. A second choice would be to have a combinatorial auction protocol, where the 4PL company would act as a "center".

In this paper we mainly explore the first option, since we feel it allows us more flexibility in dealing with side constraints and incomplete information. However, the auction option is also being considered, especially if the protocol could be adapted to quantify issues such as trust or other constraints. Further discussion of this issue is given in Section 5.

3. ORDER ALLOCATION AND NEGOTIATION PROCESSES AT VLO

This section aims to give a more in-depth look at how the order allocation and negotiation processes are currently performed at Vos Logistics. This is an important part of any industry analysis, in order to assure that the models considered can lead to usable pilot applications within the company and are not of merely theoretical interest. We focus here on the daily outsourcing (i.e. "spot orders"), which is the main area that could be automated through agent technologies, since it is unlikely that automated agents can be entrusted to take higher-level or strategic decisions.

3.1 Order set characteristics

There are several characteristics (parameters) that describe every transportation order. The following is a non-exhaustive list:

- The volume (or mass) to be transported
- The price (computed either per unit volume or unit mass)
- The time windows (in the form of time for picking up the goods and the deadline for delivery)
- Locations where the order is picked-up/delivered
- Extra transport conditions (e.g. refrigeration, liquids, fragile merchandise etc.)
- Arbitrary constraints that the shipper may impose (e.g. do not transport my goods at the same time as company X's)
- Flexibility of contractual terms (e.g. time ahead of the actual transport when a contract may be re-negotiated or cancelled)

Due to the time limitation of human planners, currently most of the parameters are not explicitly negotiated about every order. From the above set we identify two characteristics that are particularly important from the perspective of how orders are currently priced by carriers:

- The percentage a load takes from the total volume of a truck, commonly referred to in the field through the acronyms FTL (full truck load) and LTL (less than truck load)
- The "fruitfulness" of the region the order originates from or is to be delivered. Here by "fruitfulness" we mean the likelihood that there will be return freight from that region.

In the following sections we discuss these two dimensions in more detail and show their importance with respect to the different types of bundling.

3.2 Bundling of LTL shipments

Making bundles out of individual orders is a well known way to increase offer value [9, 4]. Two potential improvements have been found in the area of bundling; consolidating multiple part loads with overlap in route and the offering of return shipments or subsequent loads at the unloading destination.

VLO can gain considerable savings when multiple LTL or part loads, with overlap in (part of their) route, are offered as a bundle. To illustrate, a typical price table, using actual carrier data, is displayed in Figure 2 which depicts the price per pallet for the various loading percentages of a truck[2]. From Figure 2: Relationship between load and price per pallet, we can see that the pricing of LTL (less than truck load) orders follows a logarithmic–like pricing function. An order for a quarter of a truckload is roughly 50% of the FTL price for example whereas half of a truckload equals approximately 70% of the FTL price.

Currently, the process of bundling is executed by hand by VLO for the shippers that request it. A number of solutions exist, both agent-based and non agent-based, to automate and optimize the process of making efficient bundles out of a given set of orders.

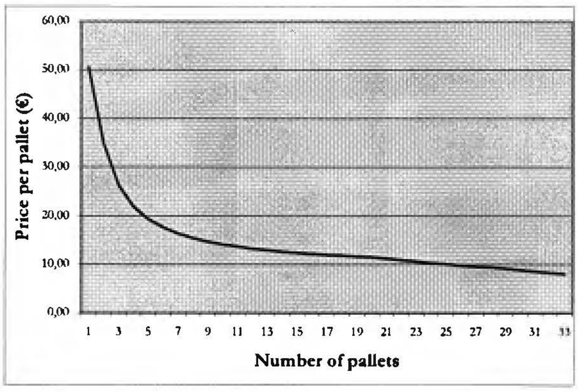

Figure 2: Relationship between load and price per pallet

3.3 Bundling of return or subsequent freight

For the bundling of a shipment with a corresponding subsequent or return shipment, the notion of fruitfulness plays a central role. In a fruitful region much freight is offered and a truck runs only a limited amount of empty kilometers, whereas in a fruitless region not much freights are offered and on average trucks run a significant amount of empty kilometers before pickup of the next freight. Depending on the fruitfulness of the unloading area and the quality of the carrier's own network and his own capabilities in matching demand and supply, a truck has to run a certain number of empty kilometers from the unloading point to the next pickup location. If VLO was to offer a new freight at or close to the unloading location, a significant discount might be obtained from the carrier as the truck is decreasing its empty kilometers. Savings depend on the area the new freight is offered in and the quality of the carrier's own network. If a lot of freight is offered in the region, the discount will be smaller. Similarly, if a carrier's own network is mature and the carriers are very capable of finding subsequent shipments, the discount will be smaller.

This concept can be seen in current business practice at VLO, in which a certain price/km value is used for a 'country of origin' to 'country of destination' combination. Different values are used for each combination, e.g. for a shipment from France to the Netherlands a lower value is used than for shipments from the Netherlands to France. This has to do with the amount of return freights generally available in the country of destination. If a truck coming from France has to deliver freight in the Netherlands, chances are high that there is a freight weighting to get from the Netherlands to France. It is different the other way round. If a truck is empty in France there is a much smaller chance that there are freights weighting to get from France to the Netherlands and as a result there is a higher chance that the truck has to return empty. To illustrate, rates from France to the Netherlands are about € 0,60 to € 0,80 per kilometer, whereas prices from the Netherlands to France range from € 1,25 to € 1,50 per kilometer.

[2] A regular trailer (truck) has a volume of 33 euro pallets, while large-volume trailer can take 38 pallets. Note that a euro pallet is 1.20 meters wide and 0.80 meters long.

4. AUTOMATED MULTI-ISSUE NEGOTIATION: MODELS & RELATION TO THE TRANSPORTATION DOMAIN

The concept of electronic negotiations or e-negotiations is a very broad one. As shown in [1], it covers a whole spectrum of negotiations ranging from the unstructured exchange of messages using email and chat systems, to partially structured e-negotiations supported by negotiation support systems, negotiating software agents or online auctioning platforms for selected tasks, to completely structured negotiations conducted autonomously by computer systems.

The scope of our approach is the automated case, where parties are represented by software agents. More specifically, we are interested in multi-issue or multi-item negotiation models, which allow agents to exploit so-called "win-win" opportunities. As shown by Rosenschein & Zlotkin [10], such negotiations represent non-zero sum games, where "as the values shift in multiple directions, it is possible for both parties to be better off". In our application domain, this means that negotiations between agents representing different transport providers (carrier companies) do not focus exclusively on price, but also allow the discovery of mutually beneficial bundles of orders, which are customized to accommodate for niches in their supply chains.

In the following we discuss some of the issues identified by our case study at VLO that could potentially form the object of automated negotiation techniques. Some of them (especially the question of time windows) is important because it influences the potential gains which can be achieved through the bundling of orders.

4.1 Negotiation over price

In current practice at VLO, price is the only issue negotiated. This negotiation currently is performed by humans and takes place over the phone. Even for this one issue there are some advantages to be gained from automation.

First, efficiency could be improved, since transaction costs would be reduced by automating the process. Furthermore, humans have a cognitive limitation on how many parties they can negotiate with at the same time and how many counter-offers they can make in each negotiation. In current VLO practice this leads to rather large bid-offer spreads between offers and between negotiations for similar orders. If these negotiations could be automated, this would increase the effectiveness of the deals made as well.

However, we should point out that automated negotiations are however no panacea and should be treated with care. In human-controlled, traditional negotiations, the communication, formulation of offers and making of concessions is a vehicle for both a consensus and understanding [7]. In vaguely defined negotiation situations, a human-controlled negotiation process will probably be more efficient and effective than what would be possible with even the most sophisticated intelligent agents currently available. Therefore, having a clear protocol is crucial in automated negotiation models.

4.2 Negotiation over time windows

Currently, time windows (i.e. time interval when an order is to be delivered) are considered to be fixed, due to the complexity and high cost of negotiating a potentially exponential number of combinations of order bundles/time windows. It has however been indicated that VLO's customers would be willing to be more flexible if doing so would result in savings to them. Basically there are two ways to handle this option. VLO could give a discount if shippers would be willing to extend their time windows, e.g. a 5% discount if the time windows are increased from 1 to 3 days. This would require that VLO knows what savings can be achieved in the various situations, to make sure that the discount percentage given is a realistic one. The other option is to let the customer specify discounts or penalties in case of earlier or later delivery.

	Three days earlier	Two days earlier	One day earlier	Original date	One day later	Two days Later
Initial amount/ shipper	€ 650,00					
Penalty for date change	Not accept	- €150,00	- €50,00	€ 0,00	- €150,00	Not accept
Actual revenue	n/a	€ 500,00	€ 600,00	€ 650,00	€ 500,00	n/a
Best carrier's offer	n/a	€ 530,00	€ 530,00	€ 630,00	€ 490,00	n/a
Gross margin of VLO	n/a	- € 30,00	€ 70,00	€ 20,00	€ 10,00	n/a

Table 1: Example of margin fluctuations with flexible time windows

Table 1 illustrates this later concept through a fictional example (but which, nevertheless matches characteristics of real orders – as discussed with VLO planners), how VLO can benefit from deviating from the original date, e.g. because capacity on the original date is hard to find and prices are high.

There are several reasons why rates could fluctuate at different time periods:

a) Using extended time windows there is the possibility to better match freights with the location of a carrier's vehicles. For example, in the case of shipments from Germany to the Netherlands, a Dutch carrier will be cheaper as they are likely to have freight from the Netherlands to Germany and can pick it up on the way home. However, these carriers do not arrive in Germany until Tuesday, as trucks and drivers return to their home base during the weekend. If the time windows for a freight which is scheduled at Monday are extended by 1 day, a Dutch carrier is able to take on this shipment, whereas VLO otherwise would have to go with a more expensive German carrier.

b) Extended time windows might also lower specific costs. Again, a simple example helps illustrating this principle. Consider freight from the Netherlands to the North of France with an original pickup date of Wednesday and one from the North of France back to the Netherlands with an original pickup date of Thursday. If the time windows are extended, the carrier could load the freight to France very early Wednesday morning for example and drive to the North of France. If the carrier can pickup the return freight that same Wednesday right after unloading, he can drive back the same day. As a result, instead of chartering an international driver, a much cheaper so-called national driver can take care of these shipments, as there is no need to sleep over in the truck and wait to pickup the freight the next day.

Besides these effects, specific to certain carriers, there may be market-wide or industry-wide effects as well, such as the "end of the month" effect, when shippers want to transport the goods to remove them from their inventory lists, and one-time effects caused by disruptive events such as strikes etc., which cause a backlog of orders in certain periods. In this case, extending the time windows to help carriers better cope with such events may be desirable.

5. PROPOSED SOLUTIONS FOR MULTI-ISSUE NEGOTIATION AND BUNDLING

From the discussion in Sect. 2-4 above, we can see that there is a wide variety of issues that could, potentially, be considered in automating the negotiation processes al VLO.

Here we focus on one of them: automating the "closed group" negotiation (see Sect. 2) between the 4PL and 3PL companies over the distribution of transportation orders. We chose this setting because of its relation both with existing research lines at CWI and with current practice at VLO. In our models, we consider that orders can exhibit utility dependencies of two types:

- Complementarity dependencies, if the orders can be transported by the same truck (i.e. their pick-up/destination regions, delivery time windows and/or capacity fit)
- Incompatibility (or substitutability) dependencies, if orders cannot be bundled together, due to a mismatch between their delivery time windows and/or capacity.

In our model, dependencies are represented in the form of a utility graph, which encodes complementarity/substitutability relations between orders. In previous work (in part by the same authors) presented at the research track of AAMAS [9] a general framework was proposed to handle this type of dependencies, and this was successfully applied to the logistics setting. A software tool was built for this paper (a screen shot of the negotiation phase is shown in Fig. 3). The tool should enable planners to compute (close to) optimal bundling of different sets orders and to explore different scenarios, by changing the constraints (e.g. time window constraints) and the information shared between parties.

This approach works by dividing the one-to-many negotiation between the 4PL and 3PL companies from the closed group in a series of one-to-one negotiation threads. This approach allows us to preserve the privacy of each party, since each company has to reveal their exact preferences and valuation only to its own automated agent. Furthermore, agents representing different companies do not have to reveal their preference information directly to other agents in the group, since approaches to automated negotiation such as those proposed in [9] allow agents to reach efficient agreements incrementally, with partial or incomplete information revelation.

There are, however, challenges when applying this model to a real-world setting. First, we assume all companies are represented by a proxy agent that does the bidding on their behalf. Second, we do not say much about how planning is performed, our approach concentrates only on optimizing the task allocation between a group of companies. Clearly for such approach to work well in practice, the planning of transportation within each company would need to be automated as well and connected to the negotiating agent. Alternatively, if planning is still done by humans, better mechanisms are needed to encode and elicit the preferences over the bundles - especially time and capacity preferences. An alternative to this automated one-many negotiation approach would be to use an auction-type of approach, instead of automated negotiation. For example, in other work, such as proposed by Sandholm and exemplified in the engine built by Combinenet [14], a similar problem is solved by means of a combinatorial auctions. This has other advantages (e.g. humans could also specify bids, so full automation from proxy agents is not needed), but also assumes that parties are willing to share truthfully their planning information and there is one trusted "center" to compute an optimal allocation.

In any case, it is realistic to assume that at any time, human planners or negotiators should be allowed to overrule the suggested agreements reached by their negotiation/auction proxies. As such, we envisage that the system would work more as a decision support tool which helps to explore various allocation scenarios, rather than a replacement for human negotiators.

A practical disadvantage of traditional auction mechanisms is that competition occurs entirely on price and the seller (in our case, the 4PL company allocating the orders) cannot discriminate between subcontractors based on other aspects, such as trust. This is a departure from real-life settings, where it may be possible that a party with a higher bid is offered the deal, if it is deemed more trustworthy (although this is difficult to quantify, since it is based on previous interactions and experience of the human planners).

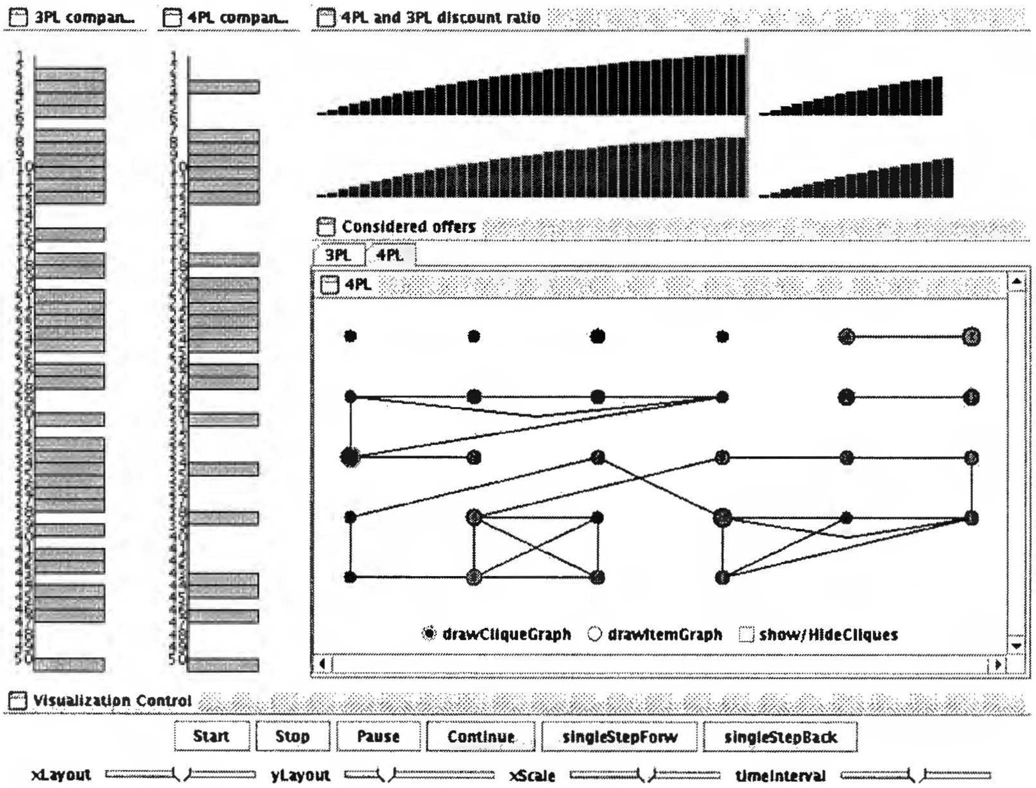

Figure 3: Screen shot of the negotiation tool built to visualize a closed group negotiation thread

By modeling the negotiation as a set of private one-one threads, asymmetric concessions to different parties (based on their trustworthiness) are possible. An alternative would be to modify the traditional open auction mechanism to take into account such considerations. Two alternatives have been proposed (c.f. [13]):

- Allocating closed-group orders through an auction with a pre-selection step, in which only certain companies are allowed (or invited) to submit bids. In this way, 3PL companies are already "screened" before accepting a potential offer.
- Modifying the winner determination mechanism of a traditional auction, such that not only price is minimized, but also a weighed element of trust is taken into account.

All the alternatives discussed above (concurrent, bilateral negotiation and modified auction mechanisms) will be considered as potential implementation options in the proposed pilot project.

6. ANALYSIS OF POTENTIAL GAINS ACHIEVED FROM BUNDLING ORDERS IN THE CASE STUDIED

From Section 5, we see that the way our negotiation model works is by finding more efficient "bundles" of transportation orders, which best exploit the niches in the supply chains of different market participants. The theoretical model presented above has been shown, through simulations, able to discover Pareto-efficient allocations, even in incomplete information settings [9]. However, for a practical setting, validating a model through simulation is clearly not sufficient and we need to explore what are the potential savings which can be achieved through such techniques in practice.

A thorough investigation of the potential savings which can be achieved through bundling of orders for Vos Logistics was performed using historic order data. The data consisted of the set of over 6000 transportation orders handled by the forwarding desk of Vos Logistics for the year 2004. We should mention, however, that in order to protect the competitive advantage of VLO as well as the privacy of their customers and associates, much of this analysis cannot be reported in this paper. For this reason we report here only the percentage improvements achieved through bundling, but without entering into details or monetary figures.

There are two main types of bundling considered with respect to transportation orders:

- Bundling of LTL shipments (i.e. bundling of orders that are less than one truck load)
- Bundling of subsequent/return orders for FTL shipments (full truck loads)

For the bundling of LTL shipments, we considered orders for which both the pick-up/delivery locations (computed based on the first 2 digit of the postal codes area) and the date matched. Additionally the sum of part loads in a combination should not exceed the maximum load capacity.

For the bundling of FTL shipments, the delivery location and delivery date of a first order had to match the delivery location and delivery date of a second order. In both cases, feasible allocations are considered, of course, only those in which an order belongs only to one bundle.

The results of the savings which can be achieved for a set of over 6216 orders handled in 2004 are shown in Table 2:

	Savings over the total over the total value of LTL orders	Savings over the value of all orders in the order set
Bundling of LTL shipments	19%	2-3%
Bundling of FTL shipments	-	12%

Table 2: Potential gains which can be achieved through bundling of orders using historic VLO order data for 2004

From the results in Table 2, two things stand out. First, we see that the potential gains which can be achieved from bundling partial loads seem rather modest, compared to that from bundling return or subsequent shipments. This can actually be explained by the fact that, overall, the percentage of partial (i.e LTL) loads in the order set was rather small. However, if one considers only the value of the subset of LTL orders, one can see that using more efficient bundling the average truck utilization (load) increases from 18% to 39%. Using actual carrier price data, this results in savings of 19% in terms of price per unit load. The result is significant, since it is estimated that in the future, the number of partial truck loads handled by VLO is likely to increase considerably. Finally, for the results above, we assume that only same-day orders can be matched, in order to be consistent with current practice. If more flexible time windows are allowed (through better negotiations), we estimate that the potential savings from bundling can increase considerably.

7. DISCUSSION

There are several other approaches which address similar problems to the ones discussed above, both in the literature on agent systems, but also implemented by commercial companies. Here we review them briefly and compare their functionality to our approach. The LS/ATN system developed by Whitestein Technologies and presented in Dorer and Calisti [3] is a multi-agent system for dynamic transport optimization. The system provides agent-based optimization and execution capabilities that automate order dispatching, a crucial phase of transportation planning. The chief difference from our work is that the system proposed by Dorer & Calisti is mostly concerned with distribution of orders in the planning phase between trucks of the same company, while our system is concerned with automating the negotiation over loads between different companies in a supply chain.

The system proposed by Magenta Technologies [5] uses a multi-agent system to provide intelligent support for transportation scheduling. At the core, the system also relies on a virtual market engine to distribute loads. One feature of the MAGENTA system not currently considered by us are the semantic representation capabilities, as provided in the Ontology Management Toolkit.

Another set of solutions which address problems very similar to the ones described in this paper are provided by Combinenet [14].

Combinenet aims also at capacity optimization, by allowing more expressive bidding and scenario generation. We assume most of their solutions are based on efficient algorithms developed, in fundamental research by Sandholm and collaborators (reported, for example, in [11]). The main difference with the approach discussed in this paper, these solutions rely mostly on combinatorial auction algorithms to compute efficient bundle allocations.

Finally we should point out that there are also several electronic freight exchange sites, such as Teleroute [15] and Transporeon [16]. Teleroute (which is also currently used by VLO for their open market operations) acts more as a platform on which carriers and shippers advertise their order and transport capacity, but any negotiation and matching is done by human through the phone. Transporeon is another platform that provides a slightly more advanced functionality, such as bidding and order matching, yet well short of what can be achieved through automated agent-based solutions. Nevertheless, Transporeon has been used in daily operations by other partners of VLO, with considerable savings.

In comparison to these approaches, we focus mostly on the order allocation between several companies, more specifically on the order allocation between a 4PL and several 3PL companies. Our approach allows parties to discover optimal allocations in an iterative way, without revealing private planning information except to their own negotiating proxy agents. We envisage our tool being used as a human decision support tool, which allows human negotiators to investigate different scenarios, by changing the constraints, information shared and negotiation parameters of their agents. Humans are then free to accept/reject the proposed allocations, or re-run the negotiation in a new scenario.

Finally, our paper would not be complete without outlining some of the challenges we face in getting a pilot project on automated negotiation actually working at a company such as Vos Logistics. In general, in order for such a system to be adopted in practice, we need to show that the profit margins which can be achieved from adopting the new technology must be sufficiently high to warrant the effort and costs. Also, in our case, due to the fact that the system automates the interaction between several companies ("actors") in the supply chain, each of these must be willing to use this technology. Finally, the integration of automated planning of orders for each company with the negotiation proxy agent would be desirable in order to fully exploit the capacity of our system. Even if it is true that some of the companies use automated planning systems, we cannot assume this is necessarily the case for all companies in the supply chain. An alternative would be to allow humans to specify bids and offers, such as in an auction like protocol.

Despite the above challenges, our results from the approach so far have been very well received and a full scale pilot project is under way to apply such techniques in the daily outsourcing processes at Vos Logistics Organizing.

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