IDENTIFYING OPPORTUNITIES OF CO-LOADING BY MEANS OF SIMULATION

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ABSTRACT

This paper discusses bundling of freight activities at the operational level. Shippers attain scale economies and a better utilization of transport equipment through consolidation of freight inside a loading unit. This may on the one hand reduce the costs of pre- and end-haulage by road or on the other hand increase the attractiveness of intermodal freight transport for further continental distribution. A discrete event simulation model is developed to investigate possible benefits of consolidation in a real-life situation in which three shippers each operate a distribution centre (DC) in the neighbourhood of an intermodal terminal in Western Europe. The organization of a crossdock to consolidate freight of multiple shippers may lead to a reduction in throughput time of loading units. Second, simulation results show that capacity gains can be realized through a shift to non peak periods. The third performance measure to evaluate the consolidation scenario is the fill rate of loading units. The consolidation scenario leads to an increase in the average fill rate over all load orders in all three DC's. Finally, the consolidation scenario leads to a reduction in number of loading units necessary over the observed period.

Keywords: horizontal collaboration, shipper consolidation, discrete event simulation

1. INTRODUCTION

In this paper a simulation study is described in which potential benefits of horizontal cooperation between shippers are identified. The cost of freight transport may be decreased by raising the fill rate of loading units. Shippers attain scale economies and a better utilization of transport equipment through consolidation of freight inside a loading unit. This may reduce costs of pre- and end-haulage by road and increase the attractiveness of intermodal freight transport for further continental distribution. Co-loading of freight reduces the amount of trucks on the road. Societal gains are achieved by decreasing the amount of air pollution, transport noise, accidents and congestion.

According to Van der Horst and De Langen (2008), coordination in hinterland transport chains is required to make hinterland transport chains efficient and effective. The authors identify coordination problems and evaluate mechanisms to enhance coordination in hinterland freight transport. Ergun et al. (2007) study shipper consolidation in the context of collaborative logistics in the trucking industry. Their goal is to identify sets of lanes of multiple shippers that can be submitted to a carrier as a bundle rather than individually, in the hope that this results in more favorable rates. The authors focus on the simplest variant, which is static and involves only full truckloads. The problem is formulated as a lane covering problem and heuristic solutions are proposed. Consolidation of freight is often proposed to reduce truck traffic in urban areas. Kawamura and Lu (2007) compare logistics costs with and without delivery consolidation in urban centers, under different sets of conditions that include population density, area size and truck weight regulation. Factory gate pricing (FGP) is an alternative approach to transport consolidation, as proposed by le Blanc et al. (2006). Under FGP, products are no longer delivered at the retailer distribution center, but collected by the retailer at the factory gates of the suppliers. The authors study asymmetric distribution networks in which supplier sites greatly outnumber retailer distribution centers. A case study is performed of a Dutch retail chain of slow moving dry grocery goods. This setting differs from the type of distribution network studied in this paper.

We study a real-life situation in which three shippers each operate a distribution centre (DC) in the neighbourhood of an intermodal terminal in Western Europe. The intermodal terminal is situated in the hinterland of a major port, offering rail, barge and road connections to the port area. Inbound flows arrive at the DCs through the intermodal terminal. The DCs are responsible for further continental distribution of goods. In this paper the consolidation of these outbound flows is analysed. Outbound flows are mainly transported by truck. To a limited degree freight is carried by rail or short sea shipping. Warehousing operations are centralized at the three DCs, implying lower warehousing costs, but higher transport costs. Each DC is specialized in a certain product category (in order to guarantee confidentiality, product categories are referred to as A, F or Q) and uses a separate planning system. A discrete event simulation model is built to analyze opportunities of consolidating outbound freight flows of the three DCs through a crossdock, situated at or nearby the intermodal terminal. No assumptions are made on the operational implementation of the crossdock. The crossdock is a fictitious location where the three flows of the warehouses arrive jointly, so that load orders with the same destination may be grouped in a single loading unit.

2. DISCRETE EVENT SIMULATION MODEL

A discrete event simulation methodology is described to analyze the bundling of outbound freight flows of three nearby DCs to their joint hub destinations. Long haul truck transport distances are considered for the continental distribution of freight in Europe. The model is constructed in the simulation software Arena. In section 2.1 a conceptual model is developed of current operations in the shipping area of each DC. A DC has its own warehouse and shipping department and plans the loading of its own trailers and containers. Data is registered at the DCs for a time period of ten weeks to serve as input for the simulation model (section 2.2). Assumptions underlying the simulation model and consolidation strategy are summarized in section 2.3. Section 2.4 gives an insight in the performance measures generated by the simulation model.

2.1. Conceptual model

Figure 1 depicts the current operations in the shipping area of each DC. The customers or entities in our discrete event simulation model are load orders arriving from the warehouse into the shipping department of each DC and need to be handled at one of the available gates. Load orders consist of boxes in various sizes, which may be palletized or not. In the shipping department the boxes or pallets are loaded into trailers or containers. The arrival of load orders from the warehouse serves as an input for the simulation model of the shipping department. The warehouse planning and operations are an external source of load orders and thus not incorporated in the simulation model. The arrival time depends on the warehouse planning and operations and is thus assumed to be given. Next, load orders queue for handling at the gates. DC 1 has 16 gates available, DC 2 and DC 3 each have 17 gates available. The service delivered by the resources or gates is the loading of boxes or pallets onto loading units, which may be containers or trailers.

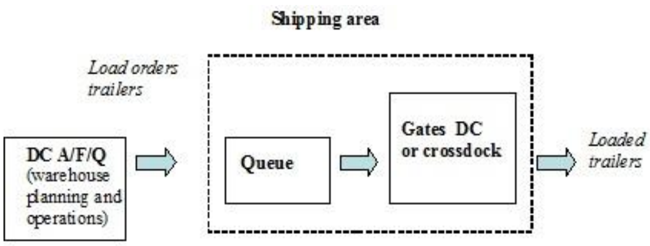

Figure 1: Conceptual model

Examples of state variables in this discrete event system are the status of the gates (idle or busy), the number of load orders waiting in a queue for handling at a gate or the time of arrival of a load order in a queue for handling at a gate. Events are the arrival of a load order in the shipping department or the completion of service of a load order at a gate.

In the simulation model of the current situation three separate queueing systems for each DC are constructed. The assignment of load orders to loading units is taken from the given planning in the available data set described in section 2.3. Containers or trailers leave the site when the last load order is put onto the loading unit at a gate in the shipping department. Between the first and last load order assigned, a loading unit is waiting at a gate or at the parking area close to the gates. In the simulation model of the future scenario the load orders of the three DCs arrive as a joint input process for a single service system representing the shipping area of the fictitious crossdock.

2.2. Data requirements

The simulation model requires data on the arrival process of load orders in the shipping department and on the service process of load orders at the gates.

A data set of load orders is tracked over a time period of ten weeks in each DC. Information is provided on the following attributes of a load order. The first attribute *'shipping time'* represents the moment at which the load order arrives in the shipping department. In the data set only the arrival times of the first and last carton are given. A random moment based on a uniform distribution between this minimum and maximum arrival time in shipping is assigned to each load order. In the data set of the current situation, each load order is destined for a certain loading unit, represented by an *identification number*. The next five attributes *(number of cartons, cubage, weight, palletized or not and number of pallets*) are necessary to determine the fill rate of containers or trailers and to consolidate load orders in the consolidation scenario. The next attribute marks whether the load order follows from either one of two special systems for warehouse operations in the distribution centres under investigation. The abbreviation '*WOW*' refers to Warehouse on Wheels. In this system load orders are loaded and stocked on site for a short time period with the objective to balance the warehouse operations. '*PH*' stands for 'pack and hold', which is a similar system but load orders are stocked internally at the shipping department of DC 1. The attribute '*DC*' indicates from which distribution centre a load order is originating. The attribute *'consolidator block*' identifies the carrier and hub for which the load order is destined. 34 possible consolidator blocks or destinations are identified. *Direct drops* are loading units which are delivered directly to the end customer. The final attribute *'cut off time'* refers to the moment at which the container or trailer must leave the site to arrive on time at destination.

The service process represents the loading of cartons or pallets onto loading units at the gates. Each load order requires that a number of cartons or a number of pallets is loaded onto a container or trailer. A probability distribution is applied to model the time necessary to load a single carton or pallet onto a loading unit. To this end a triangular distribution is chosen. The triangular distribution is identified by three parameters: mode, minimum and maximum value. The triangular distribution offers the advantage that only a fixed range of values is allowed and parameters are simply to determine. For the service time of pallets a mode of 5 minutes is experienced in practice. The minimum and maximum value are assumed to deviate 20%, leading to a minimum of 4 minutes and a maximum time to load a pallet of 6 minutes. When goods are not palletized, a service time per carton is applied. A service time of 0.45 minutes per carton is mostly observed, leading to a minimum value of 0.36 minutes and a maximum value of 0.54 minutes.

2.3. Assumptions

In the consolidation scenario the simulation model recombines load orders of various DCs in a single loading unit, based on a number of predefined rules. Load orders from the three DC's destined for the same consolidator block are bundled. Consolidator blocks represent joint hub destinations. Figure 2 depicts the restrictions imposed on the possibility to bundle freight. First, load orders for certain export destinations are not sent through the crossdock. Pack lists for these export destinations have to be generated in advance and cannot be changed. Secondly, direct drops are treated in the shipping department of the three warehouses separately and not in the crossdock. These load orders are sent directly to customer sites and therefore cannot be bundled with other load orders. Since the crossdock scenario does not yet exist, an assumption has to be made about the number of gates available in this future situation. Simulation results presented in section 3 are based on 30 gates in the crossdock and 5 gates remaining in the three separate DC's to handle load orders related to certain export destinations and direct drops. A volume of 2 m³ per pallet is assumed when combining palletized and not palletized load orders. In the new crossdock loading units are filled to their maximum volume of 60 m³. The cut off time of load orders is taken into account. Load orders are added to a loading unit when their cut off time matches the cut off time of load orders already assigned to the loading unit. Over the observed data period 34 consolidator blocks or destinations are served, of certain combinations of consolidator blocks are allowed in a single loading unit.

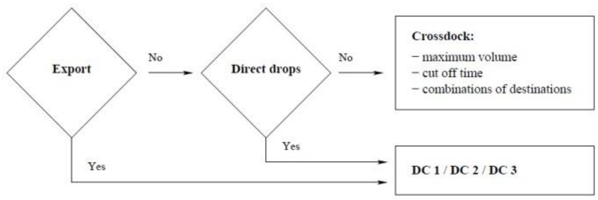

Figure 2: Consolidation through crossdock

2.4. Performance Measures

Table 1 presents the relevant outputs measured in the simulation model. The throughput time is the total time that a loading unit spends on site, including loading time and standing time. Standing time is the time period in which a loading unit is waiting at the gate or on the parking area. Load orders in the WOW or PH system are not taken into account when calculating the throughput times and standing times. These load orders are meant to wait and thus would give a misleading impression of the real throughput time and standing time. Weekends are excluded from the time performance measures, as the three DCs normally do not operate during this time. The capacity utilization of the gates is expressed as the percentage of time that the gates are in use for loading a carton or pallet onto a container or trailer. In this definition a gate is not in use when a loading unit is waiting but nothing is being loaded. The fill rate is expressed as the percentage of the maximum volume of a loading unit filled. Due to the type of products, weight is not a limiting factor. However, weight could be taken into account when consolidating load with other parties. The fill rate is measured for each DC and for palletized and non-palletized loading units separately. Load orders in the WOW and PH systems are included in the calculation of fill rates. A final output to compare the current and consolidation scenario is the number of loading units necessary for delivering all goods to their destination.

Table 1: Performance measures

Throughput time	Average Maximum
Standing time	Average Maximum
Capacity utilization gates	% time in use (avg and max)
Fill rate	% of volume per distribution centre Palletized or not
Number of loading units	

3. SIMULATION RESULTS

In this section simulation results are presented based on ten separate simulation runs, each representing a single week of operations. First, results on all performance measures listed in Table 1 are discussed. Next, in section 3.5 a statistical comparison is made between the current scenario and consolidation scenario, demonstrating significant differences in performance measures.

3.1. Throughput Time and Standing Time

The throughput time of loading units is defined as the time between the first and last order loaded onto the loading unit. When a loading unit is immediately loaded and so doesn't have to wait, this equals the sum of service times of its load orders at the gate. Table 2 summarizes the average and maximum throughput time of loading units for the current scenario and the consolidation scenario. In the consolidation scenario the throughput time for the separate DC's refers to the loading units for certain export destinations and direct drops, which are excluded from consolidation as stated in section 2.3. Results are expressed in days and weekends are not included. Nine outliers with a throughput time of at least seven days are excluded from the analysis.

Table 2: Throughput time of loading units (days)

	Current		Consolidation	
	Avg	**Max**	**Avg**	**Max**
DC 1	1.0679	4.8923	0.5751	4.8923
DC 2	1.3361	6.2023	0.8701	4.7052
DC 3	1.4471	6.1232	1.7311	4.9941
Crossdock	/	/	0.4968	4.7926

The comparison in table 2 shows a reduction in maximum throughput time of loading units of one day when consolidating freight and assuming the warehouse operations as given. The average throughput time also reduces from at least one day in the current scenario to half a day at the crossdock in the consolidation scenario. Throughput times depend on the warehouse planning and operations. Considerable time may pass between the arrival in shipping of the first and last load order destined for the same loading unit. Time lags also occur between the arrival of the first and last carton of a single load order. However, through consolidation a significant reduction in throughput time of loading units may be realized.

The standing time is equal to the throughput time of a loading unit minus the total service time of all load orders assigned to the loading unit. The same reduction in standing time is observed as discussed in the previous section on throughput time. The loading of containers or trailers only takes up a very limited amount of time. Loading units spend most part of their time waiting on site.

3.2. Capacity Utilization

The capacity utilization is the proportion of time the gates are in use during the simulation run. This only includes the time during which a container or trailer is being loaded, not the time while a loading unit is just standing at the gate. The simulation run includes nights and weekends, which are retained in the performance measures on capacity utilization. Weekends and nights account for respectively 28 % and 23.8 % of simulation time. Results of the current scenario in Table 3 show that the 17 available gates in DC 2 are at most used for 81 %. In DC 1 and DC 3 available gates are fully occupied during peak periods but on average only 20% of the available capacity are loading a container or trailer. Capacity is thus still available during other non-peak periods during the day or during night and weekend shifts. Capacity utilization in the consolidation scenario depends on the assumptions made on the number of gates. It is assumed that the crossdock disposes of 30 gates and 5 gates in each DC are available for handling certain export load orders and direct drops. The assumed capacity level is sufficient to deliver the same service level as in the current situation. Capacity gains could also be realized through a shift to non peak periods.

Table 3: Capacity utilization of gates (%)

	Current		Consolidation	
	Avg	**Max**	**Avg**	**Max**
DC 1	0.1950	1.0000	0.1400	1.0000
DC 2	0.0811	0.8235	0.0780	1.0000
DC 3	0.2013	1.0000	0.2004	1.0000
Crossdock	/	/	0.1668	1.0000

3.3. Fill Rate

Considering the type of goods, the fill rate is calculated based on volume. The maximum volume for loading units is set equal to 60 m³. In Table 4 and Table 5 the average fill rates in the three DC's are given for the current and future scenario. A further distinction is made between palletized and non palletized goods. In the current situation coloading between the three DC's already occasionally exists on an ad hoc basis. Tables 4 and 5 show the results without taking these loading units with coloading in the current situation into account. First, an important difference in fill rate is noted between palletized and non palletized goods in all three DC's. Second, fill rates in DC2 are lower than in the other two DC's in the current scenario, offering opportunities for bundling freight. The average fill rate in the crossdock increases to 72%. In particular an increase in fill rate of palletized goods is observed. The separate DC's in the crossdock scenario represent loading units for certain export destinations or direct drops.

Table 4: Average fill rate current scenario (%)

	Total	Palletized	Non palletized
DC 1	0.5975	0.4266	0.6428
DC 2	0.4148	0.3672	0.4289
DC 3	0.6844	0.4466	0.7469

Table 5: Average fill rate consolidation scenario (%)

	Total	Palletized	Non palletized
DC 1	0.5045	0.4214	0.5271
DC 2	04223	0.3105	0.4214
DC 3	0.6718	0.4292	0.7516
Crossdock	0.7239	0.6216	0.7753

Results presented are based on the assumption that the current warehouse planning and operations are given. A further improvement in fill rates could be obtained by taking consolidation opportunities in the warehouse planning and operations into account. Finally, simulation results showed that 43% of all loading units are less than 60% filled in the current scenario. This proportion decreases to 36% of all loading units that are less than 60% filled in the consolidation scenario over the time period of the data set.

3.4. Required Number of Loading Units

A final performance measure to evaluate the opportunities of consolidation between the three DC's is the number of loading units necessary for serving all destinations. In the crossdock scenario 2771 loading units are needed instead of 2930 loading units in the current scenario. Clustering freight thus leads to a total reduction of 159 loading units (5%) over a period of ten weeks.

3.5. Statistical comparison of scenarios

Table 6 reports the 95% confidence intervals for differences in performance measures between the current scenario and consolidation scenario. No significant differences in capacity utilization are recorded, as the number of gates in the future scenario is chosen to match the service level in current operations. In Table 6 confidence intervals for differences in throughput time and fill rates are given.

Table 6: 95% confidence intervals

	Confidence interval current - consolidation
Throughput time	
DC 1 - Crossdock	0.1032; 1.0391
DC 2 - Crossdock	0.1493; 1.5293
DC 3 - Crossdock	0.0402; 1.8604
Total fill rate	
DC 1 - Crossdock	-0.2284; -0.0243
DC 2 - Crossdock	-0.3913; -0.2268
DC 3 - Crossdock	-0.0964; 0.0173
Fill rate palletized	
DC 1 - Crossdock	-0.3597; -0.0301
DC 2 - Crossdock	-0.3905; -0.1182
DC 3 - Crossdock	-0.3261; -0.0239
Fill rate non palletized	
DC 1 - Crossdock	-0.2784; 0.0132
DC 2 - Crossdock	-0.4404; -0.2525
DC 3 - Crossdock	-0.0893; 0.0324

First, the organization of a crossdock to consolidate freight of multiple shippers leads to a significant reduction in average throughput time of loading units compared to the current situation in all three DC's. The throughput time depends on the warehouse planning and operations. Considerable time may pass between the arrival in shipping of the first and last load order destined for the same loading unit. Time lags also occur between the arrival of the first and last carton of a single load order. However, through consolidation a significant reduction in throughput time and standing time of loading units may already be realized.

A second performance measure reported in Table 6 is the total fill rate. The fill rate increases significantly in the crossdock scenario compared to current operations in DC 1 and DC2. In particular, fill rates in DC 2 are lower than in the other two DC's in current operations, offering opportunities for bundling freight. However, no significant difference in total fill rate is noted for DC 3, as loading units served in this DC already demonstrate on average a higher fill rate compared to the other two DC's in the current scenario.

Finally, table 6 mentions the 95 % confidence intervals for the fill rate of palletized and non palletized freight. Significant differences are found for palletized loading units, indicating that the crossdock also offers the opportunity to increase the fill rate of loading units containing pallets.

4. CONCLUSIONS AND FUTURE RESEARCH

This paper investigates clustering of freight at the operational level. Potential benefits of shipper consolidation are quantified by means of discrete event simulation. Simulations are performed for a realistic situation consisting of three distribution centres.

First, a significant reduction in throughput time of loading units is realized in the consolidation scenario, making use of a crossdock. Second, the fill rate of loading units may be improved by consolidating freight of shippers inside a loading unit. A higher fill rate implies a better utilization of transport equipment. This may on the one hand reduce the costs of pre- and end-haulage by road or on the other hand increase the attractiveness of intermodal freight transport for further continental distribution. Third, simulation results show that the available gates are used at full capacity during only a limited period per day. Capacity gains can be realized through a shift to non peak periods. Finally, the consolidation scenario leads to a reduction in number of loading units necessary over the observed period.

These simulation results show the opportunities of bundling freight without a change in planning. In both scenarios the warehouse planning and operations are assumed to be given and serve as an input for the simulation model. Further improvements in performance measures would be possible with the introduction of smart planning rules aimed at taking maximum advantage of consolidation opportunities.

Based on these simulation results, external cost calculations of the different scenarios will be presented in future work. Future research may also investigate the relations between customer demand, warehouse planning and shipping operations. Finally, consolidation of freight and the organization of a crossdock imply managerial changes. A revision of business models may be necessary.

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