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JOINT ROUTE PLANNING UNDER VARYING MARKET CONDITIONS

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Joint route planning under varying market conditions

Abstract

Purpose - To provide empirical evidence on the level of savings that can be attained by joint route planning and how these savings depend on specific market characteristics.

Design/methodology/approach - Joint route planning is a measure that companies can take to decrease the costs of their distribution activities. Essentially, this can either be achieved through horizontal cooperation or through outsourcing distribution to a Logistics Service Provider. The *synergy value* is defined as the difference between distribution costs in the original situation where all entities perform their orders individually, and the costs of a system where all orders are collected and route schemes are set up simultaneously to exploit economies of scale. This paper provides estimates of synergy values, both in a constructed benchmark case and in a number of real-world cases.

Findings - It turns out that synergy values of 30% are achievable. Furthermore, intuition is developed on how the synergy values depend on characteristics of the distribution problem under consideration.

Practical implications – The developed intuition on the nature of synergy values can help practitioners to find suitable combinations of distribution systems, since synergy values can quickly be assessed based on the characteristics of the distribution problem, without solving large and difficult Vehicle Routing Problems.

Originality/value – this paper addresses a major impediment to horizontal cooperation: estimating operational savings upfront.

Keywords - Horizontal cooperation, Distribution, Retail, Outsourcing, Vehicle Routing with Time Windows

Paper type - Research paper

1.   Introduction

Fierce competition in global markets, the shortening of product life cycles, and the heightened expectations of customers are examples of trends that cause profit margins to shrink. As a result, companies show a strong tendency to decrease the costs of non-value adding activities, such as basic distribution. Moreover, the increasing number of mergers and acquisitions provide the required momentum for companies to rethink and rebuild their logistics processes (Eye for Transport, 2003). Consequently, the European logistics market is currently going through a structural reorganization. Nowadays however, the potential of internal reorganization of these processes has been almost completely exploited, and attention has shifted from optimizing internal logistics processes to better managing external relations in the supply chain (Skjoett-Larsen, 2000). As a result, one of the most fundamental

choices that companies face in redesigning their logistics processes is whether they i) keep the execution in-house, ii) outsource the logistics activities, or iii) seek partnerships with sister companies to exploit synergies (Groothedde, 2005). Combinations of these three possibilities may also prove a valid option. This paper considers companies opting for choices ii) and iii), i.e. *outsourcing* and/or *horizontal cooperation*.

1.1 Outsourcing

Razzaque and Sheng (1998) define outsourcing (or: third party logistics) as the provision of single or multiple logistics services by a vendor on a contractual basis. It has been estimated that about 40 percent of global logistics is outsourced (Wong et al., 2000), and increasingly many shippers consider it an attractive alternative to the traditional logistics service mode (Hong et al., 2004). Razzaque and Sheng (1998) and Wilding and Juriado (2004) provide literature reviews on outsourcing, investigating which activities are typically outsourced and the main reasons for doing this. The top five reasons found for outsourcing relate to 1) costs or revenue, 2) service, 3) operational flexibility, 4) business focus, 5) asset utilization or efficiency. Service Providers are able to achieve economies of scale by providing logistics services to a number of customers, making cost or revenue related reasons as the most important for shippers wishing to outsource logistics processes. The most commonly outsourced processes are Transportation and Shipment, Warehousing and Inventory, Information Systems and Value Added Services.

1.2 Horizontal cooperation

Horizontal cooperation is defined by the European Union (2001) as "concerted practices between companies operating at the same level(s) in the market". Whereas this horizontal cooperation is common and well documented for the maritime shipping and aviation industry, the literature on horizontal cooperation in logistics and transport on the landside is fairly limited.

In maritime shipping, *conferences* are a common concept. A conference is an alliance of multiple shipping companies that offer their services on a specific transport line against collective tariffs and identical service levels (van Eekhout, 2001). The advantages of these conferences are economies of scale as a result of larger volumes shipped and improved customer service (Shepperd and Seidman, 2001). Moreover, conferences prevent price wars by offering rate stability. Generally, shippers oppose conferences because they feel that the ability of carriers to effectively compete is greatly reduced by membership of a conference (Clarke, 1997). The frequent investigations into this claim have for example resulted in a series of US government acts ranging from as early as 1916 to 1998 (cf. Lewis and Vellenga, 2000).

Alliances also play an increasingly dominant role in aviation. Some examples of major alliances are: Skyteam (9 airlines), Star Alliance (16 airlines), Qualifier (11 airlines), and OneWorld (8 airlines). Economically, there are of course strong incentives for airlines to operate dense international networks. Growth through mergers and acquisitions may provide a strong expansion of a network. However, the granting of international traffic rights is largely confined to specific carriers substantially owned by individual countries. This has left alliances of independent carriers as an effective compromise to international carriers to increase their joint market power (Fan, 2001). In addition to the quality customer service that is offered, aviation alliances enable higher load factors for aircrafts and more efficient back office organization. For further information on airline alliances, see e.g. Park (1997) and Oum et al. (2000).

This paper focuses on horizontal cooperation initiatives with a long-term horizon involving a certain level of operational integration, i.e. type II and type III partnerships in the categorization of Lambert et al. (1996). The objective of horizontal cooperation in logistics is to improve service, efficiencies, and costs

associated with the transport and delivery process (Esper and Williams, 2003) thus rendering it an example of Collaborative Transportation Management (CTM). Horizontal cooperation in logistics is mainly gaining momentum in Western Europe. In Belgium and the Netherlands, the European logistics center of gravity, the authors are aware of over 50 (in)formal horizontal logistics partnerships.

Through close cooperation, the partnering companies aim at increasing the competitiveness of their logistics networks. Some examples of specific goals are: reducing purchasing costs (e.g. onboard computers, storage systems, fuel, etc.), saving on storage costs by using joint facilities, and saving on non-core activities (e.g. safety trainings, joint fuel facilities, etc.). All these cost savings can be estimated quite accurately by means of basic cost calculations. This is however not the case for savings on distribution costs that result from so-called *joint route planning*, i.e. horizontal cooperation that merges the distribution processes of the partnering companies to obtain scale economies.

With joint route planning, the *synergy value* is defined as the (percent) difference between distribution costs in the original situation where all entities perform their orders individually, and the costs of a system where all orders are collected and route schemes are set up simultaneously. The bottom line is that both outsourcing and horizontal cooperation aim at increasing scale economies to ensure a more efficient execution of logistics processes.

Empirical research (Cruijssen et al., forthcoming) has indicated that problems in quantifying the operational savings upfront constitute a major obstacle to horizontal cooperation. Therefore, the aim of this paper is to calculate the synergy value that cooperating companies may expect through joint route planning.

1.3 Gain sharing

The focus of the paper will be on determining the total savings that partners can attain by means of joint route planning. The question remains however as to the allocation of these savings. An appropriate approach would be to employ solution procedures from cooperative game theory for this task. Cooperative game theory models the negotiation process within a group of cooperating agents and allocates the generated savings. Game theoretical methods are able to objectively take into account each player's impact within the group as a whole and produce allocations that distribute the synergy value based on clear-cut fairness properties. In general, this level of fairness cannot be attained by more simple proportional rules (e.g. proportional to the number of orders, to the total load shipped, or to the turnover of participants), as suggested by Altwegg (1995). A detailed discussion of gain sharing rules lies beyond the scope of this paper. This can be found in Cruijssen et al. (2005).

This remainder of the paper is organized as follows: in the next section the research framework and the routing model employed are explained. Furthermore, results are given on the synergy value in a benchmark case. In Section 3, the results are put into perspective by comparing them to the synergy values attained in a practical case concerning the distribution of frozen goods in the Dutch catering sector. Section 4 then describes a sensitivity analysis that is performed on six market characteristics of the benchmark case. Finally, in section 5, some concluding remarks are made.

2.   Joint route planning

Consider a system with multiple companies, each having a separate set of distribution orders. These distribution orders are requests for the delivery of goods from a single distribution centre to specified drop-off locations at customers' sites. Such a situation both fits the case of outsourcing of warehousing and distribution processes to an LSP, and the case of horizontal cooperation between shippers or LSPs through a joint distribution centre. It also offers a good approximation for the more general situation in which joint route planning is done by a group of companies whose vehicle depots are located 'sufficiently close' to each other. In this setting whether these companies are shippers, logistics service providers, or even receivers of goods is of little importance: it is enough that the players have direct control over the flows of goods. Who executes the orders is irrelevant from the point of view of synergy. Therefore, in the remainder of this paper the companies will be referred to as *flow controlling entities (FCE)*.

2.1 Research framework

This section presents a framework for comparing the sum of the distribution costs of individual FCEs with the distribution costs under joint route planning. This framework is based on the extended Solomon instance RC110_1 of the Vehicle Routing Problem with Time Windows (VRPTW, Solomon, 1987; Gehring and Homberger, 2001) and allows the examination of the synergy value of cooperation.

The distribution network consists of a set of nodes in a plane, each node representing a single drop-off location. Furthermore, there is one node in the centre of the plane, which represents the distribution centre, from where the orders are collected. Each pair of nodes is connected by an arc. On these arcs, Euclidean distances are assumed. The travel time (expressed in minutes) between each pair of nodes is proportional to the Euclidean distances, and therefore based on a constant speed of 60 distance units per hour. Travel times are relevant to determining synergy values since distribution orders generally have time windows and working days of drivers are of limited length.

In the original system without joint route planning, each customer belongs to a single FCE. This is implemented by successively assigning orders from the VRPTW instance to the FCEs, until the pre-set market shares in terms of number of distribution orders have been reached. Furthermore, FCEs have a sufficiently large homogeneous fleet of trucks that start and end their trips at the distribution centre. These trucks have a capacity of 200 units and operate at a cost of €1.42 per kilometre, and a €274 fixed cost per truck. Unloading (i.e. service time) takes a fixed time of 10 minutes for each customer.

2.2 Benchmark case

Problem instance RC110_1 is used to construct the benchmark case. This instance consists of 1000 orders of which the first 250 have been selected for the benchmark case. The orders have an average size of 17.82 and a standard deviation of 8.08 units. In the benchmark case, there are three FCEs that engage in joint route planning, and their market shares are all equal. Finally, it holds that the time window widths equal 30 for all customers, and the distribution area is a square of 500x500. A more detailed description of the problem instances can be found in Solomon (1987) and Gehring and Homberger (2001).

The developed benchmark scenario is summarized in Table I. Seven characteristics are assumed to have significance for the synergy values: number of orders per FCE (1 and 2), average order size (3), variance of order sizes (4), time window width (5), size of distribution area (6), and market shares of FCEs (7).

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	Characteristic	Benchmark case values
1	Number of orders	250
2	Number of FCEs	3
3	Average order size	17.82
4	Standard deviation of order size	8.08
5	Time window width	30
6	Size of distribution area	500x500
7	Market shares of FCEs	All equal

Table I: The benchmark scenario

The next section introduces the routing heuristic that is used to determine the synergy values.

2.3 Routing heuristic

In the classical formulation of the VRPTW, the objective is to construct routes from a common origin to multiple destination nodes. These routes are performed by identical trucks that start and end at the origin node and must be such that each destination node is visited exactly once, time windows are not violated, and the compound demand of the customers visited along a route does not exceed the truck's capacity.

The customary objective function for the VRPTW is of a two-stage nature. As a first criterion, the number of routes is minimized, and only then the distance travelled (some authors also minimize waiting time as a third criterion). In the current setting however, interest is in the minimum-cost solution based on the cost structure outlined in Section 2.1. This renders the two-stage objective function inappropriate because the minimum-cost solution is not necessarily the solution with the minimum number of routes. To accommodate this alternative objective function, a new VRPTW heuristic is constructed, which is described below.

The heuristic starts with the construction of an initial solution, which it then attempts to improve upon. The initial construction heuristic is based on the modified application of Clarke and Wright's (1964) savings heuristic by Liu and Shen (1999). The difference between the current heuristic and the original is that, when merging two routes A and B, not only positions at the start and end of route A are considered for insertion of route B, but also all other positions in route A. This means that in Figure 1, in addition to cases 1 and 2, cases 3 and 4 are also considered.
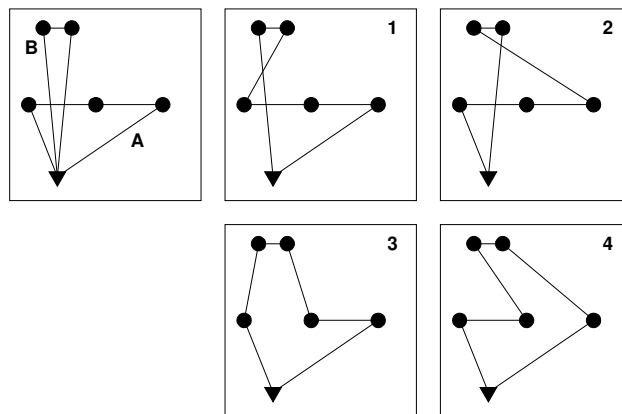

Figure 1. Modified savings construction algorithm

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Once the initial solution has been generated, the algorithm attempts to reduce the number of routes by looping through all routes, trying to insert the customers one-by-one into other routes. All routes are considered for elimination in a random order. The customers in the route selected for elimination are inserted in partial random order into other routes according to how critical they are. A customer's criticality depends on his demand, time window width and distance from the depot, as formalized below.

$$C_1 = \frac{D_i}{\max_i (D_i)} \tag{1}$$

$$C_2 = \frac{TW_i}{\max_i (TW_i)} \tag{2}$$

$$C_3 = \frac{Dist_i}{\max_i (Dist_i)} \tag{3}$$

$$Crit_i = \alpha + (1-\alpha)\left(\frac{C_1}{C_2} + \beta C_3\right) \tag{4}$$

, where:
$0 < \alpha < 1, \beta > 0$

D_i	=	Demand of customer i
TW_i	=	Width of customer i's time window
$Dist_i$	=	Distance of customer i from the depot
$Crit_i$	=	Criticality of customer i

If a route cannot be eliminated because not all customers could be reinserted into other routes, the successful insertions into other routes are undone. After the route elimination procedure, two local search operators, ICROSS and IOPT, are executed iteratively until no further improvement of costs can be found. ICROSS and IOPT are the same respectively as the well-known CROSS (Taillard et al., 1997) and Or-opt (Or, 1976) operators, except that the relocation of segments is also attempted in inverted order. Both operators are described in detail in Bräysy et al. (2004).

2.4 Benchmark case results

For the benchmark scenario developed in section 2.2, the synergy value is calculated. Because the algorithm starts with a random seed, 25 replications are performed and the average savings are calculated (see Figure 2 and Table II).
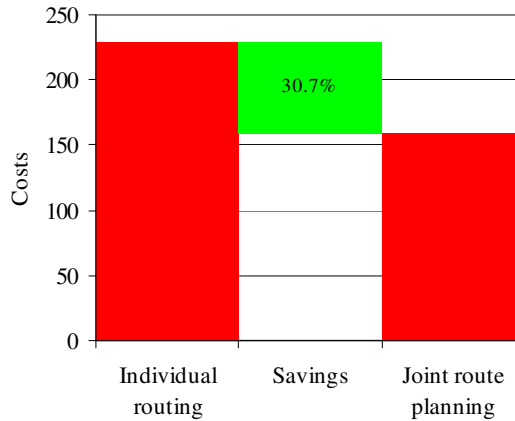
Figure 2: Synergy value for the benchmark case

	Original	Joint route planning	Improvements
Cost	56,884.71	39,438.65	30.7%
# Kilometres	29,778.87	20,595.67	30.8%
Load factor	0.43	0.62	43.2%
# Drops per route	4.72	6.76	43.2%
# Trucks	53	37	30.2%

Table II: Details of benchmark case savings

As expected, in this specific benchmark scenario, the FCEs benefit from joint route planning. The customer base to construct routes has after all been increased so that truck space can be used more efficiently. A cost reduction of 30.7% becomes possible as a result of joint route planning. Furthermore the savings in kilometres driven and trucks used are around 30%. The average load factor of trucks increases by 43.2% from 0.43 to 0.62. These relatively low levels of truck space usage are a direct result of the structure of the RC110_1 problem instance under consideration: time window constraints are far more restrictive than capacity constraints.

The scale of these benefits is of course very case specific. It is easy to construct instances where savings are very high or very low. Therefore, the next section discusses a case study to underpin the range of savings found in the benchmark case.

3. Joint route planning in practice

This section illustrates joint route planning by means of a case study in the Dutch catering sector. In 2001, three Dutch companies (Douwe Egberts, Unipro and Masterfoods) started a cooperation to increase the efficiency of their distribution networks for frozen products. All three companies supply frozen products to catering outlets at schools, companies, hospitals, government organizations, etc. For Douwe Egberts, these products are mainly coffee extracts, for Unipro bread and pastry, and for Masterfoods mostly ice cream. These products are delivered by means of expensive temperature controlled trucks, which means that logistics costs make up a relatively large share of the product price. Given the existence of a considerable amount of overlap between customers, 68% on average, the companies decided that a joint distribution of their products could be an interesting opportunity.

The inventory was moved from three private distribution centres in Wolvega, Dongen and Beuningen, to a new purpose-build joint distribution centre in Utrecht, the geographical centre of the Netherlands. In addition, the warehousing and distribution activities were outsourced to logistics service provider C. van Heezik. This shift to a centralized distribution system with joint route planning is illustrated in Figure 3.
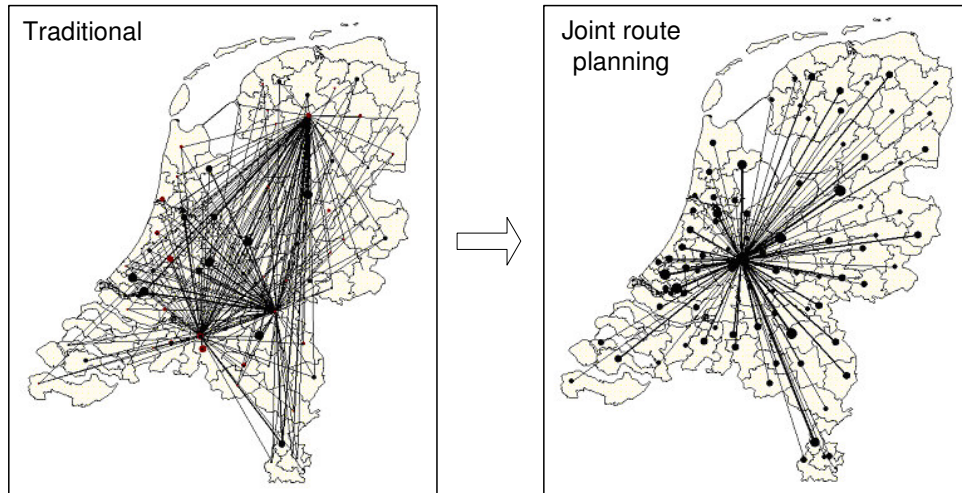

Figure 3: Case study: centralization and joint route planning

Actual routes for weekly order sets were used to compare key performance indicators of the ex-ante and ex-post situations. The results can be found in Table III, and are based on a homogeneous fleet consisting of trucks with a capacity of 26 units. The average drop size improves in the new situation, because Douwe Egberts, Unipro and Masterfoods have a number of joint customers. The orders of these customers are consolidated which improves the efficiency of the distribution process. Additionally, savings are attained because the customers belonging to different companies are located 'close' to each other so that their orders can be combined in one route.

	Before	After	*Improvements*
# Trucks	4245	2106	50.4%
Drop size	2.52	3.5	38.9%
Drops per year	21,225	15,161	28.6%
Kilometres per year	1,460,000	1,010,000	30.8%

Table III: Results of introduction of central distribution centre

For this case joint route planning saves 30.8% of distance travelled. In the new situation load factors are very high (over 95%), resulting in a fleet reduction of 50%.

The synergy value of 30.8% in terms of kilometres driven in this specific case is well in line with the results of the benchmark scenario in the previous section. This is however not true in general. The possible reduction in fleet size for example is much higher here. Furthermore, there are several other existing cases of joint route planning, where the savings deviate quite strongly from the 30% attained in the benchmark case. For example, Bahrami (2002) describes the merge of separate distribution networks pertaining to two producers of consumer goods (Henkel and Schwarzkopf) into one joint distribution network. In this case distribution costs are estimated to fall by (only) 15.3% as a result of joint route planning. Cruijssen et al. (2005) also discuss a case of joint route planning wherein four grocery retail chains cooperate by performing joint route planning for the distribution of their frozen goods to local supermarkets. The savings in distribution costs reported there amount to 20.3%. Finally LeBlanc et al. (forthcoming) discuss

a case relating to the primary transport (i.e. from supplier sites to distribution centres of retailers) of grocery products. The authors discuss two cases of cooperation:

1. Joint route planning by the suppliers: they deliver the goods to the retailers' distribution centre.
2. Joint route planning by the retailers: they pick up the goods at the suppliers' sites.

The first constitutes a traditional situation whereas the second is an example of so-called *Factory Gate Pricing*. The reported savings due to joint route planning are 27.1% in the traditional situation, and 11.4% in the Factory Gate Pricing situation.

It can be concluded that synergy values in the cases mentioned in this section show a quite strong variability. It is however very important for potential partners to have a reliable estimate of potential savings, before they engage in joint route planning. Since it is not always possible for companies to make a detailed estimation of the distribution costs in the ex-ante and ex-post situations, the next section will develop an intuition on the impact of scenario-specific characteristics on the synergy value. This can be useful for partners wishing to obtain an indication of the maximum achievable savings quickly. These insights may in turn both intensify and speed up the negotiations, and increase the probability of the actual start and prosperity of a cooperation (cf. Verstrepen et al., 2006).

4. Sensitivity analysis

The variability in synergy values is a direct consequence of operational (routing) characteristics of the sectors in which cooperation takes place. The characteristics were already listed in Table I. In this section, various markets are resembled by varying one characteristic at a time and fixing the others at their benchmark scenario value. Table IV defines the range for each characteristic and the corresponding step sizes.

Characteristic	Minimum	Maximum	Step size
Number of orders per FCE	10	-	10
Average order size	0.2	8	0.2
Standard deviation of order size	0	4	0.1
Time window width	0	20	0.5
Size of distribution area	0.1	1	0.025
Market shares of FCEs	0	1	0.025

Table IV: Range of characteristics values

In the following subsections the synergy values are plotted for the characteristics listed in Table IV. Each data point in the plots corresponds to the average result of 25 runs of the VRPTW heuristic described in Section 2.3. The data point corresponding to the benchmark scenario is denoted by a larger grey dot. In each plot, the horizontal axis represents the values of the characteristic under consideration. The vertical axis represents the average per cent savings due to joint route planning as compared to the benchmark scenario.

4.1 Number of orders per FCE

Figure 4 shows the sensitivity of the synergy value with respect to the number of orders per FCE. The number of orders per FCE is increased in intermediate steps of 10, till the total reaches 1000. The maximum number of orders per FCE therefore varies from scenario to scenario depending on the number of FCEs. In general, synergy values tend to increase initially, and then, having attained the maximum level, decrease. The rationale behind this is that when there are very few orders available there is not enough scale for a strong efficiency improvement through joint route planning. Isolated drop-off locations

have a high probability of remaining isolated also in the joint route planning scenario, even more so when time windows avoid efficient combinations in a single route. On the other hand, when the number of orders per FCE is very large, each individual company has better economies of scale and is able to carry out routes more efficiently. Theoretically, the synergy values will tend to zero if the number of orders per FCE runs to infinity. However, even when only two FCEs cooperate each having a 'large' individual orderset of 500, joint route planning still offers a promising opportunity to reduce costs (synergy value is 17.8%). Figure 4 also indicates that the more FCEs active in joint route planning, the higher the maximum savings, and the slower the synergy value tends to zero. This analysis demonstrates that, in relative terms, joint route planning is more profitable for small transport companies than for larger ones. This is an important consideration in, for example, the Netherlands and Belgium, where fragmentation in the road transport industry is high. In these two countries, there are approximately 15,000 transport companies, or 1 company per 1,800 inhabitants. Furthermore, Cruijssen et al. (2006) demonstrate that for Flemish road transport companies it holds that 'large' companies operate more efficiently than 'small' ones. Consolidation through joint route planning could therefore prove a promising option. However, it may not be reasonable to expect a very large number of small FCEs to cooperate in joint route planning, since the transaction costs needed for setting up and maintaining such a partnership will eventually outweigh the absolute cost savings FCEs can attain. An elaboration on the role of transaction costs however lies beyond the scope of this paper. A detailed discussion of various types of transaction costs in collaborative transport networks can be found in Groothedde (2005).
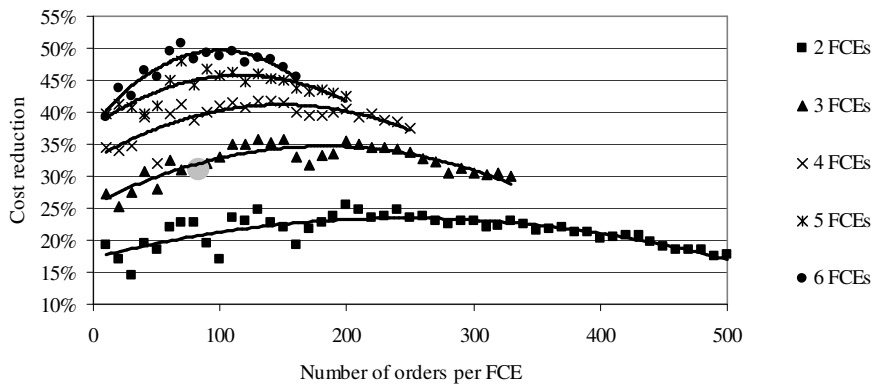

Figure 4: Sensitivity: number of orders per FCE

4.2 Average order size

Figure 5 depicts the influence of order size on the maximum achievable synergy values. The average demand of the orders is varied by multiplying the size of every order by a factor that is defined per scenario. Fractional demands are rounded to the nearest integer. In the benchmark case, the average demand is 18.82 and the multiplication factor is equal to 1. At the left-most part of Figure 5, the factor is 0.1, and capacity restrictions are virtually absent. In this case, time window restrictions become the critical element in the route construction. With the maximum value however (right-most side of Figure 5), even average orders cannot be combined in a single truck, making capacity restrictions most important. In that case the average order size equals 134, and most of the orders are larger than half a truck capacity, rendering opportunities for consolidation in a single truck rare. The interpretation for real world applications is that joint route planning is more profitable in sectors where orders are small (e.g. consumer electronics or fashion), than in sectors where the average order is large (e.g. wood or paper).
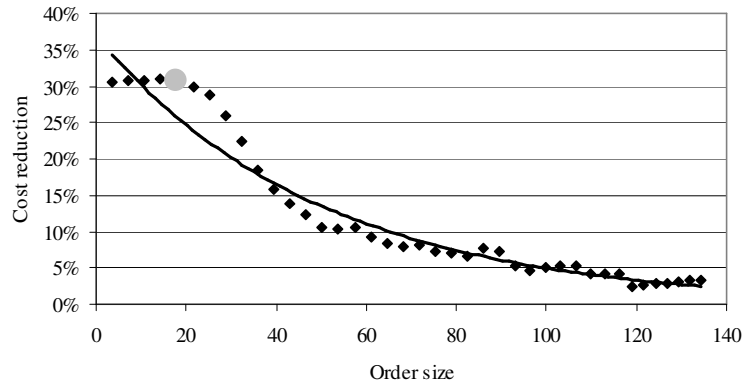
Figure 5: Sensitivity: average order size

4.3 Standard deviation of order size

Figure 6 shows the relation between synergy values and the variability in order sizes. The standard deviation of the demand size is adjusted by multiplying an order's deviation from the average order size by a scenario-dependent factor. In this process the minimum order size remains 1, and the maximum order size 200. With the exception of these cut-off values, this transformation leaves the average demand size unaltered. It turns out that there is no apparent relation between order size variability and synergy value or, in other words, increased scale is no solution to the operational problems imposed by a strong variability in order sizes.
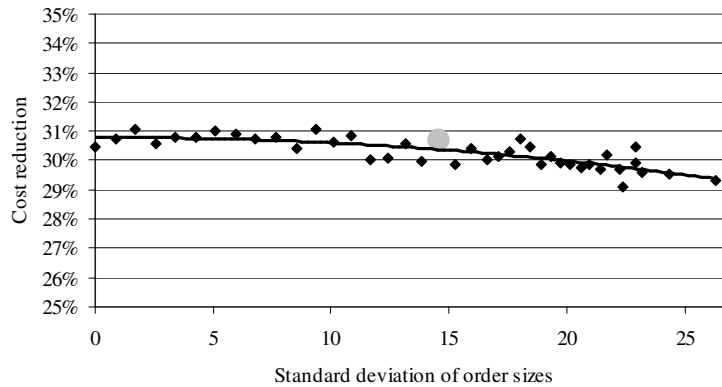

Figure 6: Sensitivity: standard deviation of order sizes

4.4 Time window width

In the benchmark case, all time windows have a half-width of 15. In order to study the impact of time window width on the synergy value of joint route planning, the half-width is multiplied by a scenario-dependent factor. For example, a time window of [200, 230] and a factor of 2 result in a new time window of [215-15*2, 215+15*2], or [185,245]. Each time the window is limited however by the earliest and latest possible time at which a truck can leave and enter the depot. Figure 7 reveals the results of this sensitivity analysis. It shows that synergy values are highest in a situation with time windows of 'average' width.

The reason for this lies in the fact that when time windows are very narrow there is hardly any flexibility in building the routes and it is thus hard to fully capitalize on increased economies of scale. On the other hand, when time windows are very wide, the synergy value also tends to decrease. This is because FCEs can already build quite efficient routes individually, because many orders can be combined into a feasible route. This illustrates the strong impact of time window constraints on the solution value for VRPTWs. For example, on the left-most side of the graph, the value of 0 refers to time windows that are in fact single points in time where service at a customer's drop-off location must start. In that case, total distribution costs under joint route planning amount to 55,588.28. When time windows are really wide (factor 8; time window width of 240), these costs are 28,768.55. This means that imposing these strict time windows results in a cost increase of 93.2% in the case of wide time windows.
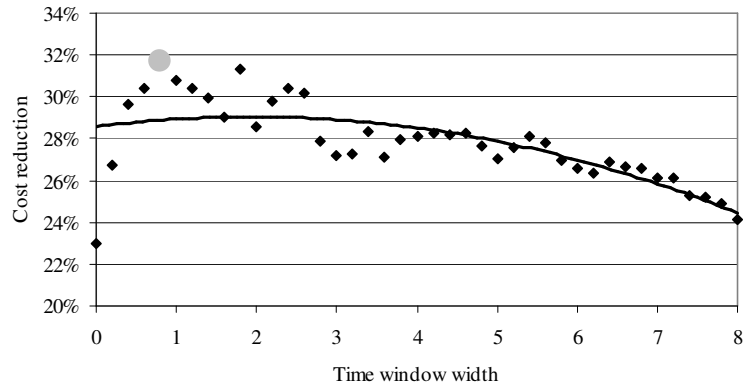

Figure 7: Sensitivity: Time window width

4.5 Size of distribution area

The sixth characteristic that potentially influences the level of synergy is the size of the distribution area, since this has direct consequences for the average distance between drop-off locations. To vary the size of the distribution area, the distance of each drop-off location from the depot is multiplied by a scenario-defined factor, and its position relocated on the line that starts at the depot site and crosses the customer's former position. For example, with a factor of 0.5, a customer that was located at coordinates $[300,150]$ in the benchmark scenario, is relocated to:

$$[250+(300-250)*0.5, \ 250+(150-250)*0.5]=[275,200].$$

The results in Figure 8 show that the synergy value gradually increases as the average distance between customers increases. This suggests that joint route planning is more profitable in sectors where customers are located across a large region (e.g. Europe), than in sectors where customers are located quite close to each other (e.g. regional distribution).
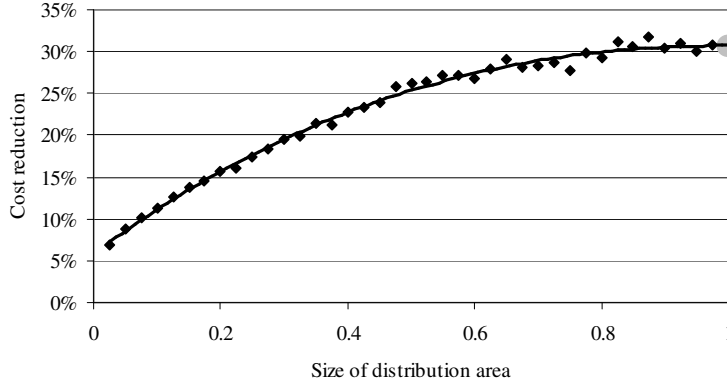
12

Figure 8: Sensitivity: size of distribution area

4.6 Market shares of FCEs

The last characteristic that is varied in order to study its impact on the synergy value is the distribution of market shares over the three FCEs present in the benchmark scenario. The market concentration is determined by the Gini coefficient. Although this measure originates from social welfare theory, it can be straightforwardly applied to describe the inequality of market shares of FCEs in the setting of joint route planning. The Gini coefficient is defined as $G = \dfrac{\sum_{i=1}^{n} x_i \left(2i - n - 1 \right)}{n(n-1)x}$, where x_i is the market share of FCE i, and x is the average market share. Without loss of generality, it is assumed that the market share of FCE i is smaller than the market share of FCE j, when $i < j$. More specifically, $x_i = \beta x_{i-1}$, and $\beta > 1$. Under these conditions and $\sum_{i=1}^{n} x_i = 1$, it is possible to choose the Gini coefficient for the benchmark scenario with three FCEs and construct unique corresponding market shares by means of the following:

$$\beta = \frac{-G - \sqrt{4 - 3G^2}}{2G - 2} \tag{6}$$

$$x_1 = \frac{G \sum_{i=1}^{3} x_i}{\beta^2 - 1} \tag{7}$$

$$x_2 = \beta x_1 \tag{8}$$

$$x_3 = \beta^2 x_1 \tag{9}$$

When the Gini coefficient is at the benchmark level of 0, there is perfect equality of market shares and the order set is distributed evenly over the FCEs. On the other hand, a Gini coefficient of 1 indicates that the total market is in the hands of only one FCE. Figure 9 shows that the synergy value decreases when the total order set is divided less evenly over the participating FCEs. This is explained by the fact that in a strongly concentrated market, the leading FCE will be able to construct efficient routes, even without joint route planning.
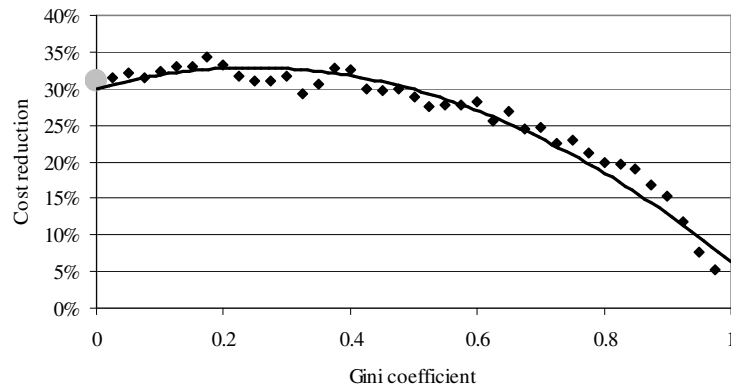
Figure 9: Sensitivity: Market concentration in terms of Gini coefficient

5. Concluding remarks

This paper discussed the concept of joint route planning. Joint route planning can essentially be achieved in two ways: outsourcing or horizontal cooperation. The goal of both concepts is to attain larger economies of scale that help to cut down distribution costs. For example, in the benchmark scenario described in Section 2.2, the savings due to joint route planning are considerable: 30.7% of total distribution costs.

Sensitivity analyses were conducted to gain insight into the main drivers for synergy, and how these affect the synergy value. The results indicate that joint route planning is most beneficial in situations where there are a large number of FCEs of a uniform and not too large size. Furthermore, the synergy value increases if order sizes are small compared to a standard truck's capacity, time windows are narrow, and inter-customer distances are large. Finally, the variation in order sizes does not seem to play an important role. These results are easily interpreted and can be used by practitioners to develop intuition on synergy value should there be no time or budget to go through all the calculations. This intuition thus allows for a rapid determination as to whether a group of FCEs has a strong synergy potential.

The paper dealt with a basic distribution setting. Further research is needed to understand the impact of joint route planning in more complex distribution systems. For example a significant contribution would be an investigation into how the results of the analysis would be influenced by the introduction of e.g. multiple depots or pick up and delivery orders.

6.   References

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