Factory Gate Pricing: An Analysis of the Dutch Retail Distribution

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Abstract

Factory Gate Pricing (FGP) is a relatively new phenomenon in retail distribution. Under FGP, products are no longer delivered at the retailer distribution center, but collected by the retailer at the factory gates of the suppliers. Owing to both the asymmetry in the distribution networks (the supplier sites greatly outnumber the retailer distribution centers) and the better inventory and transport coordination mechanisms, this is likely to result in high savings. A mathematical model was used to analyze the benefits of FGP for a case study in the Dutch retail sector. Extensive numerical results are presented to show the effect of the orchestration shift from supplier to retailer, the improved coordination mechanisms, and sector-wide cooperation.

Keywords: Supply chain management; Retail distribution; Factory Gate Pricing
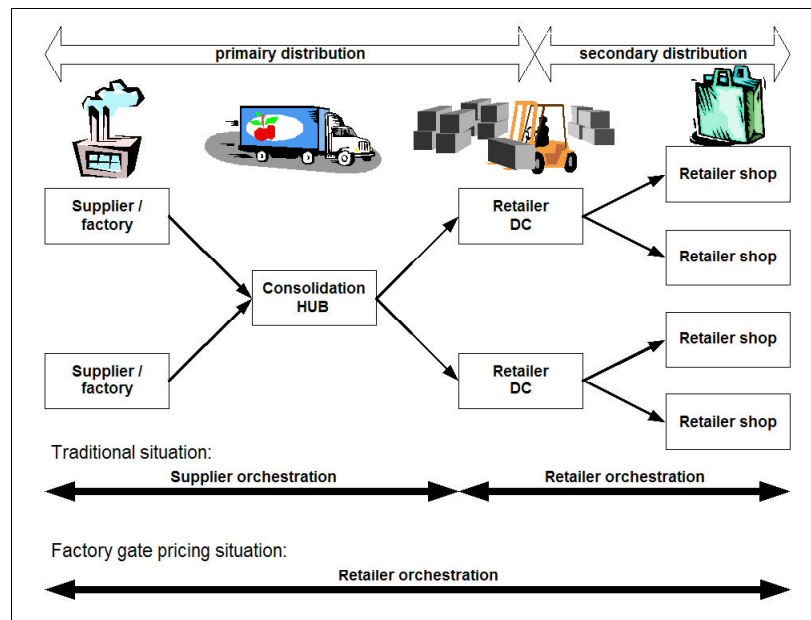
1. Introduction

Retail supply chains are under pressure: margins are getting thinner, customer requirements in terms of product freshness and product assortment are growing and product life cycles are becoming shorter. In response to this, retail logistics is going through drastic changes. In the early 1980s, it was common practice for suppliers to deliver products directly to the shops (Mercer 1993). In the mid-eighties, retailers gradually moved towards central warehousing: suppliers delivered to a retailer distribution center (DC), enabling retailers to supply their shops more efficiently. As a result of this change, the retail supply chain was separated into two parts:

- Primary distribution: from the supplier to the retailer distribution center

- Secondary distribution: from the retailer distribution center to the shops

In most cases, suppliers maintained control of the primary distribution. The retailer, however, controlled the secondary distribution. As a result, external logistics became part of the day-to-day business environment of the retailer. Since the nineties, logistics has become one of the crucial determinants of success in retail (Fernie and Staines 2001). FGP is the latest trend in retail logistics. Under FGP, the retailer takes over the orchestration of the primary distribution from the supplier. More specifically, this means that the cost of transportation is no longer included in the price that suppliers charge the retailer. Instead, the retailer buys the products 'at the factory gate' and takes care of the transport himself. Figure 1 presents a graphic overview of the general retail chain and the shift from the traditional situation to FGP.

Figure 1   The retail chain

The increasing product range and demand variability is forcing retailers to focus on inventory reductions. In recent years, this has resulted in more frequent and smaller replenishment orders that

were delivered by the suppliers to the retailer DCs. To manage this efficiently, suppliers introduced consolidation hubs where many small orders for the same retailer DC are combined. In addition, seamless information interchange between shops, distribution centers, and suppliers has become a prerequisite (Abernathy et al. 2000). Despite the advances in information technology, there is still no information transparency in the supply chain.

On the one hand, solely the suppliers incur the costs of primary transportation. On the other hand, the retailers incur inventory costs at the distribution centers. Because of this lack of a bird's-eye view on logistic costs, the optimal balance of transportation and inventory costs in the replenishment policy of retailers is seldom achieved. The reason is simple: the retailer is not directly charged for the higher transportation costs that are a consequence of the increased frequency of delivery. Bringing the control of primary transportation and inventory into one hand, as in FGP, is likely to generate cost savings.

In addition to the savings resulting from coordination of transportation and inventory, FGP offers two other sources for savings. Firstly, retailers generally have a vast product range for which they can make the transportation-inventory trade-off simultaneously. This means that orders from suppliers that are located close to each other may be synchronized in time, such that they can be combined in the same vehicle route. Secondly, under FGP, primary and secondary distribution can be integrated. For example, on the backhaul of a delivery trip to a shop, the same vehicle may, if this is efficient, visit a supplier to pick up a shipment destined for a retailer distribution center.

A well-known concept that is related to FGP is Vendor Managed Inventory (VMI, see for example, Cheung and Lee 2002 and Disney et al. 2003). VMI also places the control of inventory and primary transportation, and sometimes even secondary transportation (Silver et al. 1998), in one hand. This differs from FGP in that, under VMI, the supplier and not the retailer is in control. In the light of supply chain control, FGP and VMI can therefore be considered each other's counterpart. VMI is typically implemented in situations in which a few large suppliers deliver a substantial volume to retailers, but it becomes unmanageable if hundreds of small suppliers frequently visit the retailer's

warehouse for new supplies. Moreover, it is unlikely that small suppliers have the logistic and ICT capabilities to carry out VMI. With FGP, this problem does not occur since in general retail supply chains there are many more suppliers than retailers. Furthermore, the logistic capabilities of retailers and their logistic service providers seem to be well enough developed to take over the transportation from the suppliers. Which concept is more suitable depends in large part on product characteristics (like size, weight, temperature conditioning, vulnerability) and the capabilities of both the supplier and the retailer.

The promising future of FGP has already been demonstrated in the UK where leading retailers such as Tesco and Sainsbury's have implemented FGP for a part of their product range. Other British retailers such as Asda, Somerfield, Safeway, and Waitrose have announced plans for FGP (IGD website, Finegan 2002). Potter et al. (2003) report significant potential kilometer reductions due to FGP for the case of Tesco. Interviews with Dutch retailers indicate that they have high expectations for FGP as well.

The aim of the present study was to quantify the expected benefits of FGP for the Dutch retail sector. To achieve this aim, we constructed route schemes down to the operational level of execution. For each product group/distribution center combination, we decided on the size of the shipments, the frequency of delivery of the products, the safety stock, and the *delivery mode* (i.e., direct or via a consolidation hub). We then solved the operational vehicle routing problem. Although this is a strategic-tactical study, we chose to solve the operational problem to get a good estimation of transportation costs and performance indicators. The reasons for this is that the small nuances in different scenarios cannot be adequately expressed in strategic models and go back to the operational level; therefore we needed detailed route schemes to analyze the differences. The main contribution of the study is that it addresses a concept that is fairly new, and very promising, as an approach to reduce supply chain costs for networks with a larger supplier than customer base.

The paper is organized as follows. In section 2 we discuss the literature on optimization problems that is relevant for FGP. Section 3 includes a detailed description of the case selected in the Dutch retail sector and a discussion of issues such as consolidation, cooperation, and chain orchestration. The methodology in section 4 is elaborated on. In section 5, the results of the case study are discussed. In section 6 we discuss practical barriers for FGP implementations and directions for further research. The conclusions are presented in section 7.

2. Literature

Perhaps because of the relative novelty of Factory Gate Pricing, there is little literature on the subject as such. Moreover, because of its many aspects and enormous size, it is very hard to develop efficient algorithms for what we call the *Factory Gate Pricing optimization problem*. To cope with this, we constructed a two-phase heuristic. Firstly, by determining the frequency and amount of delivery for each product a good balance between inventory and transportation costs could be made. Secondly, orders are combined into routes by solving a vehicle routing problem. During these phases, some well-known optimization problems occur. In this section, we present a brief survey of the literature on these problems: periodic routing, routing with a consolidation hub, combined inventory and route planning, and routing with a large customer base.

2.1 Periodic routing

Since the dataset (see section 3.1) contains frequencies for each transportation order, our routing problem has a periodic character. This Periodic Vehicle Routing Problem (PVRP) is identical to the classical Vehicle Routing Problem, except that the planning period consists of M days instead of one day. Each client i must be visited k_i times during this period where $1 \leq k_i \leq M$. We call k_i the frequency of delivery to client i. Sets of daily routes are generated to minimize transportation costs while satisfying the constraints. To use this type of model the delivery mode must be known or determined

beforehand. Some references on periodic vehicle routing are Baptista et al. (2002), Chao et al. (1995), Christofides and Beasley (1984), Cordeau, et al. (1997), Drummond et al. (2001), Russell and Gribbin (1991), and Tan and Beasley (1984).

2.3 Routing with a consolidation hub

The routing of products through a network may improve when a consolidation hub is introduced. One of the first papers on a transportation system in which both direct shipping and shipping via one or more hubs is allowed, was written by Aykin (1995). The problem consisted of determining the best hub locations and the best delivery modes for clients. The objective was to minimize total transportation cost. Four heuristic algorithms were proposed to solve the problem. Unfortunately, the problem instances solved were limited to 5 hubs and 20 demand points. Liu et al. (2003) showed that, when compared to a pure hub-and-spoke system or a pure direct shipment system, allowing *both* delivery modes results in roughly a 10 % saving. Furthermore, it was concluded that demand distribution significantly influences the relative performance of a mixed system. Again, problem sizes are relatively small: the largest solved instance dealt with 5 suppliers and 25 customers.

Irnich (2000) introduced a problem with multiple depots in a pickup and delivery setting. In this problem, all requests have to be picked up at or delivered to one central location that has the function of a consolidation hub. A two-phase set-covering algorithm based on column generation was proposed. This approach severely limits the maximum size of the instances since it is assumed that all possible routes can be enumerated. The largest instances that are solved consist of 130 orders and 22 depots.

2.4 Combined inventory and route planning

An important aspect of FGP is that decisions on replenishment orders influence the transportation and handling costs as well as the inventory costs. Improving supply chain efficiency thus requires an

integrated approach to inventory control and transportation planning. The references given in this subsection can be used for FGP in the sense that they provide a good understanding of how transportation costs and inventory costs interact.

Daganzo and Newell (1985) conducted an early study on the simultaneous routing and inventory problem. They illustrated how the nature of the objects carried (cheap products, expensive products, people, etc.) affects the optimal configuration of a distribution system. The results also depend on factors such as: the inventory carrying cost per item per unit of time, the transportation cost per unit distance, the demand per unit area and unit time, the average distance from the depot, the average vehicle speed, and the time per stop. Other references for the simultaneous minimization of transport and inventory costs in various settings are Anily (1990), Anily and Federgruen (1993), Bell et al. (1983), Chien et al. (1989), Dror and Ball (1987), Dror and Levy (1986), Herer and Levy (1997), and Viswanathan and Mathur (1997). We mention Qu et al. (1999) in particular since they come closest to the FGP situation. In their setting, the control of the supply chain lies with a central distribution center that collects products from a set of suppliers. Again, problem sizes are small: the heuristic was tested on instances with a maximum size of 50 items.

For issues concerning inventory policies for the retail sector in particular, we refer to Dubelaar et al. (2001) and Kapalka et al. (1999).

2.5 Routing with a large customer base

Because of the large instances we are facing, most of the standard optimization techniques cannot be applied. In the literature, little attention is given to huge routing problems. However, some research has been done on very large instances of the generalized assignment problem, a problem that can be reformulated as a basic vehicle routing problem (see Higgins 2001). To our knowledge, routing problems that incorporate characteristics such as periodicity and the presence of consolidation hubs have not yet been discussed in the literature for the very large instances at hand.

2.6 Discussion

No publications could be found in the literature that incorporate all the problem characteristics of the FGP situation. Nevertheless, there is extensive literature on some of the building blocks of the FGP optimization problem. Some ideas and concepts are readily usable for FGP. The biggest challenge is the enormous size. Compared to the FGP problem, most problems that are solved in the literature are fairly small.

3. Case description

SuperUnie, a Dutch purchasing organization for food retailers and three SuperUnie members, CoopCodis, Dekamarkt, and Jumbo, provided the data for the case study described here. Together, the SuperUnie members make up approximately 25% of the Dutch food retail market. The dataset consisted of 355 slow moving dry grocery products that all retailers have in their assortments. The retailers consider a product to be a slow mover if the turnover in a distribution center is less than 66 pallets a week. The product volumes are for a representative period of 24 days without seasonal and promotional effects.

For a fair comparison between the current situation and Factory Gate Pricing, we required more than only the data of the SuperUnie members. Restricting the case to the SuperUnie retailers would bias the current situation by underestimating the economies of scale of the suppliers. To avoid this, we scaled up our dataset on the basis of the market shares of the other Dutch food retailers and their known locations of distribution centers. This resulted in a dataset with the characteristics listed in Table 1. The consolidation centers are the current sites of logistic service providers, sometimes working for multiple suppliers.

| Number of suppliers	340
Number of product groups	355
Number of retailer distribution centers	47
Number of consolidation centers	25
Number of flows	11,980
Number of monthly orders	Appr. 60,000

Table 1   Size of the problem

The data for handling activity (like truck loading, unloading, storing), transport (driving, stopping), and administration (ordering) were obtained from a sector-specific database (Stichting Ketenmoduul 2000) and verified by the three retailers. These data are displayed in Figure 2.
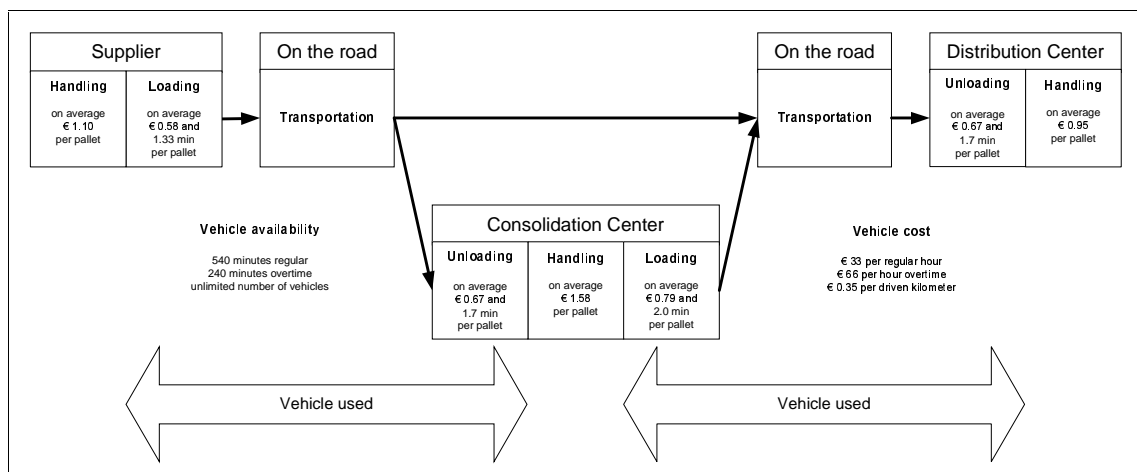
Figure 2   Overview of processes with data

Inventory costs were directly derived from the value per pallet, which was obtained from the retailer's databases and the cost per pallet position (Stichting Ketenmoduul 2000). In general, inventory costs are not dominant for the product groups considered as the average pallet value is only € 784.

In order to assess the potential of FGP, we defined seven scenarios, corresponding to different *chain orchestrators*, *degrees of cooperation* and *flow synchronization*. An overview of the scenarios is presented in Figure 3.

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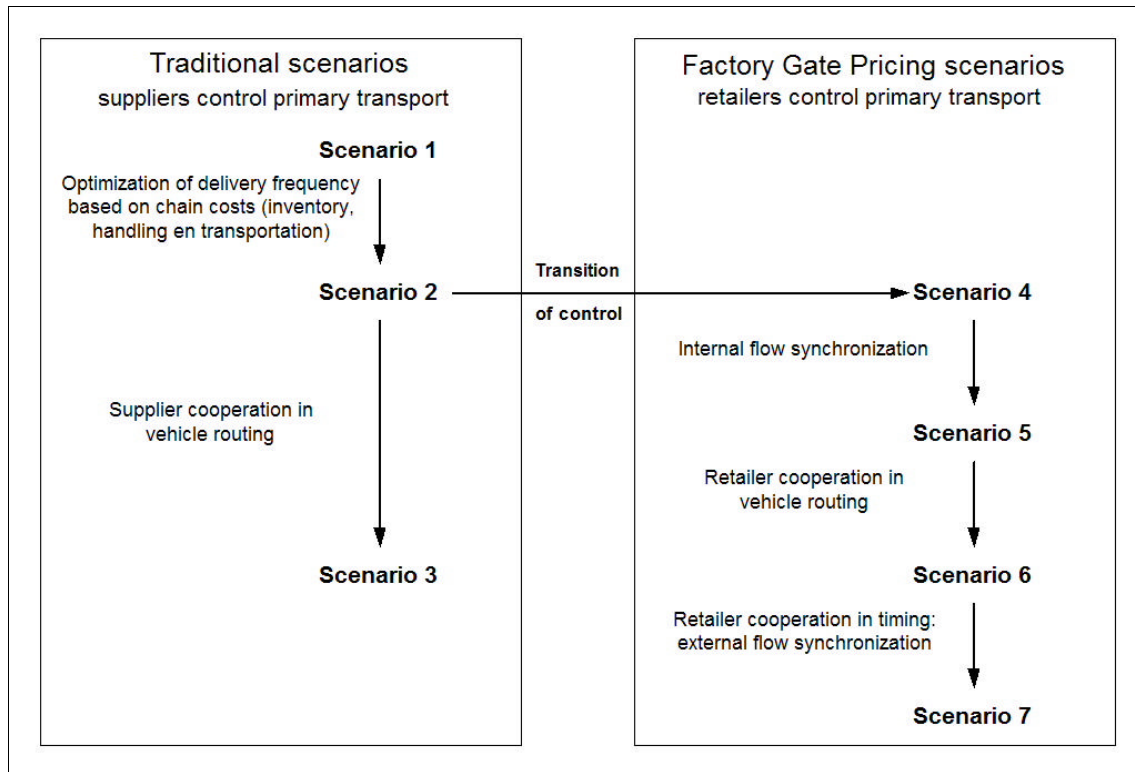
Figure 3   **Overview of the interrelation of the scenarios**

We will now explain what we mean by the terms. First, we make a distinction between *flows* and *orders*. A flow is a sequence of orders of equal size. The number of orders corresponding to a flow is equal to its frequency of delivery and we assume that the time interval between each two of these orders is equal. The chain orchestrators have the planning authority over the transportation flows and are responsible for execution of the corresponding orders. Under FGP, the retailers are the chain orchestrators. By cooperation, we mean that it is allowed to jointly plan the vehicle routes for all transportation orders for a certain day, regardless of the owner of these orders. Synchronization is the process of moving flows within the time horizon to obtain better flow combinations. We distinguish between internal and external flow synchronization. Internal synchronization means that the chain orchestrators can only shift their own flows over time. With external synchronization, the chain orchestrators cooperate in synchronizing their flows. We note that external synchronization can only take place if there is cooperation. Furthermore, flow synchronization can only take place if the coordination of inventory and transportation decisions is in the same hand.

Scenario 1 is the traditional situation, where the suppliers are in control of the transport. Scenario 2 is equal to scenario 1, except that frequencies of delivery are optimized based on supply chain costs. For an analysis of the impact of frequencies of delivery, see Ha et al. (2003). Scenario 3 extends scenario 2 with full cooperation between suppliers. Scenarios 4 and 5 are basic FGP situations. Retailers are the orchestrators and the frequencies of delivery are optimized on the basis of supply chain costs. Scenario 5 differs from scenario 4 because of the internal flow synchronization, which is not present in scenario 4. Finally, scenario 6 and 7 are FGP situations with different degrees of retailer collaboration. In scenario 6, the retailers jointly plan their transportation orders, while in scenario 7 the timing of the replenishment flows (external flow synchronization) is also tuned between the retailers. In section 5, we make a statement about the impact on the total cost of each transition from one scenario to another.

In assessing the value of FGP, we concentrated on the primary distribution. The reason is that our case consists solely of slow moving (grocery) products. Given the trend of central warehousing as described in Mercer (1993) and the inherently small volumes of slow movers, it is unlikely that these products will be transported from the supplier directly to the shops. We assume that we have an infinite number of vehicles at our disposal, which is realistic given the large transportation capacity available in the Netherlands. The remaining restrictions on vehicle trips are the maximum (legally allowed) working time of a driver and the vehicle capacity (expressed in m^2 footprint or number of pallets).

4. Methodology

In this section we describe our methodology for solving the Factory Gate Pricing optimization problem. Considering the huge size of the problem (see Table 1), we followed a two-phase heuristic approach. We will now discuss phase 1 in detail and briefly look at phase 2.

4.1 Phase 1: mode of transportation and frequency optimization

We distinguished four cost factors: transportation, handling, order processing, and inventory costs. The main goal of the first phase of the heuristic is to find the right balance between inventory costs and transportation costs. This balance can be influenced by means of the frequency of delivery of the products. Furthermore, we determined which delivery mode it used.

Throughout our calculations, we worked with a planning period of four weeks (24 working days). Since our dataset covers a representative period of the year, the results of the study can be used to estimate yearly cost. After consulting the SuperUnie experts, we allowed for six frequencies of delivery that often occur in practice during a 24-day period (see Table 2). However, for some products, certain frequencies may not be feasible because of restrictive product characteristics. When this was the case, this was added to the model as an extra restriction.

Frequency	Interpretation
1	Delivery once every four weeks
2	Delivery once every two weeks
4	Weekly delivery
8	Delivery twice a week
12	Delivery three times a week
24	Daily delivery

Table 2 The allowed frequencies

Choosing a high frequency for a given flow generally increases transportation, order processing, and handling costs, but it decreases inventory costs. We made a cost estimate and determined the best choice for every flow for every combination of frequency of delivery and mode of transportation,.

We assumed that every distribution center works with an (R,s,Q)-inventory policy. For the currently used frequencies of delivery, the safety stocks of each product are given in the dataset. However, we adjusted the safety stock in case of changes in the frequency of delivery. Since we considered demand to be constant over time, it was straightforward to calculate inventory cost for a given frequency of delivery. Total order processing costs exhibit a one-to-one relation with the frequency of delivery,

while handling costs only depend on the mode of transportation, i.e., the number of loading/unloading activities for each flow. As a result, estimating these costs was relatively straightforward. Estimating transportation costs of an order, however, is harder since this to a large degree depends on the possible combinations with other orders. We tackled this problem by analyzing a large set of pick-up and delivery routes, calculated by our routing heuristic on selected instances of the periodic pick-up and delivery problem resulting from our case study. The cost of each route was then assigned to the orders according to square meters per kilometer from pick-up to delivery address. This routine led to an estimate of the transportation costs for each order. Finally, we estimated transportation costs by means of a regression model with a number of order characteristics as explanatory variables. These characteristics relate to:

- The number of DCs, suppliers, and consolidation centers (all current consolidation centers were taken into account) within a fixed driving time from the pickup/delivery location of the order.

- The total load to be picked up (delivered) at suppliers (DCs) within a fixed distance from the pick-up/delivery location of the order, on the day concerned.

- The size of the order (in m^2)

- The driving time from the pick-up address to the delivery address of the order

The regression equation constructed exhibited an adjusted R^2 of 0.90. By using the regression coefficients, we were able to make an estimate of the transportation costs of a flow in phase 1 without having to solve a routing problem. The precise transportation costs are calculated later in phase 2 with all frequencies of delivery and modes of transportation set to the values chosen in phase 1.

We now had all the ingredients to make a choice on the frequency of delivery and mode of transportation for each order. Since there are only twelve possible combinations (six frequencies of delivery and two modes of transportation), we estimated the cost for every combination of choices and chose the cheapest feasible possibility. More details about phase 1 can be found in the appendix. We finished phase 1 by constructing an instance of the Periodic Pick-up and Delivery Problem based on the generated transportation orders, corresponding to this cheapest combination.

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4.2 Phase 2: Periodic Pick-up and Delivery Problem

To get reliable distribution cost estimations, we had to solve a very large Periodic Pick-up and Delivery Problem. Like many other routing heuristics, ours consists of a construction part and an improvement part. Since this heuristic uses classical techniques only, a savings-like construction and re-insertions in the improvement part, we will not discuss our PVRP heuristic in detail. However, we do point out that, to our knowledge, our heuristic is the first that is able to deal with very large instances of the Periodic Pick-up and Delivery Problem. Instances that cover all Dutch food retail chains (for slow movers) consist of up to 60,000 transportation orders that have to be planned. These were all solved in thirty minutes to twelve hours of calculation time.

4.3 Verification and validation of the model

In order to verify our model, we tested the internal consistency of the models by test runs and sensitivity analysis. We varied parameters to their extreme values in order to check if the behavior of the models was in line with our expectations and whether the outcomes were correct. In the validation process, we tested the external correctness of the models: Does the model give a good representation of the real world system? Several organizations helped us validate the model, among them the three retailers participating in the project, a consultancy firm specialized in retail distribution, and some academics. Finally, we were able to conjecture that the model with its assumptions was representative.

5. Results

In this section, we discuss six statements derived from the numerical results of our case study. We report yearly cost figures.

Statement I: The optimization of frequencies of delivery creates large costs savings.

In Figure 4, we illustrate a comparison of the supply chain cost under the present frequencies of delivery used by the retailers and the cost under the optimized frequencies. With the optimized frequencies of delivery, the transportation, handling, and order processing costs decrease at the expense of slightly higher inventories and the overall cost reduction amounts to 15.8%. Beside this cost effect, we observed that the use of the consolidation hubs is drastically reduced. The reason is that, owing to lower frequencies of delivery, the average size of the shipments increases. Furthermore, the average load factor of the vehicles increases by 3.0% and the number of empty kilometers per route decreases by 9.5%.
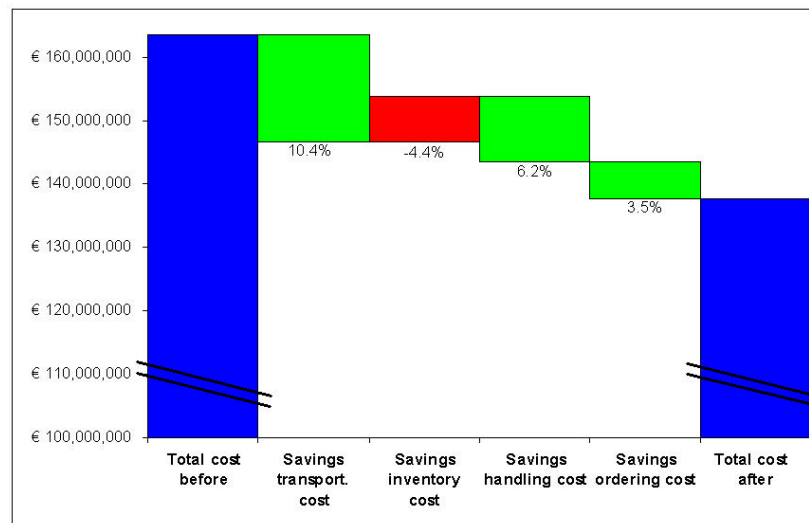

Figure 4   Statement 1: The optimization of frequencies of delivery creates large costs savings

Statement II: Shifting to Factory Gate Pricing decreases the supply chain costs.

Figure 5 illustrates our second statement: in the Dutch retail chain for slowing moving dry grocery goods, FGP is beneficial. By shifting the control of the supply chain from the suppliers to the retailers, supply chain costs go down by 7.5%. This shift of control changes the transportation process from a delivery system to a collection system. Since the supplier sites greatly outnumber the retailer distribution centers, the collection network of the retailers is denser than the delivery network of the suppliers. Therefore, retailers can construct route schemes that are more efficient than the suppliers

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can possibly create. Under FGP, the total number of kilometers driven exhibits a spectacular decrease of 21% from more than 65 million to less than 52 million kilometers. These results are in line with the observations of an FGP study undertaken by Tesco in the UK where a kilometer reduction of 25% for ambient products and 23% for fresh products was reported (Potter et al. 2003).
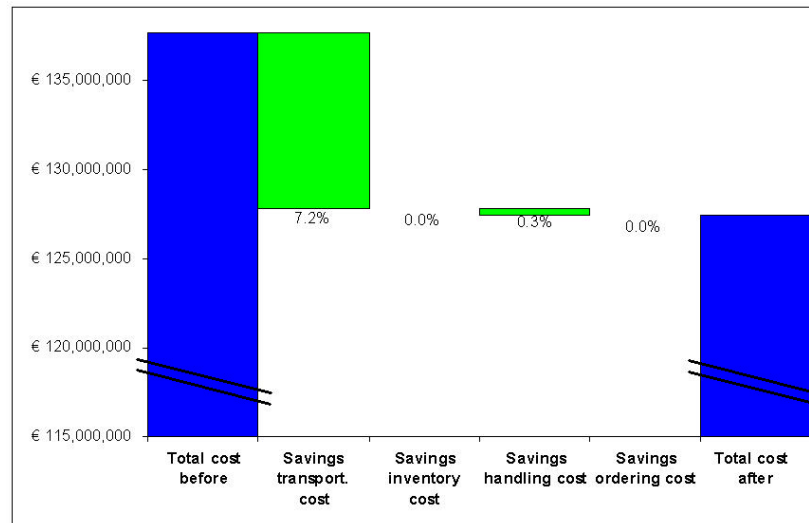
Figure 5   Statement II: Shifting to Factory Gate Pricing decreases supply chain cost

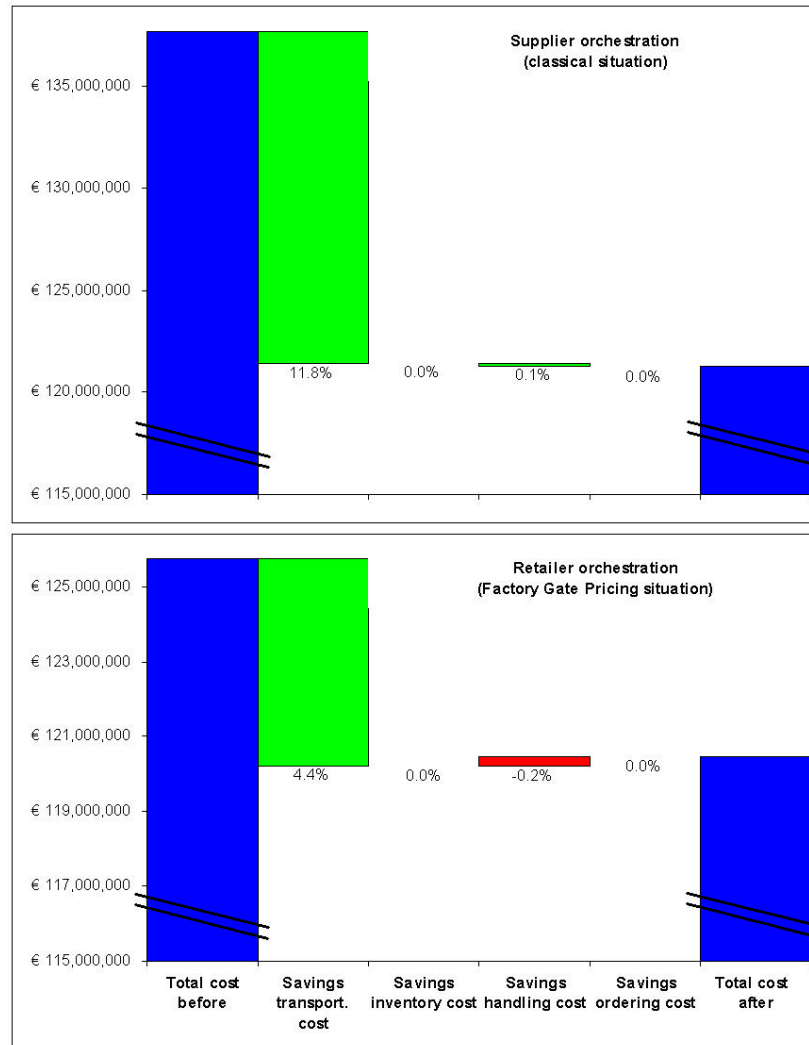*Statement III: Internal flow synchronization creates value.*

Under FGP, we can enhance the planning decisions of an individual retailer by internally synchronizing the transportation flows. By this we mean the shifting of orders belonging to one and the same transportation flow over the planning horizon to attain more suitable combinations between orders. This does not influence the frequency of delivery and the time between two consecutive visits. Although the resulting decrease of 1.3% of total logistic costs is relatively small (see Figure 6), this reduction can be easily attained without organizational changes.
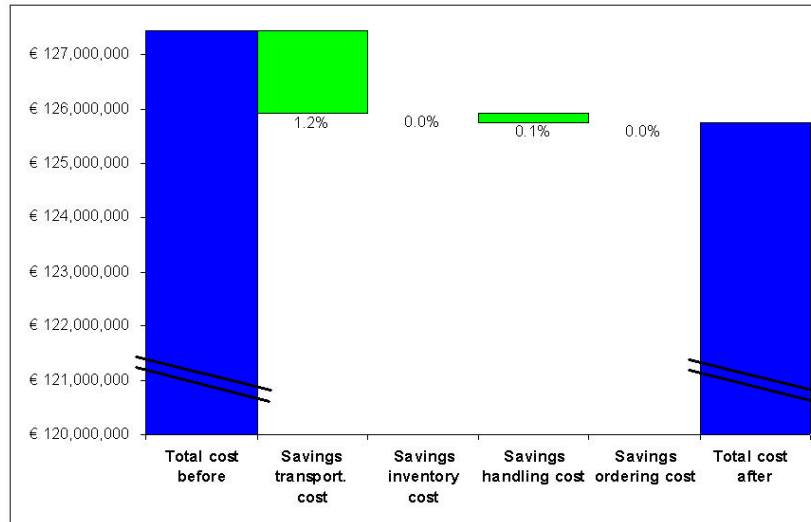
Figure 6   **Statement III: Internal flow synchronization creates value**

*Statement IV: Cooperation is profitable regardless of the orchestration.*

In Figure 7, we show the effect of cooperation. The upper part of the chart illustrates cooperation between suppliers in the classical situation; in the lower part of the chart, retailer cooperation under FGP is illustrated. Although cooperation is profitable regardless of the cooperation, in the classical situation the cost savings from cooperation are much larger than in the FGP situation, 11.9% and 4.2%, respectively. This is explained by the fact that in the FGP situation the retailers already have a dense collection network that enables them to construct quite efficient routes.

Figure 7   Statement IV: Cooperation is profitable regardless of the orchestration

*Statement V: External flow synchronization creates value.*

The results of combining cooperation between retailers with external flow synchronization are shown in Figure 8. Besides combining transportation orders in the same truck, retailers also collaborate in determining the timing of the transportation orders; this results in an additional cost benefit of 1.2%. Taking into account the significant organizational cost that is needed to externally synchronize orders and the small benefit of this, external flow synchronization is probably not attractive for the retailers.
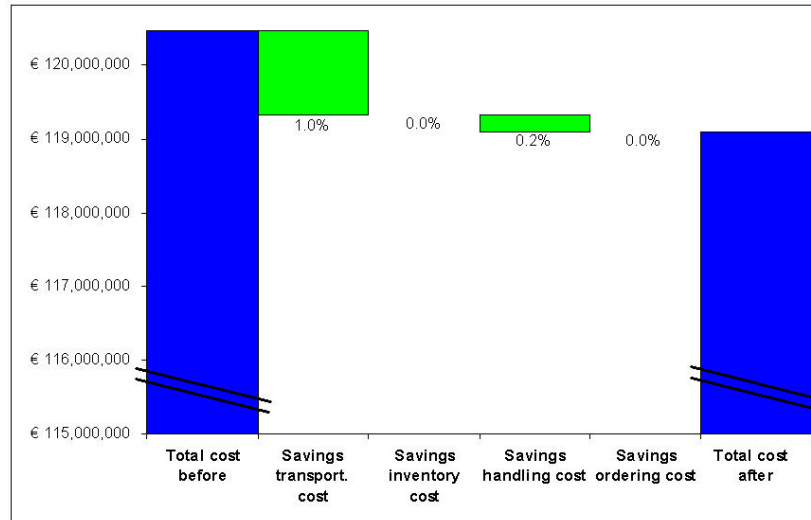
Figure 8   **Statement V: External flow synchronization creates value**

Statement VI: When a small subset of the retailers engage in FGP, adverse cost effects due to the reduced network density for the suppliers are small.

In practice, it is unlikely that all retailers in the sector will change their logistic structure at the same time. Similarly for collaboration, we may expect that only retailers that are already in some way organized will collaborate. We illustrate statement VI by showing the cost effects of a shift to FGP of only the retailers participating in this study. This group, referred to as JuDeCo, operates five distribution centers in the Netherlands. Figure 9 gives a comparison of the total transportation costs in the sector before and after the JuDeCo retailers moved to FGP. We restrict ourselves to transportation costs because this is the only cost group that is affected by the reduction in network density of the suppliers delivering to the other retailers. The reduction in total transportation costs of the system amounts to 2.6% for the total system, which is brought about by a strong transportation cost saving of over 20% for JuDeCo. The transportation costs for the other retailers increases by 1.7%. Taking into account the market share of the JuDeCo group, the net effect on overall transportation costs is a reduction of 1.1%.

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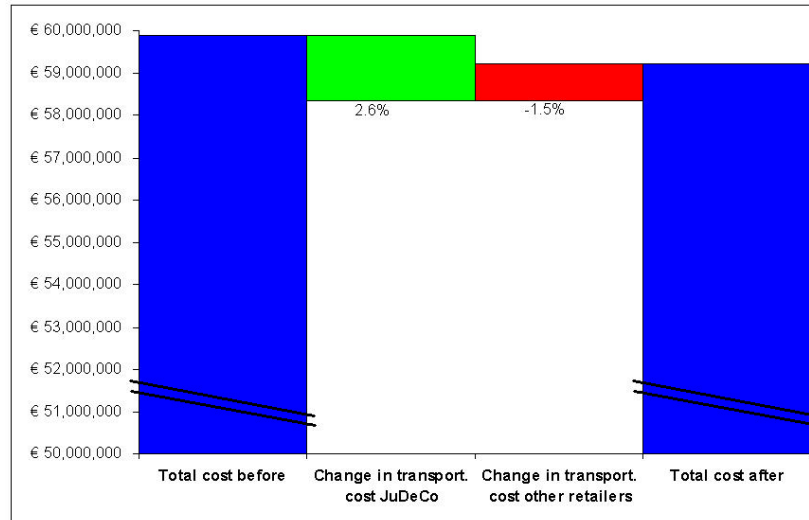
Figure 9   **Statement VI: When a small group of retailers engage in Factory Gate Pricing, cost increases due to the decrease in network density for the suppliers are small**

6. Points requiring special attention and additional remarks

In the preceding sections we have shown that Factory Gate Pricing is a very promising concept for optimizing logistic operations. However, there are some points practitioners and researchers should attend to that we would like to put forward. Additional research is needed to fully map the consequences of FGP. Practical barriers to FGP implementation are discussed in section 6.1. In section 6.2, we give some directions for further research.

6.1 Practical limitations and attention points

Our case study indicates that FGP is attractive for slow-moving dry grocery products. From a logistic point of view, these products are easy to handle. They have a long storage life, low value per unit, small volumes, and temperature-conditioned transportation is not required. For other products or industries, the savings reported in this paper may not be attainable.

Suppliers may be concerned about the implications of the decreased density of their distribution network caused by some of their customers shift to FGP. Obviously, this makes their networks less dense. The results presented in section 5.2, however, show that this effect does not seem to cause dramatic cost increases if only a small number of retailers apply the concept.

Finally, we mention the core assumption behind the FGP concept. It is assumed that retailers can always buy products from their suppliers at a price from which transportation costs are filtered out. This means that suppliers must have both the ability and the willingness to provide insight into their price structure. In particular, it is assumed that suppliers offer some form of service-based pricing. This may not always be possible in practice. Moreover, suppliers might not have the flexibility to allow retailers to pick up products because of limited dock capacity at the supplier site or long-term contracts with carriers or logistic service providers for the transportation of products to the retailers. However, if a retailer is a very important customer for a supplier, he might be able to enforce FGP.

6.2 Directions for further research

In its present form, the model only incorporates primary transport. It seems possible to also incorporate secondary transport in the routing problem. For certain (large) flows, it may even be optimal to bypass the DC and travel directly from the supplier to a retail outlet. This would create a higher degree of freedom and possibly increase the total cost savings of FGP.

In our analysis, we disregarded the backhauling of reusable product carriers from the distribution centers by assuming that sufficient transport capacity for backhauling is always available.

When retailers cooperate to achieve a collaborative planning, they all contribute to the benefits that this cooperation yields. In order to provide good incentives for retailers considering participation, a fair allocation mechanism of the total gain is needed.

Consolidation hubs can be of great use for combining small loads in order to increase load factors and cut down on empty kilometers. Clearly, the locations of the consolidation hubs are of great importance for the overall functioning of the system. It is worthwhile to calculate the optimal locations from real data and compare the present savings to the simulated savings with the consolidation hubs at their optimal locations. Moreover, it would be interesting to calculate the cost advantages in case cooperating retailers open their distribution centers for consolidation activities. Potter et al. (2003) included the location decision in their analysis for 10 consolidation centers, applying a center-of-gravity approach. They reported a maximum total cost decrease of about 5%.

Throughout our calculations, we assumed that a planning period of four weeks gives a representative picture of a whole year. This may not be true for products other than dry grocery goods. This could, for example, be the case for products with strong seasonal demand.

Finally, it would be very interesting to perform our analysis for other countries. Unfortunately, we did not have access to the data required for such an analysis.

7. Conclusions

In this study, we explored the concept of Factory Gate Pricing and the opportunities it offers. A model was developed that is capable of simulating different scenarios for a distribution system in terms of the orchestration, cooperation, and flow synchronization. We then generated computational results for a Dutch retail chain of slow moving dry grocery goods.

The cost savings with respect to the traditional situation are mainly due to three factors. Firstly, we optimized the frequencies of delivery based on supply chain costs. This is possible because FGP brings the coordination of inventory and transportation in the hands of the retailer. Secondly, there is the synchronization of replenishment orders: the retailer can determine the timing of replenishment

orders so that suppliers that are located close to each other can be combined in one route. Finally, the asymmetry in the network is exploited to create more efficiency. In the case we studied, the suppliers outnumber the distribution centers.

In our experiments, we have shown that compared to the traditional situation, FGP results in a 22% decrease in supply chain costs. If there is also cooperation between retailers, savings up to 26% are possible. We noted that these savings are based on a transition of all retailers in the market to FGP. However, experiments with the transition of only a small number of retailers to FGP still show significant savings for the participating retailers.

More research on the subject is needed. Our model was developed to assess the potential of FGP on a strategic level, focusing on the primary distribution part. The extension of combining primary and secondary distribution is appealing since this may increase the savings resulting from FGP even more. Although there is extensive operations research literature on subproblems of the FGP optimization problem, there are no models that tackle the complete problem. Since FGP is being implemented more and more in practice, academic interest in the subject will grow.

FGP may help optimize supply chain operations in industries with many suppliers. Since profit margins are under pressure, logistic efficiency is of vital importance. Innovations such as FGP are needed to achieve cost reductions. However, it is not only the cost benefits for the retailers that argue in favour of FGP; society also benefits. Since the number of kilometers driven is reduced, the burden on the environment as well as road congestion decreases.

Acknowledgement

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Appendix: description of phase 1

In this appendix we explain how we estimated inventory, ordering, handling and transportation costs in phase 1. For each product group (pg) - distribution center (dc) combination we minimize total logistic costs, i.e. the sum of the four cost groups listed above.

(1) $$TC_{pg,dc} = InventoryCosts_{pg,dc}(Freq_{pg,dc}) + OrderingCosts_{pg,dc}(Freq_{pg,dc}) +$$
$$HandlingCosts(Freq_{pg,dc}, Mode_{ag,dc}) + TransportationCosts_{pg,dc}(Freq_{pg,dc}, Mode_{ag,dc})$$

The decision variables for each (pg,dc)-combination in the cost function are: (1) the frequency of delivery and (2) the delivery mode. For these variables it holds:

$$Freq_{pg,dc} \in \{1, 2, 4, 8, 12, 24\}$$
$$Mode_{pg,dc} \in \{0, 1\}$$

Here $Mode_{pg,dc} = 1$ means that products pg travel directly from the supplier to distribution center dc, while $Mode_{pg,dc} = 0$ means that product pg is consolidated at a consolidation center before it goes to distribution center dc.

We now give the formulas for inventory, ordering and handling cost:

(2) $$InventoryCosts_{pg,dc}(Freq_{pg,dc}) =$$
$$\left(\frac{2WeeklyVolume_{pg,dc}}{Freq_{pg,dc}} + CurSafetystock_{pg,dc}\sqrt{\frac{CurFreq_{pg,dc}}{Freq_{pg,dc}}} \right) \cdot ProductValue_{pg,dc}HoldingCosts\%_{dc}$$

(3) $$OrderingCosts_{pg,dc}(Freq_{pg,dc}) = CostPerOrder_{pg,dc} \cdot Freq_{dc,ag}$$

(4) $HandlingCosts_{pg,dc}(Freq_{pg,dc}, Mode_{pg,dc}) =$

$$Freq_{pg,dc}\left\lceil \frac{4 \times WeeklyVolume_{pg,dc}}{Freq_{pg,dc}} \right\rceil \left(handlingcosts_{pg,dc}^{sup,dc} + loadingcosts_{pg,dc}^{sup} + unloadingcosts_{pg,dc}^{dc} \right.$$

$$\left. + (1-Mode_{pg,dc}) \left(unloadingcosts_{pg,dc}^{cc} + handlingcosts_{pg,dc}^{cc} + loadingcosts_{pg,dc}^{cc} \right) \right)$$

For the transportation costs it is not possible to give an exact formula since this is the result of solving a Periodic Pick-up and Delivery Problem (PPDP). We tackled this problem by analyzing a large set of pick-up and delivery routes, calculated by our routing heuristic on selected instances of the PPDP resulting from our case study. The cost of each route is then assigned to the orders according to square meters per kilometer from pick-up to delivery address. Finally, we estimated transportation costs for each order by means of three regression models with a number of order characteristics as explanatory variables.

The three regression models relate to three types of transportation links:

1. From supplier to distribution center

2. From supplier to consolidation center

3. From consolidation center to distribution center

Link 1 is direct mode, links 2 and 3 correspond to the indirect mode. For each type of link we determined a set of characteristics with the corresponding parameter estimations β_s.

$S^{sup,dc}$ = set of characteristics for estimating the transportation cost for sup-dc links

$S^{sup,cc}$ = set of characteristics for estimating the transportation cost for sup-cc links

$S^{cc,dc}$ = set of characteristics for estimating the transportation cost for cc-dc links

These sets contain the following characteristics:

- Driving time in minutes from the pick-up to the delivery location

- Distance in kilometers from the pick-up to the delivery location

- Volume to be shipped

- Volume within 30, 45, 60 minutes of driving time from the pick-up (delivery) location

- Number of DCs within 30, 45, 60 minutes of driving time from the pick-up (delivery) location

- Number of suppliers within 30, 45, 60 minutes of driving time from the pick-up (delivery) location

$X_s(Freq_{pg,dc}, Mode_{pg,dc})$ specifies the values of the explanatory variables in each of the three regression equations. We are now able to estimate the transportation cost for a given (pg,dc)-combination:

if $Mode_{pg,dc} = 1$ (direct mode), then

$$(5a) \quad TransportationCosts_{pg,dc}(Freq_{pg,dc}, Mode_{pg,dc}) = \sum_{s \in S^{sup,dc}} \beta_s \cdot X_s(Freq_{pg,dc}, Mode_{pg,dc})$$

if $Mode_{pg,dc} = 0$ (via a consolidation center), then

$$(5b) \quad TransportationCosts_{pg,dc}(Freq_{pg,dc}, Mode_{pg,dc}) =$$
$$\sum_{s \in S^{sup,cc}} \beta_s \cdot X_s(Freq_{pg,dc}, Mode_{pg,dc}) + \sum_{s \in S^{cc,dc}} \beta_s \cdot X_s(Freq_{pg,dc}, Mode_{pg,dc})$$

The explained variance of this regression model equals 90%. This level of precision suffices for making a reasonable estimate of the transportation costs that can be used for the optimization of the frequencies and delivery mode in phase I. In phase II of our algorithm we solve the Periodic Pickup and Delivery Problem to obtain more precise transportation cost figures for the chosen frequency and delivery mode.

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