EVALUATION OF OUTSOURCING TRANSPORTATION CONTRACT USING SIMULATION AND DESIGN OF EXPERIMENT

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Abstract: This paper aims to develop an approach to identify optimal fleet size under uncertainty and to identify important factors affecting transportation performance. The methodologies used in this paper are two folded. The first methodology is to develop a simulation model that allows manager to evaluate the impact of having different number of trailers on delivery and cost in order to identify the optimal fleet size. The second methodology is to use a Design of experiment (DOE) together with the simulation model to identify important factors that affect transportation performances. The result shows that the company should hire 16 trailers, which will reduce the delivery delay from 14% to 0.02%. Furthermore, it is found that variation in demand has a strong impact on late delivery and cost. There is also an interaction between demand variation and transportation time variation.

Key words: design of experiment; optimal fleet size; outsourcing; simulation modelling; transportation contract; transportation management; variation

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Introduction

To be competitive in today market, a company needs not only to offer the right products, but also to deliver them to the customer fast while keeping the costs low. Transportation and logistics related costs range from 9% to 14% of sales. If properly managed, the costs can drop to 4% to 7% (Robinson, 2014). Since outsourcing can help company ensure its competitive advantage by improving economic activity and maintaining core competencies, outsourcing of information technology and business process becomes dominant (Bilan et al., 2017). As a result, for a company that does not have resource and expertise, outsourcing transportation activity becomes a popular option to reduce cost and improve delivery performance. Generally, there are two ways to deal with transportation providers either by forming transportation contract or buying at spot rate. From cost standpoint, transportation contract generally offers a better rate, but the company has to commit to the minimum requirement such as fleet size and number of trips. It may eventually pay more with the contract if minimum requirement is not met. Due to the fluctuation of the demand from customers and uncertainty of transportation time, the delivery requirement may be differed. As a result, it is

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difficult for a company to determine appropriate fleet size to form a contract with the transportation provider and negotiate for the right level of minimum requirement that will yield the most benefit to the company.

This research aims to develop a simulation model to support a company in making decision regarding transportation contract. By experimenting with the simulation model, one can see the impact of having different number of trailers on on-time delivery and cost performance under uncertain situations including demand and lead time uncertainties. This will allow the company to better manage and negotiate the contract condition with the transportation provider. Furthermore, Design of Experiment (DOE) will be performed in order to investigate the factors that has strong impacts on performance. This will enable the company to gain better insight and understanding of the contracting situation in order to effectively and efficiently manage the contract.

Literature Review

Logistics and supply chain systems have been recognized as the systems that are characterized by uncertainty in nature, complexity in the systems, and high inter-relationships between various components. Simulation modelling is an appropriate modelling approach to investigate and understand this kind of systems due to its capability to include stochastic situation (Heidary et al., 2018; Lee et al., 2002; Longo and Mirabelli, 2008; Manuj et al., 2008; Rebs et al., 2019). Furthermore, discrete-event simulation also offers ability to understand system behaviour when parameters and policies are changed. This makes simulation a useful tool for a manager to perform trade-off analysis especially between cost and customer service. Transportation management is one of the area that simulation modelling can be used to determine fleet size or evaluate policies so that delivery performance and transportation cost can be balanced. Jagatheesan and Kilcullen (2011) incorporated cycle time variability and skewness in determining fleet size using simulation. They found that variability affects fleet size requirements and needed to be considered for more accurate projection of fleet size requirements. Sha and Srinivasan (2016) used simulation to evaluate the impact of different fleet sizes and routing policies on supply chain performance. Other researchers also use simulation model to identify fleet size under uncertainty or to evaluate different management policies on performance (Dong and Song, 1999; Herrel, 2014; Kavakeb et al., 2016; Lesyna, 1999; Park and Kim, 2015; Shen et al., 2017).

Furthermore, simulation modelling as a decision making tool can be enhanced if Design of Experiment (DOE) and Analysis of Variance (ANOVA) are respectively used for experiments planning and simulation results analysis (Longo and Mirabelli, 2008). It can offer a high precision in manipulation of variables, and therefore, can address the precision goal, but not the generalizability (Bienstock, 1994). Bienstock and Mentzer (1999) used simulation model to perform experimentation and concluded that when making transportation decisions, volume of shipments, degree of operational uncertainty, and availability and cost of requisite assets should be considered. Without simulation, it would be difficult or too costly to use experimental design to gain insight into the situation of interest. Dang (2018) found that one of the main causes for ineffective decision is the lack of optimal decision making model and the lack of methods to evaluate the effectiveness of the decision before putting into practice. This emphasizes the importance of using simulation and DOE to enable a manager to make better decision in outsourcing transportation.

Methodology

A simulation software package, ARENA version 14 (Rockwell Automation, Milwaukee, WI, USA), is used to develop a discrete-event simulation model to replicate an outbound distribution system of the case study company. The model will be used to identify the appropriate number of fleet size such that the company can deliver its product on-time and within reasonable costs. The results from the simulation can also help the company to negotiate with the transportation provider which will result in a more appropriate contract. Furthermore, a 2^k factorial design will be performed in order to identify factors that impact delivery performance and cost. This can help the company gain better insight into the situation and be able to make a decision that meet its objectives.

The case study company in this paper is an automobile manufacturer and distributor in Thailand. The company has to distribute cars to its dealers which are located in different regions. The focus will be on the distribution in the east and the central regions which can be grouped into three zones. The current policy is to deliver the cars within two days after receiving orders. Each day, orders from dealers will be sorted into appropriate zones and loaded onto car carrier trailers. Each car carrier trailer has a capacity to carry seven cars. Once, the trailer is fully loaded, it will depart to the destination. Only orders from the same zone can be loaded onto the same trailer. After arriving and unloading the cars at the dealers, the trailer will travel back to the company for further loading. Currently, the case study company has a contract for 10 car carrier trailers to be used at all times. However, if the company needs more trailers, it can call for additional trailers at spot rate which is usually higher than the contract rate. With the current contract, there are approximately 14% of the orders that are unable to deliver within two days. Therefore, the case study company would like to identify an appropriate number of trailers needed so that the orders can be delivered within the timeframe. The insight learned from simulation can help company to better negotiate for more appropriate contract with a transportation provider.

The next step is to collect the data. Daily demands from dealers were collected for one years (240 data points). The daily demand is normally distributed with a mean of 176 units and a standard deviation of 54. It was found that 33% are orders from zone 1; 14% from zone 2; and 53% from zone 3. The transportation times (include loading/unloading) also follow normal distribution with a mean of 0.42 days and a standard deviation of 0.05 for zone 1; 0.26 and 0.03 for zone 2, and 0.21 and 0.025.

The company current policy is to fully load the trailers before leaving. If the number of cars on a trailer is less than seven, the trailer will have to wait. In addition, the company will call for additional trailer (at spot rate) when there are cars waiting to be delivered but no contracted trailer available. Regarding cost, the company will be charged based on the number of trips incurred. The cost per trip, regardless of the zone, if using contracted trailer is 3,000 Bath (80 Euro) per trip. The spot rate for additional trailer will be 3,500 Baht (93 Euro) per trip. Note that there is a minimum charge for contracted trailers per month. The transportation provider expects that each contracted trailer should make at least 40 trips per months. This means that if the total number of trips by contracted trailers is less than 400 trips per months (10 trailers x 40 trips), the company will be charged for 400 trips. One can see that this makes the situation more complicated. If the case study company increases the number of trailers in the contract, late delivery and the use of spot rate trailer can be reduced, resulting in lower costs. However, more contracted trailers also mean higher minimum charge. If the company cannot meet the minimum number of trips per month due to lower number of orders, costs may increase.

After collection data, a simulation model is created to represent the outbound distribution system of the case study company. The model can be divided into three sections as shown in Figure 1. The first section represents incoming orders which will be generated once a day. The orders will be grouped into one of the three zones based on the probability mentioned earlier. After that, the order will be waiting in the queue for a trailer to pick up and deliver. The second section is the trailers. Contracted trailers will be generated according to the number agreed (10 currently). The trailer will load the orders (cars) when there are seven cars waiting in the queue, according to the full truck load (FTL) policy. If there are less than seven cars in the queue, the trailer will have to wait at the trailer yard. On the other hand, if there are seven cars waiting in the queue and no contracted trailer available, an additional spot trailer will be hired to deliver those cars. The last section is the delivery section including zone 1-3. This section starts by the trailer loading the cars and travelling to the destination. The trailer will unload the cars and travel back to the trailer yard, and be available again. For the cars, once arriving at the destination, the total time will be recorded to determine whether the delivery is on-time. Each zone functions are the same; only travel time is different. The simulation model will be run for 200 replications with each replication length of 30 days (1 month). Several verification techniques suggested by Law and Kelton (1991) were used to verify the model including structured walkthrough, running the model under simplified assumption, and tracing animation. For the model validation, the author compared the results of the model against real world performances especially late delivery. It was found that the model result is consistent with the real word performance (about 14% of the orders are late). In addition, face validation was also performed to ensure that the model logics and assumptions were correct.

The key performance measures in this case are the percentage of late delivery (% Late Delivery) and average cost per unit delivered (Cost Per Unit). The % Late Delivery is calculated from the number of orders delivered longer than two days divided by the total orders delivered. Currently, approximately 14% of orders are late, resulting in customer dissatisfaction. For the Cost Per Unit, it is calculated from total trip costs divided by total number of orders (cars) delivered. The total trip costs consist of 1) cost of using contracted trailers, which is 3,000 Bath (80 Euro) per trip and 2) cost of using spot trailer which is 3,500 Baht (93 Euro) per trip. However, for contracted trailers, there will be a minimum charge based on the number of trailers in contract. For the current contract, the minimum charge is 40 trips per trailer per month which is equal to 1,200,000 Baht (32,000 Euro) per month (400 trips). For each simulation run, the model will automatically calculate % Late Delivery and Cost Per Unit by collecting the statistics needed such as total number of contracted trailer trips, total number of spot trailer trips, total number of orders delivered, etc.

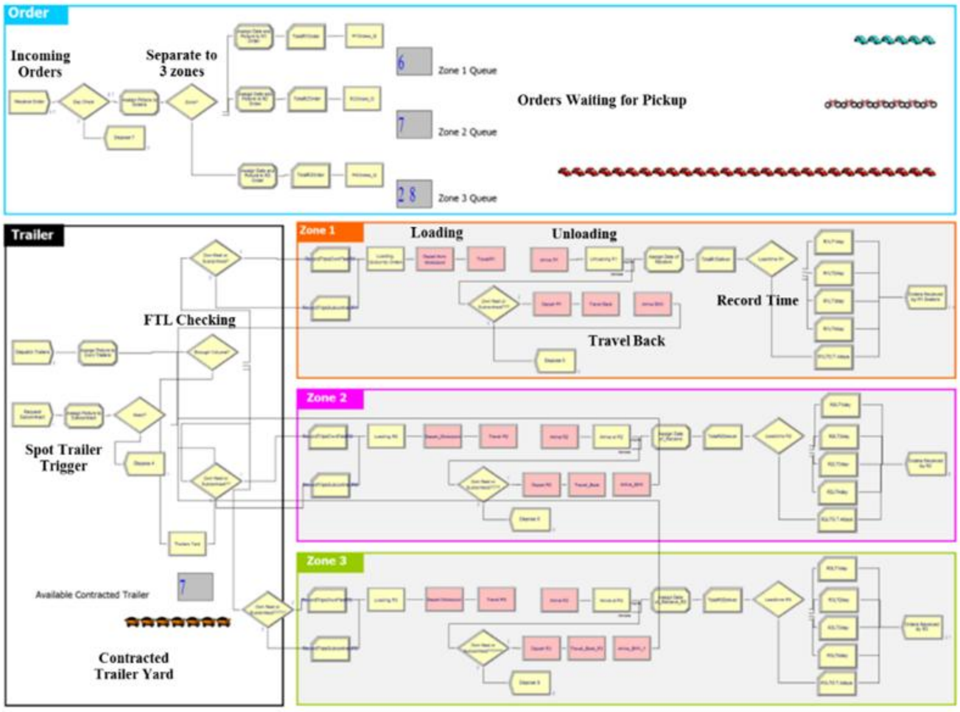

Figure 1. The simulation model for outbound distribution system

Results and Discussions

The result section is divided into two subsections. The first subsection discusses the evaluation of the transportation contract by identifying the appropriate number of contracted trailers. The second subsection focuses on using design of experiment to gain more insight into the factors that have the greatest impact on % Late Delivery and Cost Per Unit. This can help the company gain better understanding of its distribution system and contract situation which will contribute to better decisions in the future.

Identification of Appropriate Fleet Size

The company currently has a contract with a transportation provider to provide 10 dedicated car carrier trailers. It was found that, approximately 14% of the orders took longer than two days to reach the destination. Therefore, the company would like to find the optimal fleet size that would reduce late delivery to less than 1% while maintaining a reasonable cost. To identify the appropriate fleet size, the author experiments with the model by varying the number of contracted trailers from 10 to 20 trailers. It is found that % Late Delivery decreases significantly when the number of trailers increases. However, when the number of trailers is 15 or more, the % Late Delivery is not statistically significant different at 0.05 level. For Cost Per Unit, one can see that it decreases when the number of trailers increases from 10 to 15. The reason is that when there are not enough contracted trailers, the company has to use spot rate trailers, resulting in higher cost per trip. Nevertheless, Cost Per Unit starts to increase when the number of trailers is more than 15, although, the company may use less spot rate trailers, but will have to pay more for the minimum charge. Figure 2 shows the % Late Delivery and Cost Per Unit under different number of contracted trailers.

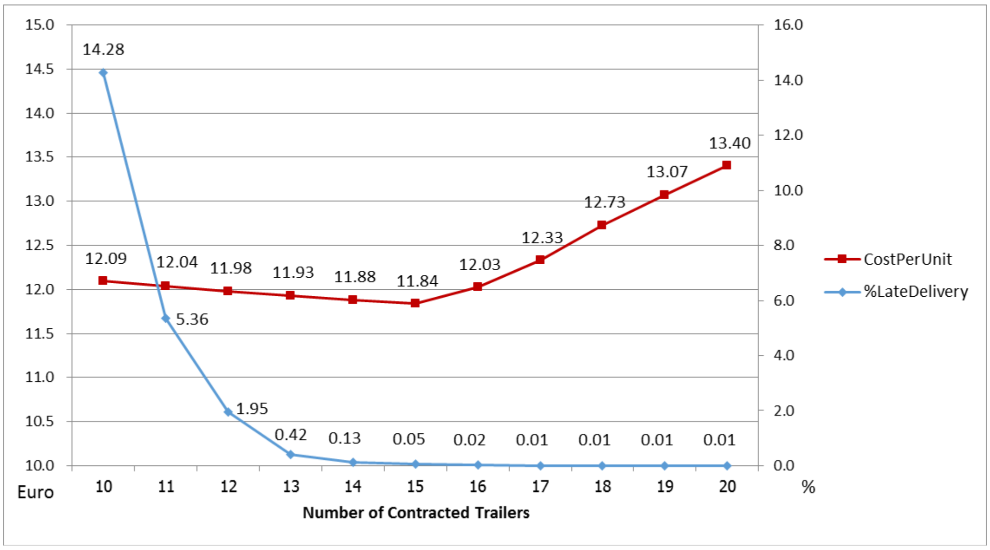

Figure 2. % Late Delivery and Cost Per Unit under different number of contracted trailers

Based on these results, it can be concluded that having a contract for 15 trailers results in an acceptable level of % Late Delivery with the lowest cost. However, the % Late Delivery shown in Figure 2 is, in fact, an average value. This means that it is possible that out of 200 replications, % Late Delivery in some replications may be higher than one percent. Therefore, it is important to examine the probability that % Late Delivery will be higher than one percent. This emphasizes another advantage of simulation that allows one to evaluate the risk or the probability that the result will meet/not meet the target (Balakrishna et al., 2006). To evaluate the probability of % Late Delivery less than one, a simulation model is run for 200 replications and data are collected for each replication. The result shows that the probability of having % Late Delivery less than one is 97% for 15 trailers, and 100% for 16 trailers or higher. Since the company is more concerned with on-time delivery performance, it should make a contract for 16 trailers. Although the cost per unit is a bit higher than 15 trailers but it is still lower than the current situation of 10 trailers while the late delivery reduces significantly from 14% to 0.02%.

Identification of Important Factors Using Design of Experiment

Based on the literature reviews and the findings in earlier sections, four factors are believed to affect the performance of the company in terms of on-time delivery and costs. These factors are variability in demand (DemandVar), variability in transportation time (LTVar), skewness in transportation time (LTSkew), and loading policy (FTL). A 2^4 factorial design with 10 replications for each design point [a modest sample size from a statistical viewpoint (Law and Kelton, 1991)] is performed with a total of 160 runs. Table 1 shows the factors and their levels.

Table 1. Factors and levels in factorial design

Factors	Levels		Parameters	Descriptions
Variability in Demand (DemandVar)	2	Low	0.1	Variability in demand represented by coefficient of variation
		High	0.4	
Variability in Transportation Time (LTVar)	2	Low	0.1	Variability in transportation time represented by coefficient of variation
		High	0.4	
Skewness in Transportation Time (LTSkew)	2	Low	No (Normal)	Skewness represented by distribution of the transportation time data
		High	Yes (Lognormal)	
Loading Policy (FTL)	2	Low	7 (Full Truck Load)	Loading policy whether to use FTL (7 cars) only or allow for flexibility (3 or more cars)
		High	3 (Flexible)	

The author, first, performs a 2^4 factorial design where % Late Delivery is a response (dependent) variable to explore the impacts of the four factors on on-time performance. It was found that the main effects of only two factors, which are demand variability and transportation time variability, are statistically significant at

0.05 level. As expected, the increase in demand variability and transportation time variability result in higher % Late Delivery. This finding agrees with Herrel (2014), Jagatheesan and Kilcullen (2011), and Kavakeb et al., (2016) that variability and uncertainty impact fleet size and delivery performance. Figure 3 on the left shows the main effect plot for % Late Delivery.

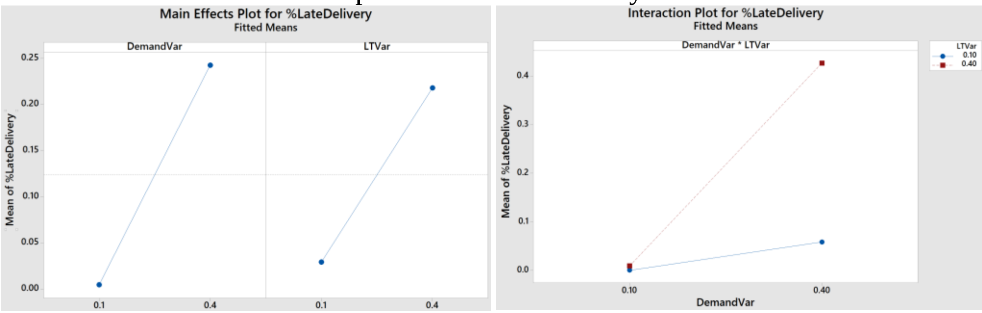

Figure 3. Important factors affecting delivery performance (% Late Delivery)

In addition, the interaction effect between variability in demand and variability in transportation time is also significant. To understand the behavior of the interaction, an interaction effect plot is created as shown in Figure 3 on the right. The magnitude of the impact of transportation time variation on % Late Delivery depends on the demand variation level. When demand variation is low, increasing transportation time variation rarely increases % Late Delivery. However, when demand variation is high, % Late Delivery increases significantly when transportation time variation is also high. This indicates that the company should focus more on minimizing demand variation in order to improve its on-time delivery performance.

To evaluate the impact on Cost Pe rUnit, the author conducts another 2^4 factorial design where Cost Per Unit is a response variable. It is found that the main effects of two factors which are Loading Policy (FTL) and demand variation (DemandVar) are statistically significant ($p<0.001$). Figure 4 shows the main effect plot and the Pareto chart. Loading policy has the strongest impact on Cost Per Unit. Transportation cost per unit increases when the company uses flexible policy which allows trailers to travel less than truck load. The reason is that more trips are needed to transport the same amount of car. In addition, more trips also means that the company has to use more spot rate trailers which cost higher per trip. This finding is in line with the best practice in transportation management that FTL will reduce cost per unit (also reported by Bienstock and Mentzer (1999) that volume of shipments impacted costs).Another important factor is demand variation. When demand variation is high, the cost per unit delivered is also high since it is likely that the demand for transportation is higher than the capacity. Therefore, there is a higher chance that spot rate trailers will be called for, contributing to higher transportation costs. This agrees with Bienstock and Mentzer (1999) who found that uncertainty increased transaction costs.

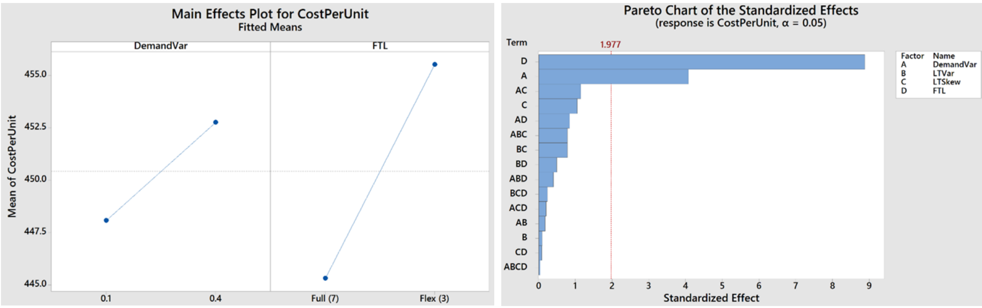

Figure 4. Important factors affecting cost performance (Cost Per Unit)

Based on the results from the two factorial designs, one can conclude that variation in demand is very important since it impacts both % Late Deliveryand Cost Per Unit. In general, the higher the demand variation, the higher the % Late Delivery and Cost Per Unit. Another factor that impacts % Late Delivery is transportation time variation. The company should try to reduce the variation in order to reduce % Late Delivery. One interesting finding is that the % Late Delivery increases significantly when both variations in demand and in transportation time are high. So the company should try to reduce the variations at least in one of the factors, especially demand variation. For the loading policy, it impacts Cost Per Unit but not % Late Delivery. The company should continue using FTL policy in order to reduce transportation cost. Having flexible policy that allows for less than truck load does not help in reducing % Late Delivery, but increases cost significantly. One can see that with DOE, the company can gain more understanding and insight of the impacts of different factors and their interactions on its performance and be able to make better decisions

Conclusion

This research aims to help a company make decision regarding transportation contract in order to meet on-time delivery objective while reducing costs. By using simulation modelling, it is found that the case study company should hire 16 car carrier trailers. With this fleet size, the percentage of late delivery will be only 0.02%, comparing to the current late delivery of 14%.In addition, to further understand the situation, experimentation using a 2^4 factorial design is performed. It is found that demand variation strongly impacts both % late delivery and cost per unit. The company should try to reduce demand variation by establishing new ordering policy or consider using vendor managed inventory (VMI) so that it can better plan when to deliver cars to the dealers. Another way to help the company reduce late delivery is to control transportation time variation by selecting the route that rarely have traffic jam problem resulting in a stable travel time and/or provide proper training and equipment for employees to load and unload the cars. It is interesting to note that the impact of transportation time variation on late delivery percentage will be significantly stronger when demand variation is high. This should make the company realizes that it is important to reduce variation at least in one of those factors. Another interesting finding is the impact of loading policy. One may think that it will be better to use flexible policy which allow for less than truck load when needed. In fact, it was found that using flexible policy does not improve on-time delivery performance but significantly increases the cost per unit. Thus, the company should keep its FTL policy which will contribute to cost saving. Without simulation, it will be rather difficult for the company to fully understand the situation and be able to make decisions that best suit its objective. Simulation allows one to examine different alternatives/policies without interfering or interrupting the operations. In addition, using simulation together with DOE allows one to gain better insight into the situation and see the impacts of different factors and their interactions on delivery performance and cost. This emphasizes the important of using simulation and experimentation to help a company to clearly understand the situation and be able to make better decisions**.**

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OCENA KONTRAKTÓW OUTSOURCINGOWYCH W TRANSPORCIE Z WYKORZYSTANIEM SYMULACJI I PROJEKTU EKSPERYMENTU

Streszczenie: Niniejszy dokument ma na celu opracowanie podejścia do określania optymalnej wielkości floty w warunkach niepewności oraz określenie ważnych czynników wpływających na wydajność transportu. Metodologie stosowane w tym artykule są złożone. Pierwszą metodologią jest opracowanie modelu symulacyjnego, który umożliwi menedżerowi ocenę wpływu posiadania różnych przyczep i kosztów w celu określenia optymalnego rozmiaru floty. Drugą metodologią jest wykorzystanie projektu eksperymentu (DOE) wraz z modelem symulacyjnym w celu zidentyfikowania ważnych czynników wpływających na wydajność transportu. Wynik pokazuje, że firma powinna wynająć 16 przyczep, co zmniejszy opóźnienie dostawy z 14% do 0.02%. Ponadto stwierdzono, że zróżnicowanie popytu ma duży wpływ na opóźnienia w dostawie i koszty. Istnieje również interakcja między zmiennością popytu a zmiennością czasu transportu.
Słowa kluczowe: projekt eksperymentu; optymalny rozmiar floty; outsourcing; modelowanie symulacyjne; umowa transportowa; zarządzanie transportem; zmiana.

用模拟和实验设计评估外包运输合同

摘要:本文旨在开发一种在不确定性下识别最佳车队规模的方法，并确定影响运输性能的重要因素。本文中使用的方法是两个折叠。第一种方法是开发一种模拟模型，使管理者能够评估不同数量的拖车对交付和成本的影响，以确定最佳的车队规模。第二种方法是使用实验设计(DOE)和模拟模型来识别影响运输性能的重要因素。结果表明，公司应该雇用16辆拖车，这将把交货延迟从14%减少到0.02%。此外，发现需求的变化对延迟交付和成本具有强烈影响。需求变化和运输时间变化之间也存在相互作用。
关键词:实验设计;最佳车队规模;外包;仿真建模;运输合同;运输管理;变异。