

Redesigning one-warehouse n-retailer routing model in inter-store stock transfer operations of an international retail chain distribution

Abstract

Purpose - The effectiveness of product replenishment and responsiveness of customer service delivery impacts greatly on satisfaction and retention of customers in retail chain logistics distribution. The fast moving of goods in the complex delivery network and limited vehicle resource often lead to long customer waiting time in stock replenishment. With a lack of literature to systematically review factors affecting retail distribution in inter-store stock transfer services and improve operations, this paper aims to analyse and enhance such services to reduce customer dissatisfaction by developing an integrated quality service improvement methodology and an optimisation tool for product delivery.

Methodology - This paper reviews inter-store stock transfer operations and the process capability of an international retail chain, and proposes improvements by integrating six sigma, factor analysis, and optimisation modeling. User experience and expectations are evaluated through an empirical survey. A novel principle component factored inter-store stock transfer model is developed to improve replenishment operations. Eleven factors affecting inter-store stock transfer delivery time are analysed. An extended model with principal component factors incorporated is developed for the simulation.

Findings - The C_{pk} value shows 0.51 with significant difference between the experienced and expected waiting time. With the inter-store stock transfer optimisation model developed, the model assists traffic personnel on the vehicle route planning with multiple pick-up and drop-off locations. The system also ensures the best routing with a minimal travelling time planned, facilitating a reduction of the inter-store stock transfer time, thus shortening the customer waiting time. Four significant factors affecting delivery time are also identified from exploratory and confirmatory factor analysis. The results are analysed with an extended principal component factored inter-store stock transfer model.

Implications - The inter-store stock transfer models developed minimize stock transfer time, increase customer satisfaction, and reduce loss of sales. An integrated service quality improvement methodology is introduced and applied in reviewing significant factors affecting inter-store stock transfer operations.

Originality - This paper presents an analysis on inter-store stock transfer operations of an international retail and proposes enhancements on its operations by integrating six sigma, factor analysis, and optimisation modeling. A novel principal component factored inter-store stock transfer model is developed to improve the stock replenishment operations.

Keywords Retail logistics, Inter-store stock transfer, Vehicle routing, Factor analysis

1 Introduction

Complex distribution networks, coupled with the growth of short lead time manufacturing and responsive supply chain have stimulated investigations on ways to improve retail distribution management. The availability of products and the order fulfillment for a retail store affect the in-store shopping experience of customers (Deb and Lomo-David, 2014). It is important to capture the time-strapped customers' dwell time in a retail store under a limited sales floor area displaying a variety of products. BagariaAmit (2014) compared the fashion retailing models among Uniqlo, Zara, and H&M. He highlighted the success of Zara on its high responsive supply chain that supports the delivery of new fashions. Petro (2012) evaluated the business models of H&M and revealed the success of H&M on pursuing vertical integration with its own distribution network. He stressed the importance of an efficient distribution system with short lead time manufacturing. Fernie et al. (2010) reviewed the

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retail global supply chain, particularly on the grocery and fashion sectors, for example, Marks and Spencers, Tesco, Zara and H&M. The research studied the logistical transformation of retail and reflected the importance of retail distribution management and delivery networks. Burt et al. (2002) examined the retail internationalization strategy of Marks and Spencer. A study on the exit and failure of particular segments of retail business was carried out. It reflected the importance of retail management and business control on a decentralized model. Various studies on stock replenishment operations in retail stores have also been published. Hübner et al. (2013) proposed a decentralized approach in coordinating and planning of interrelated activities among the operations of the grocery retail stores while Aastrup and Kotzab (2009) analyzed the centrally controlled retail chain stores on handling an out-of-stock situation. The capabilities in logistics and supply chain management in retail operations helped to build the foundation for a company's sustainable competitive advantage (Sandberg, 2013; Wiese et al., 2012).

The demand for better retail management has attracted research in modeling to optimise stock replenishment and distribution and prevent out-of-stock situations (Craig et al., 2015; Christopher et al., 2004; Schwarz et al., 2006; Rushton et al., 2014; Fernie and McKinnon, 1991; Triqui-Sari et al., 2016). Running out-of-stock in retail stores impacts customer service and sales results (Whitin, 1955; Joseph, 1999). Customer service performance affects customer satisfaction and loyalty (Lin and Bennett, 2014; Chen, 2008; Qureshi et al., 2008). Various models on replenishment from the warehouse to retail stores were developed to improve customer service. Agrawal and Smith (2013) focused on inventory management in retail stores by formulating a dynamic stochastic optimisation model. The model assisted in determining the total order size and optimal inventory allocation to non-identical stores in each time period. Various distribution models for the one-warehouse n-retailer system have also been discussed by several researchers. Rahim et al. (2016) developed a two-phase optimisation approach for coordinating the shipments in a one-warehouse n-retailer system to minimise the overall inventory cost and transportation cost incurred in the system. In the first phase, the replenishment cycles of the retailers are optimised with the objective of minimising the inventory cost of the system. Then, in the second phase, the retailers are clustered into several subsets and a vehicle routing problem is generated for each of the subset in order to minimise the transportation cost. Huang et al. (2015) simulated a one-warehouse n-retailer distribution system and evaluated different routing strategies. An optimisation decision support model had been developed for the warehouse distribution in replacing the traditional routing planning which is heavily relied on the experience of the route planer. The results showed that a great amount of cost saving can be achieved by the optimisation-based methods. Zhai et al. (2011) modeled one-warehouse n-retailer distribution system with a dynamic allocation and static routing policies. The paper explored the scenarios of retailers competing in the internal stocks and further proposed an internal transfer-payment between two retailers. Cha et al. (2008) investigated the one-warehouse n-retailer system by introducing a mathematical model and two efficient algorithms. The research proposed a new policy on the joint replenishment and delivery schedule of a warehouse. A hybrid Genetic Algorithm (GA) is further developed and its simulation results are compared with the two algorithms developed. Solis and Schmidt (2007) extended a deterministic lead times multi-echelon inventory model from Graves (1996) by introducing stochastic lead times between warehouse and retail stores. Anily and Federgruen (1990) developed a replenishment and distribution model aimed to minimize transportation and inventory costs. It simulated the business of one warehouse and multiple retailer systems considering the vehicle routing costs. Other literature on retail distribution and management with emphasis on demand accuracy can be found in Filho et al. (2016), Chen and Mersereau (2015), Shen and Honda (2009), DeHoratius et al. (2008), Fisher and Rajaram (2000), Herer and Roundy (1997), and Agrawal and Smith (1996).

The rental price increase in the retail sector in recent years has inevitably led to a maximisation in the usage of sales floor area. Hong Kong is still the second most expensive shopping location in the world, despite a drop in rental prices in the past 12 months (CNBC, 2016). The rental prices for shops were still increasing in the first quarter of 2014, with Hong Kong, New York, and Paris as the worlds most expensive cities for retailers (Reuters, 2014). Retailers in Hong Kong seek to fully-utilize the space available to display a great variety of products, thus, this results in having the practice of keeping a minimum level of stock on the sales floor (Dubelaar et al., 2001; Corsten and Gruen, 2003; Rajagopalan, 2013). Cardos and García-Sabater (2006) stressed the importance of striking a balance between the design of inventory management policies for each shop, and the design of delivery policies from the central warehouse. The critical factors of customer responsiveness, the space available and being allocated in the retail shop, the planning of inventory level, and delivery management should all be considered. For the companies with multiple warehouses, if certain kinds of products have a low demand in local warehouses, the company may set up a support warehouse which has a low inventory cost to carry out expedited deliveries to respond to the stock-outs of the local warehouses. Van der Heide et al. (2017) investigated the stock levels for rental systems with a support warehouse and partial backordering. To determine the optimal stock policy, the research proposed an enumerate method for systems with up to six local warehouses, and developed a greedy algorithm for larger systems. Ton and Raman (2010) examined the effect of product variety and inventory levels on store sales, by using data generated from a period of four years from stores of a large retailer. It showed that a higher sales level is associated to an increase in product variety and inventory levels. Their study concluded that a higher product variety and high inventory levels would lead to an increase in defect rate. Thus, retailers encounter the increasing need of an efficient stock replenishment model to cope with the high cost related to the sales floor area, and the high expectations from customers on product variety.

Keeping a minimum stock level requires retailers to closely monitor the sales floor stock level and ensure timely stock replenishment. The replenishment model of an international retail chain has been examined, and the opportunities of inter-store stock transfer to improve customer responsiveness in stock transfer and replenishment operation has been explored. This paper evaluates the current operation process of the retail distribution system in an international retailer selling clothings, household accessories, and food products. The process capability of the inter-store stock transfer process has been reviewed. The T-test has been applied to validate the significance of the gap between the expected waiting time and actual waiting time for stock transfer. With the objective to minimize the time between the inter-store stock transfer order and the arrival of the requested product at the retail store, opportunities for improvement on the vehicle routing process in inter-stock transfer have been identified. An inter-stock transfer optimization model has been developed to schedule and plan for the optimal routing on stock order picking and delivery at the stores, taking into the travelling time and distance into consideration. The model has been developed into the routing and scheduling system to assist the decision making process of a traffic planning personnel in complex daily planning operations. The correlation of other potential dominating factors has been further evaluated with the use of factor analysis, and the principle component factors have been identified. The selected factors have great significance on the future development of the model.

2 Methodology and operations review

The distribution and replenishment operations of the retail stores have been reviewed and analyzed through a methodology integrating six sigma, factor analysis, and optimization modeling. Different tools have been used, and a series of steps have been taken after the kick-off of the project, including operations review and data collection. Measure and analysis phases in six sigma have been adopted, in addition to the use of process stability and capability review, normality test, and failure mode and effect analysis.

After the identification of the one-warehouse n-retailer distribution problem, an improvement model has been developed with mathematical formulation and programming modelling. Several scenarios of inter-store stock transfer operations have been simulated and reviewed. Significant factors affecting decisions on route planning have been evaluated with the use of factor analysis to refine the developed model. The flow of the integrated methodology to enhance the inter-store stock transfer operations is shown in Figure 1.

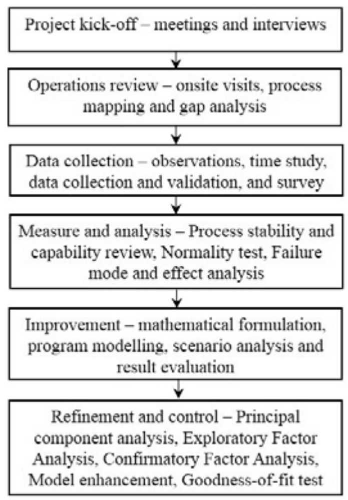

Figure 1: Integrated quality improvement methodology for inter-store stock transfer service enhancement

An operations review on current warehouse-retail stock replenishment distribution and inter-store stock transfer model of the retail chain stories have been carried out. The current performance level on stock replenishment and inter-store stock transfer has been reviewed. The international retailer has two warehouses and 17 retail stores in Hong Kong, focusing on groceries and fashionable products. The retail branches emphasize on displaying a large variety of products with minimum stock, resulting a need of inter-store stock transfer when the requested size of a fashion item is out-of-stock. There are five trucks and one van operating and delivery the products from the ware house to the retail shops. The process of the inter-store stock transfer is mapped out in a detailed process flowchart. The process stability and capability of the inter-store stock transfer delivery service have been evaluated, and the results are shown in Figure 2. The p-value of the Anderson-Darling Normality Test shows a value of 0.071, indicating a normal distribution, and the null hypothesis cannot be rejected at the 5% level of significance. The process capability value (C_{pk}) stands at 0.51, showing that the process is not capable, as the inter-store stock transfer delivery time is far from the specification limit. There is also room for improvement for process capability and stability. A survey conducted with 135 customers has been carried out to review the experience and expectations related to the waiting time for inter-store stock delivery services. The waiting time required is around 4 to 6 days. 16.3% of respondents expected less than 2 days, and about 60% of respondents expected about 3 to 4 days. A paired-samples t-test has been carried out with a significant value of 0.0004, which is less than 0.05. This indicates a statistically significant difference between the mean days of experience of waiting time and the expectation of waiting time. The existing expectation of waiting time has a mean of 3.61, and the Z-value in the Z-test for 2 days waiting time stands at -1.29581. This indicates that the inter-store stock transfer service fulfills the requirement of 90% of the customers, if it can be delivered within 2 days. With the results of the p-value, C_{pk}, and the paired samples t-test, a gap is being illustrated between the current service level and the required service level. Thus, there is a need for improvement on the operations. Through the operations review, a gap has been found from the current methodology of stock replenishing from other stores, with the need of passing through a centralized warehouse. The proposed novel inter-store stock transfer model eliminates the time and cost for the truck to deliver the surplus products from the stores to the central warehouse. This can be achieved by optimizing the routing in the model with the shortest travelling time and distance, taking into consideration the pick-up and drop-off products to and from the multiple retail stores, without the need to pass through the central warehouse.

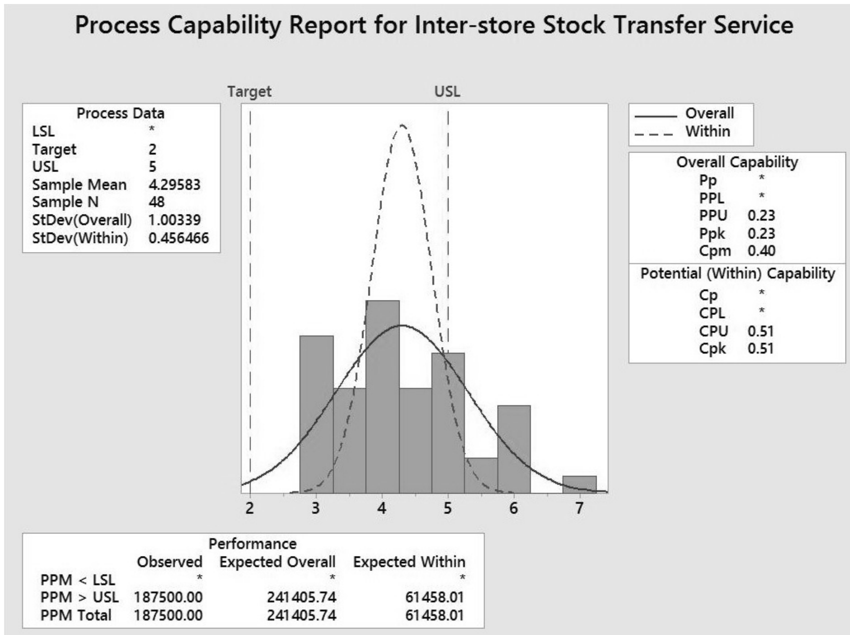

Figure 2: Statistical results on the process capability of inter-store stock transfer service

3 Inter-store stock transfer quality improvement model

Various one-warehouse n-retailer distribution models have been proposed to systematically improve the performance of retail operations. Huang et al. (2015) studied the basic vehicle routing problem, with the objective to minimize the sum of all route costs. A VRP Spread Solver has been applied in Huang et al. (2015) to solve the problem. Rahim et al. (2016) studied a two-stage one-warehouse n-retailer supply chain system with the coordination of the incoming shipments into the warehouse and the outgoing shipments from the warehouse to the retailers. The objective of Rahim et al. (2016) is to minimize the system cost, which includes the inventory holding costs at the central warehouse and all retailers, as well as the transportation cost for incoming shipment into the warehouse, and outbound shipment for the replenishment for the retailers. In this paper, we shall study the stock transfer in a one-warehouse n-retailer system, where the stock-out of the retail stores can be served by the transfer from other stores. In particular, we shall focus on the stock transfer within the stores, rather than passing through the central warehouse, i.e. the pick-up and drop-off are done alternatively by a single vehicle. The objective of this problem is to determine the vehicle route by minimizing the relevant vehicle utility function. The notations are defined as follows.

Let $V = \{0, 1, \ldots, n\}$, where 0 is the warehouse and $\{1, \ldots, n\}$ is the set of retailers. D_{ij} and T_{ij} are the travelling distance and time required from node i to node j, respectively. A total of m orders are assigned to the distribution system. Let $\mathcal{O}$ be the set of all orders. For each order $O_i \in \mathcal{O}$, $i = 1, \ldots, m$, a pickup-delivery paired-retailers (O_i^P, O_i^D) is defined, representing that order O_i is transferring stock from retailer O_i^P to retailer O_i^D. This imposes visit precedence among each pickup stop and its corresponding delivery stop. For the whole distribution system, the sets of pickup and delivery retailer nodes are denoted by $\mathcal{N}^P$ and $\mathcal{N}^D$, respectively, i.e. $\mathcal{N}^P = \{O_i^P | i = 1, \ldots, m\}$ and $\mathcal{N}^D = \{O_i^D | i = 1, \ldots, m\}$. A single vehicle is assigned to the distribution system, with a route of $2 + 2m$ stops, i.e. departing from warehouse node 0, then traversing the nodes in $\mathcal{N}^P$ and $\mathcal{N}^D$ to complete the stock transfer from O_i^P to O_i^D, ($\forall i = 1, \ldots, m$), returning to the warehouse node 0 in the end. Let $\mathcal{N}^R = \{0\} \cup \mathcal{N}^P \cup \mathcal{N}^D \cup \{0\}$ $=\{0, O_1^P, \ldots, O_m^P, O_1^D, \ldots, O_m^D, 0\}$ denote the set of nodes which need to be traversed by the vehicle. There may be several repeated elements in $\mathcal{N}^P$ or $\mathcal{N}^D$, i.e. several pickup or delivery requests at one retailer, so each retailer node is allowed to be visited more than once.

The binary decision variable x_{kt} ($k = 1, \ldots, 2m + 2$, $t = 1, \ldots, 2m + 2$) equals to 1 if the kth node in $\mathcal{N}^R$ is visited by the vehicle at the tth stop, and 0 otherwise. The binary succeeding variable z_{ij} ($i = 1, \ldots, 2m + 2$, $j = 1, \ldots, 2m + 2$) equals to 1 if the vehicle travels from node i to node j, and 0 otherwise.

The following notations are used for the model's description:

Input Data

n	Number of retailers
m	Number of orders
V	Set of nodes in the distribution system, $V = \{0, 1, \ldots, n\}$, where 0 is the warehouse and $\{1, \ldots, n\}$ is the set of retailers
D_{ij}	The travelling distance required from node i to node j
T_{ij}	The travelling time required from node i to node j
$\mathcal{O}$	Set of orders, $\mathcal{O} = \{O_1, O_2, \ldots, O_m\}$
(O_i^P, O_i^D)	A pickup-delivery paired-retailers, representing that order O_i is transferring stock from retailer O_i^P to retailer O_i^D
$\mathcal{N}^P$	The set of pickup retailer nodes, $\mathcal{N}^P = \{O_i^P | i = 1, \ldots, m\}$
$\mathcal{N}^D$	The set of delivery retailer nodes, $\mathcal{N}^D = \{O_i^D | i = 1, \ldots, m\}$
$\mathcal{N}^R$	The set of nodes which need to be traversed by the vehicle, $\mathcal{N}^R = \{0\} \cup \mathcal{N}^P \cup \mathcal{N}^D \cup \{0\}$ $=\{0, O_1^P, \ldots, O_m^P, O_1^D, \ldots, O_m^D, 0\}$

Decision Variables

x_{kt}	Equals to 1 if the kth node in $\mathcal{N}^R$ is visited by the vehicle at the tth stop, and 0 otherwise, ($k = 1, \ldots, 2m + 2$, $t = 1, \ldots, 2m + 2$)
z_{ij}	Equals to 1 if the vehicle travels from node i to node j, and 0 otherwise, ($i = 1, \ldots, 2m+2$, $j = 1, \ldots, 2m + 2$)

The inter-store stock transfer problem is formulated as follows:

$$\min \quad U = \alpha_1 \sum_{i \in \mathcal{N}^R} \sum_{j \in \mathcal{N}^R} D_{ij} z_{ij} + \alpha_2 \sum_{i \in \mathcal{N}^R} \sum_{j \in \mathcal{N}^R} T_{ij} z_{ij} \tag{1}$$

$$\text{s.t.} \quad x_{i1} = \begin{cases} 1, & \text{when } i = 1 \text{ or } i = 2m + 2 \\ 0, & \text{otherwise} \end{cases} \tag{2}$$

$$\sum_{j \in \mathcal{N}^R \setminus \{0\}} z_{0j} = 1 \tag{3}$$

$$\sum_{j \in \mathcal{N}^R \setminus \{0\}} z_{j0} = 0 \tag{4}$$

$$\sum_{i \in \mathcal{N}^R \setminus \{2m+2\}} z_{i\ 2m+2} = 1 \tag{5}$$

$$\sum_{i\in\mathcal{N}^R\setminus\{2m+2\}} z_{2m+2\ i} = 0 \tag{6}$$

$$\sum_{j\in\mathcal{N}^R} z_{ij} = 1,\ i = 2,\dots,2m+1,\ i \neq j \tag{7}$$

$$\sum_{i\in\mathcal{N}^R} z_{ij} = 1,\ j = 2,\dots,2m+1,\ j \neq i \tag{8}$$

$$z_{ij} = \sum_{t=2}^{2m+2} x_{i,t-1}x_{jt},\ i,j = 1,\dots,2m+2,\ i \neq j \tag{9}$$

$$\sum_{k=2}^{t-1} x_{ik} \geq x_{i+mt},\ i = 2,\dots,m+2 \tag{10}$$

$$\sum_{i\in S}\sum_{j\in\mathcal{N}^R\setminus S} z_{ij} \geq 1,\ \forall S \subset \mathcal{N}^R \tag{11}$$

$$x_{kt} = \{0,1\},\ k = 1,\dots,2m+2,\ t = 1,\dots,2m+2 \tag{12}$$

$$z_{ij} = \{0,1\},\ i = 1,\dots,2m+2,\ j = 1,\dots,2m+2 \tag{13}$$

In Eq.(1), $\sum_{i\in\mathcal{N}^R}\sum_{j\in\mathcal{N}^R} D_{ij}z_{ij}$ and $\sum_{i\in\mathcal{N}^R}\sum_{j\in\mathcal{N}^R} T_{ij}z_{ij}$ are the traveling distance and time of the distribution system, respectively. The objective function in Eq.(1) minimizes the system routing utility of the two components with utility coefficients, i.e. α_1 and α_2, indicating the preference of the routes with the shortest travelling distance and time, respectively. Constraint (2) indicates that the vehicle route starts from and ends at the warehouse. Constraints (3)-(6) ensure that the vehicle departs from the warehouse and returns to the warehouse exactly once. Constraints (7)-(8) state that each pickup request or delivery request is visited exactly once. Constraint (9) defines the relation between the decision variables x and z. Constraint (10) ensures the precedence among the two operations in each order, i.e. the pickup node must be visited before visiting the associated delivery node. Constraint (11) imposes a subtour elimination to the route, stating that for any subset S in $\mathcal{N}^R$, the route must enter and exit that set. Constraints (12)-(13) refer to the binary of the decision variables. The volume of the inter-store transfer is not significant as one vehicle is able to support the demand. The comparison between the current operation process and this improved operation process are shown in Figures 3 and 4.

To solve this routing problem, two methodologies are developed. The first one is an optimisation routing planning toolkit, ProRP, with the use of Microsoft Visual Basic for Application (VBA) and Premium Solver engine. The second one is large neighborhood search (LNS) compiled in Matlab.

Three common scenarios adopted from daily operations are simulated and listed in Table 1. The related locations in the three scenarios, including the warehouse and the retailers, are plotted in the Figure 5. Scenario 1 illustrates multiple stores require the delivery of products from various stores with available inventories to these requested stores: Upon customer request, City Plaza (CP), Tai Koo requests Central Tower (CT), Central to transfer trousers; East Point City (EPC) in Tseung Kwan O needs to replenish socks while Telford Plaza (TP) in Kowloon Bay has overstocks. EPC has a customer order in picking up the goods in Tuen Mun Town Plaza (TM) after three days. Scenario 2 shows an example of stores with both pick-up and drop-off activities. Scenario 3 demonstrates one store requesting stock transfer from different stores. The simulated results for the three scenarios are shown in Table 2. For each scenario, the results obtained by ProRP and LNS are the same, but the LNS can find the solution in a shorter time than the ProRP.

Multiple stores have pick-up and drop-off demands in inter-store stock transfer are shown in Scenario 1. The stores in City Plaza, Tai Koo (CP) and Eastpoint City, Tseung Kwan O (EPC) request to transfer products from Central Tower (CT) and Telford Plaza (TP), Kowloon Bay respectively. EPC store is required to transfer stocks to the store in Tuen Mun Town Plaza, Tuen Mun (TM). With the support

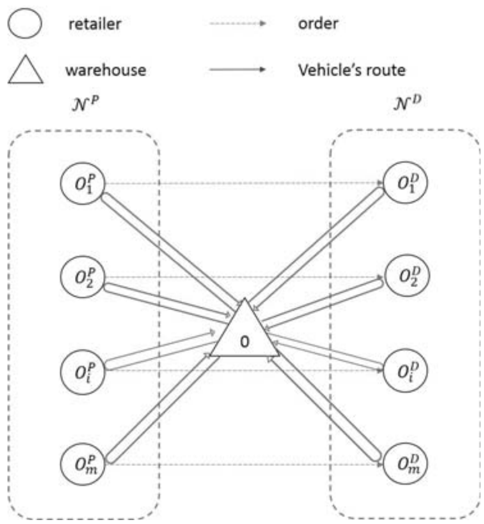

Figure 3: Current operation process

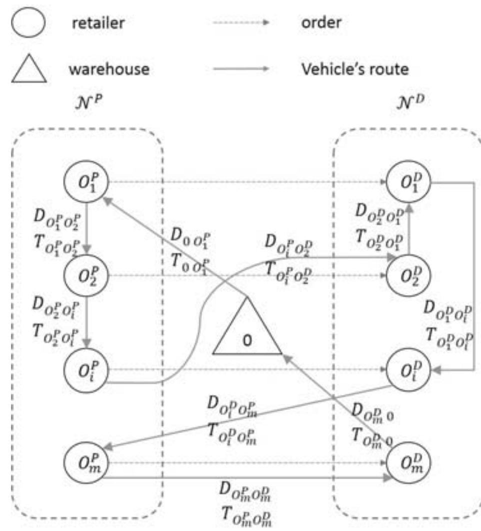

Figure 4: Improved operation process

Scenario	Retail store	To/from	Retail store
1	City Plaza (CP), Tai Koo	from	Central Tower (CT)
	Eastpoint City (EPC), Tseung Kwan O	from	Telford Plaza (TP), Kowloon Bay
	Eastpoint City (EPC), Tseung Kwan O	to	Tuen Mun Town Plaza (TM), Tuen Muen
2	Eastpoint City (EPC), Tseung Kwan O	to and from	Harbour City (HC)
	Hollywood Plaza (DH), Diamond Hill	to	City Walk (CW), Tsuen Wan
	Hollywood Plaza (DH), Diamond Hill	to and from	Time Square (TS), Causeway Bay
	Hollywood Plaza (DH), Diamond Hill	to	Harbour City (HC), Tsim Sha Tsui
3	Central tower (CT), Central	from	Telford Plaza (TP) Kowloon Bay
	Central tower (CT), Central	from	Hollywood Plaza (DH), Diamond Hill
	Central tower (CT), Central	from	Olympian City (OC), Tai Kok Tsui
	Central tower (CT), Central	from	Eastpoint City (EPC), Tseung Kwan O

Table 1: Scenarios of inter-store stock transfer operations

	Methodology	Scenario 1	Scenario 2	Scenario 3
Planned Time (min)	Solver	130	115	94
	LNS	130	115	94
Planned Distance (km)	Solver	126.1	98.2	81.3
	LNS	126.1	98.2	81.3
CPU Time (s')	Solver	49.06	3.12	50.60
	LNS	0.59	2.76	0.93

Table 2: Simulated results of different scenarios

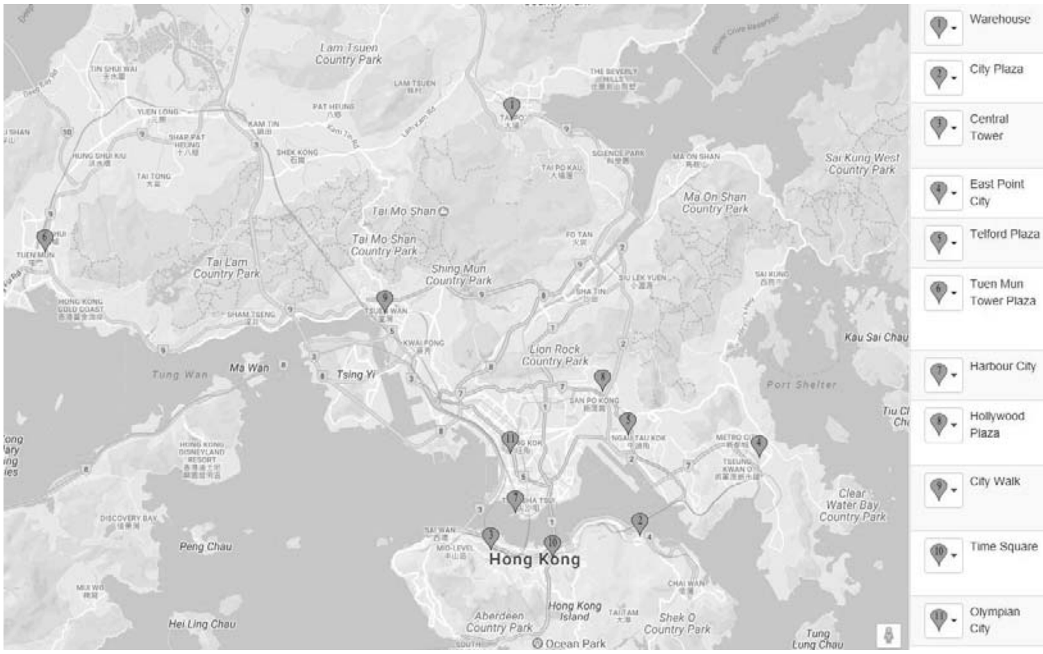

Figure 5: Locations of the warehouse and the retailers

from the developed system, among the 23,790 possible routes, an optimal routing plan is recommended as shown in Table 3. The sequence of the pick-up and drop-off products are listed, with the total travelling time as 130 minutes and total travelling distance as 126.1 km. Scenario 2 illustrates the case of pick-up and drop-off products in the same store. The decision making process of the traffic planning team is supported by the system, with the recommended route shown in Table 4. The estimated total travelling time is 115 minutes and total distance is 98.2 km. For Scenario 3, the suggested truck travelling route and order pick-up sequence is shown in Table 5. The total travelling time is 94 minutes and total distance is 81.3 km. The recommended routing and order pick-up sequence have assisted the inter-store stock transfer services to be fulfilled in less than two days as expected by the customers.

Code	Simulated route sequence	Pick (P) / Drop (D)	Planned Time (min)	Planned Distance (km)
WH	Warehouse			
TP	Telford Plaza	P	18	19.3
CT	Central Tower	P	15	11.3
CP	City Plaza	D	10	7.9
EPC	Eastpoint City	D	14	11.1
EPC	Eastpoint City	P	0	0
TM	Tuen Mun Town Plaza	D	42	40.5
WH	Warehouse		31	36
Total			130	126.1

Table 3: Simulated results of scenario 1

The developed inter-store stock transfer retail distribution model assists traffic personnel on the vehicle route planning with complex multiple pick-up and drop-off locations. The system also ensures the best routing with a minimal travelling time planned. This facilitates a reduction of the inter-store

Code	Simulated route sequence	Pick (P) / Drop (D)	Planned Time (min)	Planned Distance (km)
WH	Warehouse			
DH	Hollywood Plaza	P	17	18
HC	Harbour City	P	13	9
TS	Time Square	P	8	6.1
TS	Time Square	D	0	0
EPC	Eastpoint City	P	17	13.6
EPC	Eastpoint City	D	0	0
DH	Hollywood Plaza	D	14	10.1
HC	Harbour City	D	13	9
CW	City Walk	D	15	11.6
WH	Warehouse		18	20.8
Total			115	98.2

Table 4: Simulated results of scenario 2

Code	Simulated route sequence	Pick (P) / Drop (D)	Planned Time (min)	Planned Distance (km)
WH	Warehouse			
DH	Hollywood Plaza	P	17	18
TP	Telford Plaza	P	5	3.4
EPC	Eastpoint City	P	13	8.3
OC	Olympian City II	P	21	15.2
CT	Central Tower	D	11	8.3
WH	Warehouse		27	28.1
Total Time (minutes)			94	81.3

Table 5: Simulated results of scenario 3

stock transfer time. Comparing the results with other studies, Petersen and Aase (2004) focused on the picking, routing and storage operations and obtained an experimental result showing batching has a large impact on reducing total fulfillment time. Schwarz et al. (2006) examined a one-warehouse n-retailers problem and developed a combined system inventory-replenishment, routing, and inventory-allocation policy model aimed to minimize total expected cost over an infinite time horizon. Applying the model to designated number of retails in simulation tests indicates that the model can reduce inventory-related costs in the distribution system. Solis and Schmidt (2007) extended the model of Graves (1996) on one-warehouse n-retailer model by introducing stochastic leadtimes between a central warehouse and retail stores, aiming to determine the appropriate base stock. The result obtained indicated it is better to use the deterministic model with an accurately estimated mean leadtime than a stochastic model with a poorly estimated mean leadtime, and the distribution of uncovered demand is influenced by stochastic leadtime. Pandelis et al. (2013) developed a mathematical theoretical model for an infinite-time horizon problem in finding the optimal routing of a single vehicle pick-up from a depot and deliver to multiple customers. The result showed that the optimal policy has a particular threshold-type structure. This paper developed an inter-store stock delivery model with multiple pick-up and drop-off and simulated in a one-warehouse and n-retailer distribution problem and solved practical situation in an international retail with fifteen chain stores to enhance the inter-store stock transfer service from central warehouse distribution to a multiple pick-up and drop-off directly from available stores. The results in the optimisation model showed an improved service delivery with a shorter time when comparing the routing results described in Section 3 with the performance collected in the operations review described in Section 2. The model assisted the route planning process of logistics practitioners. The simulation results are obtained and a further study is carried out to incorporate other significant factors in the objective functions. The mapped stock replenishment and inter-store stock transfer process is revisited together with the cause and effect diagram. Eleven factors are identified and listed in Table 6.

4 Extended inter-store stock transfer model

Decisions in route planning for inter-store stock transfer are often affected by various significant factors rising in retail stores, road, and warehouse. The inter-store transfer model proposed in Section 3 considered the factors of travelling time and distance, which may not reflect the transfer process comprehensively. An extension of this research line is concerned with the model that involves all eleven factors listed in Table 6. However, representing the objective function with eleven factors is not necessary since the correlation exists among the factors. Principal component analysis (PCA), as a type of factor analysis, is adopted in the evaluation of the possible factors. PCA transforms the original set of variables into a smaller set of linear combinations, accounting for most of the variances of the original set. With the adoption of PCA, the factors determined in the analysis are able to represent as much of the total variation in the data as possible with minimal factors being used (Dillon et al., 1984). Table 6 provides the descriptive statistics of eleven critical factors and four principal components identified with sample data from the warehouse, weather reports and retail stores. Among the eleven important factors and their corresponding values observed in the daily operations, the dimensionality can be reduced into a smaller number of factors, i.e. the principal components. Table 7 shows the correlation matrix among the eleven influential factors.

To determine the number of components to be retained, the root of greater than one criterion approach is adopted by retaining the components with eigenvalues greater than one (Hair et al., 2006). Table 8 reveals four important factors. Grouping the variables into the factors depends on the value of loadings. Thus, the largest absolute value of each variables loading in each row across the factors should be grouped

Items	Influential variable factors	Mean	Standard Deviation	Minimum	Maximum
i	Travelling distance (D) (km)	11.5188	6.3774	1.5	30.7
ii	Travelling time (T) (min)	14.3125	5.8643	3	30
iii	Inter-store cross checking time (CT) (min)	22.4167	8.9391	10	45
iv	Truck emission (E) (kg CO2e)	0.0245	0.0136	0.003	0.065
v	Traffic condition (TF) (1-10 rating)	4.25	3.5159	1	12
vi	Temperature (TP) (°C)	15.3333	2.9415	8	20
vii	Transportation Cost (C) (HKD)	89.1458	31.8507	40	143
viii	Weather condition (WC) (1-10 Rating)	2.5	2.0936	1	6
ix	Fuel consumption (F) (Litre)	9.0208	4.9271	1	24
x	Retail frontline work experience (R) (Years)	5.0625	1.1375	3	7
xi	Trucker work experience (WE) (Years)	6.4792	1.2026	5	8

Table 6: Descriptive statistics of sampled data

Items	Influential factors	i	ii	iii	iv	v	vi	vii	viii	ix	x	xi
i	D	1	0.9524	-0.146	0.9997	0.0894	0.2008	0.5743	0.0753	0.9983	-0.1483	-0.1871
ii	T	0.9524	1	-0.106	0.9519	0.154	0.185	0.5394	0.0182	0.9526	-0.1784	-0.2389
iii	CT	-0.146	-0.106	1	-0.1418	0.1239	0.1071	-0.1765	0.058	-0.149	0.0371	0.1453
iv	E	0.9997	0.9519	-0.1418	1	0.0894	0.1957	0.5745	0.0759	0.9977	-0.1439	-0.194
v	TF	0.0894	0.154	0.1239	0.0894	1	-0.0267	0.6719	-0.2862	0.0844	0.2993	0.0415
vi	TP	0.2008	0.185	0.1071	0.1957	-0.0267	1	0.0142	0.3179	0.2006	-0.2862	0.3869
vii	C	0.5743	0.5394	-0.1765	0.5745	0.6719	0.0142	1	-0.1619	0.5771	0.1853	-0.0746
viii	WC	0.0753	0.0182	0.058	0.0759	-0.2862	0.3179	-0.1619	1	0.067	-0.1742	0.1225
ix	F	0.9983	0.9526	-0.149	0.9977	0.0844	0.2006	0.5771	0.067	1	-0.1445	-0.1884
x	R	-0.1483	-0.1784	0.0371	-0.1439	0.2993	-0.2862	0.1853	-0.1742	-0.1445	1	-0.3956
xi	WE	-0.1871	-0.2389	0.1453	-0.194	0.0415	0.3869	-0.0746	0.1225	-0.1884	-0.3956	1

Table 7: Correlation matrix among eleven influential factors

into the respective factors shown as bold-faced variables in the table. The first factor refers to travelling distance, travelling time, truck emission, transportation cost and fuel consumption, and is regarded as 'vehicle travelling condition'. The second factor refers to temperature, weather condition and retail frontline work experience. This factor is categorized as 'weather and retail condition'. The third factor includes traffic condition and trucker work experience. This factor is labeled as 'traffic condition'. The fourth factor includes inter-store cross checking time, which is named 'inventory system condition'. To confirm the validity and reliability of the four factor measurement models resulting from the Exploratory Factor Analysis (EFA) above, Confirmatory Factor Analysis (CFA) technique was applied. The criteria of fit indices are satisfied, with root mean squared error (RMSE) 0.0322.

Items	Influential factors	Vehicle travelling condition	Weather and retail conditions	Traffic condition	Inventory system condition
i	Travelling distance	**0.4645**	0.0659	-0.068	0.0441
ii	Travelling time	**0.454**	0.0404	-0.055	0.0534
iii	Inter-store cross checking time	-0.0863	0.0683	0.3496	**0.7251**
iv	Truck emission	**0.4644**	0.0629	-0.0707	0.051
v	Traffic condition	0.1073	-0.3996	**0.5804**	-0.0191
vi	Temperature	0.0964	**0.4319**	0.3576	0.0866
vii	Transportation Cost	**0.325**	-0.3011	0.3314	-0.1462
viii	Weather condition	0.0141	**0.4128**	-0.0723	0.407
ix	Fuel consumption	**0.4645**	0.0635	-0.0701	0.0401
x	Retail frontline work experience	-0.0533	**-0.4991**	-0.0236	0.4034
xi	Trucker work experience	-0.0992	0.3535	**0.5291**	-0.3281
	Variance Explained by each factor (λ)	4.4786	2.0887	1.4569	0.9977
	% of variance	40.71	18.99	13.24	9.07
	Cumulative %	40.71	59.7	72.95	82.02

Table 8: Eigenvectors in the rotated component matrix by factor analysis on variables

To enhance the model as a principal component factored inter-store stock transfer delivery model for routing planning, eleven influential variables were identified. There are factors such as truck emission, and travelling distance are highly correlated. Including all factors in building the model will violate the assumptions such as independence among explanatory variables and multicollinearity. Thus, to predict the delivery time, the proposed model is

$$y = \beta_0 + \beta_1 F_1 + \beta_2 F_2 + \beta_3 F_3 + \beta_4 F_4 + \epsilon \quad (14)$$

where y is the delivery time, $F_1, \ldots, F_4$ are the four factors (vehicle travelling condition; weather and retail conditions; traffic condition; and inventory system condition respectively) and ϵ is the error term. The proposed model is based on the four factors identified in the previous section, the data is reduced from eleven variables to four variables. The estimated model is examined with the goodness-of-fit tests. Notably, traffic condition and inventory system condition, i.e. the third and fourth factor, are statistically insignificant with p-values greater than 0.5. Hence, the model is modified to

$$y = \beta_0 + \beta_1 F_1 + \beta_2 F_2 + \epsilon. \quad (15)$$

The goodness-of-fit tests show that the model satisfies the issues of validity and reliability. Thus, it can be used to estimate the delivery time. The estimated intercept, β_0, is 4.3 and the other coefficients are positive, indicating that the minimum delivery time is 4.3 days. In order to reduce the inter-store stock transfer delivery service, further enhancement on the optimisation routing planning model could be explored with the result of the principal component analysis.

In the principle component analysis, the vehicle travelling condition, as shown in Table 8, including five influential factors, shows a great impact on the service quality. In this light, the objective function of the one-warehouse n-retailer distribution problem proposed in Section 3 can be extended to a utility function with five components instead of two. Define E_{ij}, C_{ij} and F_{ij} as the truck emission, transportation cost and fuel consumption incurred when vehicle travel from node i to node j, respectively. The objective function can be reformulated as follows:

$$\min\ U = \sum_{i \in \mathcal{N}^R} \sum_{j \in \mathcal{N}^R} (\alpha_1 D_{ij} + \alpha_2 T_{ij} + \alpha_3 E_{ij} + \alpha_4 C_{ij} + \alpha_5 F_{ij}) z_{ij} \tag{16}$$

where α_3, α_4 and α_5 are the utility coefficients for the truck emission, transportation cost and fuel consumption, respectively.

In Scenarios 1-3, the results for each component in the objective function are shown in Table 9. For Scenario 1, when compared with current operation model, travelling distance, travelling time, truck emission, transportation cost and fuel consumption are reduced by 62.27%, 57.24%, 61.97%, 60.16% and 62.27%, respectively. The average improvement rate for each count component has achieved 80.48% and 78.40% for Scenario 2 and Scenario 3, respectively.

Scenario	Model	Travelling Distance	Travelling Time	Truck Emission	Transportation Cost	Fuel Consumption
1	Current	334.2	304	0.71	2151	262.01
	Improved	126.1	130	0.27	857	98.86
2	Current	541.3	507	1.14	3542	424.38
	Improved	98.2	115	0.21	716	76.99
3	Current	398.7	382	0.84	2622	312.58
	Improved	81.3	94	0.17	587	63.74

Table 9: Results for different distribution models in Scenarios 1-3

5 Conclusion

Continuous upsurge in retail shop rental price, increasingly complex transportation networks and higher expectation in customer responsiveness in supply chain have stimulated the need for improving retail distribution management. A one-warehouse n-retailer distribution model of an international retailer is examined to improve the inter-store stock transfer delivery service. The operation process of the retail distribution from a warehouse to the designated retail chain stores is reviewed. The retail stock delivery service stability and process capability are evaluated, followed by a survey on the gap between the expected and actual delivery time to the customers. The risks of failure in the key inter-store stock transfer process are reviewed and the enhancement on route planning process is identified. Two optimisation routing planning systems, e.g. ProRP and LNS are developed to assist the decision making process of a personnel in planning the order pick-up schedule and routing. The inter-store stock delivery scenarios are simulated with the results analysed. From the 23,790 possible routes, an optimal routing plan is derived from the system, with the pick-up and drop-off points listed. The total travelling time and distance of each scenario are generated. The recommended routing and order pick-up sequence aim to assist planners in the retail distribution and retail frontlines to improve their inter-store stock transfer services. The fulfillment of the expectation of customers to less than two days for the inter-store stock transfer is hence achieved.

Further significant factors affecting the inter-store stock delivery are identified and their corresponding correlations are reviewed with the use of factor analysis. The set of variables are transformed by PCA into a refined smaller set of linear combinations representing as much of the total variation in the data set as possible, namely vehicle travelling condition, weather and retail conditions, traffic condition, and inventory system condition. The four-factor measurement model is verified with the EFA with positive results. A Principal component factored inter-store stock transfer model is further developed, representing a more comprehensive model with significant factors being included.

The integrated service quality improvement methodology, integrating six sigma, factor analysis and optimisation modelling, provides managerial implications on the bottom-up operations enhancement in international retail distribution from identifying the opportunities for improvement to carrying out statistical analysis and optimising stimulation. The process re-design and simulation results from the developed models also provide practical implications in significantly minimising inter-store stock transfer time, increasing customer satisfaction, and reducing loss of sales. The research is initially limited by the number of variables that the Solver engine can support. To overcome the limitation, Premium Solver engine is procured and installed to support the optimisation model with over 200 variables. To avoid possible limitation of Premium Solver in searching local optimal as solution in the more complex problem with significant factors affecting the stock delivery, large neighborhood search with Matlab programming is used to ensure global optimal are searched in the complex optimisation problem. Future development of the research could be explored by including the capability of catering sudden traffic accidents which requires rerouting as well as the fluctuation of fuel prices or changes in tunnel charges.

This paper provides a novel insight into the improvement of the inter-store stock transfer process of an international retail by using an integrated approach. An operations review is carried out, with the major processes analyzed using six sigma analysis phase methodology, including process mapping and capability analysis from the results of a customer survey with a sample size of 135. According to the statistical analysis, the inter-store stock transfer service can fulfill the requirement of 90% of customers if the product can be delivered within two days. A route planning system is developed to enhance the inter-store stock transfer service in a one-warehouse n-retailer system, increase customer satisfaction on the overall waiting time, and reduce the loss of sales due to prolonged waiting time for foreign customers in obtaining out-of-stock products in the retail stores. Route planners are benefited by the developed system during the decision making process for the operations in fifteen retail stores. The inter-store stock transfer model provides a breakthrough in the inter-store stock transfer process from traditional stock replenishment from other stores through central warehouse to optimised direct inter-store stock transfer, significantly reducing the time required for stock replenishment. Thus, the customer waiting time is reduced from an average of 5 days to less than 2 days. The model assists route planner of the retail industry as a decision support tool in selecting the best route from over 23,700 routes. Unlike other route planning models in which the objective functions involved only one factor, i.e. the travelling distance or the travelling time, the route planning model proposed in this paper considers the above two factors simultaneously first and then be extended to a more general multi-factor optimisation-based model. The unique route planning model is enhanced by adopting factor analysis to allow minimal factors being used to represent as much total variation in the data variables as possible.

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