The Planning for the Cross-docking Operations of a Large Supermarket Retail Supply Chain

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Abstract
With the knowledge accumulated from participating the first cross-docking network development, this paper summarizes the key planning and modeling issues for the cross-docking operations of a large supermarket retail chain in Taiwan. The insights gained from this study can aid large retail chains to better plan their cross-docking operations.

Keywords: Supermarket chain, Cross-docking, Planning

Introduction
A retail cross-docking strategy is an advanced supply chain strategy which builds a virtual order management and operational execution system between geographically dispersed stores of a retail chain and its multiple suppliers. It is particularly critical to install supply chain collaborative/control scheduling system and sophisticated automatic material handling equipments for the carton or item-based orders to ensure the accurate and fast flow-through of store ordered products directly from the suppliers’ warehouses to the cross-docking facilities and continue on to the retail stores.

In practice, the cross-docking set-up of a retail chain can create competitive advantages and value to the retail chain and its suppliers through supply chain inventory reduction, fast turnover of inventory at stores and supplier warehouses, reduced order cycle time, increased truck load factors and fleet utilization, streamlined information flow and better supply chain collaboration, and so on. Several cross-docking literatures also validate the value mentioned here (Kulwiec 2004; Kumar 2008; Van Belle et. al. 2012).

In Japan supermarket sector, a dry goods distribution center normally serves from 80 to 150 stores utilizing advanced cross-docking operation and sorting equipments where a distribution center does not store products, rather it serves as a flow-through facility for products sold in retail stores. In contrast, a dry goods distribution center in Taiwan will keep 2 to 6 weeks’ inventories of different products to supply the needs of 100 to 200 stores designated to its service in the chain.

With the knowledge accumulated from participating the first dry goods cross-docking development and transformation of a large supermarket chain in Taiwan for over four years since 2009, this paper attempts to summarize the key planning and modeling issues for the cross-docking operation of a large supermarket retail chain in Taiwan, with a focus on the practical or heuristics approach, rather than the theoretical or optimization
approach (since the problem size is quite large and the available optimization tools are not available to and familiar with the planning team and this kind of limitation is very typical in Taiwan and possibly in other Asia countries.).

In this paper, we will present a comprehensive cross-docking planning and modeling framework for the cross-docking facilities of a large retail supermarket supply chain in Taiwan. The cross-dock distribution campus in Northern Taiwan, for example, serves 274 stores with normal daily demands ranging between 30,000 and 100,000 cartons, and peak demand can reach 180,000 cartons in special Chinese holiday seasons. The number of products handled is more than 10,000 and the number of suppliers is more than 600.

We hope the knowledge and insights gained from this study can aid large supermarket retailers in Asia to understand better how to plan their cross-docking operations.

Literature Review
Cross-docking operations exist in many different types of supply chains, including those involved in retail distribution, those transshipping from locally collected small parcels to line-haul full-truck-load transportations, those sending parts and assemblies to manufacturing plants, those managing finished vehicle distributions using rail based cross-docks, and many others (Vogt 2010).

Few cross-docking literature review papers can be found. Boysen and Fliedner (2010) discuss papers about the truck scheduling problem and provide a classification of the considered problems. Agustina et al. (2010) provide a general picture of the mathematical models used in cross-docking papers. These models are classified based on their decision level (operational, tactical or strategic) and then subdivided by problem type. Van Belle et al. (2012) provide a comprehensive literature review and classify reviewed literature into eight categories: location of cross-docking facilities, layout design, cross-docking networks, vehicle routing, dock door assignment, truck scheduling, temporary storage, and other issues. These literature review papers focus on the review of papers using mathematical modeling and engineering methods to solve some specific but only partial cross-docking planning issues. Even though Walmart is a highly cited cross-dock benchmark case in the supermarket retail chain (Stalk et al 1992; Apte and Viswanathan 2000; Kumar 2008), a comprehensive cross-dock operational planning framework specifically for the cross-dock facility of supermarket retail chains is almost non-existent in literature.

Market saturation, extreme competition and shifts in demographics, and the recent economic slump restrict players in the supermarket industry to limited external market growth. In an attempt to face these challenges, supermarket retailers are forced to customize various operating strategies – expanding the array of services and products, increasing loyalty of profitable customers, generating profits through private labeling, and reaching customers through new delivery methods like cross-docking, internet shopping and home delivery (Kumar 2008).

A cross-docking business model is a collaborative supply chain system that attempts to optimize the upstream and downstream supply chain business processes to speed up movement of products from source to consumption, reduce the supply chain inventory and warehouse facilities, and increase supply chain transportation efficiency.
Because a cross-dock supply chain can do without product storage, supply chains using cross-docking systems are different from the supply chains using warehousing systems (Vogt 2010).

In this paper, a supermarket retailer has transformed its traditional multi-layer warehousing based distribution business model to a cross-docking based supply chain business model, thus, gained competitive advantages which support the past findings revealed by the cross-docking literature discussed in this section.

**Supply Chain Transformation of the Case Firm**

Forty years ago, Taiwan economy was very backward. The government passed a special commercial law to set up sales tax-free stores within the government and academic institutions to take care of the low income government and academic employees. It was operated as a consignment-based grocery store run by the amateur institutional employees. The institutions selected the suppliers who could put inventory in the stores and get paid after the goods are sold. Due to the tax-free advantage, the suppliers can price less than the general markets. This allows the government and academic employees to buy consumer goods with cheaper prices than other citizens. Later on, some tax-free stores were developed by the authorized local co-op organizations so that grocery goods could also be purchased in general marketplaces. However, the law restricted this type of stores could only sell to the government and academic employees.

In 1998, the tax-free stores run by co-ops were banned by the government due to many wrong and unfair conducts accused by the “normal” retail sector. Additionally, due to its nature of legal protectionism, these stores were lack in the service quality and retail technology adoption and could not compete with the emerging modern supermarket chains. The largest co-op was taken over by a local housing developer with 68 stores to begin with. However, it is no longer tax-free. With the smart strategies to modernize the stores, collaborate with suppliers and stick to the consignment-based transactions, the new supermarket chain is run under the new name, PxMart, and has been growing in a very fast speed to become the largest supermarket chain in Taiwan in less than 10 years. At one time, Wal-Mart even benchmarked PxMart’s store model for its China market.

![PxMart Distribution Channel before Business Model Transformation](image)

**Figure 1 PxMart Distribution Channel before Business Model Transformation**

PxMart has grown in a very fast speed, opening up more than 30 stores yearly in its first five years. In the next five years, PxMart opened in average 60 stores per year. In
2009, the number of stores had already exceeded 500. For the dry goods, there were about 400 medium and small local distributors spread out in the country to distribute more than 10,000 product items from more than 600 suppliers to over 500 stores. The complexity of this decentralized and fragmented distribution system had caused many delivery problems at the store level and in the distribution channel. The management felt great pressure from the instability of its traditional distribution channel, illustrated in Figure 1.

First of all, the store inventories were growing to such an extent that the suppliers had great pressure on the capital tied up on inventory and they sought out many local distributors to help undertaking the burden of inventory capitals in the distribution channel. Some distributors violated their agreements with the suppliers to sell only to PxMart to get fast cash turnover and this had also caused the concern of PxMart regarding its competitive position. Each supplier relied on between 5 to 15 local distributors to deliver and replenish its products to the stores from local warehouses run by these distributors. Since each distributor served only very small proportion of the suppliers, typically from 10 to 15, there is no distribution economy of scale at all. Thus, distributors were reluctant to invest in logistics resources and technologies. Many trucks and sales drivers called on each store every day often caused traffic congestion and long waiting times, even conflicts among drivers and store staffs.

In 2009, one of the authors was invited to attend a briefing by a VP of PxMart and provide advices to the future direction regarding PxMart’s supply chain plight. Due to its consignment-based nature and frequent transactions between the retail chain and its suppliers, a business model centered on the cross-docking seemed to be a better alternative than consolidating several hundreds of distributors into ten of fewer large distributors. To validate this proposition, PxMart authorized a one year supply chain study to discover the potential values a cross-docking business model can bring to the company and its supply chain (Su et al. 2010). In the same study, the initial cross-docking facility design and facility locations of the cross-docking network were also investigated.

The study identified many areas that could create new values to the retail stores and its supply chain partners. In 2010, PxMart approved the research suggestions and has started its multiple-year supply chain transformation journey from the old business model to the cross-docking business model. Two locations were selected, one in north and one in south, as the cross-dock distribution campuses. PxMart also established a logistics subsidiary to plan and operate the cross-docking investment and operations. The construction of the cross-docking facilities was completed by the end of 2011 and followed by the cross-docking and warehouse handling equipments’ installation and testing. Since the supermarket cross-docking operations in Japan are very popular and has a long history with the modern technology adoption, PxMart had signed a formal consultancy contract with a well-known Japanese logistics consulting firm along with authors as local consulting partners in 2010. The core cross-docking equipment is designed by a well-known Japanese material handling firm and its local business partner. It is typical in Taiwan for a large engineering project to combine Japanese technology know-how and local equipment manufacturers to reduce the hardware and software costs.

The transition from the traditional distribution model to the cross-dock distribution model started with the northern campus in March of 2012 in a small tested area. One month later, the southern campus joined with a small tested area. The full
implementation was completed in June of 2012 for the southern and northern regions. The transition of the central region is planned to start in the March of 2014. The total investment for the business model transformation is estimated to be more than $3 million dollars (i.e. 90 million New Taiwan Dollars). Figure 2 presents the distribution network after the business model transformation.

Figure 2 PxMart Distribution Channel after Business Model Transformation

With the 2009-10 study analysis and the cross-docking implementation results until the end of 2012, a comparison on the key changes before and after the transformation allows us to understand better the values brought by this strategic move of PxMart. Table 1 provides the comparison. It is obvious that the substantial values are created through the transaction frequency reduction, the dramatic decrease of distributors, the order cycle time reduction, the inventory reduction, the reduction of delivery trucks, the reduction of store traffic congestion, receiving times and personnel, the increase in fill rate, and the rationalization of store shelf utilization.

Table 1 Before and After Comparison of PxMart Business Model Transformation

<table>
<thead>
<tr>
<th>Category</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Model</td>
<td>Traditional multi-layer local distribution channel</td>
<td>Direct cross-docking distribution channel</td>
</tr>
<tr>
<td>Yearly orders</td>
<td>2.21 millions</td>
<td>0.71 millions</td>
</tr>
<tr>
<td>Delivery</td>
<td>Average 30 distributors</td>
<td>One distributor and two major cross-docking DCs</td>
</tr>
<tr>
<td></td>
<td>Product late delivery, shortage, damage were often</td>
<td>Dramatic improvement on product late delivery, shortage and damage</td>
</tr>
<tr>
<td>Receiving</td>
<td>Small receiving area with many inbound trucks causes congestion and long waiting time for many inbound trucks</td>
<td>Two or one deliveries per day</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No more congestion and long waiting time</td>
</tr>
<tr>
<td>Display</td>
<td>Delivery people fought for display shelves for their suppliers</td>
<td>Store staffs display according to the shelf display plan</td>
</tr>
<tr>
<td>Fill rate</td>
<td>20% fill rate was satisfactory to avoid late delivery penalty</td>
<td>Above 95% fill rate Late delivery penalty is charged for the portion less than 100%</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Order cycle time</td>
<td>2 weeks + 72 hours</td>
<td>30 hours</td>
</tr>
<tr>
<td>Channel inventory (fast moving goods)</td>
<td>42 days</td>
<td>14 days (only at stores)</td>
</tr>
<tr>
<td>Logistics resources</td>
<td>&gt;400 small and medium size distributors’ warehouses &gt; 2000 delivery trucks</td>
<td>2 major cross-dock distribution campuses &lt; 500 delivery trucks</td>
</tr>
</tbody>
</table>

**Entities in the Cross-docking Planning System and their Relationships**

In figure 3, E and S represent chain stores and suppliers respectively. A chain store, E, will place an order to purchase an item (or product), I, from a supplier, S, with quantity, Q. An order from a store normally includes more than one item ordered mostly in carton(s); but for some items, the store may purchase in piece(s) or item(s), that is less than a carton load order, due to the nature of their low demands or large carton size. Large suppliers often supply many items to the stores with large total volumes. Therefore, scheduling daily inbound shipments from hundreds of suppliers of various sizes providing different types of products becomes a very complex operational planning problem.

![Figure 3 Cross-docking Planning System Entities](image)

For each entity shown in figure 3, a set is defined to represent its constituents in the set. In (1), $S$ is the set including all suppliers. In (2), $I$ is the set for all items. In (3), $E$ is the set of all stores. In (4), $Q$ is the set of all possible order quantities.

\[
s \in S = \{1,2,...,S_T\}, \quad S_T = \text{total number of suppliers} \quad --- (1)\\
i \in I = \{1,2,...,I_T\}, \quad I_T = \text{total number of items (i.e. products)} \quad --- (2)\\
e \in E = \{1,2,...,E_T\}, \quad E_T = \text{total number of customers (i.e. stores)} \quad --- (3)\\
q \in Q = \{1,2,...,Q_T\}, \quad Q_T = \text{maximum order quantities of all items} \quad --- (4)\\
\]

Figure 4 shows how the handling unit converts between different stages in an order cycle. In the order placing stage, Q is the demands of items ordered from stores in a planning period which may be a day(operational plan), a month(tactical plan), or even a year(long term plan). In the second stage, most of the suppliers will receive carton orders (C) for cross-docking or item orders (B) for inventory purpose. In the third stage, the
retailer distribution campus will receive pallet shipments of carton orders and feed those cartons directly into the cross-docking facility, i.e. xDC; on the other hand, the campus will receive pallet or carton shipments of item orders and move them to the storing facility, i.e. iDC, waiting to be picked and consolidated into logistics boxes (C). In the fourth stage, the cross-docking sorting system will receive cartons (C) from xDC and logistics boxes (C_l) from iDC. The cartons and boxes will be sorted into their store chutes and then collected to movable store cages (G). In the final stage, the cages will be loaded into the delivery trucks (T) and ship to the stores. From the historical store order data, we can derive the logistics demands at each stage and use them as inputs for logistics planning.

![Figure 4 Conversion of the handling unit at different cross-docking distribution stages](image)

**Planning and Analytics Issues**

For a traditional supermarket chain, it is a daunting initiative to transform from a multi-layer inventory-based distribution channel to a direct inventory-free cross-docking distribution supply chain. To be successful, it requires developing and implementing various good plans along different timelines. The following will discuss three most crucial planning types.

1. **Long-term planning**

   There are several key issues in a long term plan for the cross-docking investment of a supermarket chain. First, the plan needs to answer the question whether a cross-docking is a right business model that can effectively satisfy the current and future market demands. If the answer is yes, then the next question would be what does the cross-docking logistics network look like? How many cross-docking facilities are required? What is the processing capacity needed for each facility? Where should they locate? What kind of cross-docking technology are the most suitable to adopt? How might these demands cost?

   For each cross-docking facility, key questions including the land size, cross-docking equipments, building specifications, flows and interior layout design, type and rough number of delivery trucks required, rough estimate of set-up funds need to be addressed.
The yearly data, sometimes multiple years’ data are used to forecast future demands for the design of facility layout, storage/handling equipments, and fleet size, et al. EIQ analytics is a very useful demand analysis method for the long term planning (Suzuki 2008, 2009). Network optimization and channel simulation are more advanced analytics useful for the long term planning regarding location and supply chain profit sharing decisions.

2. **Tactical planning**

Tactical planning looks for the cost effective decisions in the mid-term for the smoothness and workload balancing of the key cross-dock operations such as the requirements and scheduling of the facility space, logistics equipments, fleet, workforce, et al.

In the cross-docking distribution center case, the demands of the key logistics activities must be first analyzed (by EIQ or other demand analytics method), followed by the planning and securing of the logistics resources to meet those demands. First planning issue is how to schedule the shipments from suppliers to the inbound docks in the cross-docking facility. According to the historical inbound shipment volumes, the suppliers can be categorized into several levels. For those with large volumes, the suppliers are required to deliver every operating day; at the next volume level, the suppliers will deliver every other day; and at the next level, the deliveries will be made on a weekly basis; some suppliers may deliver their products according to the special needs rather than on a regular basis. This information will serve as the input for the operational planning of the inbound truck scheduling and dock assignment to increase inbound delivery speed and reduce inbound truck waiting time.

Once the inbound cartons and logistics boxes are fed into the cross-dock sorting line, they need to be sorted and moved to their designated chutes assigned to the destination stores. Depending on the scale of the store, each chute can be assigned to one to four stores (each chute has the capacity to process up to four stores). The chute assignment of stores is a complex problem and needs to consider both the store proximity and the chute volume balance at the same time. The goal is to achieve chute volume balancing while the stores in the same delivery routes can be geographically proximate. Base on the store chute assignment decision, the staging location for the cages of each store can be determined for the minimal movement from chutes to staging locations, and from staging locations to outbound docks. The delivery route planning must consider simultaneously the store proximity, the load size and truck type, and the docks assigned.

In the storage and picking facility, the planning issues relate to the capacity decision regarding the amount of storage and picking equipments required, what kind of solutions to choose for storage and picking technologies, how to allocate different products to the appropriate storage and picking locations, how many are needed to put into these locations, and when to replenish the needs. These are the planning issues similar to the traditional inventory-based warehousing decisions.

This type of planning requires the use of monthly or seasonal demand data which can be derived from EIQ analysis (Suzuki 2009).

3. **Operational planning**
The operational planning requires the use of the store POS order data to schedule and arrange logistics resources to fulfill the store orders. The operational planning is conducted for the store order execution to utilize the logistics resources acquired and operational rules set up during the long term and tactical planning periods. When store orders are issued, the logistics operational and management team need to schedule supplier inbound shipments, set up cross-dock sorting machine, arrange store cage loading for each chute, move loaded cages to the assigned staging locations, load the cages to the delivery trucks, and deliver the cages to the stores. The empty cages and returned products from stores will be collected by the delivery trucks and return to the distribution center for the reuse of the loading cages and the return goods processing.

In summary, since the consumer demands may vary by season, region, special natural conditions (such as typhoon), new store opening, old store closing or new product launches, it is noted that the three types of planning must be conducted at the right time on a continuous basis.

**A Comprehensive Cross-docking Operational Planning and Modeling Framework**

There are several interesting and important planning issues for the cross-docking operations in xDC. These issues are all subtle operational problems requiring careful quantitative analyses to get good planning results. These planning issues can be tackled as either tactical or short-term planning problems. Figure 5 provides a comprehensive cross-docking operational planning and modeling framework in a typical xDC. There are ten planning issues and two of them (P2 & P10) relate to iDC which is not studied in this paper. Table 2 shows the eight planning issues for xDC and their planning goals.

![Planning & Modeling Framework for the Cross-docking Operations in a xDC](image)

These planning issues can be formulated as optimization problems that may be modeled as some classical operations research problems (Wang & Regan 2008; Rosales et al 2009). P8, for example, can be actually modeled as a typical vehicle routing problem (Gillett and Miller 1974; Wen et al 2009). In conclusion, there are still many research opportunities to be pursued in this field.
Table 2 Planning Issues and their Goals for the Cross-docking Operations in a xDC

<table>
<thead>
<tr>
<th>Code</th>
<th>Planning Issue</th>
<th>Planning Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Inbound Supplier Scheduling (ISS)</td>
<td>Prioritize the daily supply schedule of suppliers</td>
</tr>
<tr>
<td>P3</td>
<td>Inbound truck dock assignment Plan (ITDA)</td>
<td>Maximize the utilization of the fixed number of receiving docks per inbound shift</td>
</tr>
<tr>
<td>P4</td>
<td>Inbound dock workforce Plan (IDWP)</td>
<td>Minimize the receiving workforce requirements per inbound shift</td>
</tr>
<tr>
<td>P5</td>
<td>Store class analysis (SCA)</td>
<td>Classify the stores based on demands into quartile</td>
</tr>
<tr>
<td>P6-1</td>
<td>Store chute allocation and volume balancing plan (SCAVBP)</td>
<td>Allocate stores to automatic sorting line chutes to balance the case volume of each chute and achieve store geographical proximity</td>
</tr>
<tr>
<td>P6-2</td>
<td>Store cage loading workforce plan (SCLWP)</td>
<td>Minimize the store cage workforce requirements per outbound shift</td>
</tr>
<tr>
<td>P7-1</td>
<td>Store cage staging capacity plan (SCSCP)</td>
<td>Design the optimal store cage staging cell capacity to minimize total staging costs</td>
</tr>
<tr>
<td>P7-2</td>
<td>Store cage cell allocation plan (SCCAP)</td>
<td>Allocate staging cells to stores to minimize the walking distance from chutes to staging cells</td>
</tr>
<tr>
<td>P8</td>
<td>Delivery truck routing and dock assignment plan (TRLP)</td>
<td>Design the delivery truck routes and assign shipping docks to delivery routes to minimize the total traveling distances</td>
</tr>
<tr>
<td>P9</td>
<td>Truck and driver assignment plan (TDAP)</td>
<td>Assign trucks and drivers to delivery routes</td>
</tr>
</tbody>
</table>

Reference


Su, S.I., C.L. Liao, T.Y. Shih, Y.F. Hu. 2010. *A Study on the sustainable supply chain development for PrMart*, SCLab, Department of Business Administration, Soochow University.


