RESEARCH PROJECT REPORT

Case Pick or Unit Pick? A Decision Model Using Total Relevant Cost

by

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Bachelor of Management (Marketing)
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Submitted to the MIT Malaysia Supply Chain Management Program in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE IN SUPPLY CHAIN MANAGEMENT

at the

MALAYSIA INSTITUTE FOR SUPPLY CHAIN INNOVATION

May 2021

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ABSTRACT

In a modern retailer setting, having their own Distribution Centre (DC) is a common practice among retailers. Suppliers deliver their Stock Keeping Units (SKUs) to retailer's DC, from where the retailer oversees their distribution to its stores according to each store's demand. One important question is whether the stores should order an SKU from the DC in (one or more) full cases in which the supplier delivered the specific SKU to the DC ("case-pick"), or any quantity they wish ("unit-pick"). We worked with Delta, a Malaysian retailer, to develop an analytical model to compare the Total Relevant Costs to assess the tradeoffs between case-pick and unit-pick. Our analysis considers the cost of picking an SKU at the DC, as well as the cost for retail store operations to process the merchandise for store display by the two options. We extend this analysis further to specify the optimum case sizes for delivery by suppliers to the DC. In summary a retailer should consider to reduce its case sizes and pick in smaller multiples before moving to picking by units, due to the reduction in productivity at the DC.

Research Report Supervisor: Dr. Shardul Phadnis
Title: Associate Professor

Acknowledgements

I would like to thank my advisor, Dr. Shardul Phadnis, for the support and guidance given to me during the span of this paper.

I would also like to thank the company that has provided the relevant data for me to study and model my research on, without it, the existence of this paper is not possible.

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1 Introduction

In the retail industry, shelf space is a finite resource at the store level and required to generate revenue (Draganska & Klapper, 2007). Retail operations efficiency plays a very important role in the generation of profits as traditionally low margin plagues the industry (Wensing, Sternbeck, & Kuhn, 2018).

Wagner (2002) acknowledges there are impact from pack size, on supply chain strategy and order quantity by the company, and there is a logistics trade-off between handling cost and inventory holding cost (Tápler & Csík, 2010). Pack size can be defined as the number of units in a carton, and effectively becomes a minimum order quantity (MOQ) constraint (Yan, Robb, & Silver, 2009). Every time the store orders the SKU, it will be shipped by multiple of the pack size, thus affecting the instore inventory level (Wensing, Sternbeck, & Kuhn, 2018).

A larger pack size causes the store to "starve" at times because the quantity required does not exceed the quantity to trigger a carton in the system and other times it can cause the SKU to be over-stocked due to order batching principle leading to "lumpy" ordering and deliveries (Geary, Disney, & Towill, 2006). This would require additional handling to move the remaining units to a temporary storage in the backroom (Eroglu, Williams, & Waller, 2011; Waller, Tangari, & Willaims, 2008). Resulting in double handling and in turn increasing costs (Wen, Graves, & Ren, 2012). Furthermore, the impact of larger pack size will increase the demand variability at the DC level (Yan et al., 2009, Broekmeulen et al., 2007), hence could cause bullwhip effect (BWE) (Geary et al., 2006, Lee et al., 1997). On the other hand, Waller et al. (2008) mentions, larger case pack reduces the frequency of store replenishment and reduces the number of exposures to stockouts.

Manufacturers has a fixed case size for all their customers, regardless of their demand, hence currently retail companies solve the problem on how to quantify a suitable pick type of SKU to be send to stores (Sternbeck, 2015) by intuition, as an example; average days of inventory (Sternbeck & Kuhn, 2014). A critical factor is ignored by using the intuition, is the handling cost of dealing with different pick type in both DC and Stores (Wen, Graves, & Ren, 2012). Another, common strategy applied by retailers is “one case-pack size for all stores” (Sternbeck, 2015), means the same pack size is used across all stores.

1.1 Research Setting: Delta

The company that is sponsoring our data is from a Malaysian Hypermarket retailer of Fast-Moving Consumer Goods (FMCG) and shall be referred to with a pseudonym as Delta. They operate in the Peninsular of Malaysia or commonly known as West Malaysia.

Delta, the company operates a two-echelon supply chain consisting of a Distribution Centre (DC) and Stores. At the point of this study the company has more than 60 stores ranging with various store size, such as convenience stores, and stores that are above 2,000 sqm of selling floor space. They also have presence online, through various e-commerce platform in country.

Delta only uses a 40 and 45-footer trailers to deliver goods from its distribution center to the stores. To ensure efficiency during transportation, trucks could have multiple drop points. Transportation is a mix between in-house and outsource, where inhouse is used for stores within the state of the DC location and outsourced trucks are used for interstate deliveries.

Delta’s DC, is a 50,000 sqm warehouse with 50,000 pallet positions, the company has only one Non climate controlled, Ambient DC in Malaysia. Here suppliers will come to deliver their goods on pallets, for it to be kept at the DC until the store orders the particular SKU. Ordered SKU will be picked by the DC and to be transported to the Store for replenishment of its shelf to fulfill the store’s demand. The activity of the DC includes but is not limited to receiving the goods, put away, replenishment of pick location, picking and dispatch. During picking, SKU are placed on a roller cages, and each roller cage will be for a specific store allocated by the system. Total number of active SKUs carried by the DC is 16,000 ranging from Groceries to Hardline and even Apparel.

1.2 Retail Industry in Malaysia

Delta, does not only compete with direct competitors from the Hypermarkets space, but also other convenience marts. In the past few years, the convenience store format has been growing, opening in areas closer to customers home, giving the customers the flexibility to shop nearer to their home. Furthermore, shopping from online platform is becoming easier while online prices in some cases are cheaper compared to traditional brick and mortar stores. This threatens Delta's model of selling consumer goods at low prices at a high volume.

Besides online and offline competitor, direct or indirect competitor, the industry is also facing headwinds from disruptive technology, such as 'Hargapedia' a FMCG price tracker application (app). Previously where consumer has to view the newspaper or go to the physical store in person, and the convenience of comparing between retailer's offering is often difficult. However, consumer can now look for the lowest price on their phone app and decide to shop based on the offerings by the retailers. This is an issue for retailers where previously discounts and deals were used to pull crowd in to the shop, and subsequently also do their grocery shopping for other necessities. In contrast, now consumers have the ability to quickly identify and buy discounted items and leave to do the rest of their shopping at another retailer.

With the increase competition, not only from the direct competitors, but from various retails channels and disruptive technology advancement. Delta has to find efficiencies in the supply chain to reduce operating cost while improving on its offering to the end consumer.

1.3 Operation Overview

Figure 1, shows the Summary of Flow of Goods Operations in the DC, from supplier to the shop floor. Once Supplier have received a Purchase Order (PO), goods will be delivered the DC, once the SKU is check it will be received by the DC Receiving team according to their pallet arrangement pattern. Tier (Ti), which is the number of cartons per layer on a pallet and High (Hi), the number of layers on a pallet. This is important to ease the counting of cartons during receiving also provides uniformity to all the pallets that are delivered. The next step is for the pallet to be put away (DC Putaway) in to the racking location for future demand. DC

Putaway activity is a step cost, it is a constant cost if the number of cartos is within a pallet, and increases in cost if there is a spill over. When the system is triggered for replenishment of the picking location, the SKU, it will be brought down. Pick location will be replenished (DC Replenishment) to avoid Out of Stock situation when the picker comes around to pick (DC Picking) the SKU as per system suggestion.

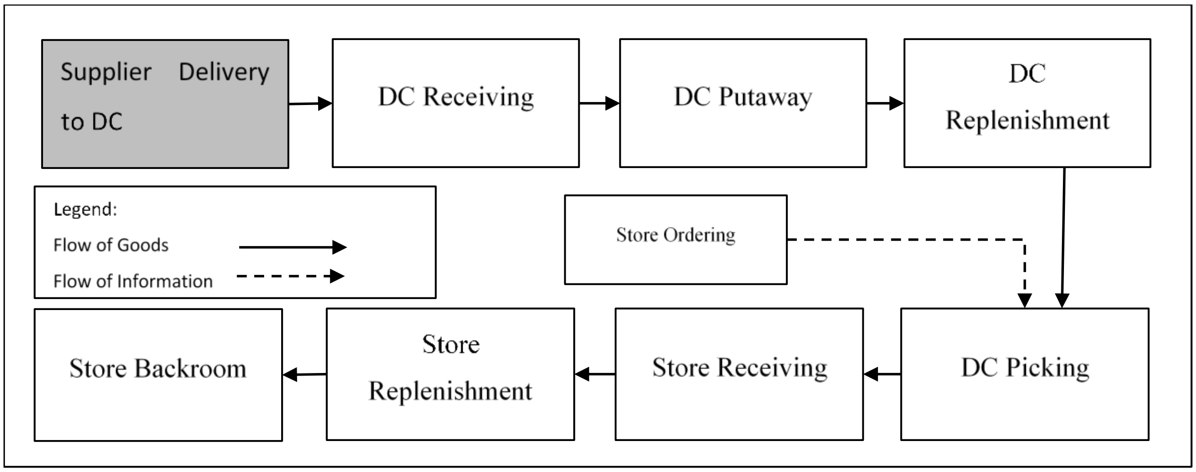

Figure 1: Summary of Flow of Goods Operations in the DC

DC Replenishment differs between case and unit, as the pick location for case pick is allocated for one pallet. In comparison unit pick location, only one layer is able to fit the location. Remaining of the SKU quantity on pallet needs to be re-rack for future replenishment.

SKU that is case pick, DC personnel will pick the whole case, which houses any number of units that has been set by suppliers during their cartonization process. On the other hand, when SKU are unit picked, they are place in to a basket to minimize damages during transportation to stores.

All SKUs that have been picked will be loaded in to the truck and will be shipped to the store, for store team to receive and replenish according to quantity each store has ordered. If store orders (Store Ordering) a SKU, which is to pick by its original pack size, it will receive and Store Inventory increases by minimum of a pack size and by multiples of pack sizes in a delivery (Store Receiving). The same pick method and pack size is being use for all stores.

After receiving the SKU, store team will head over to the shop floor, to replenish the shelf (Store Replenishment). If there is any physical excess of units, whether SKU is case or unit pick after the replenishment is done, it will be brought back to be kept in the backroom (Store Backroom) for replenishment in the future.

1.4 Research Question

In the DC currently, there are two picking method and it is either Pick-by-case or Pick-by-units. As a retail company, Delta has to identify the most efficient pick method for each SKU stored at the DC, which in essence means the minimal cost to move the product from DC to Stores, also taking in to account Inventory Carrying Cost.

The current method to decide the pick method is by using the average sales of the SKU per week over the number of stores SKU is listed for sales. If the average sale is less than a case, the pick method recommended is by units. While simplicity is good, the current model, only looks at the average rate of sales per store, it does not take any cost elements in to consideration in the decision tool.

The cost elements, that are not taken in to consideration could be separated in to two broad categories, Capital Expenditure and Operating Expenditure. For Capital Expenditure, are cost associated to infrastructure cost. For example, the gravity flow rack used for unit picking, where this rack is tilted, and the picking side is lower than the replenishment side. It also has rollers to ease the carton to slide from the higher side to the lower side. As for Operating Expenditure, as an example would the DC require more manpower to pick the same amount of quantity units if the SKU is being picked as a carton.

The reason for item to be unit picked in DC is for Delta to save on the Inventory Carrying Cost, and we are to find out if the current method meets its objective in minimizing cost. As DC serves as a central point of stock keeping, is able to cushion the variation of demand with its Inventory.

The primary question in the paper is how should Delta decide whether an SKU should be picked per-case or per-unit in its Distribution Center for delivering to its stores?

To answer this question, we model the two-echelon system of Delta. Once modelled, we then explored to optimize the pack size of each SKU to minimize the Total Relevant Cost. The structures for this paper are organized as follows:

1. Identify and model the DC and Store Operations as seen in Section 3.4
2. Run the model and compare the results for Case pick versus Unit pick in Section 4.2.1
3. Optimize the Pack Size of a SKU in section 4.2.2

With this study, retailers of the same nature will be able to implement the solution in this study to increase their supply chain efficiencies, taking a pragmatic approach compared to using intuition or just average inventory days as a yardstick (Sternbeck & Kuhn, 2014).

The remainder of this paper is organized as follows. Section 2, is the literature review. In Section 3, about the method of data collection, assumptions and modelling of the research question. After that, in Section 4, the data set is explored and results are shared. In Section 5, a summary of the findings presented and points for future research.

2 Literature Review

In this section, our literature review is separated in to two parts, Distribution Centre Operations and Retail Stores. Past research was review and compared to our research paper.

2.1 Distribution Centre operations

Wen et al. (2012) argue that distribution center operations incur three types of costs: replenishment cost, picking cost and inventory cost. As a comparison, our research included additional cost components such as receiving and put away in to the equation. In their research (Wen et al., 2012) also their inner picking cost was done on a straight-line cost calculation method, however our paper deems it equivalent to case picking, as the replenishment of pick location is the same as case picking.

When evaluating whether the SKU is to be case pick or unit pick, Waller (2008) suggests to include other factors to evaluate which includes cases stack on pallets, transport utilization and DC material handling equipment, our paper has cases stack on pallet incorporated in to DC Put away equation. Yan et al. (2009) mentioned on soft cost to be considered which covers breakages, pilferage, labour to be included in to the case pick or unit pick study. However only considered labour cost in Delta's two-echelon supply chain and excluded the other soft cost recommendation that is presented by Yan et al. (2009). A study done by Wensing et al. (2018), was in to optimizing the case pack based on demand and weekly delivery schedules, however did not take in to account additional handling costs in the DC, thus does not reflect the entire logistics costs. At this point in time Delta do not have much influence over the supplier pack size.

Ketzenberg et al. (2002), concluded that a balance between benefits and additional cost of case or unit pick should be studied before implementation, which is in line with our research paper, as different pick method has different activity cost. Broekmeulen et al. (2017) concluded that unpacking in DC results in cost savings provided the retailer invest in automation to bring the unit pick cost down by improving pick rate and reduce travel time.

This is one area Delta, can consider looking into, to reduce dependencies on manpower at the DC.

2.2 Retail Stores

Research in to the store replenishment done by Eroglu et al. (2011) and Waller (2008), concluded if SKUs that are not replenish immediately to the shelf and there is leftover to be stored in the backroom for later replenishment, is an unreliable process. This is due to the need for increase labour to locate back-room inventory, higher information processing costs, and loss of sales, as stocks are available at the back room but not on the sales floor. Which later on was suggested by Eroglu et al. (2011), to increase the shelf space, however to be done with taking account of the product's rate of sales.

Papers from Sternbeck (2015), Waller (2008) puts the point across to review pack size of SKUs that have a low rate of sales, as this would enable the SKU to be appropriately replenish in to the shelf space, thus avoiding the back room and its inefficiencies, on the other hand to increase the pack size for higher rate of sale products, these papers are relevant, as the findings in our paper is inline. A similar study has been done by Wen et al. (2012), however the section on instore operations only reflected at a high level without taking in to detail account of store replenishment cost as they were only working on expected extra handling, as compared to our paper where actual historical data is used.

Studies done by Wensing et al. (2018), and Broekmeulen et al. (2017) all allowed backorder with a penalty cost, on the other hand our back-order penalty was nil as we do not allow back-ordering and if an order is not able to be fulfil it will be considered loss of sales. Besides the backorder penalty Yan et al. (2009) also does not allow transshipment from across stores, which is in line with our paper, as all replenishment are pulled only from the DC.

In summary, the literature reviews show an insufficient research into the total end to end question of whether to Case Pick or Unit Pick, many research is on Optimization of case pack, or focus on heavily on one side, either the store or DC of two-echeleon supply chain. However, the goal of this paper to explore and shed light to areas that could yet uncovered by previous research, and the key areas are, DC Receiving Cost and DC Replenishment, to include Putaway and Replenishment of Pick Location, and extended in to optimizing the case size for our selected SKUs. From the above literature (Section 2.1 and 2.2), there are other points that requires focus, which could be a potential future research area such as stock loss due to shrinkage and accounting for vendor failure, which will be covered in Section 5.3.

The next section would be about our research method (Section 3) and followed by our research results in Section 4. In Section 5, our paper discuss about what Delta can do with the model and finding in this paper.

3 Research Method

For the section the content that would be covered will revolve around how the research was conducted. In Section 3.1, talks about the case selection on how the SKUs were chosen and in Section 3.2, how the data was collected. The assumptions of our research paper are also covered in Section 3.3, moving from there we develop our model under 3 major buckets which are DC Handling (Section 3.4.1), Store Handling (Section 3.4.2) and Inventory Carrying Cost (Section 3.4.3) for both DC and stores. And lastly putting all in to a Total Relevant Cost model in section 3.4.4.

3.1 Case Selection

Despite Delta carrying about 16,000 SKUs, in this paper will be exploring only 14 SKUs, from the personal care category of Shampoo, hence able to compare SKU's sales volume and how the different type of picking method impacts costs.

In terms of popularity of the product in terms of usage by the general population, a survey study done on the usage of personal care products the number of respondents that was using shampoo is 97.6% for the study conducted in California (Wu, et al., 2010) and 96.7% in Netherlands (Biesterbos, et al., 2013). As the stores are all over the country, the buying pattern will not be affected by geographical biasness in term of usage of product, eg. population who are at the suburban areas do not use shampoo. However later on, brand biasness by store do occur as discovered in our findings below.

Based on the given fact above from studies of two different countries about the high population using Shampoo, the 14 out of the 206 SKUs that was selected for this paper, was based on the volume of sales high, medium and low. The top 5 SKUs represented 10.7% of the total volume of sales, and the total contribution for the 14 SKUs is 13.1% of total volume of sales in the shampoo category to Delta. Sales volume plays a very important part of this research as it affects Store Operations from shelf replenishment all the way upstream to the number of cases to be delivered by the supplier to the DC.

Not only Top SKUs was chosen, middle and slower SKUs which accounted for the 2.4% of total volume are also part of this paper, as it would give insight for our findings in Section 4, as it would then be possible to compare them, and based on the results, how does it answer our research question.

Since SKUs are homogenous, the pick rate at the DC and the replenishment time taken by the store colleagues will be comparable. Out of the 14 SKUs, there is only two different pack size variants, in 12s or in 6s. In fact, there is only two SKUs that has a pack size of 6, the others are 12 units per carton.

3.2 Data Collection Method

Method of data collection was based on Historical Sales Data, extracted from Delta's system for the specific SKUs, and time frame was from WK1 to WK25 in 2018 from all stores across the 14 SKUs, this was the time frame that was given to allow our study to base on The data has been well organized and structured, hence not much time was spent to clean the data, which allow more time to be spend on modelling and discovery of the results.

As for the Operational Numbers, eg. KPI, it was extracted from the Productivity Portal, that has been set in place to measure each colleague's performance, as each colleagues has their own unique login identification in order to use the system. All data was structured, and no time spend on cleaning and reorganizing the data. However, all data here has been masked to ensure anonymity of Delta.

To understand the data, there was an interview session, with the person who provided the data to ensure full understanding of the data, the interview also covered the operations of the DC and Store, as the requirements were taken down to ensure our model reflects the real-world activities, eg. pallet putaway, and travel time for replenishment. Furthermore, the session, we gone through the data to eliminate any potential errors, such as misinterpretation of data.

3.3 Modelling Assumptions

The following points are the assumption that has been made for this research paper, to focus on the key cost elements.

Assumption 1:

SKU_k is ordered and delivered by Supplier on a weekly basis and fulfils the demand ordered all the time. In our model, vendor failure has no implication to our results.

Assumption 2:

Wage is deemed to be a constant throughout the two-system echelon, as the skill level required in the DC and Store Operations are the same.

Assumption 3:

The two-echelon system is assumed to be damage- and theft-free.

Assumption 4:

Lead time from DC to Store and Replenishment is assumed to be zero, this is used to calculate the expected extra units that is left over due to limited capacity of the shelf. Increasing the lead time can be easily accommodated in to our model.

Assumption 5:

Transportation cost is not taken in to account and assumed to be constant, as Delta has a fix delivery schedule to each store per week.

Assumption 6:

Stock will be reordered from DC to stores once it reaches the Reorder Point, s_k or below that of s_k, and the same threshold is applied to all stores.

Assumption 7:

Cost of handling one unit is assumed to be proportional to the cost to handle a case , except for the cost of picking at the DC due an additional task required to be performed during Unit Pick. Also, the cost to handle one case is assumed to be the same across the 14 SKUs as they belong to the same category and all but 2 SKUs is in pack size 12's. The other two is in pack size 6s.

Assumption 8:

When ordering a case is not as flexible as ordering in units to fill up the shelves with the exact quantity needed. Therefore, ordering in cases is expected to have extra units, as stocks ships to store has to be by a multiple of Pack Size, P_k.

$$Q_k^{Case} = \frac{Q_k^{Unit}}{P_k} \quad \text{(Eq 1)}$$

$$Q_k^{Extra\ Case} = Q_k^{Case} - (Max\ Shelf_{i,k} - Q_k^{On\ Shelf}) \quad \text{(Eq 2)}$$

Assumption 9:

Handling one pallet cost the same regardless if there is only 1 carton or 10 cartons, as long as it is within the limits of the pallet. Whenever an equation involves pallet, the notation Tier, $L_k$the number of cartons per layer on the pallet and High, H_k the number of layers per pallet is used.

$$Number\ of\ Pallets = \frac{\left(\frac{Q_k^{Unit}}{P_k}\right)}{L_k * H_k} \quad \text{(Eq 3)}$$

Assumption 10:

We assume the shelf space is to be a constant of P_k received from supplier multiplied by a constant of Shelf Space Multiplier SSM_k.

$$Max\ Shelf_{i,k} = P_k * SSM_k \quad \text{(Eq 4)}$$

3.4 Model Development

Our model development can be broken down in to three major parts, covering DC Handling Cost, Store Handling Cost, and Inventory Carrying Cost. Table 1, shows the notation that would be used throughout this paper.

The inventory policy that is used in our research is (R, s, S), where every store is review periodically in our case daily, and if the inventory position is less than or equal to s_k, stocks will be orders (section 3.3, assumption 6). $Max\ Shelf_{i,k}$ is the max shelf space which is mentioned in assumption 10 in section 3.3. The difference between $Max\ Shelf_{i,k}$ and s_k, would be the multiple of pack sizes of the SKU.

Symbol	Explanation	Symbol	Explanation
i	Store Indicator	C_k^{RDC}	Cost per Case DC Receiving
k	SKU Indicator	C_k^{PADC}	Cost per Pallet DC Putaway
t	Week of the Year	C_k^{ROPDC}	Cost per Pallet DC Replenishment
P_k	Pack Size	C_k^{UP}	Cost per Unit DC Pick
s_k	Threshold before Order is Triggered	C_k^{CP}	Cost per Case DC Pick
Avg	Average of the subject number set	C_k^{Unit}	Unit Cost for SKU ($ per Unit)
StD	Standard Deviation of the subject number set	C_k^{OStore}	Cost per Case Store Order
$Q_k^{On\ Shelf}$	Expected Units on Shelf	C_k^{RStore}	Cost per Case Store Receiving
Q_k^{Unit}	Expected Units Demanded per Week	$C_k^{ROPStore}$	Cost per Case Store Replenishment
Q_k^{Case}	Expected Case Demanded per Week	$C_k^{Store\ Extra}$	Cost per Case Store Extra Handling
$Q_k^{Extra\ Case}$	Expected Extra Case per Week	$C_k^{TTStore}$	Cost per Time Travel from Backroom to Floor
L_k	The number of Cartons in a Layer on a Pallet	$C_{k,t}^{ICC}$	Inventory Carrying Cost per Week
H_k	The number of Layers on a Pallet	$I_{k,t}^{SSOH}$	Initial Shelf Stock
SSM_k	Shelf Space Multiplier	VAR_k	Difference from the mean
z	Z score from the desired service level	**W**	Wages for a colleague per hour

Table 1: Notation

3.4.1 DC Handling

Picking by case will be cheaper than picking by units due to reduced need for action unlike unit picking, where the picker needs to open the case to get to the units, hence consuming more time and thus increasing cost. Overall, DC has four distinct handling, Receiving, Replenishment, and Picking.

3.4.1.1 DC Receiving

This is the cost equation for the DC to receive a case from the carton, using Assumption 2, therefore we deem the cost of handling one unit is proportional. If SKU_k is received in Units, we will look for the proportion of a case it represents.

$$DC\ Receiving\ Cost = \frac{Q_k^{Unit}}{P_k} * C_k^{RDC} \qquad \text{(Eq 5)}$$

3.4.1.2 DC Replenishment, which includes Putaway and ROP

For putaway it has been model as such, where the Expected Sales Demand per Week is converted to carton then divided it by the total number of cartons that a pallet can fit to find out the number of pallets that will be required to be putaway.

$$DC\ Putaway\ Cost = \left(\frac{\frac{Q_k^{Unit}}{P_k}}{L_k * H_k}\right) * C_k^{PADC} \qquad \text{(Eq 6)}$$

As for ROP_k there are differences between Unit Pick or Case Pick, this is because Case Pick Location can fit a full pallet but Unit Pick Location can only fit one-layer of carton SKU_k, hence the remainder of the pallet has to be put back to its original location, except for the last layer on the pallet does not need to be rerack. Thus, capture as such and Eq 3 is not applicable for Eq 8, as this is Unit Pick specific scenario

$$DC\ Replenishment\ for\ Unit\ Pick\ Cost = \left(2 * \left(\frac{\frac{Q_k^{Unit}}{P_k}}{L_k}\right) - \left(\frac{\frac{Q_k^{Unit}}{P_k}}{L_k * H_k}\right)\right) * C_k^{ROPDC} \quad \text{(Eq 7)}$$

As for ROP for Case Picking

$$DC\ Replenishment\ for\ Case\ Pick\ Cost = \frac{Q_k^{Case}}{L_k * H_k} * C_k^{ROPDC} \quad \text{(Eq 8)}$$

3.4.1.3 DC Picking

To model this Expected Demand for the Units and Case was taken and multiplied by the Pick Type Cost.

$$DC\ Unit\ Pick\ Cost = Q_k^{Unit} * C_k^{UP} \quad \text{(Eq 9)}$$

As for Case Picking the equation will be below, and when Eq 8 is used automatically Eq 10 is used.

$$DC\ Case\ Pick\ Cost = Q_k^{Case} * C_k^{CP} \quad \text{(Eq 10)}$$

3.4.2 Store Handling

The store will receive the goods from DC, and bring it to the selling floor for replenishment and if there are extra units, they will have to bring it to the backroom for storage and retrieve it later to replenish the shelf.

For this section a deep dive in to the store's operation and how the two different picking types affect the stores handling cost. The areas that have been taken in to account is ordering, receiving, replenishment and travel time.

For replenishment and travel time, besides the normal replenishment and travel time, also taken in to account for extra handling for additional units and travel time.

3.4.2.1 Store Order Cost

This equation will be model by using the Expected Demand by case and multiply with the Order Cost.

$$Store\ Order\ Cost = \left(\frac{Q_k^{Unit}}{P_k}\right) * C_k^{OStore} \quad \text{(Eq 11)}$$

3.4.2.2 Store Receiving

As for this equation, the Expected Demand by case, if it is in units, it will be divided by its Pack Size and multiply with the Receiving Cost.

$$Store\ Receiving\ Cost = \left(\frac{Q_k^{Unit}}{P_k}\right) * C_k^{RStore} \quad \text{(Eq 12)}$$

3.4.2.3 Store Order Cost

For replenishment, there is two equations, firstly is to calculate the replenishment cost by case at the store to handle the Expected Demand.

$$Store\ Replenishment\ Unit\ Pick\ Cost = \left(\frac{Q_k^{Unit}}{P_k}\right) * C_k^{ROPStore} \quad \text{(Eq 13)}$$

As for extra handling, which is only applicable to Case Pick, because every unit sold is replenish one for one, as for Case, it becomes a MOQ and every order will be at least a pack size of SKU_k.

$$Store\ Extra\ Handling\ Cost = Q_k^{ExtraCase} * C_k^{Store\ Extra} \quad \text{(Eq 14)}$$

3.4.2.4 Store Travel Time, including normal travel time and extra travel time

This element, can be incorporated in to the Store replenishment, however the ability to control this as a separate element was given to Delta.

$$Store\ Travel\ Unit\ Pick\ Cost = \left(\frac{Q_k^{Unit}}{P_k}\right) * C_k^{TTStore} \quad \text{(Eq 15)}$$

As for extra travel time due to excess units during replenishment by case, the cost calculation is per below.

$$Store\ Additional\ Travel\ Cost = Q_k^{Extra\ Case} * C_k^{TTStore} \quad \text{(Eq 16)}$$

3.4.3 Inventory Carrying Cost

In this section, the elements of EOQ, will be examine, where smaller pack size to stores will mean more frequent orders, lesser inventory in the two-echelon supply chain and on the other hand larger pack size equates to lesser orders from store but higher inventory in the system. DC demand for stocks to Supplier, will be the sum of all the stores demand (Wen et al., 2012). Both Stores and DC Inventory Carrying Cost is calculated.

3.4.3.1 Store Inventory Carrying Cost

Each Store has its own Expected Demand however, Shelf Space, Initial Shelf Stock and Threshold of the reorder point is fixed throughout the stores.

$$Store\ Inventory\ Carrying\ Cost = ½ * \left(Q_k^{Unit} + I_{k,t}^{SSOH}\right) * C_k^{Unit} * C_{k,t}^{ICC} \quad \text{(Eq 17)}$$

3.4.3.2 DC Inventory Carrying Cost

For DC Inventory, it would be a summation of all stores Expected Demand and since each store is independent of the other, we can use the add up all the variance and convert it to standard deviation for total Expected Demand. Once Standard Deviation is established, along with the DC Service Level to Store, the safety stock required was calculated.

$$DC\ Inventory\ Carrying\ Cost = ½ * \left[\sum\left(Q_k^{Unit}\right) + \sqrt{\sum\left(Var_{i,k}\right)} * z\right] * C_k^{Unit} * C_{k,t}^{ICC}$$

(Eq 18)

3.4.4 Total Relevant Cost

From Equation 19, this part of the equation $\sqrt{\sum\left(Var_{i,k}\right)} * z$ will create BWE, as the more variable it is the quantity, it will be amplified by the z score.

3.4.4.1 Total Relevant Cost for Unit Pick

Moving forward in joining the equation together, when Unit Pick, the expected cost for SKU_k in DC and $Store_i$ is a summation of the above equation:

Equation 5, 6, 7 and 9 for DC handling:

$$DC\ Cost\ Unit\ Pick_k = \frac{Q_k^{Unit}}{P_k} * C_k^{RDC} + \left(\frac{\frac{Q_k^{Unit}}{P_k}}{L_k * H_k}\right) * C_k^{PADC} + \left(2 * \left(\frac{\frac{Q_k^{Unit}}{P_k}}{L_k}\right) - \left(\frac{\frac{Q_k^{Unit}}{P_k}}{L_k * H_k}\right)\right) * C_k^{ROPDC} + Q_k^{Unit} * C_k^{UP} \quad \text{(Eq 19)}$$

Equation 12, 13, 14, 15, 16, 17 and 18 for Store Handling and Store Inventory Carrying Cost:

$$Store\ Cost\ Unit\ Pick_k = \left(\frac{Q_k^{Unit}}{P_k}\right) * C_k^{OStore} + \left(\frac{Q_k^{Unit}}{P_k}\right) * C_k^{RStore} + \left(\frac{Q_k^{Unit}}{P_k}\right) * C_k^{ROPStore} + Q_k^{ExtraCase} * C_k^{Store\ Extra} + \left(\frac{Q_k^{Unit}}{P_k}\right) * C_k^{TTStore} + Q_k^{ExtraCase} * C_k^{TTStore} + ½ * \left(Q_k^{Unit} + I_{k,t}^{SSOH}\right) * C_k^{Unit} * C_{k,t}^{ICC} \quad \text{(Eq 20)}$$

Therefore, the total relevant cost would be a summation of Equation 19, 20 and 21

$$Total\ Relevant\ Cost\ for\ Unit\ Pick_k = DC\ Cost\ Unit\ Pick_k + \sum\left(Store\ Cost\ Unit\ Pick_{k,i}\right) + ½ * \left[\sum\left(Q_{k,i}^{Unit}\right) + \sqrt{\sum\left(Var_{k,i}\right)} * z\right] * C_k * C_{k,t}^{ICC} \quad \text{(Eq 21)}$$

3.4.4.2 Total Relevant Cost for Case Pick

When Case Pick, the expected cost for SKU k in DC and Store i is a summation of the following equations, where we use Equation 3, to update the model:

Equation 5, 6, 8 and 10 for DC handling,

$$DC\ Cost\ Case\ Pick_k = Q_k^{Case} * C_k^{RDC} + \left(\frac{Q_k^{Case}}{L_k * H_k}\right) * C_k^{PADC} + \frac{Q_k^{Case}}{L_k * H_k} * C_k^{ROPDC} + Q_k^{Case} * C_k^{CP} \quad \text{(Eq 22)}$$

Equation 12, 13, 14, 15, 16, 17 and 18 for Store Handling and Store Inventory Carrying Cost

$$Store\ Cost\ Case\ Pick_k Q_k^{Case} * C_k^{OStore} + Q_k^{Case} * C_k^{RStore} + Q_k^{Case} * C_k^{ROPStore} + Q_k^{ExtraCase} * C_k^{Store\ Extra} + Q_k^{Case} * C_k^{TTStore} + Q_k^{ExtraCase} * C_k^{TTStore} + ½ * \left(Q_k^{Case} + I_{k,t}^{SSOH}\right) * C_k^{Case} * C_{k,t}^{ICC} \quad \text{(Eq 23)}$$

Thus, the total relevant cost would be summation of Equation 22, 23, and 24

$$Total\ Relevant\ Cost\ for\ Case\ Pick = DC\ Cost\ Case\ Pick_k + \sum\left(Store\ Cost\ Case\ Pick_{k,i}\right) + ½ * \left[\sum\left(Q_{k,i}^{Case}\right) + \sqrt{\sum\left(Var_{k,i}\right)} * z\right] * C_k^{Case} * C_{k,t}^{ICC} \quad \text{(Eq 24)}$$

3.4.5 Store Order Cost

To summarize, the objective function will be to find a MIN.

MIN:

$$Total\ Relevant\ Cost = DC\ Cost_k + \sum\left(Store\ Cost_{k,i}\right) + DC\ Inventory\ Carrying\ Cost_k \quad \text{(Eq25)}$$

Above are the core elements which are included in the model hence with it in Section 3.4.4.1 for unit pick and Section 3.4.4.2 for case pick, the 14 SKUs data is run and compared in Section 4.1. As for Section 3.4.5, the results of the optimization would be in Section 4.2.2.

4 Results

Within this section, data will be broken down by SKU to show its contribution towards the sales of the company (Section 4.1). After that, the result of the findings is presented in Section 4.2, which is broken down in to two parts, where Section 4.2.1, is the result when comparing Case Pick to Unit Pick, and as for Section 4.2.2, is the result of Optimum Pack Size for each of the 14 SKUs.

4.1 Data

The obtained data from Delta, and they provided us 26 weeks of actual sales data for 14 SKU, where Week 1 is 1st of January 2018, also given the relevant KPI to our study, eg. the number of cases pick per hour, which than was converted to cost per case handled, also the Inventory Carrying Cost. To gain a better understanding of the given data set the exploration is as follows.

Despite having 67 stores, not all stores are selling the total range of products, as a matter of fact only two of the 14 SKUs are carried in all stores as seen from Table 2. However, our model is robust enough to accommodate different number of $Store_i$ for different SKU_k, the analysis is done store by store and summing up their results. Looking at the Table 2, the Min and Max Average Sales per Week per Store is derived from dividing each stores' total sales by 26 Weeks and comparing them between stores.

SKU	Number of Stores Selling the SKU	Total Sales in Units for 26 Weeks	Avg Sales Per Week Per Store	Min Avg Sales per Week Per Store	Max Avg Sales per Week Per Store
SKU_1	67	44,604	25.6	8.3	76.9
SKU_2	66	29,405	17.1	3.6	53.4
SKU_3	67	24,149	13.9	3.6	49.5
SKU_4	58	13,235	8.8	4.2	12.4
SKU_5	65	8,550	5.1	1.7	11.2
SKU_6	57	8,265	5.6	2.8	7.2
SKU_7	64	7,864	4.7	0.9	15.3
SKU_8	56	3,414	2.3	0.9	7.4
SKU_9	55	1,789	1.3	0.1	3.5
SKU_{10}	57	1,780	1.2	0.4	2.7
SKU_{11}	58	1,447	1.0	0.1	3.2
SKU_{12}	57	1,416	1.0	0.5	3.1
SKU_{13}	52	563	0.4	0.2	0.9
SKU_{14}	57	460	0.3	0.0	0.7

Table 2: SKU Breakdown by number of Stores, total and average sales in units

Also, from the data 80% of total sales of all 14 SKUs are actually coming from 36 stores, and the highest selling store accounts for 4.8% total sales, and the slowest moving stores are the convenient stores as seen in Table 4, which in total contributes to 0.1% after adding up 5 stores, despite the low sales inclusion of the store would be reflective of the real-world situation. As SKU's pack size would be require to accommodate all store needs.

Figure 2, shows the breakdown by Total Sales by SKU_k, going from Highest Total Sales for all SKUs Store to the lowest. The general observation of a reducing volume from left to right for the x-axis. Another observation, would show despite SKU_1 is the top SKU in our data set, it does not conclude that it will be the number 1 SKU in all store.

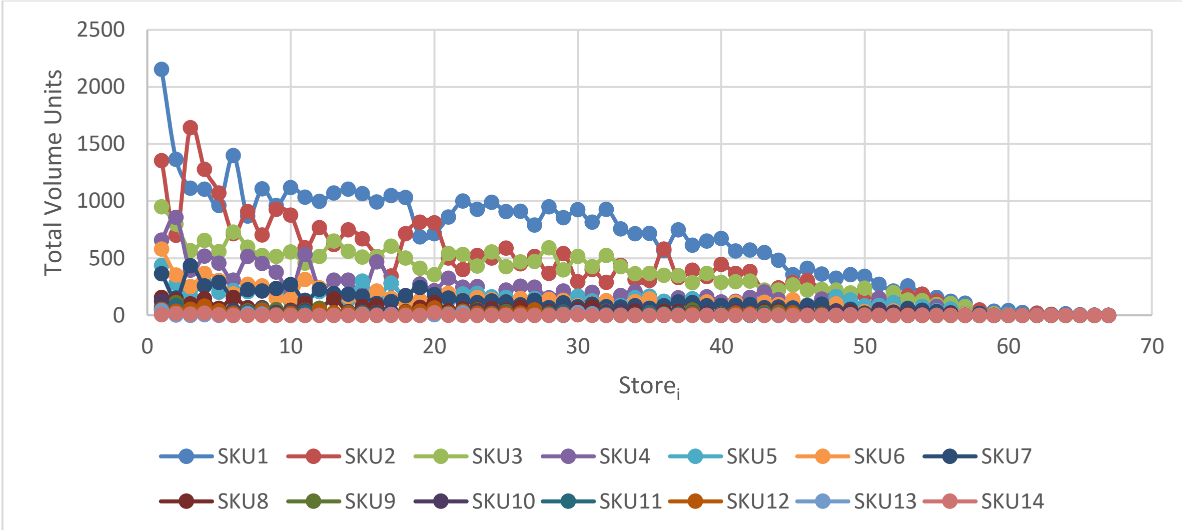

Figure 2: Total Sales by SKU by Total Sales Stores

There are multiple instances in Figure 2, where SKU_2 were selling more units than SKU_1. This can be cross reference with Figure 3 below which show the Top 3 volume store for each SKU. $Store_1$ has 8 out of the 14 SKUs, that sells the most in this store compared to the rest of the stores. Also noticeable is $Store_{20}$, has 3 SKUs where it was Top 3 by volume sold in their store, which were SKU_{14} at number 1, SKU_{12} at number 2, and SKU_{11} at number 3. This emphasizes the complexity of the problem as it is not as simple as $Store_1$, will always sell the most units regardless of SKU.

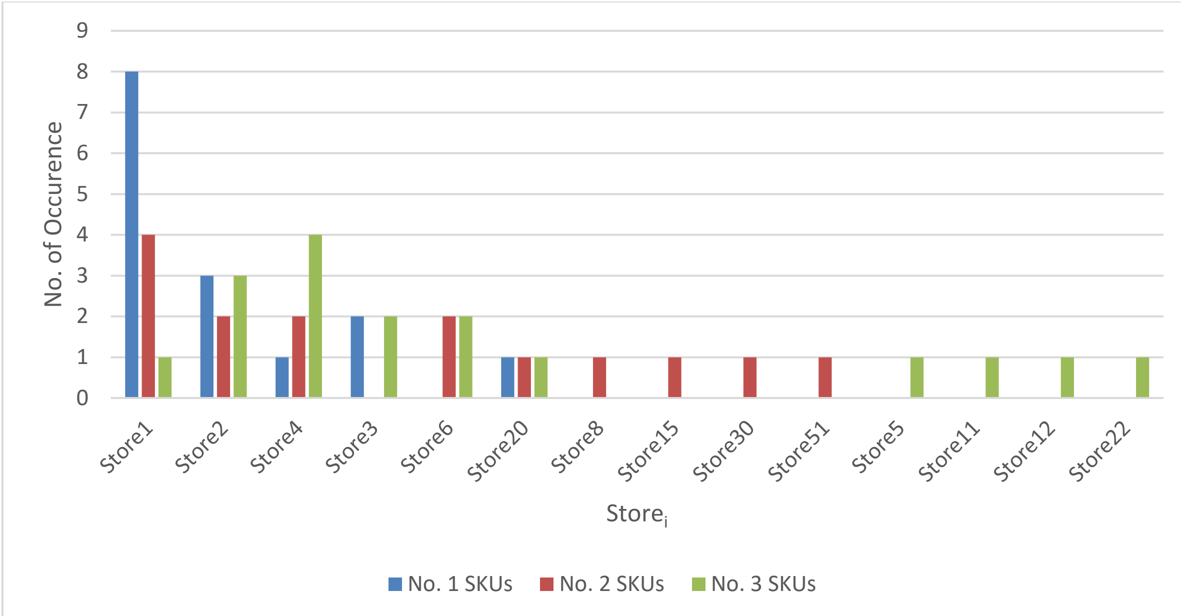

Figure 3: Number of Top SKUs by Store

Moving on to Figure 4, shows the Actual Sales Demand for the Top 5 SKU, that accounts for 84.0% of the total sales of 14 SKUs. Also, in the figure there are 8 prominent peaks for the 3 SKUs. To explain the peaks, in Malaysia salary is paid at the last week of the month, if not latest by 7th of the next month. Due to salary week, consumers have the spending power to buy groceries, in this case shampoo and also Delta does their part to attract consumers by running promotions.

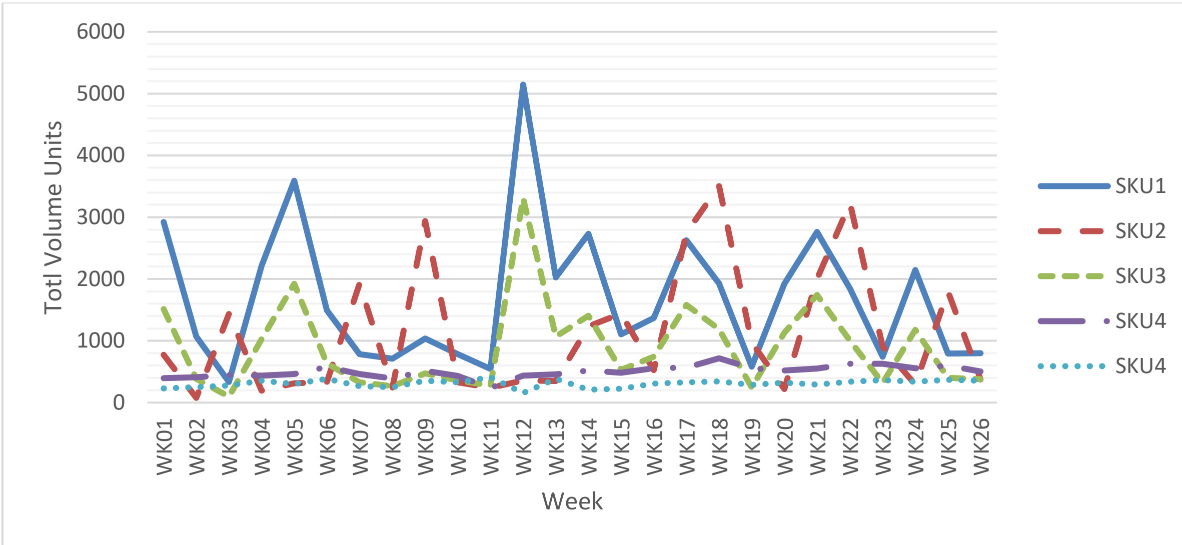

Figure 4: Top 5 SKU Sales Volume by Week

In Figure 5, compares each store's Average Volume Units per Week for the 14 SKUs, and its Standard Deviation on the primary axis and on the secondary axis is the Coefficient of Variation (CoV). There is a significant increase in CoV from store $Store_{57}$, due to high variation in demand pattern at store. Such a variation increases the difficulty in allocating the right quantity of stocks for the store, to balance between on shelf availability and inventory carrying cost. Our model in this paper do not take individual store pain and address them individually, but rather as a total business entity.

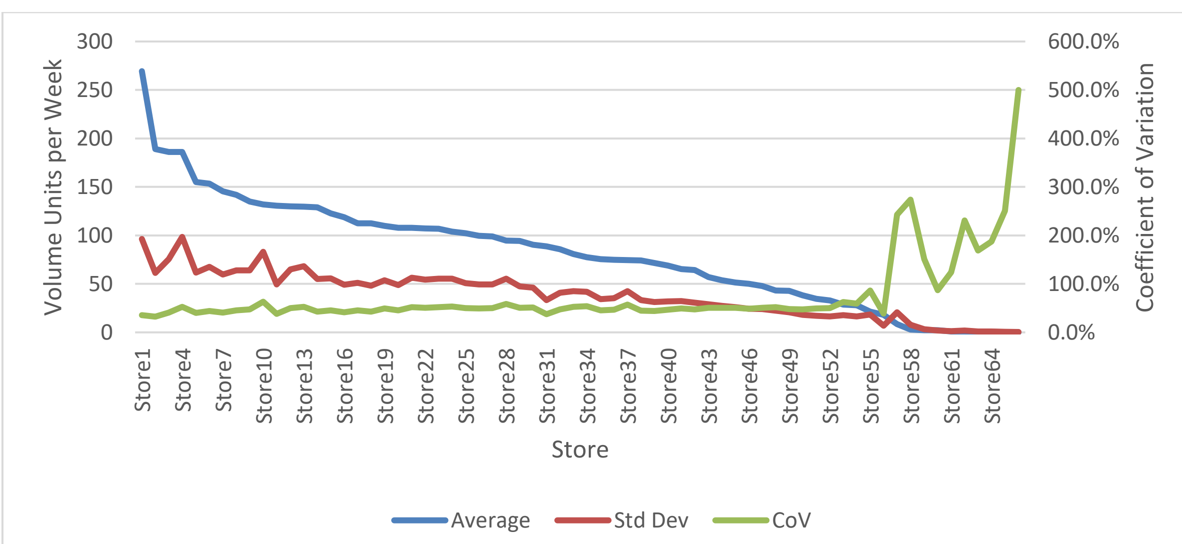

Figure 5: Average, Standard Deviation & CoV by Store

4.2 Results

Moving on to the results, the fixed settings we have put in place is

- Shelf Space Multiplier is at 1.5 times of P_k
- Initial Shelf Stock at the beginning of the system is set at 1.5 times of P_k
- Threshold for reorder, s_k is to 0.5 P_k of remaining shelf stocks,
- DC Service Level to store is 95%.

With all the parameters set Equation 22 and 24 was run, and compared the difference, the results are discussed as below.

4.2.1 Case Pick versus Unit Pick

From Table 3, DC Picking cost the most in the overall DC Handling Cost, this is true for both the type, Unit Pick and Case Pick, as it is 29.5% and 8.2% of the Total Relevant Cost respectively, which is about 4.5 times more expensive for DC to pick by Units instead of by Case. The second most expensive in DC Handling is DC ROP, for Unit Pick it is 3.7 times more expensive compared to Case Pick is because of the double handling observed as the gravity flow rack can only take in one layer of the pallet Tier configuration.

There is a higher cost for DC Receiving for case pick, as since the pack size is minimum order quantity (MOQ) constraint (Yan, Robb, & Silver, 2009) to stores. In turn more purchases have to be done from supplier and at the same time more loading to stores. By receiving less cases, Unit Pick shows a smaller DC Inventory Carrying Cost as compared to Case Pick.

As for the stores the most expensive activity is the Store Replenishment of shelf space followed by Store Average Travel for replenishment. Unit Pick has no Extra Handling and Additional Travel, this is due to the fact that store can order the exact quantity required to replenish the shelf for SKU_k sold at $Store_i$ rom the DC. Overall, for the store level, Store Total Relevant Cost does not show much differences, except for Store Handling, as Case Pick will cause the stores to have additional handling and in store travel cost due to Delta's staff will need to walk back and forth to replenish the same SKU.

From DC and Store Total Relevant Cost, Unit Pick has a 44.8% versus a 55.2% ratio and as for Case Pick the ratio is 24.6% to 75.4%. Despite the ratio for Store is vastly more in Case Pick, the actual difference in Store Handling Cost compared to Unit Pick is about 17% more. Minimal difference in Store Inventory Carrying Cost, as the stores only order what is required for sales.

The main justification for Unit Pick would be the savings in DC Inventory Cost and the volume send to stores will be a closer amalgamation to demand compared to cases.

	Breakdown by dollar value		Breakdown by % contribution	
Activity	**Unit Pick**	**Case Pick**	**Unit Pick**	**Case Pick**
DC Receiving Cost	4.55	4.68	0.4%	0.5%
DC Putaway Cost	12.42	12.42	1.1%	1.3%
DC ROP Cost	46.04	12.42	3.9%	1.3%
DC Picking Cost	347.13	77.45	29.5%	8.2%
DC Handling Cost	410.14	106.98	34.8%	11.3%
DC Inventory Carrying Cost	116.94	126.61	9.9%	13.3%
DC Total Relevant Cost	527.08	233.59	44.8%	24.6%
Store Ordering Cost	51.50	52.99	4.4%	5.6%
Store Receiving Cost	9.79	10.07	0.8%	1.1%
Store Replenishment Cost	163.10	167.81	13.8%	17.7%
Store Extra Handling Cost	-	26.14	0.0%	2.8%
Store Average Travel Cost	81.55	83.90	6.9%	8.8%
Store Additional Travel Cost	-	26.14	0.0%	2.8%
Store Handling Cost	305.94	367.05	26.0%	38.7%
Store Inventory Carrying Cost	344.78	347.80	29.3%	36.7%
Store Total Relevant Cost	650.71	714.86	55.2%	75.4%
Total Relevant Cost	1,177.79	948.45		

Table 3: Total Relevant Cost for each Pick Type and % Contribution

In Table 4, it gives in-depth view of the % difference when SKU_k is Case Pick as compared to Unit Pick. The differences for Total Relevant Cost ranges from savings of 31.3% to additional cost of 5.1%, our observation is savings reduces as Average Sales per Week reduces. Diving deeper in to the table, Case Picking always generates savings for DC Total Handling, -55.7%, on the other hand the opposite can be observed, additional cost of 9.9% for Store Total Handling, and this is justifiable, as DC is able to move more quantity per pick, but when that case reaches to the store, it might need to be handled multiple times before it is emptied out depending on the rate of sales for the SKU_k, and the Net Impact of the change from Unit Pick to Case Pick is a savings of -19.5%.

SKU_k	Avg Sales Unit per Week	DC Total Relevant Cost	Store Total Relevant Cost	Total Relevant Cost
SKU_1	1715.6	-62.1%	4.9%	-31.3%
SKU_2	1131.2	-51.2%	7.1%	-22.6%
SKU_3	929.0	-61.5%	6.8%	-28.2%
SKU_4	509.9	-59.8%	6.3%	-22.9%
SKU_5	329.5	-58.6%	20.9%	-14.0%
SKU_6	318.3	-57.3%	9.5%	-19.7%
SKU_7	302.6	-47.7%	12.5%	-10.0%
SKU_8	131.5	-44.5%	19.2%	-0.9%
SKU_9	68.8	-33.0%	16.8%	5.8%
SKU_{10}	68.5	-25.4%	16.8%	9.1%
SKU_{11}	55.7	-25.6%	19.4%	11.0%
SKU_{12}	54.5	-22.1%	17.4%	10.7%
SKU_{13}	21.7	-9.2%	16.4%	11.5%
SKU_{14}	17.9	3.7%	5.2%	5.1%
Total	5654.4	-55.7%	9.9%	-19.5%

Table 4: The % of Cost Savings when Case Pick over Unit Pick by SKU

From Table 4, SKU_8 and SKU_9, Total Relevant Cost moves from Net Savings of -0.9% to Net Cost of 5.8%, this points out that the system is able have an equilibrium state, where the Total Relevant Cost difference is RM0, and the implication is SKU_k can be pick as Case or Unit without additional cost to the total system.

DC Inventory Carrying Cost and Store Total Handling Cost is increasing while relatively unchanged for Store Inventory Carrying Cost from SKU_1 to SKU_{14}, the explanation can be found at Table 5, and also the fact that pack size acts as a MOQ constraint (Yan, Robb, & Silver, 2009) for Stores. As Average Sales Unit per week reduces, the Stock Cost per Week increase as we move from Unit Pick to Case Pick, this is purely due more units are being distributed to stores per week, and also supports the findings that supplier delivers more product when SKU_k are under Case Pick.

Safety Stock Cost per week is increasing, this is due to the sales variability of between stores as seen in Figure 5, as a store will only order once the inventory level drops to s_k level and below, another contributing factor is the rate of sales differ from one store to another, despite the general population does use shampoo, consumer is able to choose their preferred brand, either based on brand loyalty or price point or even is because of both, which result in delayed purchases. Despite the alarming percentages by SKU_k the overall increase of Stock Cost to our system is 8.3%.

4.2.2 Optimum Pack Size

An extension to this paper, a Pack Size Optimization was done to further understand, the implication on the Total Relevant Cost. Method used was Excel Solver, in Excel 2019, and the method chosen is Evolutionary, as there are various equations that uses MIN and ROUNDUP function, the Answer and Population Report can be found in Appendix B.

From Table 5, the results of optimization, shows the general trend the lower the Average Sales Unit per Week, the smaller pack size it should be. From the result, only SKU_6 has been suggested to maintain the current pack size and as for SKU_{14}, suggested to be pack in Case Size of 1, effectively means this SKU should be single picked.

		Case Pick				Optimize Pack Size				% Difference Optimize over Case			
SKU_k	**Avg Sales Unit per Week**	**Pack Size**	**DC Total Relevant Cost**	**Store Total Relevant Cost**	**Total Relevant Cost**	**Pack Size**	**DC Total Relevant Cost**	**Store Total Relevant Cost**	**Total Relevant Cost**	**Pack Size**	**DC Total Relevant Cost**	**Store Total Relevant Cost**	**Total Relevant Cost**
SKU_1	1715.6	12	57.80	136.30	194.10	13.0	56.26	136.92	193.18	8.3%	-2.7%	0.4%	-0.5%
SKU_2	1131.2	12	61.57	130.59	192.16	11.0	62.63	128.94	191.58	-8.3%	1.7%	-1.3%	-0.3%
SKU_3	929.0	12	31.73	83.69	115.42	14.0	30.23	84.18	114.41	16.7%	-4.7%	0.6%	-0.9%
SKU_4	509.9	6	17.27	57.59	74.86	9.0	13.25	60.01	73.26	50.0%	-23.3%	4.2%	-2.1%
SKU_5	329.5	12	11.53	43.04	54.57	9.0	12.60	40.40	53.00	-25.0%	9.2%	-6.1%	-2.9%
SKU_6	318.3	6	11.18	37.00	48.18	6.0	11.18	37.00	48.18	0.0%	0.0%	0.0%	0.0%
SKU_7	302.6	12	17.35	62.57	79.91	7.0	19.22	58.41	77.63	-41.7%	10.8%	-6.6%	-2.9%
SKU_8	131.5	12	6.15	28.48	34.63	7.0	6.79	25.51	32.30	-41.7%	10.5%	-10.4%	-6.7%
SKU_9	68.8	12	3.87	23.65	27.52	6.0	4.17	21.20	25.38	-50.0%	8.0%	-10.3%	-7.8%
SKU_{10}	68.5	12	4.25	29.70	33.95	4.0	4.78	25.95	30.73	-66.7%	12.3%	-12.6%	-9.5%
SKU_{11}	55.7	12	3.46	24.25	27.70	4.0	3.91	20.79	24.70	-66.7%	13.1%	-14.3%	-10.9%
SKU_{12}	54.5	12	3.62	26.79	30.42	5.0	3.76	23.51	27.27	-58.3%	3.9%	-12.3%	-10.3%
SKU_{13}	21.7	12	1.86	10.14	12.00	4.0	1.90	8.82	10.72	-66.7%	2.5%	-13.1%	-10.7%
SKU_{14}	17.9	12	1.94	21.08	23.02	1.0	1.87	20.04	21.92	-91.7%	-3.6%	-4.9%	-4.8%
Total	5654.4		233.58	714.86	948.45		232.56	691.68	924.24		-0.4%	-3.2%	-2.6%

Table 5: Comparison between Case Pack Size and Optimize Pack Size and its % Difference to Total Relevant Cost

In terms of savings for SKU_1, SKU_2 and SKU_3, it might not translate to real life savings as a study need to be conducted on the implication to Supplier's cost. Another point for consideration is if cases are pack in to Odd number of units eg. 5, 7, 11, and 13, how would the case look like, and also would it translate in to air space in the case. Consistent with the results from Table 4, smaller case size, will increase Cost for DC and a decrease for Store, since there is only one DC compared against 67 stores, having it complicated in the DC, would translate to savings at the Store level, as duplication of jobs is being lessen in the stores.

	Total Relevant Cost			% Difference over	
SKU_k	**Unit Pick**	**Case Pick**	**Optimize**	**Unit Pick**	**Case Pick**
SKU_1	282.36	194.10	193.18	-31.6%	-0.5%
SKU_2	248.12	192.16	191.58	-22.8%	-0.3%
SKU_3	160.73	115.42	114.41	-28.8%	-0.9%
SKU_4	97.11	74.86	73.26	-24.6%	-2.1%
SKU_5	63.46	54.57	53.00	-16.5%	-2.9%
SKU_6	59.98	48.18	48.18	-19.7%	0.0%
SKU_7	88.82	79.91	77.63	-12.6%	-2.9%
SKU_8	34.96	34.63	32.30	-7.6%	-6.7%
SKU_9	26.01	27.52	25.38	-2.4%	-7.8%
SKU_{10}	31.12	33.95	30.73	-1.2%	-9.5%
SKU_{11}	24.95	27.70	24.70	-1.0%	-10.9%
SKU_{12}	27.48	30.42	27.27	-0.8%	-10.3%
SKU_{13}	10.76	12.00	10.72	-0.4%	-10.7%
SKU_{14}	21.92	23.02	21.92	0.0%	-4.8%
Total	1,177.79	948.45	924.24	-21.5%	-2.6%

Table 6: Total Relevant Cost Overview

Just like SKU_1, SKU_2 and SKU_3, the last 3 SKUs as seen from Table 6, should be Unit Pick as optimizing the case size might not translate to real life savings. From Table 6, even after optimizing the case size, with savings for the top 7 SKUs is double digits from unit picking it.

From the results in Section 4.2.1 and 4.2.2, we move to the next Section 5, as it would be on the discussion on the implication of the results towards Delta and what actions they can take.

5 Discussion

In this section, is about summarizing our findings for Delta, and how their management will be able to use our model for their business decision (Section 5.1). Also discussed is the limitation of this paper (Section 5.2) mainly based around the tool accessible to our research, and the limited data of 26 weeks. And finally, in Section 5.3, what are the potential area for future studies on as an extension of our research paper.

5.1 Summary of Results

5.1.1 Case Pick versus Unit Pick

It is better to Case Pick from the DC, and if the items is creating too much handling at the store due to low sales volume, we recommend to discontinue the SKU.

5.1.1.1 DC Handling

In the DC Handling section of the cost, handling by case will reduce the cost, as there will be less double handling, and it is easier for the DC colleagues to pick the items.

5.1.1.2 Store Handling

For the Store Handling Cost, it is the reverse compared to the DC, where the slower moving SKUs will incur increase handling cost mainly due to extra units from the cases.

5.1.1.3 Inventory Carrying Cost

Most of the additional Inventory Carrying Cost is coming from the DC, this is due to more inventory is being carried at any point in time when SKUs are Case Pick compared to Unit Pick, resulting in increased Inventory Carrying Cost.

5.1.2 Optimum Pack Size Result Discussion

Most of the savings are generated from the slower moving SKUs, as those are the items that requires to have a pack size change. As in Section 5.1.1, we recommended to discontinue the SKU, if the Total Relevant Cost is more to Case Pick when compared to Unit Pick, however Delta could explore this option with supplier, to deliver in smaller pack size.

5.1.2.1 Store Handling

Overall, the Inventory Carrying Cost reduces, as the new pack size of the case fits the demand of the stores better. Hence lesser safety stock would be required to be kept at the DC.

5.2 Limitations

The limitation here is we were not able to scale to the study for more SKUs, as Delta has 16,000 SKUs. This is partly due to the limitation as excel and its solver, can only run up to 200 decisions variable. Other limitation faced is that the number of weeks provided was only 26 weeks, as we are not able to observe a full year trend for the 14 SKUs.

5.3 Future Research

There is still room for future research, which will be an extension in to an end-to-end supply chain study, as certain factors were not taken in to account such as:

- Lead Time for both Supplier to DC and DC to Stores
- No double handling for ROP during Unit Pick
- Accounting for Vendor Failure
- Stock loss due to damages and theft
- Total Relevant Cost to include Supplier's Cost to Optimize the carton
- Study on the breakeven point of all SKUs
- Automation to reduce human intervention
- Customer's correlation on buying behavior against price sensitivity

5.4 Conclusion

In conclusion of this research paper, while each store has their own demand variability one pack size, would simplify the DC Operations, which is already complex. If a SKU is found to be too costly to pick it would be recommended to discontinue the item, however at the cost of variety to customers. Each tradeoff has to be weight out clearly, and based on the business strategy, the business has to decide on the direction and approach that also encompasses their values and mission statement.

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