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Resource Evaluation and Planning at Local Distribution Centre of a Beverage Company

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CONTENTS

Page

THAI ABSTRACT ... iv

ENGLISH ABSTRACT ... v

ACKNOWLEDGEMENTS ... vi

CONTENTS ... vii

1. INTRODUCTION ... 4

1.1 Background of the research ... 4

1.2 Case company ... 7

1.3 Sale Office Warehouse (SOW) ... 9

1.4 Overall workflow of SOW ... 11

2. STATEMENT OF THE PROBLEM ... 15

3. OBJECTIVE OF RESEARCH ... 23

4. SCOPE OF STUDY ... 24

5. LITERATURE REVIEW ... 25

6. METHODOLOGY ... 28

7. SIMULATION MODEL AND VALIDATION ... 31

7.1 SIMULATION MODEL ... 31

7.1.1 Arrival control ... 33

7.1.2 Inbound ... 34

7.1.3 Inventory ... 35

7.1.4 Outbound ... 36

7.2 VALIDATION ... 38

7.2.1 Process validation ... 38

Page

7.2.2 Input validation 39

7.2.3 Output validation 40

7.3 LIMITATION OF MODEL 41

8. RESOURCE MANAGEMENT WITHIN WAREHOUSE OPERATION 42

9. SENSITIVITY ANALYSIS FOR DEMAND CHANGING...48

10. SUPPLY CHAIN IMPROVEMENT 52

11. SUMMARY AND SUGGESTION..55

REFERENCES...56

VITA 70

Table of figure

Figure 1 Logistic cost and Sale value....5

Figure 2 Marginal Logistic Cost....5

Figure 3 Food and Beverage industry of Thailand....7

Figure 4 Hub and Spoke model : Nationwide level, (TBL 2015)....8

Figure 5 Hub and spoke model: Regional level....8

Figure 6 Scope of SOW....9

Figure 7 Layout of RDC (Buriram)....10

Figure 8 Working environment of case study....11

Figure 9 SOW's scope of work and work flow....12

Figure 10 Detail steps of WMS....13

Figure 11 Workflow of Forward Logistic and Equipment usage....14

Figure 12 Workflow of Backward Logistic and Equipment usage....14

Figure 13 Cost and Budget performance....15

Figure 14 Sale volume 2015....16

Figure 15 Sale Voume of individual SOW....17

Figure 16 Sale volume and Forklift....18

Figure 17 Forklift and Truck capacity....19

Figure 18 Sale x KM. and Truck capacity....19

Figure 19 Sale volume and Forklift....20

Figure 20 On-Time-Delivery Performance of Buriram....21

Figure 21 Marginal Operational cost of Buriram (Baht per Litres)....21

Figure 22 Score Rating of Operation cost....21

Figure 23 Simulation model of warehouse activity....31

Figure 24 Time control 33

Figure 25 Inbound (part1) 35

Figure 26 Inbound (part2) 35

Figure 27 Inventory 36

Figure 28 Outbound part 1 37

Figure 29 Outbound part 2 37

Figure 30 Distribution of loading process 38

Figure 31 T test for loading process 39

Figure 32 Validation of model's output 40

Figure 33 Paired T-Test of model's output 40

Figure 34 Comparison of forklift's working hour (Collected and simulated) 41

Figure 35 Paired T-Test of forklift's working hour 41

Figure 36 Daily demand of Buriram area 42

Figure 37 Marginal total cost 43

Figure 38 Delivery competency 44

Figure 39 Forklift Utilization 44

Figure 40 Contour Plot of % Pass 45

Figure 41 Contour graph of total operation cost 47

Figure 42 Additional sale volume VS Optimal operation cost 48

Figure 43 Actual daily order 53

Figure 44 Daily order in flat month pattern 53

Figure 45 Daily order in flat week pattern and Weekly distributed pattern 53

Figure 46 Percentage of direct operation expense and saving 54

Figure 47 Saving from demand adjustment 54

Table of equation

Equation 1 Equation of Total cost....29

Equation 2 Equation of total cost in term of fix cost and variable cost....46

Table of table

Table 1Table of variable and constant of total cost....29

Table 2 Main Parts and grouped activities 32

Table 3 Process priority....32

Table 4 Historical data of inbound and outbound volume....34

Table 5 Expression of processes from collected data 39

Table 6 List of constant and variable....46

Table 7 Unit cost of warehouse equipment....46

Table 8 Comparison between actual and optimized condition 47

Table 9 Effect of Additional sale volume to optimal operation cost 49

Table 10 Table of demand sensitivity....50

Table 11 Alternative investment plan....51

Table 12 Table of cost related to flat month pattern....54

Table 13 Table of cost related to flat week pattern....54

1. INTRODUCTION

1.1 Background of the research

In globalization era, every companies have to compete and compare themselves, not just with local competitors, but also international companies. There is less constrain and barrier for international company to expand into other continental markets. Each company needs to improve their competiveness continuously to survive. Last decade, manufacturing companies in local area can have advantages based on cost of delivery and product handling. Local companies have used them as main barriers from new entries to maintain their market share. The delivering and handling costs have played significant role for product competitiveness, especially commodity product.

The commodity product refers to product we need to consume or purchase in normal day life. General characteristics of commodity product are predictable and steady demand, economic price, price sensitive, big batch of production and low profit margin. Without effective supply chain technology, production cost combines with high logistic cost will result in high retail price and reduce sale volume significantly.

Study of Atchavarattavorn (2015) showed that logistic cost is a significant portion of sale value, which is 8.06% in year 2013. Logistic cost can be categorized in to three main components which are inventory holding cost, transportation cost and administrative cost.

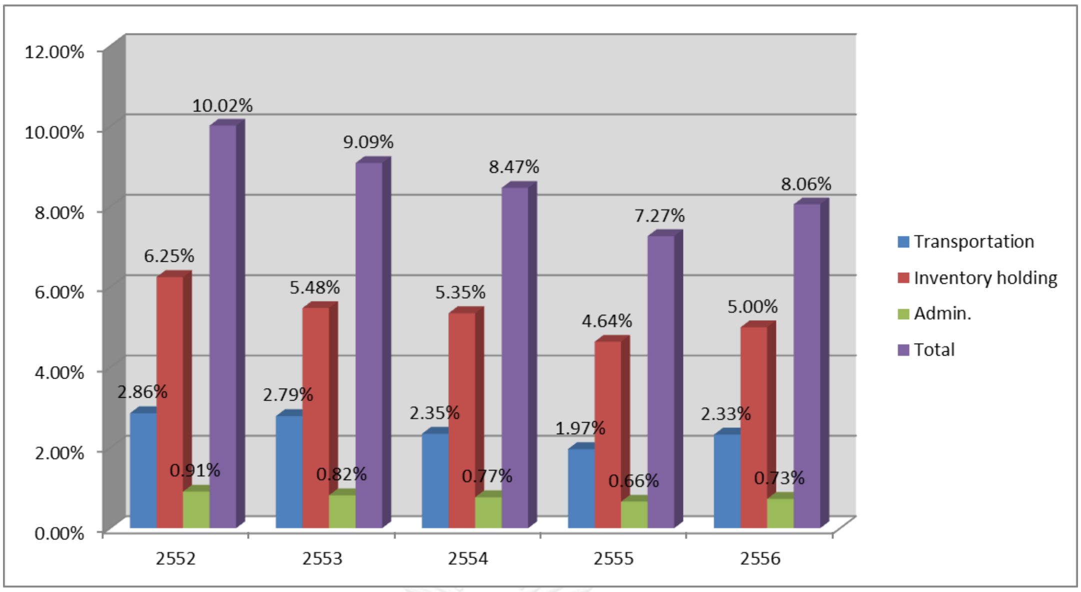

Figure 1 Logistic cost and Sale value

(Atchavarattavorn 2015)

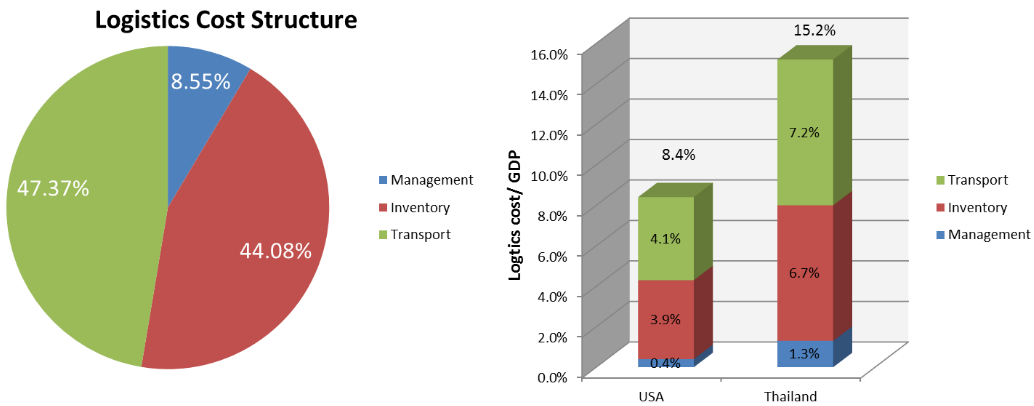

Figure 2 Marginal Logistic Cost

(Atchavarattavorn 2015)

With new technology in logistics; for example, inventory management, demand forecasting, backhauling and hub-and-spoke; operation costs and expenses can be trimmed and reduced to improve cost efficiency and increase profit. However, there is no one-fit-all pattern of distribution for all businesses. Each strategy will be chosen based on some specific characteristics of product, such as size, unit weight, price, product life and customer responsiveness, etc. For example, IT products generally have higher value compared to commodity products. On the other hand, IT products need additional product handling and humidity protection. Some products, such as cloth and luxury products, need to concentrate on customer responsiveness; otherwise it might be risky to lose opportunity of being sold and end up as a dead stock. Those conditions will be considered as significant factors to determine best solution for each scenario. We also can apply some technologies to identify suitable location to set up distribution centre in order to optimize cost efficiency.

In beverage business, there are many main factors which need to be concerned. To be more specific, this study would like to define beverage products as liquid consumable products with limited product life; for example green tea, club soda, carbonated drink, beer, and alcoholic drink. Beverages are canned and bottled consumable products, which can be consumed and purchased in everyday life. Thus, the prices of beverage product are considered to be slightly higher than those of the commodity product, which result in low profit margin. While it needs intensive care for product handling for its container, which is glass bottle and aluminium can packaging. Due to its small profit margin, beverage product needs high sale volume to cover its initial long-term investment for land, factory and manufacturing machines etc. Report of the National food institute (2015), Figure 3, showed the demand during 1994 to 2009 had increased continuously in Thailand, which provide possibility to beverage companies in expanding their sale volume and competitiveness by mass production.

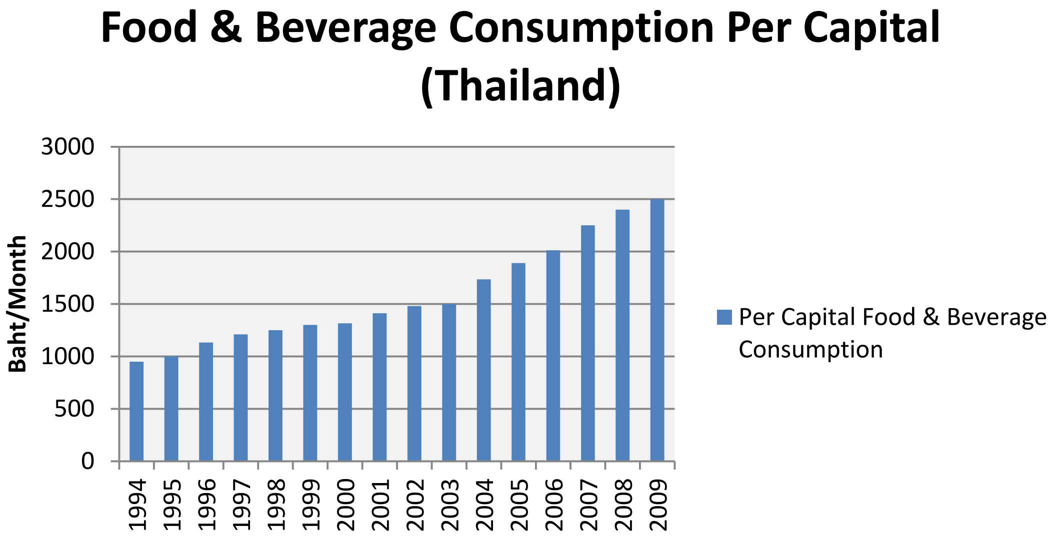

Figure 3 Food and Beverage industry of Thailand

1.2 Case company

This case study starts from one of beverage logistic company, which is a subsidiary company of one of a major beverage company in Thailand. Role of this logistic company is providing supply chain services to main company and related subsidiaries, such as transportation, replenishing, warehousing and inventory management. This company has responsibility in various products, for example green tea, beer, club soda, Thai whiskey, vodka, and canned carbonated drink, etc. Those products can generate high volume of sale to satisfy customers demand across nationwide. The most typical type of package is in form of paper carton stacking on standardized pallet. Each pallet is designed to have similar standard pattern in term of weight and height, which can be handled by the same equipment (forklift) and reduce complexity of product handing method.

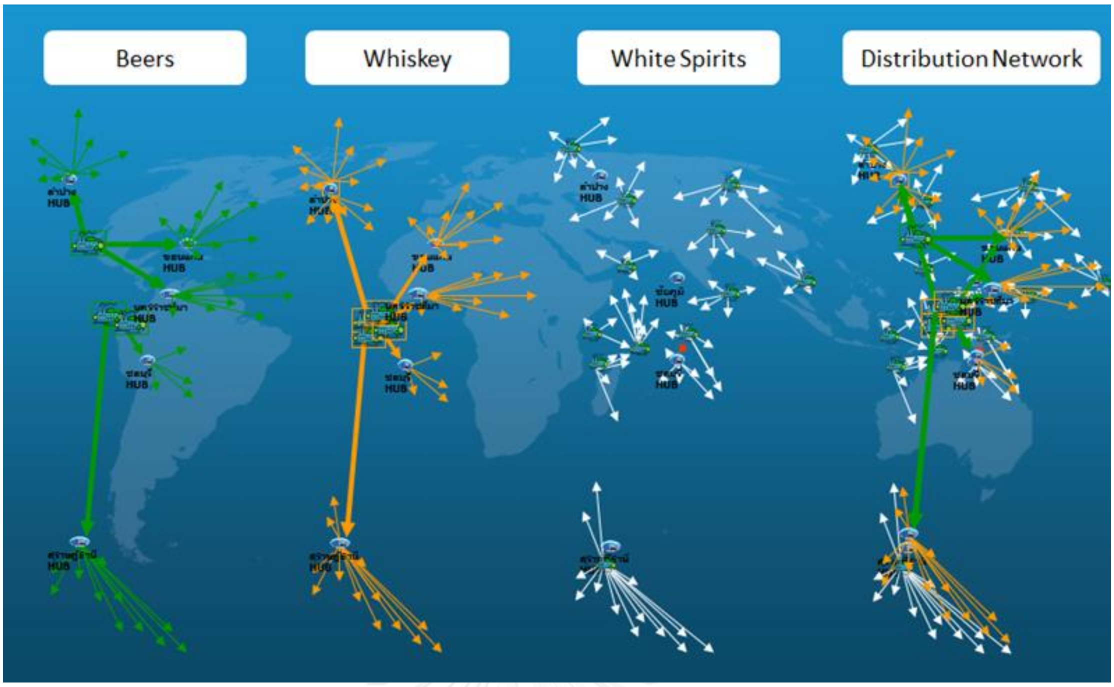

Figure 4

Hub and Spoke model : Nationwide level, (TBL 2015)

Scope of TBL responsibility begins by receiving products from end of production line in each factory, then delivery all products to Distribution centres (DC) in each region (Figure 4).

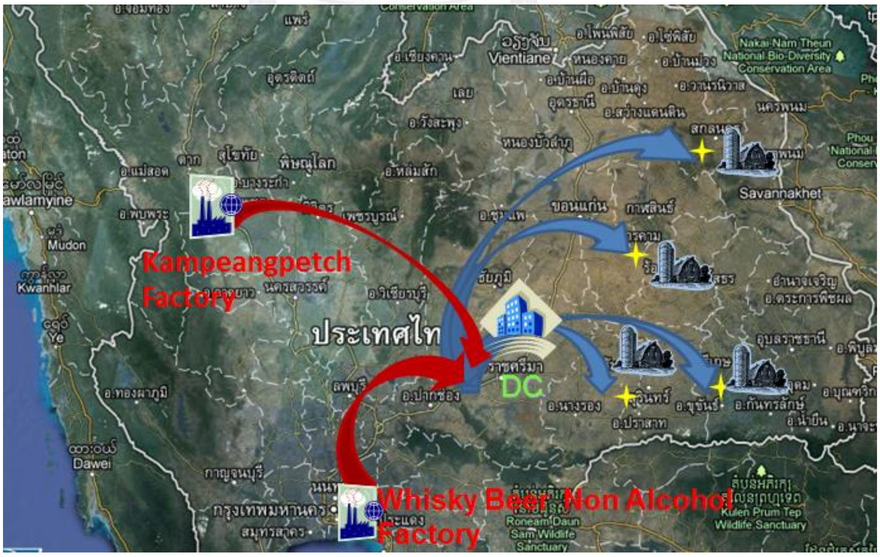

Figure 5

Hub and spoke model: Regional level

(TBL 2015)

Figure 5, Distribution Centre (DC) will act as a buffer warehouse and consolidated area for regional hub-and-spoke model. All products will be stocked and managed by WMS (Warehouse Management System). Each Stock Keeping Unit (SKU) will be classified and assigned for specific stock location based on type, packaging, popularity, expiration date and sale volume.

1.3 Sale Office Warehouse (SOW)

Inventory in Distribution Centre will be used as replenishing stock for smaller warehouse within region, which is called "Sale Office Warehouse (SOW)"; for example, KORAT DC will supply stock for North-eastern region SOWs, such as, Buriram SOW, Khon Kaen SOW, Ubon Ratchathani SOW and etc. The amount will be vary based on sale volume of each SOW. By this system, DC can control stock level in each area, arrange product within region with equal quality and expiration date, and also reduce dead stock in location during low sale volume period. Each DC will deliver products by their own fleets, prioritized by stock level and customer requirements.

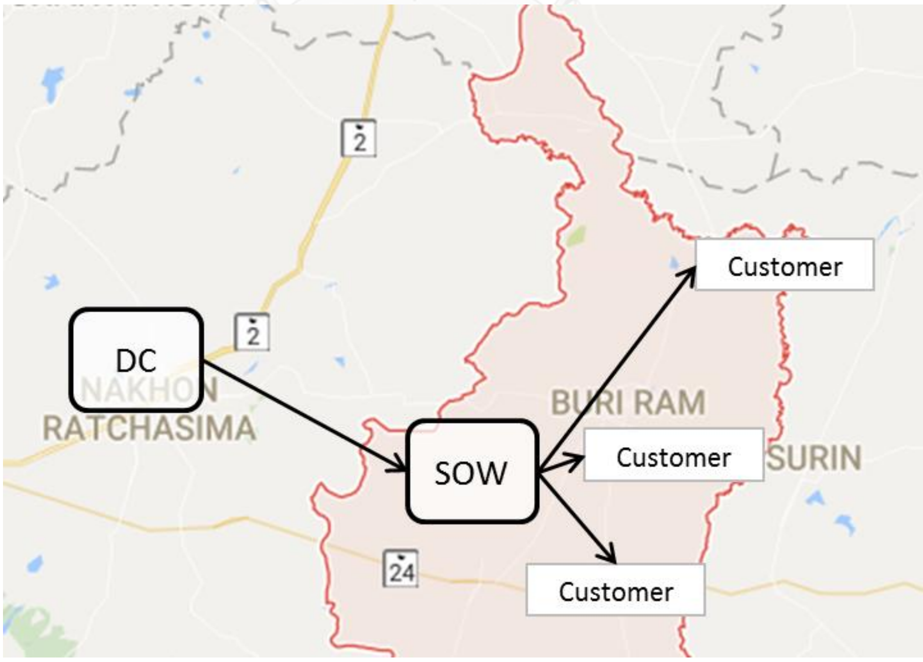

Figure 6 Scope of SOW

Each SOW also acts as a buffer for other layers of hub-and-spoke model in distribution system, (Figure 6). The location of each SOW is located in local area to improve customer responsiveness. When receiving order from customers, each SOW needs to deliver product within specific time, normally within 24-hour. The aim of company is 100% on-time delivery. Thus, company products need to be stocked in local warehouse for purpose of fast responding to customer order.

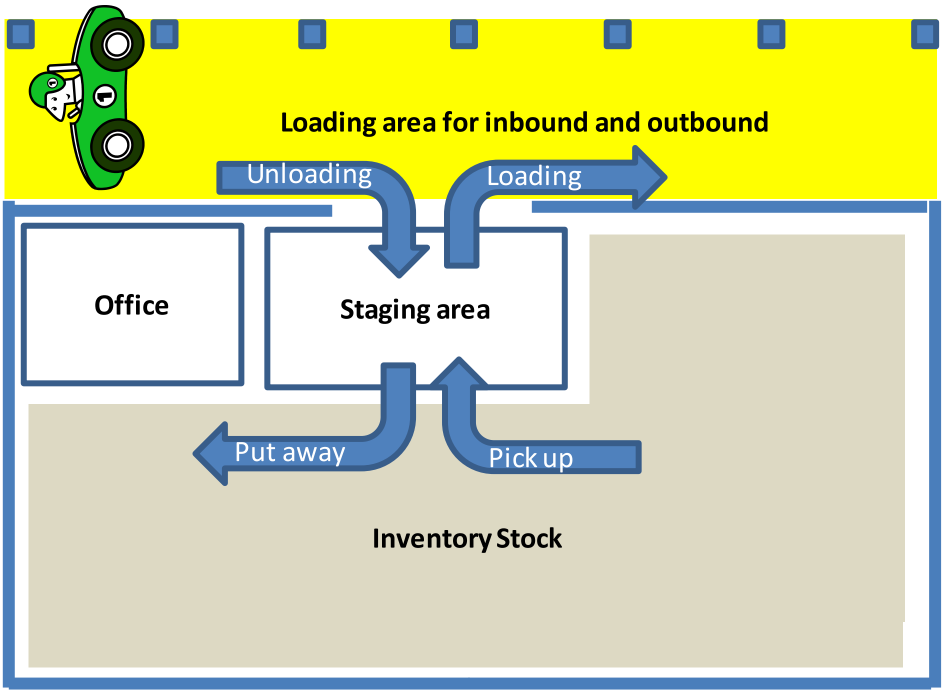

Figure 7 Layout of RDC (Buriram)

Buriram SOW, warehouse of case study, is one among 66 warehouses positioned across country. The company normally choses location based on many criteria, such as distance from customer, amount of area, rental fee, truck banding area and etc. Due to these limitations actual warehouse might not able to support best practice of general warehouse process, as shown in Figure 8.

Figure 8 Working environment of case study

1.4 Overall workflow of SOW

The responsibility of SOWs will begin after receiving products at loading area in their warehouse, which delivered by DC truck. All activities related to product handling can be categorized into 5 main steps (TBL 2015)

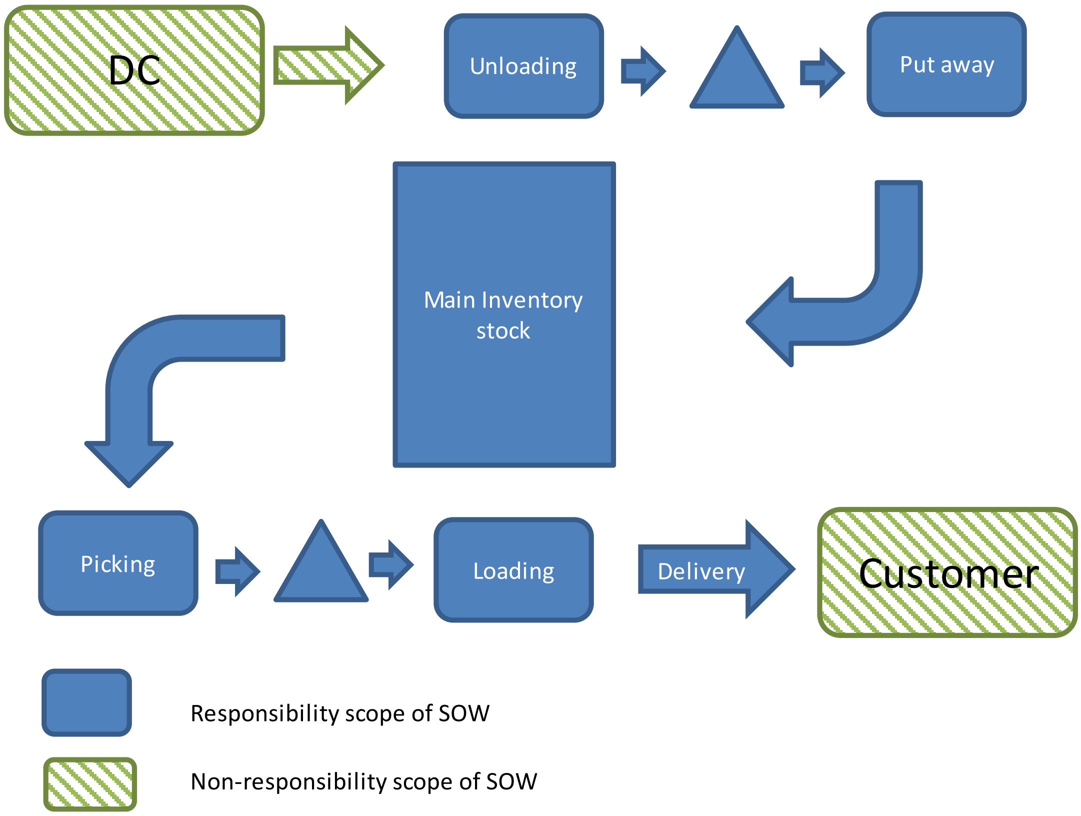

Figure 9 SOW's scope of work and work flow

Pre-inventory step

Unloading; this process is unloading finished good from truck, then put it down on loading area. After this step, the truck will be available to return to DC and can be assigned for next delivery task. In this process finished good will not be stocked in assigned stock area yet. This step will increase availability for inbound truck for further utilization.

Put away; this process will begin after forklift unloads all products from DC or there is no more available space at unloading area. Forklift will deliver all finished good to assigned location in main inventory area of SOW.

Post-inventory step

Picking; this process will occur when receiving order from customer, generally in the early morning. Forklift will pick up finished good based on picking list of Delivery Order (DO) from main inventory. WMS (Warehouse Management System) will select each pallet of finished good based on specific condition, such as allowance of product life, product lot number, and FEFO (First Expiration First Out), etc.

Loading This step will relate to 2 main resource types which are forklift and outbound truck. After this process, products are ready to be delivered to customer.

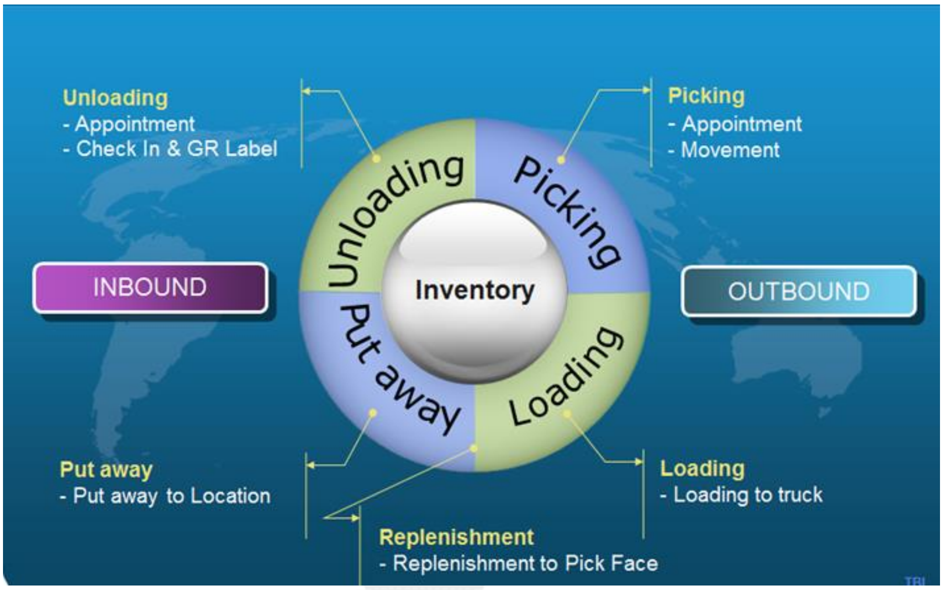

Figure 10 Detail steps of WMS

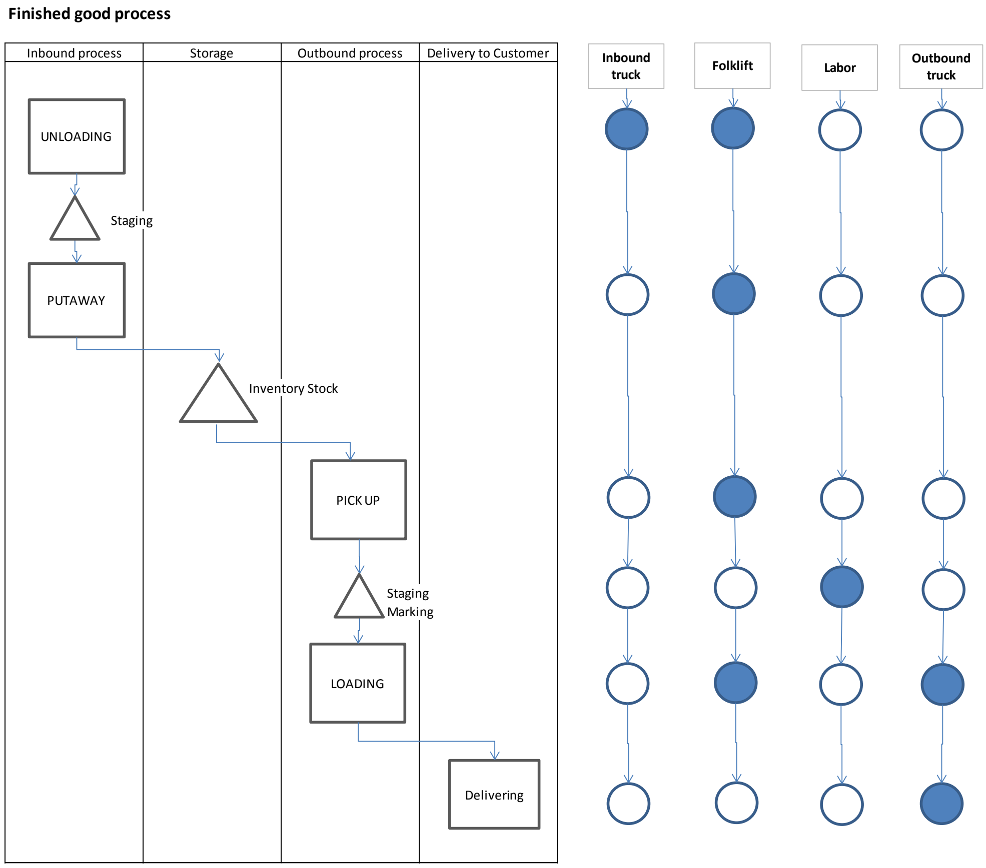

Figure 11 Workflow of Forward Logistic and Equipment usage

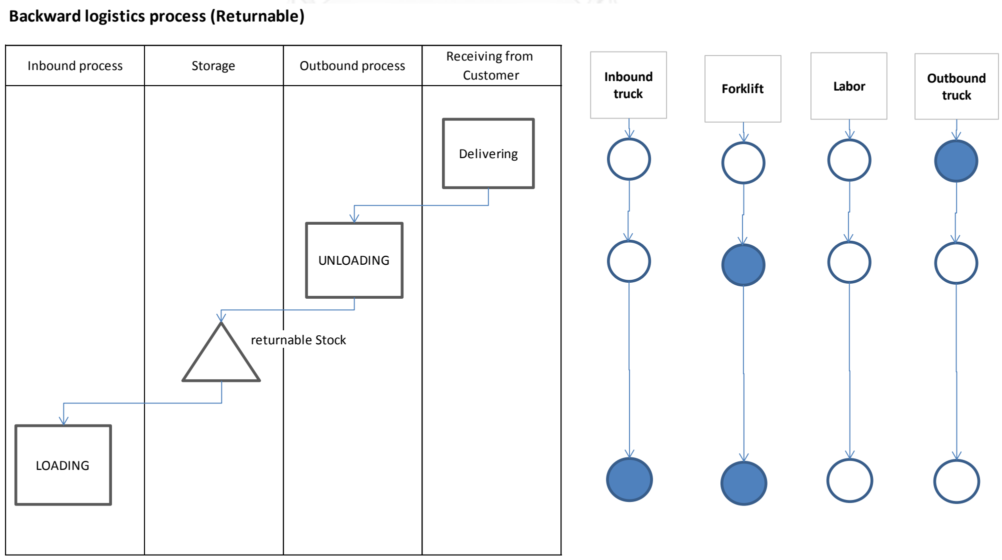

Figure 12 Workflow of Backward Logistic and Equipment usage

2. STATEMENT OF THE PROBLEM

For logistic service providers, there are certain performance measures that can indicate company competitiveness. Among them, customer responsiveness and marginal logistics cost commonly are on the top of the list. Apart from those measures, there can be such measures as on-time delivery, product handling quality, and delivery fulfilment, etc.

Since the logistics company, especially those who operate cross-dock logistics, do not own inventory, they do not keep stock as the manufacturing companies. To cope with demand fluctuation, they, instead, need to plan for appropriate amount of spare service capacity.

However, if the logistics company possesses too much spare capacity, it could face with excessive investment, underutilized equipment, and eventually these will lead to unnecessarily high cost. Capacity planning for the logistics companies is therefore one of the most important decisions to be made. For example, SOW with higher sale volume should have more forklift than smaller one.

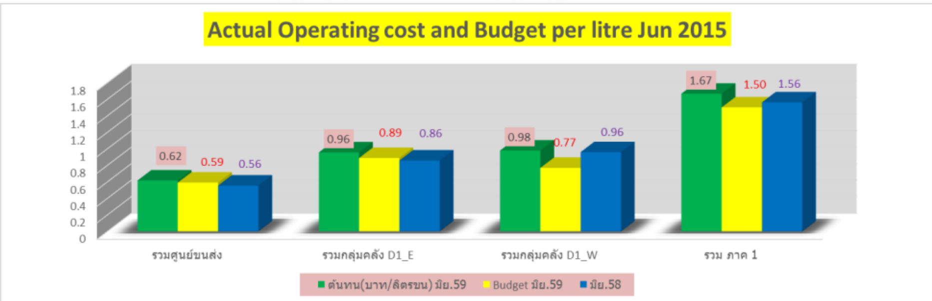

Figure 13 Cost and Budget performance

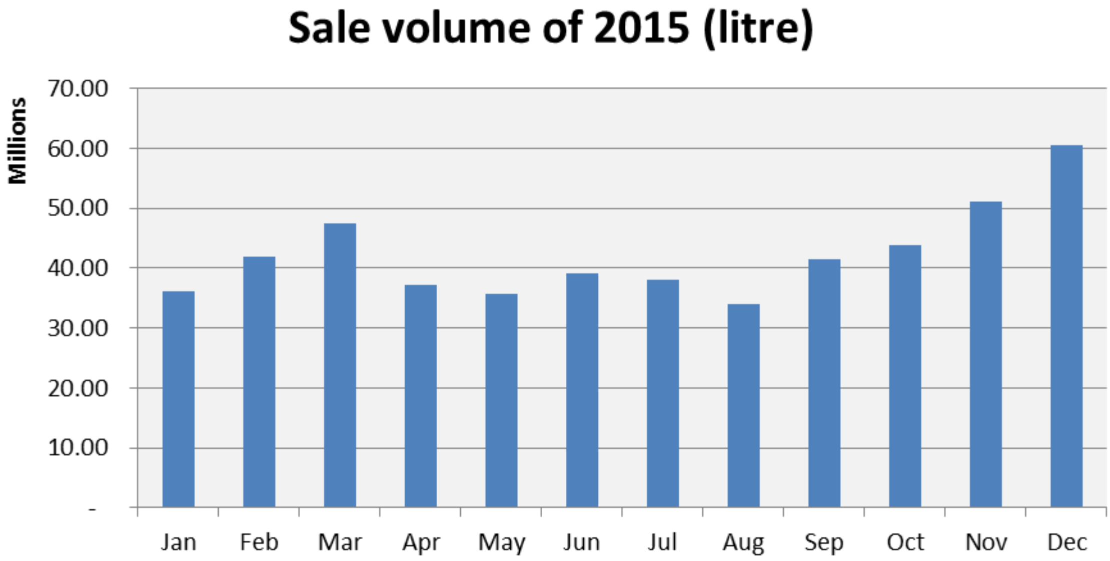

Figure 14 Sale volume 2015

From Figure 13, it showed information of cost budget compare to actual performance of June 2016. The budget was estimated based on performance of previous year with some adjustment of expected improvement. However, Figure 14 and Figure 15 showed inconsistent sale volume during first half year of 2016. Due to some variation of sale, actual operation cost per litre was hard to control and end up with higher expense than budget.

Under the current practice of the case company, the budget cost is calculated based on the previous year cost. Certainly, sales volume is one of the main cost drivers. If the sales volume remain similar to the previous years, then, the budget cost be calculated with good accuracy. However, that is not always the case. Sales volume can dramatically vary year by year. This can result in wide inaccuracy gap between budget cost estimate and actual cost

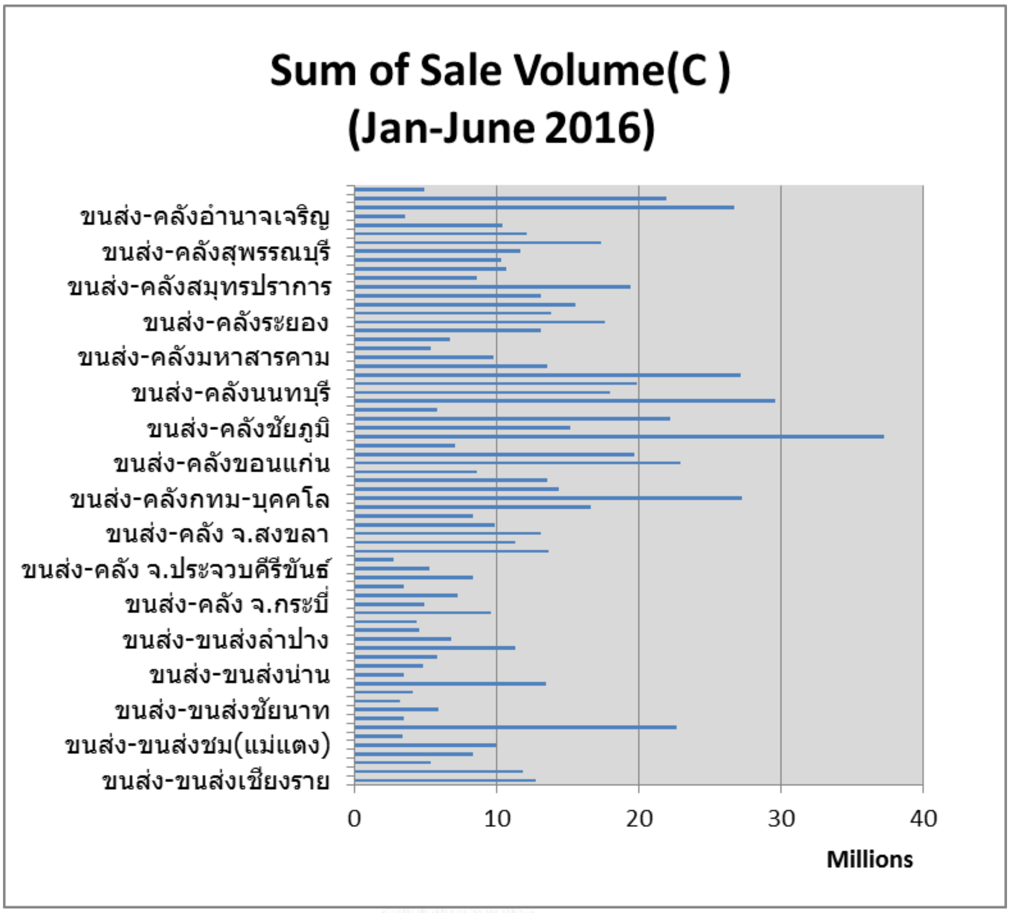

Figure 15 Sale Voume of individual SOW

Sale Office Warehouse has been established on purpose of serving customer responsiveness. However, each SOW will have to manage its annual budget to achieve cost efficiency simultaneously. To achieve both goals, which are customer responsiveness and cost efficiency, SOW needs to carefully make capacity plan that allows the company to responsively serve customer while maintain low investment and operating cost. Situated in wide variety of locations, SOWs are faced with different settings; sales volume, transport condition, distance to customer, customer requirements, etc. The sale volume varies based on customer demand in local area, which explains why each SOW potentially needs individual equipment planning.

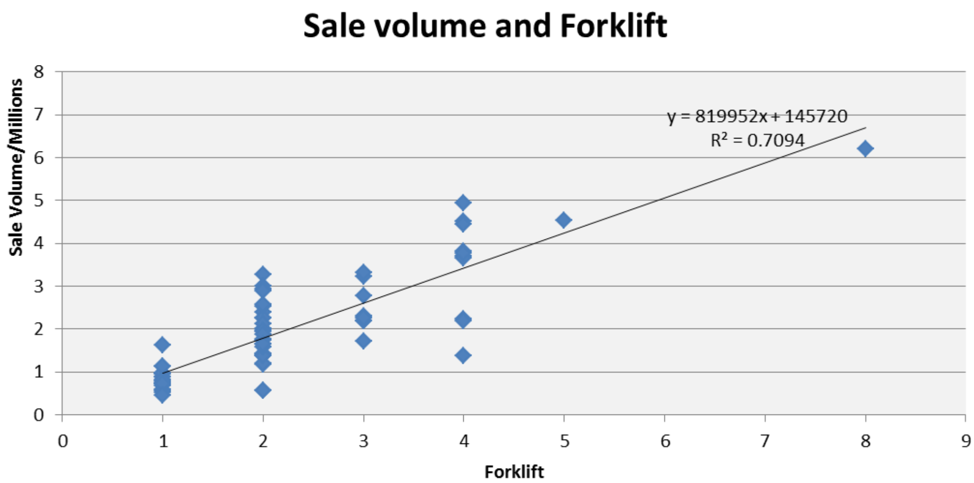

Figure 16 Sale volume and Forklift

Another factor related to direct performance is planing on equipment. Each SOW have unique characteristic in term of distribution. SOWs are vary in sale volume, distance to customer and warehouse capacity.

However, each investment suppose to be planned based on requipment from actual operation theoritically. Some of assumptions are

- Number of forklift should relate to number of truck, because forklift's duty is load and unload finished good from truck. However, Figure 17 showed relation of forklift and truck with R-square value of 0.53, which can imply both factor have some related influence between still not high value.

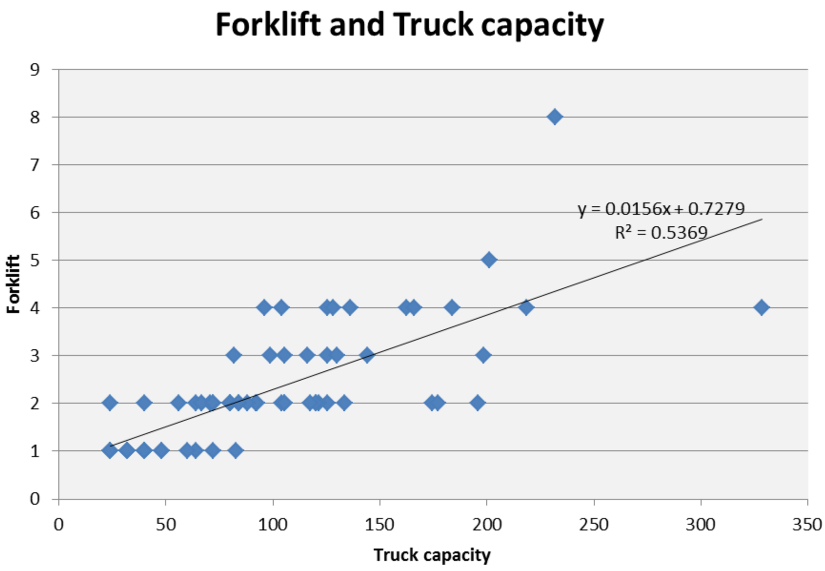

Figure 17 Forklift and Truck capacity

Truck capacity, which is number of truck multiple by its cargo, should be related to delivering volume which are sale volume and distance between warehouse and customer. Graph from Figure 18 showed R-square at value of 0.81 between truck and sale volume. Both factors have high relationship, but still have some space for adjustment.

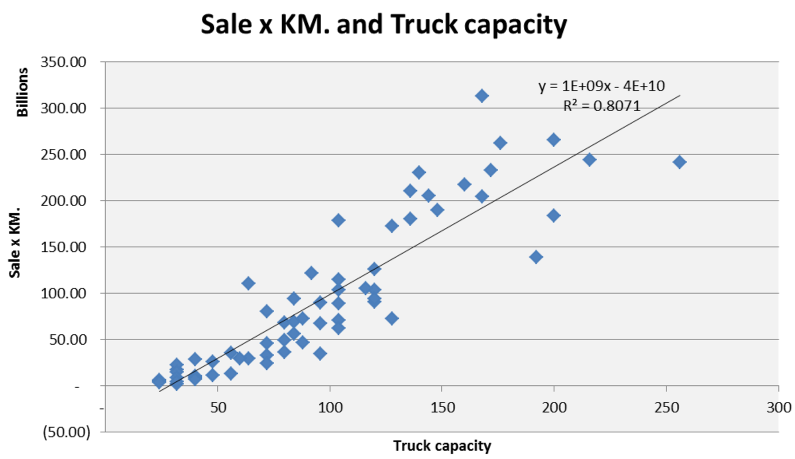

Figure 18 Sale x KM. and Truck capacity

The amount of forklift and truck capacity should vary according to sale volume. High sale volume must require higher forklift and truck to pick up and delivery finished good. From Figure 19, the range of sale volume between 1.8 -3.2 million litre have 2, 3 and 4 forklifts without any pattern.

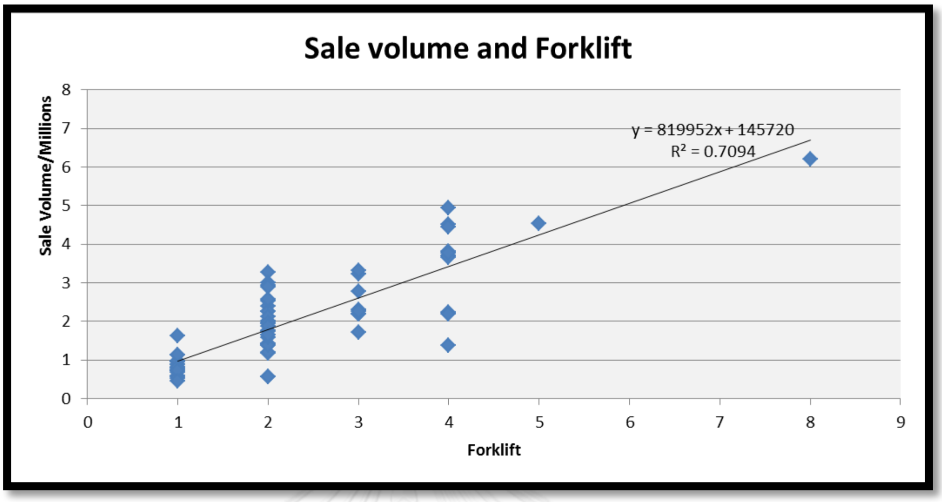

Figure 19 Sale volume and Forklift

Figure 17,Figure 18 , and Figure 19 showed that there are some relationship among those number, but R-square level are all between 0.5-0.8, which support the assumptions. However, after interview wiith some operators, the specific method from numerical equipment still can not be identified. The most common method are trial and error. They will try to operate for some period of time, then add some more equipment to improve their delivery performance. By this method, investment cannot be adjusted fast enough to match with sale volume in incoming future. The evidence are R-square values, which showed that it have some space for improving better performance and cost efficiency.

To understand pattern and current problem of this opertion ,this study will go into operation detail of specific operation site, Buriram SOW, in both aspect of operation performance and cost control.

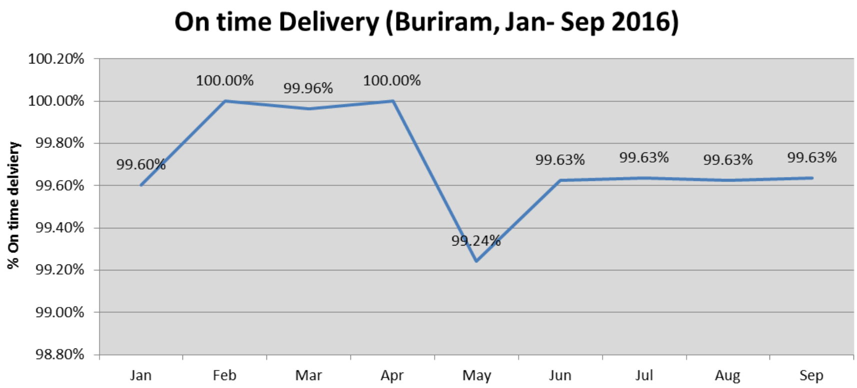

Figure 20 On-Time-Delivery Performance of Buriram

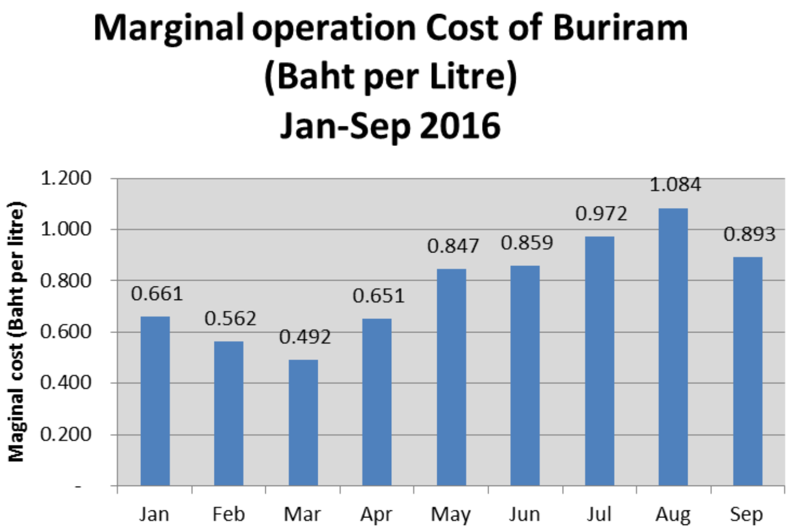

Figure 21 Marginal Operational cost of Buriram (Baht per Litres)

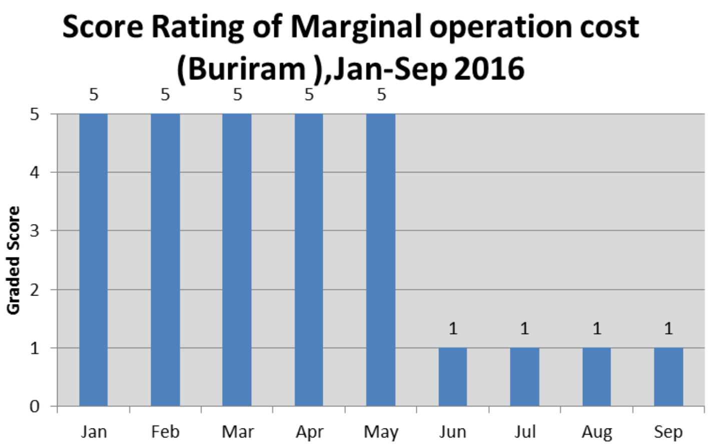

Figure 22 Score Rating of Operation cost

Figure 20 show historical data of Buriram performance. During Jan – Sep 2016, Percentage of On time delivery can be maintained above 99.7% from target of 100%. The performance of on time delivery tend to decline after May, even it still maintain percentage above 99%. However, to maintain overall performance of on time delivery, Buriram SOW needed to compensate by additional operation cost which is shown in Figure 21, Buriram's marginal operation cost was controlled under 0.67 baht per litre, between January and April. However, marginal cost has increased significantly after May, which results from lower demand while using same amount of outsourcing service. These increasing operation costs resulted in poor evaluated score of Buriram after May 2016.

3. OBJECTIVE OF RESEARCH

Objective of this study are

1. To design the logistics service capacity for Burirum SOW that meets performance requirements with least cost. The service capacity, in this research, can mainly be defined by the number of trucks and forklifts of an SOW.
2. The decision process developed for Buriram SOW can be applied to other SOWs with reasonably high accuracy and least modification effort.

4. SCOPE OF STUDY

The purpose of this study is mainly to find optimal solution of investment in Sale Office Warehouse (SOW), which is the closest contact point to customers. The scope of this study will include only investment on warehouse's equipment, which are forklift and outbound truck. SOW's responsibility does not include inbound management and customer demand forecasting. This study will focus only on Buriram SOW, in hope that the decision process obtained can be used for other SOWs.

The condition of workplace will be simulated based on current working situation. The demand of customer will be the actual sales volume in the previous year. The simulation will also study effect of priority of inbound and outbound fleet. The input factors of this study are

- Amount of forklift
- Amount of 10 wheeler outbound truck
- Amount of 6 wheeler outbound truck
- Volume of daily sale

Expected output factors from this study are

- On-time delivery performance
- Total fixed cost of warehouse equipment

On-time delivery performance is one of indicators for distributional service provider. The conditions of success delivery are both cost effective and on-time delivered

5. LITERATURE REVIEW

Due to globalization era, information can be communicated and transferred between continents within single second. It gives opportunity for marketing and advertising consumer product to expand their customer base with rapid speed. However, possibility and time duration of delivery product to the customer are also other lethal criteria to support sale. Distribution will reflect directly to important characteristic of product, which can be detected by consumer; for example, life cycle of product, damaged package, and retail price of product. The delivery cost will be calculated and added back to retail price, which is the price paid by customer. Main income of the company will be highly impacted from Price-sensitive customer, whose purchase product on condition of price rather than brand of the same product category. It becomes Trend for food and beverage distribution business, (Lewis 2016), to apply new approach to reduce warehousing cost, such as

- AS/RS picking system (Automated storage and retrieval system)
- WES (warehouse execution system linked to warehouse management system)
- Warehouse automation and space utilization
- Robotic warehouse equipment

Those are some new approach to reduce logistic cost, especially labour cost which is quite high in US. , compared to other countries.

The responsiveness of product is also another important factor for sale volume of company. For customer, there are many similar products with different brand available to be purchased in any local market. Even though customer is seduced to purchase some specific brand, they will just purchase any other product if that favourite brand is not available on market shelf. It can be concluded that both time and cost are critical conditions for business.

To reduce cost of logistic, there are many approaches depend on specific scope of study. The supply line is an integration of many components. Khataie, Defersha et al. (2010) studied order management incorporating activity-based costing.

The study result that if company can negotiate or make some agreement with customer to rearrange customer demand, it can increase some profit margin about 15% in situation in this study.

There are other possible approaches that can be considered. In general, each department will try to reduce cost on their own individual department which not consider to other department cost. However, if we integrate WP (warehousing problem) and ITP(inventory-transportation problem) into WITP(Warehouse-inventory-transportation problem) to minimize total distribution cost (Sainathuni, Parikh et al. 2014). Integrating unit within supply chain together, in some scenarios, can obtain synergized benefit from vertical integration.

However, company can also improve cost efficiency and performance from inside of warehouse unit itself. Different direction and method will also reflect different in operation cost. The operational profit might be varied in each situation based on approach chosen for Material Requirement Planning program (MRP). The study of Kirche, Kadipasaoglu et al. (2005) showed that Activity-Based Costing approach(ABC) might be suitable from low percentage ratio of direct manufacturing cost to total manufacturing cost. On the other hand, Theory of Constraints-Based approach suits for large direct cost.

Physical condition of Distribution Centre is also an important factor needed to be considered, which related directly to transportation cost. The factors needed to be considered are transport management, fleet size, vehicle capacity, manufacturer, and age of vehicle (Andrejić, Bojović et al. 2016). Geographic location of Distribution Centre is another factor needed to be considered. Hua, Hu et al. (2016) studied via adaptive particle swarm method to determine optimal Distribution Centre and optimal structure of logistics network. While Hua, Hu et al. (2016) studied mainly on location of distribution centre for optimal cost, Huq, Cutright et al. (2006) suggested study based on both criteria of cost and customer responsiveness. This study simulated two-level warehouse inventory replenishment as a purpose of improving lead time of delivery product to customer. By locating second level Distribution Centre, the distance between warehouse and customer will be shorten, result in less lead time for delivery. If we can control inventory stock at same level, marginal operation cost per square foot (stockyard) can be controlled at same level. There is also another aspect to determine Activity-Based Cost in dimension of key account customer. This study classifies aggregated operation cost into activity based on each customer account. It suggests finding break-down marginal cost distributed to each customer of refrigerated warehouse business and compares it to unit revenue (Athikiat 2011). It can generate marginal profit of each customer and can be used to price negotiation for each contract.

Most of studies, except Huq, Cutright et al. (2006), concentrated on cost of supply chain but did not concern on delivery time to the customer. Popular method used for studies are mathematics method which cannot reflect full effect of continuous variability of demand in real operational routine. The other disadvantages of ABC approach are expensive and time consuming which might not suit for small operation unit and medium-size business (Khataie, Defersha et al. 2010). Because of these limitations, it might be too risky to implement actual methods for day-to-day operation. Mathematics method is also lacked of flexibility to handle instability of demand, especially effect of back ordering and underutilized resource and handling equipment within warehouse.

This study suggests new tool of simulation program to study relation of cost and speed, and also determine optimal cost and acceptable delivery efficiency simultaneously. This study will give expected performance level to management level to foresee performance before implementation new model to current operation system, which can avoid risk of loss customer’s satisfaction and other related risk, such as investment in new truck and long-term rental contract of forklift. This model also can be used as a decision tool for management level to study equipment cost for designing new distribution network.

6. METHODOLOGY

This study is focusing on finding optimal solution for various scenarios. The purpose of this study is to understand impact of cost on performance by simulation. If company can implement and control each factor, it will be able to get benefit from actual performance. However, there are some limitations to study when using other method, such as math model, as follows

- Risk and opportunity lost for actual implementation
  The company need to adjust real operation to experiment and get real data. In some condition, the performance might be less than average and reduce customer confident, which takes long time to improve customer trust to the same level.

- Limitation of analytical method. Analytical method is another way to determine optimal solution. However it lacks of capacity to determine operation time and cycle time of operation within warehouse.

- Simulation method also provides visual object and provides more clear perception. Observer can simply look at animation of simulation to observe bottleneck and queue in each process.

The study will put varies numbers of equipment of forklift and truck to simulation model by expected 2 main results which are

- Acceptable customer satisfaction level (expected 100% on time)
- Total fix cost related to forklift and truck
    - rental fee of forklift
    - salary of forklift driver
    - salary of truck driver
    - depreciation cost of truck
    - related fix cost (license fee and insurance)

This study scopes down to related fix cost of forklift and truck. The number of variable cost will have no impact to total cost, which can be neglected; for example, fuel cost of forklift to move pallet will be varied by amount of pallet and have no impact on number of forklift in operation.

$$Total\ cost \quad = \quad Total\ fix\ cost + Total\ variable\ cost$$

$$Total\ cost \ = \ \mathrm{n} * [(F_{1a}+F_{1b})X_1+(F_{2a}+F_{2b})X_2+(F_{3a}+F_{3b})X_3] + (V_{23}Y_{23+}V_4Y_4)$$

Equation 1 Equation of Total cost

Table 1Table of variable and constant of total cost

Constant				
	F1a	=	Fix cost	Forklift
	F1b	=	Fix cost	forklift driver
	F2a	=	Fix cost	6w truck
	F2b	=	Fix cost	6w driver
	F3a	=	Fix cost	10w truck
	F3b	=	Fix cost	10w driver
	V23	=	Variable cost	own fleet (6w and 10w)
	V4	=	Variable cost	Outsource fleet
Variable				
	n	=	number of month	
	X1	=	number of forklift	
	X2	=	number of 6-wheeled truck	
	X3	=	number of 10-wheeled truck	
	y23	=	number of pallet delivered by own fleet	
	y4	=	number of pallet delivered by outsource fleet	

Gathering Information

To create tool for logistic company, the requirement and target goal are both basic criteria, needed to be understood clearly. These factors will give improving direction to satisfy company's goal. Pattern and workflow of operation will identify limitation of improvement and also weakness of operation team. There are 3 main steps as follows

- Site visits; to understand location and working environment of operation unit.
- Interview sessions; to receive information of worker and receive some suggestion and possible approach for improvement.
- Data collection; to collect process time and some related data; such as performance level, process time and etc.

Identify problem

After data collecting process, all requirements and operator's interviews will be summarized to set target for this study. This process also includes identifying scope of problem and controlled variable for model.

Simulation model and Data analysis

In this process, collected data will be analyzed to generate distribution of each process for simulation model, which operated by ARENA 14.7. The model will generate overall performance based on various level of equipment.

Discussion and conclusion

The result from simulation model will reflect relationship between performance and cost of equipment, which provide alternative to minimize operation cost, while able to maintain delivery performance.

7. SIMULATION MODEL AND VALIDATION

7.1 SIMULATION MODEL

The operations in the DC were simulated in a simulation program called ARENA 14.7, as shown in Figure 23. This model can be categorized into 3 main parts, which are Inbound logistics, Inventory, and Outbound logistics.

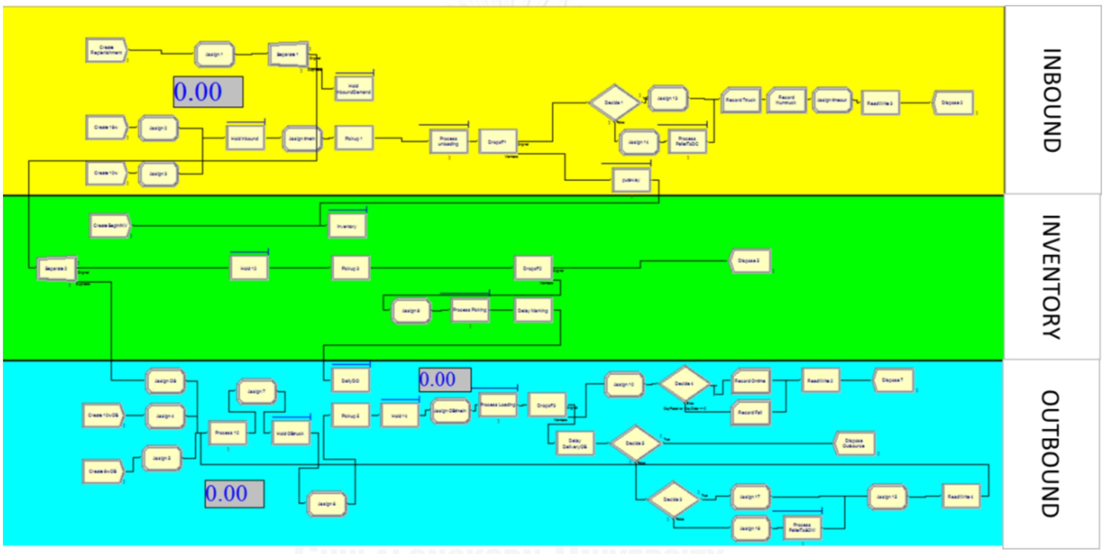

Figure 23 Simulation model of warehouse activity

Each of the three parts comprises of activities, and there are eight activities in total, as shown in Table 2.

Table 2 Main Parts and grouped activities

<table>
<tr><th>Main Part</th><th>Activity</th></tr>
<tr><td rowspan="2">Inbound</td><td>Unloading</td></tr>
<tr><td>Returnable IB</td></tr>
<tr><td rowspan="3">Inventory</td><td>Put away</td></tr>
<tr><td>Pick up</td></tr>
<tr><td>Stamping</td></tr>
<tr><td rowspan="3">Outbound</td><td>Loading</td></tr>
<tr><td>Delivery time</td></tr>
<tr><td>Returnable OB</td></tr>
</table>

The simulation model can be classified by function into 4 main parts, which are arrival control, inbound, inventory and outbound. This model is designed for operation unit based on actual data of operation day between Oct 1 to Dec 30, 80 days in total. This model was set as a terminating model, because each customer demand must be satisfied by the end of the day. According to the company's policy, the beginning inventory is set at 1500 pallet, which is equal to 60% of warehouse's capacity. This simulation model was run for 81 days, 12 operation hours per day. For the scenarios where demands were modified, so the sensitivity analysis can be carried out, the simulation was run for 81 days with 50 replications. The reason of reducing replications to 50 is because half wide or result is still less than 1% of delivered amount and indifferent to 150 replications. Forklift is main equipment that needs to handle almost all the activities in the warehouse. However, when it comes to actual operations, a forklift has to prioritize its activities according to the following table.

Table 3 Process priority

	Name	Type	Action	Priority
1	Process unloading	Standard	Seize Delay Release	Low(3)
2	Process PalletToDC	Standard	Seize Delay Release	Medium(2)
3	putaway	Standard	Seize Delay Release	Low(3)
4	Process Picking	Standard	Seize Delay Release	Medium(2)
5	Process Loading	Standard	Seize Delay Release	High(1)
6	Process PalletToSOW	Standard	Seize Delay Release	High(1)

7.1.1 Arrival control

Arrival control is part to generate inbound transportation volume and outbound transportation volume each day, based on historical data and use that number from Table 4 as a daily workload from operation.

Create Replenishment will create 1 entity per day, which stands for starting point of each day. Each entity will be duplicated by amount of *daily order(day)* (pallet), which is an amount of inbound from Table 4 and will be hold for inbound to be picked up by inbound truck. Then the entity will go to *Pickup 3* to take stock from inventory by amount of *DO(day)* (pallet), outbound amount from Table 4 . *Hold 12* gives the condition that the outbound transportation volume must be less than the main inventory and inventory must not be negative number.

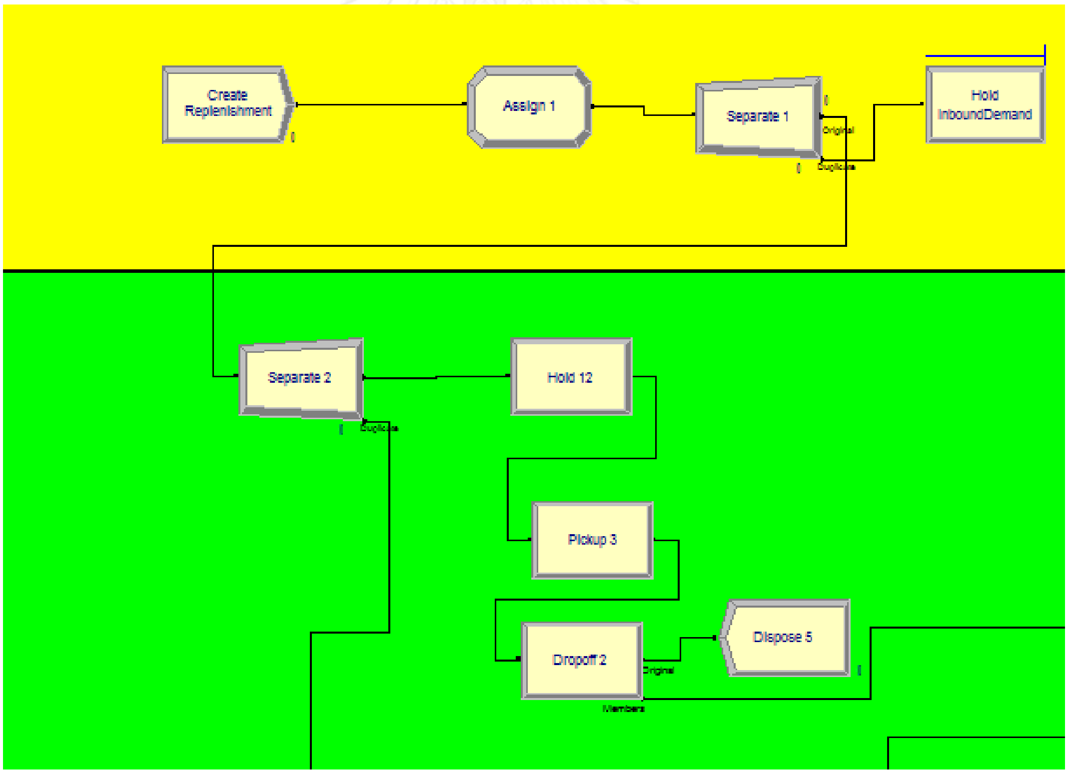

Figure 24 Time control

Table 4 Historical data of inbound and outbound volume

Day	InBound			Outbound			Day	InBound			Outbound		
	Oct	Nov	Dec	Oct	Nov	Dec		Oct	Nov	Dec	Oct	Nov	Dec
1	36			34	0	0	41		240		0	196	0
2	47			84	0	0	42		220		0	215	0
3	100			84	0	0	43		216		0	193	0
4	157			47	0	0	44		218		0	330	0
5	83			102	0	0	45		215		0	245	0
6	70			120	0	0	46		136		0	126	0
7	118			90	0	0	47		71		0	222	0
8	108			240	0	0	48		187		0	169	0
9	106			173	0	0	49		0				0
10	117			208	0	0	50		180		0	127	0
11	131			158	0	0	51		227		0	175	0
12	103			139	0	0	52		148		0	373	0
13	71			115	0	0	53			235	0	0	16
14	160			60	0	0	54			316	0	0	228
15	174			182	0	0	55			122	0	0	128
16	183			192	0	0	56			127	0	0	100
17	155			144	0	0	57			207	0	0	444
18	143			78	0	0	58			337	0	0	475
19	48			98	0	0	59			176	0	0	350
20	195			97	0	0	60			341	0	0	237
21	270			200	0	0	61			200	0	0	32
22	230			139	0	0	62			235	0	0	263
23	222			184	0	0	63			297	0	0	243
24	59			173	0	0	64			253	0	0	415
25	135			237	0	0	65			263	0	0	503
26		121		0	43	0	66			155	0	0	233
27		131		0	84	0	67			389	0	0	214
28		103		0	62	0	68			131			-
29		122		0	68	0	69			239	0	0	275
30		162		0	51	0	70			327	0	0	362
31		92		0	121	0	71			407	0	0	445
32		304		0	327	0	72			288	0	0	206
33		252		0	310	0	73			377	0	0	282
34		248		0	171	0	74			249	0	0	333
35		275		0	205	0	75			264			-
36		168		0	170	0	76			438	0	0	373
37		162		0	119	0	77			311	0	0	361
38		218		0	414	0	78			93	0	0	412
39		189		0	244	0	79			120	0	0	540
40		236		0	279	0	80			12	0	0	287

7.1.2 Inbound

Inbound transportation process starts by creating 18 wheeled trucks, each with 24-pallet capacity and 10 wheeled trucks, each with 12-pallet capacity in Figure 25. The two third of inbound amount (pallet) was delivered by 18 wheeled truck. Each truck is assigned the attribute *trucksize* to identify truck capacity. Each truck will go to *pickup 1* to pick up inbound amount equal to truck capacity For example, 18 wheeled trucks will process at pickup 1 for 24 time equal to its capacity. Then in *process unloading* , each truck will be processed as same method as pick up1.

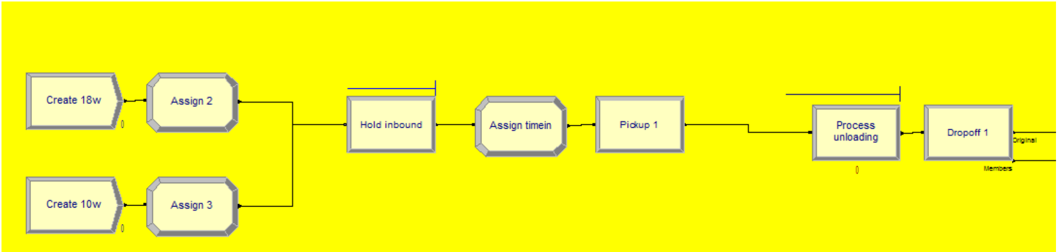

Figure 25 Inbound (part1)

Each product unloaded will be dropped off at *dropoff1* to staging area and queuing to be put away to main inventory as shown in Figure 26. For inbound truck, there is one more process needed to be done. After *dropping off1*, 15 percent of the trucks need to pick up the backhauling products, such as empty botlles, empty beer kegs, and pallets. Backhauling truck will be loading product at *process PalletToDc* before finishing its job.

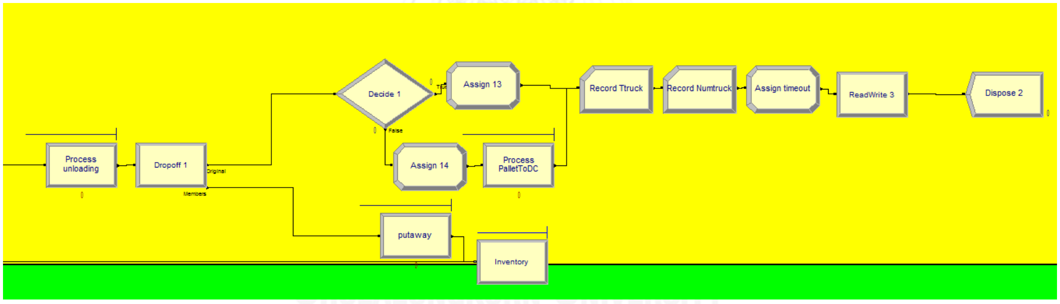

Figure 26 Inbound (part2)

7.1.3 Inventory

Inventory process is related to all activities dealing with stock after the product is put away and until it is prepared for loading onto the outbound truck (See Figure 27). At the beginning of simulation, 1500 pallets will be created as the initial stock.. In each day, stock will be replenished by inbound truck via *putaway* process and will be consumed at the amount of customer order. The day entity from arrival control part will come and pick up with *pickup3* at quantity of daily outbound, *Do(day)* (pallet). The stock entities will be dropped off at *Dropoff 2*, which represent customer orders.

Customer order will go through the process of *Picking* and *Marking* before queuing up the trucks for the loading activities.

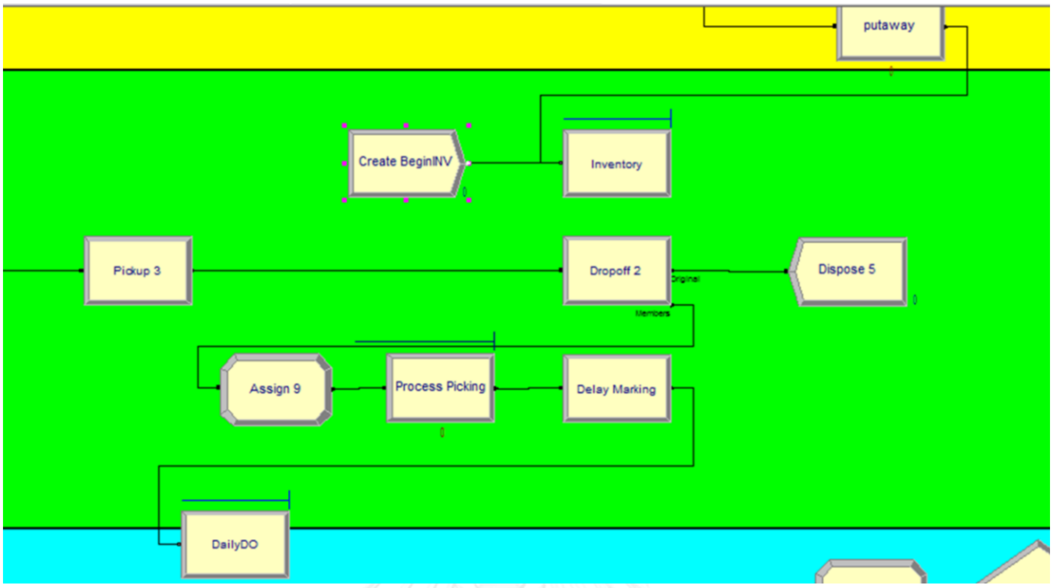

Figure 27 Inventory

7.1.4 Outbound

Outbound part simulates the product delivery activities, from warehouse to customer.. This part begins with creating outbound trucks. This happens only once at the beginning of the simulation in order to control amount of trucks, which are 10 of 10-wheeled trucks and 4 of 6-wheeled trucks (See Figure 28). These trucks will not be disposed and continue working until the end of the replication length. Referring to the inventory part, the product is picked to the staging area and ready to be picked up at *pick up 5* with the amount of the truck size. Truck goes on to pick up products and continue on to the loading process, which process time varies depending on the truck size.

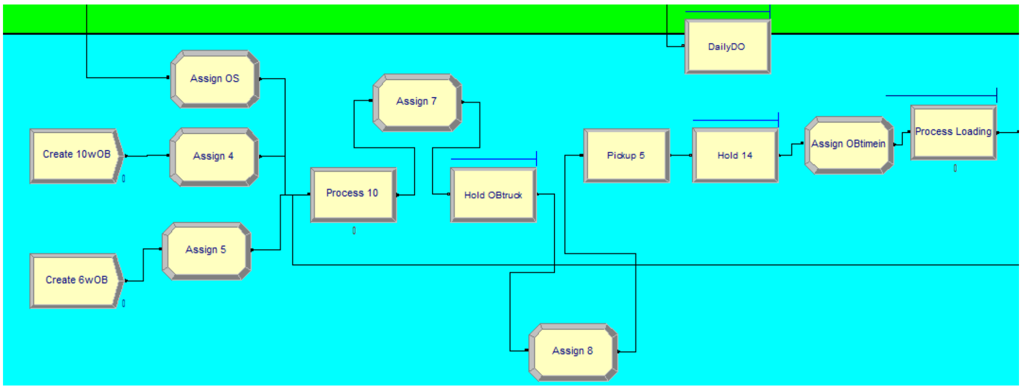

Figure 28 Outbound part 1

After the loading process , truck moves to *drop off 3* to drop off all the products (See Figure 29). Then product will be inspected and recorded as Pass or Fail according to whether it is the same-day delivery. Truck then unloads the products at customer’s site and some need to pick up the returned products. From historical data, about 20 percent of trucks at the customer site need to pick up the returned products. After that, truck will head back to the warehouse. These activities can be represented as a delay time in the simulation model.

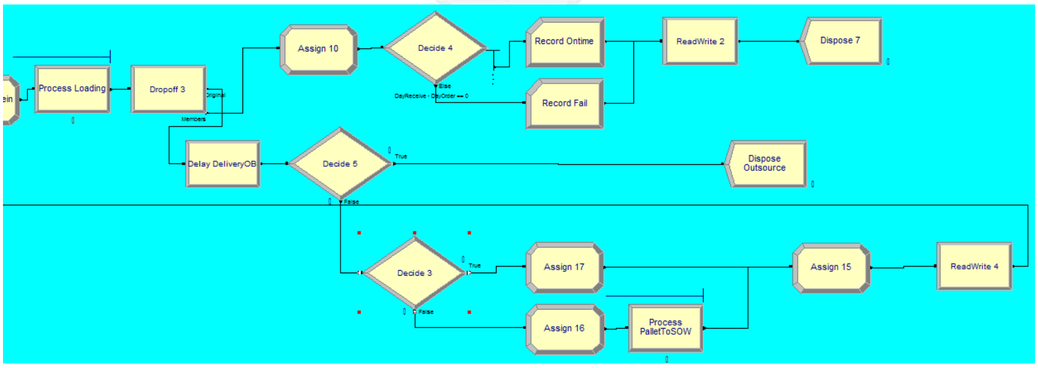

Figure 29 Outbound part 2

7.2 VALIDATION

7.2.1 Process validation

To determine distribution pattern of each activity, process times were recorded and collected at least 300 samples in each process. Collected data will be cleaned and eliminated some outliner. Then it will be randomized and separated into 2 groups. First group, 60% of collected data, will be used to fit expression at CI 95% by Input analyser (Figure 30). This distribution will be used to generate data via ARENA. The simulated data generated from expression ,referred as C3 in Figure 31, will be used to compare with second group of collected data (40%), referred as C2 in Figure 31, by T-test at CI 95%. All activities and their expressions were listed Table 5 and put into simulation model.

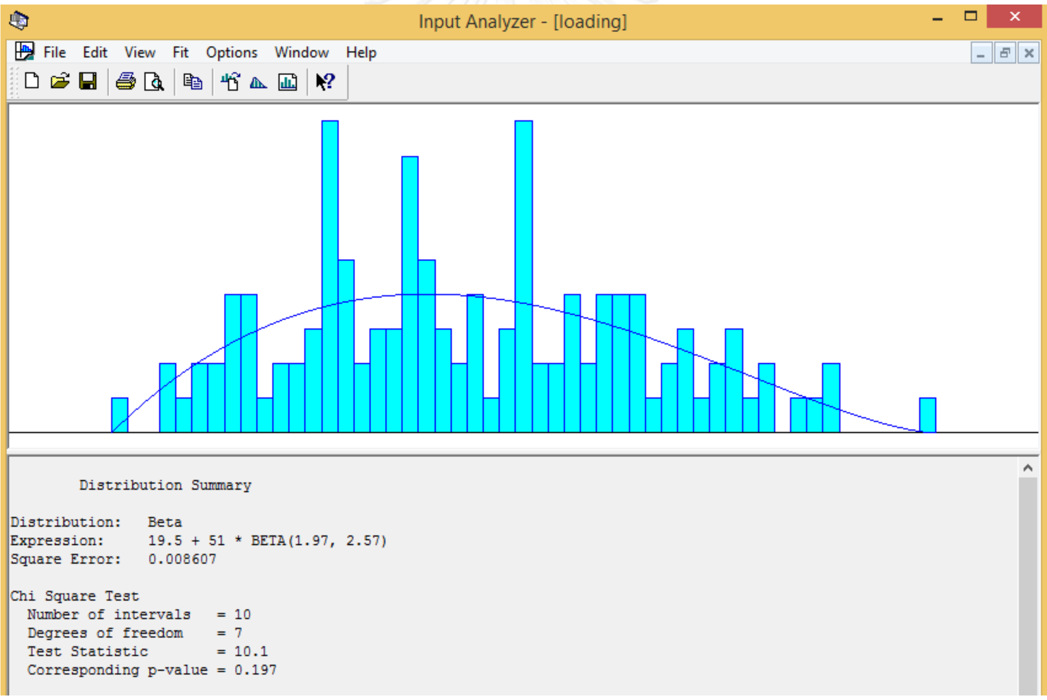

Figure 30 Distribution of loading process

```
Two-Sample T-Test and CI: C2, C3

Two-sample T for C2 vs C3

    N  Mean  StDev  SE Mean
C2  226  43.4   10.1    0.67
C3  249  42.0   10.6    0.67


Difference = mu (C2) - mu (C3)
Estimate for difference:  1.429
95% CI for difference:  (-0.433, 3.292)
T-Test of difference = 0 (vs not =): T-Value = 1.51  P-Value = 0.132  DF = 471
```

Figure 31 T test for loading process

Table 5 Expression of processes from collected data

Activity	Expression
Unloading	20.5 + ERLA(1.11, 7)
Put away	NORM(64.2, 12.9)
Pick up	NORM(82.6, 22.7)
Loading	19.5 + 51 * BETA(1.97, 2.57)
Delivery time	TRIA(74, 168, 488)
Returnable OB	NORM(50.9, 6.48)
Returnable IB	NORM(54.4, 5.75)
Stamping	140 + WEIB(157, 2.38)

7.2.2 Input validation

The objective of this study focuses on actual demand during specific time period. The pattern of demand has high fluctuated level and hard to be predicted. Thus, this study decided to keep the same actual demand as an input by expecting to reflect most realistic result for this case study.

7.2.3 Output validation

This model is simulated from warehouse operation. Thus, the outputs of this model are daily delivered order and percentage of on-time delivery within 24 hours. However, the output of this simulation model is almost 100% similar to actual operation, Figure 32. This situation might happen from overwhelm resource number of warehouse equipment, which is under-utilized. So, the study chooses to find other output, instead of delivered demand, to validate this model.

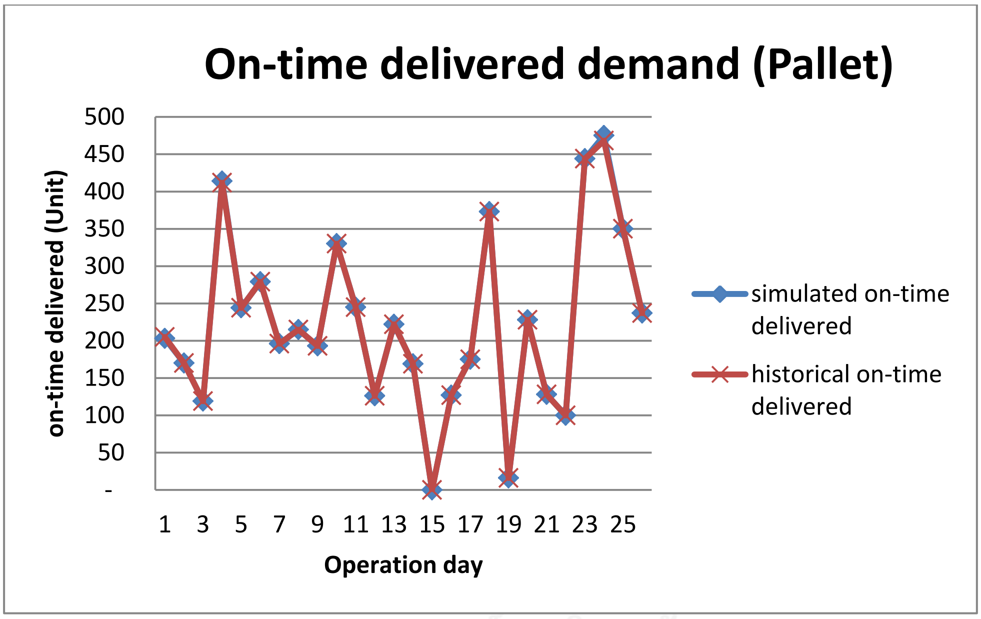

Figure 32 Validation of model's output

Paired T-Test and CI: C1, C2

```
Paired T for C1 - C2

             N   Mean  StDev  SE Mean
C1          26  222.2  119.9     23.5
C2          26  222.0  119.2     23.4
Difference  26  0.262  1.436    0.282


95% CI for mean difference: (-0.318, 0.841)
T-Test of mean difference = 0 (vs not = 0): T-Value = 0.93  P-Value = 0.362
```

Figure 33 Paired T-Test of model's output

The alternative output was forklift working hour. Forklfit is equipment related to most of process within warehouse. By same given daily demand, daily working hour of forklift should be similar to recorded working hour. Thus this model was validated by comparing actual working hour of forklifts which are main resource and relate to almost every activities in warehouse by Pair T-test method and be accepted at 95% CI. (Figure 35)

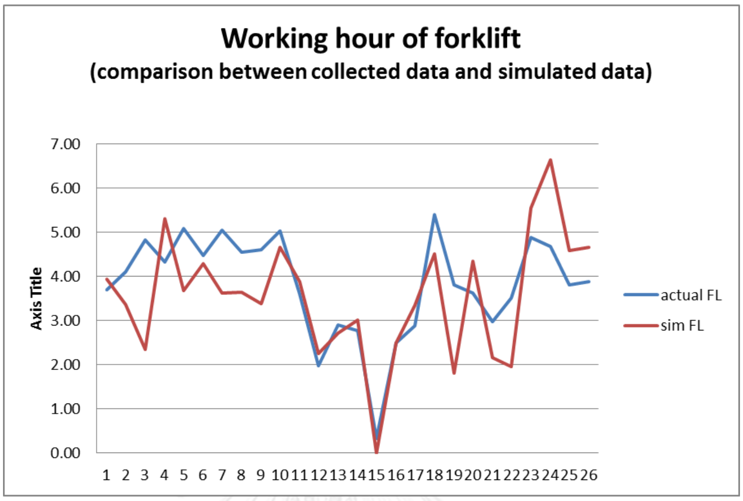

Figure 34 Comparison of forklift's working hour (Collected and simulated)

```
Paired T-Test and CI: C1, C2

Paired T for C1 - C2

              N   Mean  StDev  SE Mean
C1           26  3.815  1.147    0.225
C2           26  3.539  1.383    0.271
Difference   26  0.276  1.031    0.202


95% CI for mean difference: (-0.140, 0.692)
T-Test of mean difference = 0 (vs not = 0): T-Value = 1.37  P-Value = 0.184
.
```

Figure 35 Paired T-Test of forklift's working hour

7.3 LIMITATION OF MODEL

This simulation model also

1. This model was simulation based on only one type of warehouse equipment which is forklift. Thus if any warehouse has 2 or more types of equipment, such as forklift and reach truck, this model could not be implemented.

2. All forklifts were assigned to all activities by expecting benefit of pooling effect and reducing idle time. In case that forklifts were assigned responsibility to different jobs, this model cannot be used to simulate.

8. RESOURCE MANAGEMENT WITHIN WAREHOUSE OPERATION

Collected data from October to December 2016 provided some information about pattern related to the actual daily activity of Buriram Distribution centre. All activity will operate based on the amount of daily demand. However, the collected data of daily demand in the last quarter of 2016 showed high fluctuate level of daily demand during that period. From Figure 36, the average demand from Oct-1 to Dec-30 is 210 pallets per day, while standard deviation is 122.51.

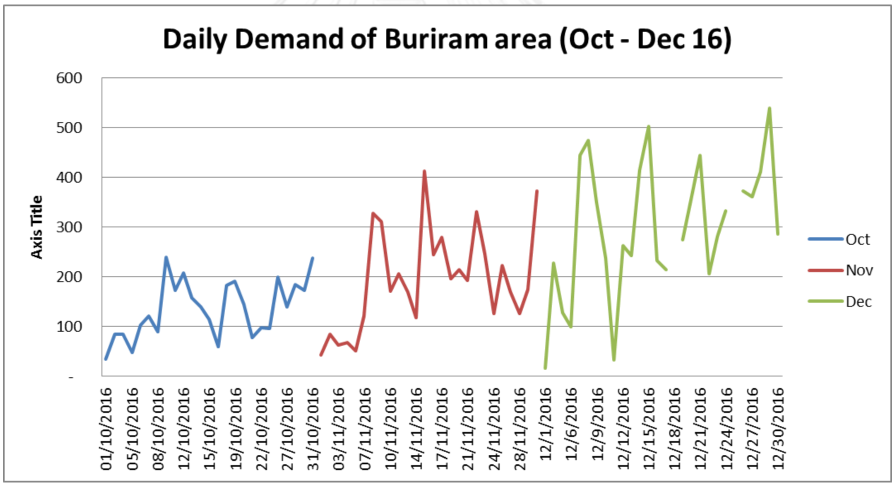

Figure 36 Daily demand of Buriram area

After running simulation model, it shows information about actual operation in some important aspects. The model was controlled to generate result by varying truck and forklift's amount and provide percentage of completed delivery order. The actual operation has basic target of 100% delivery level, thus any number of unfinished delivery order will be distributed by outsources, which have high marginal operation cost. Using high volume of outsource service can reduce fix cost and increase utilization of own truck by avoiding uncertainty of daily demand; without suitable controlling. On the other hand, it might results in low cost efficiency of operation, because outsource marginal delivery cost is the most expensive one among other options, referred from the following calculation in Figure 37.

The calculation table below shows figures of truck capacity, fix cost and variable cost of using 10-wheel trucks, 6-wheel truck and those of outsourcing. The 10-wheel truck has the highest fix cost as well as highest delivering capacity but lowest variable cost. While hiring outsource can reduce burden of fix expense but have to spend higher on variable unit cost.

		10w	6w	outsource
Truck Capacity				
	capacity per truck	12	8	
	number of trip	50	50	
	delivered pallet per month	600	400	
Fix cost				
	10w driver	12012	12012	0
	10w truck	12000	8000	0
		24012	20012	0
Var cost				
	average fixcost/pallet	40.02	50.03	0
	var cost/pallet	187.98	187.98	321.38
		228	238.01	321.38

Figure 37 Marginal total cost

The model was run based on condition of various factors which are amount of forklift (range 1-5 units), amount of 10-wheel truck (range 1-20 units) and amount of 6-wheel truck (range 0-1). The result from the model was generated into 200 patterns to find the expected percentage of own fleet completed delivery to identify the most effective amount of forklift utilization.

Figure 38 and Figure 39 explain relationship of delivery level by own fleet vehicles and forklift utilization. By increasing amount of forklift will maximize own fleet delivery performance which will reduce cost spending on hiring outsource. Refer to Figure 38, using more than one forklifts will reducing number of outsourcing while using only one forklift leads to high volume of outsourcing. On the other hand, refer to Figure 38, the case of using one forklift can enable forklift utilization and reduce fix cost in term of forklift rental fee, but the lost occurs in term of delivery performance which will generate higher additional cost by using outsource to compensate non-delivery volume.

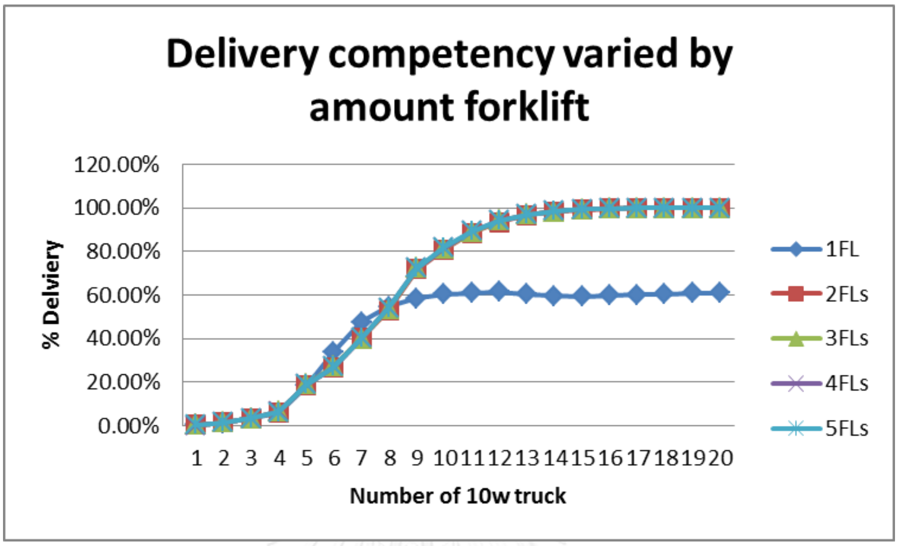

Figure 38 Delivery competency

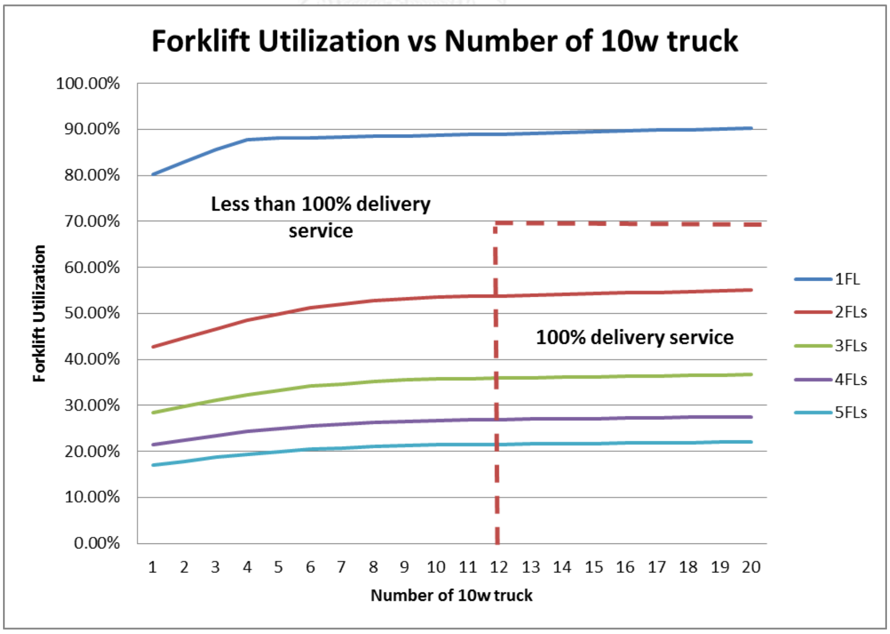

Figure 39 Forklift Utilization

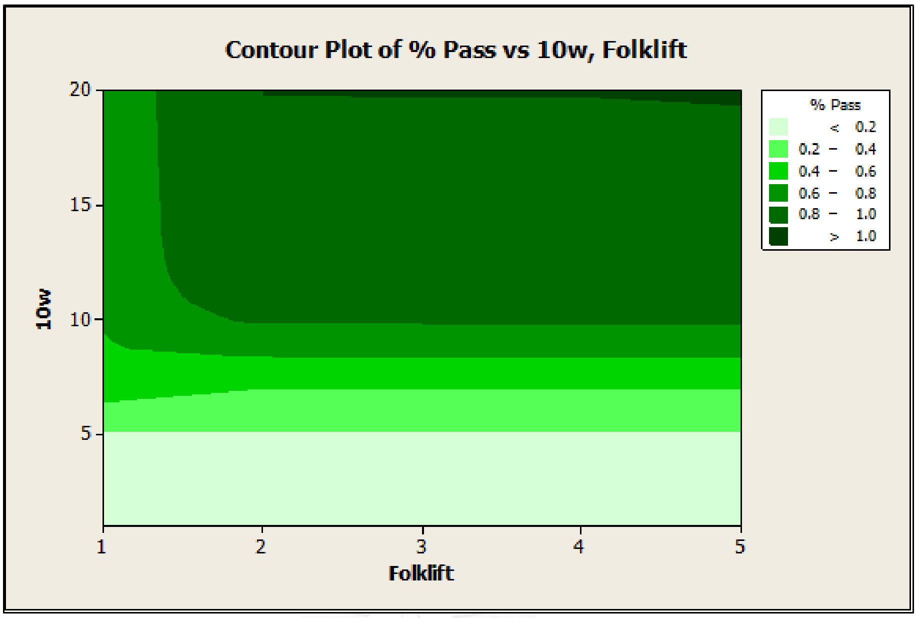

Figure 40 Contour Plot of % Pass

To identify the optimum solution for cost efficiency, the solution will depend on unit price of each cost related to warehouse. Result from simulation model will give expected complete delivery level by own fleet truck from total sale demand during the 3 months of experimental period, which is 16,174 pallets in total. The exceeded demand will be delivered to customers by outsource service. The simulation will run on combination of 3 factors, which are amount of forklift (range 1-5 units), amount of 10-wheel truck (range 1-20 units) and amount of 6-wheel truck (range 0-1), to find expected own fleet delivered volume.

For example, by setting combination of variable at (2,9,0); which are the conditions of 2 forklifts, 9 10-wheel trucks, and 0 6-wheel truck; the result of own fleet delivered volume will be 11,583 pallets from to total demand of 16,174. The surplus demand is 4591 pallets of finished good. The company set target of 100% on-time delivery level, thus all surplus amount will be unavoidably delivered by outsource service, which is costly and reflect cost efficiency of operation.

Total operation cost of each combination will be calculated based on following equation, Equation 2. The related constant was listed by Table 6 to generate total cost in each scenario to identify optimum solution for actual demand from customer.

$$Total\ cost \quad = \quad Total\ fix\ cost + Total\ variable\ cost$$

$$Total\ cost\ = \ \mathrm{n} * [(F_{1a}+F_{1b})X_1+(F_{2a}+F_{2b})X_2+(F_{3a}+F_{3b})X_3] + (V_{23}Y_{23+}V_4Y_4)$$

Equation 2 Equation of total cost in term of fix cost and variable cost

Table 6 List of constant and variable

Constant

F1a	=	Fix cost	Forklift
F1b	=	Fix cost	forklift driver
F2a	=	Fix cost	6w truck
F2b	=	Fix cost	6w driver
F3a	=	Fix cost	10w truck
F3b	=	Fix cost	10w driver
V23	=	Variable cost	own fleet (6w and 10w)
V4	=	Variable cost	Outsource fleet

Variable

n	=	number of month
X1	=	number of forklift
X2	=	number of 6-wheeled truck
X3	=	number of 10-wheeled truck
y23	=	number of pallet delivered by own fleet
y4	=	number of pallet delivered by outsource fleet

Table 7 Unit cost of warehouse equipment

TYPE	categoly	list	Unit	amount
Fix cost	Forklift	FL	per month	14200
Fix cost	Forklift	FL driver	per month	13512
Fix cost	6w	6w truck	per month	8000
Fix cost	6w	6w driver	per month	12012
Fix cost	10w	10w truck	per month	12000
Fix cost	10w	10w driver	per month	12012
Variable cost	6w,10w	own-fleet expense	per pallet	187.98
Variable cost	Outsource	Outsourcing cost	per pallet	321.38

After running simulation model of 200 combination of variable, the optimum combination is (2,12,0); which are the conditions of 2 forklifts, 12 10-wheel trucks, and 0 6-wheel truck. The amount of outsource volume is 1,021 pallet. Total cost is

4,090,869.92 Baht; which reveal possible saving of 624,532.60 Baht (compared to actual expense of 4,715,402.52 Baht of 3 month period). Total cost of every solution is displayed in pattern of contour graph in Figure 41.

Table 8 Comparison between actual and optimized condition

v		Actual condition	Optimized condition
Equipment	Forklift	4	2
	10w Truck	10	12
	6w Truck	6	0
own-fleet delivered		12,964.00	15,153.00
Outsource delivered		3,210.00	1,021.00
Total demand		16,174.00	16,174.00
Total opt cost		4,715,402.52	4,090,869.92
Saving			624,532.60
% saving			**13.24%**

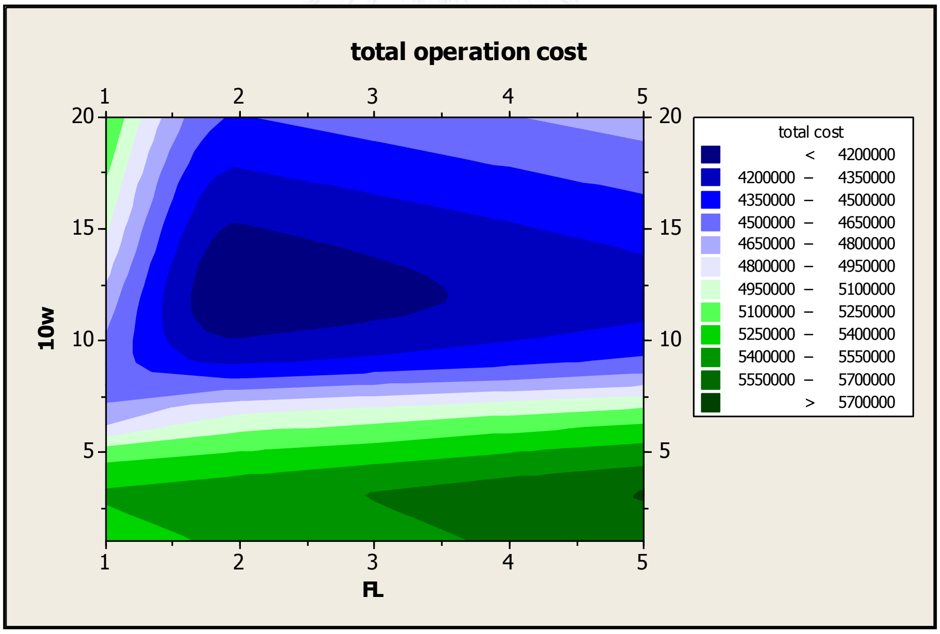

Figure 41 Contour graph of total operation cost

9. SENSITIVITY ANALYSIS FOR DEMAND CHANGING

The warehouse of this case study is part of supply chain and functioned as a support unit for sale department. Amount of workload in warehouse should be varied to the same direction with growth of sale and marketing policy. The sale volume can be increased and decreased within short period of time, even daily. But resource investments in warehouse can not keep up with sale changing ,because they are mostly long-term purchasing, such as least 1-year rental contract or leasing package. Without investment planning in advance, it is impossible to response and support incremental sale volume and might lead to extreme high outsourcing expense, worse performance in cost efficiency, because the condition of resource will hardly match with optimal solution, provided by model.

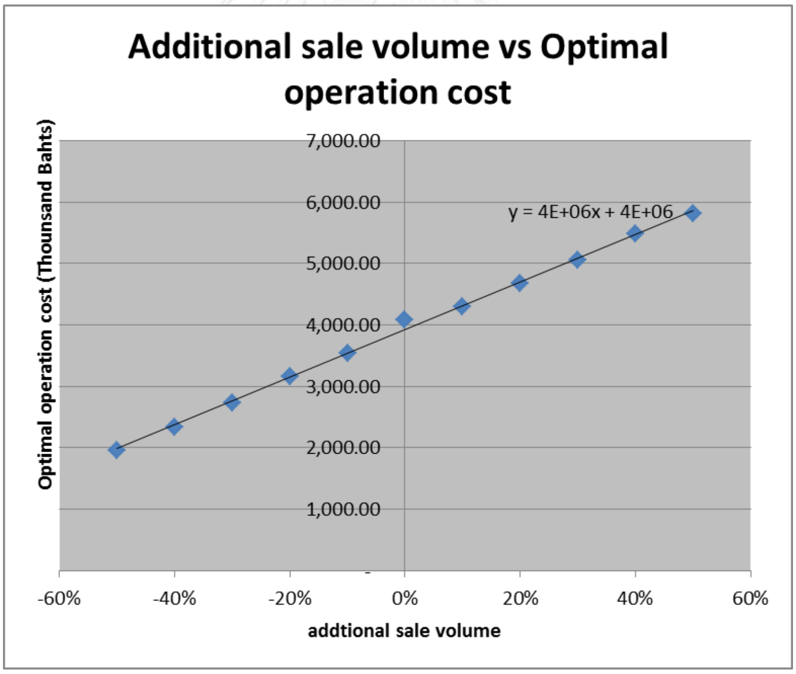

Figure 42 Additional sale volume VS Optimal operation cost

Table 9 Effect of Additional sale volume to optimal operation cost

incremental sale order	Optimal operation cost
-50%	1,961,845.42
-40%	2,344,481.60
-30%	2,724,904.56
-20%	3,162,435.66
-10%	3,539,838.90
0%	4,090,869.92
10%	4,294,958.00
20%	4,670,705.86
30%	5,049,709.90
40%	5,483,378.18
50%	5,818,314.22

However, in general, most of national manufacturing companies always have target goal in sale volume in next 3 to 5 years as a purpose for financial analysis. The operation unit can use target goal of sale department as a clue to generate resource investment planning for warehouse operation. This study provides a sensitivity table varied by sale volume with in range of +50% to -50% as shown in Table 9. This sensitivity analysis provides top-5 best solutions in each case scenario within range of demand. If management can match best solution to demand, it will generate most saving for the company. However, in some situation, the best solution might not be available, or some external factors might also influence to generate profit.

Table 10 Table of demand sensitivity

Incremental sale volume	Resource			own-fleet delivered	total sale order	outsource delivered	own-fleet expense	Outsourcing cost	total cost
	FL	10w	6w						
-50%	1	6	0	7,437	7,769	332	1,398,007.26	106,698.16	1,961,845.42
	1	5	1	7,270	7,769	499	1,366,614.60	160,368.62	1,972,123.22
	1	6	1	7,621	7,769	148	1,432,595.58	47,564.24	1,989,019.82
	1	7	0	7,683	7,769	86	1,444,250.34	27,638.68	1,992,749.02
	1	5	0	6,662	7,769	1,107	1,252,322.76	355,767.66	2,001,510.42
-40%	1	7	0	8,807	9,330	523	1,655,539.86	168,081.74	2,344,481.60
	1	6	1	8,612	9,330	718	1,618,883.76	230,750.84	2,358,494.60
	1	7	1	9,071	9,330	259	1,705,166.58	83,237.42	2,360,984.00
	1	8	0	9,152	9,330	178	1,720,392.96	57,205.64	2,362,178.60
	1	6	0	7,969	9,330	1,361	1,498,012.62	437,398.18	2,392,550.80
-30%	1	8	0	10,196	10,892	696	1,916,644.08	223,680.48	2,724,904.56
	1	8	1	10,504	10,892	388	1,974,541.92	124,695.44	2,735,537.36
	1	9	0	10,570	10,892	322	1,986,948.60	103,484.36	2,738,732.96
	1	7	1	9,985	10,892	907	1,876,980.30	291,491.66	2,741,051.96
	1	9	1	10,692	10,892	200	2,009,882.16	64,276.00	2,774,178.16
-20%	2	9	0	11,725	12,457	732	2,204,065.50	235,250.16	3,162,435.66
	2	10	0	12,136	12,457	321	2,281,325.28	103,162.98	3,171,328.26
	2	9	1	12,043	12,457	414	2,263,843.14	133,051.32	3,171,734.46
	2	8	1	11,503	12,457	954	2,162,333.94	306,596.52	3,180,050.46
	2	10	1	12,290	12,457	167	2,310,274.20	53,670.46	3,202,504.66
-10%	2	10	0	13,127	14,015	888	2,467,613.46	285,385.44	3,539,838.90
	2	11	0	13,572	14,015	443	2,551,264.56	142,371.34	3,544,195.90
	2	10	1	13,447	14,015	568	2,527,767.06	182,543.84	3,548,870.90
	2	9	1	12,903	14,015	1,112	2,425,505.94	357,374.56	3,557,720.50
	2	11	1	13,780	14,015	235	2,590,364.40	75,524.30	3,568,168.70
0	2	12	0	15,153	16,174	1,021	2,848,460.94	328,128.98	4,090,869.92
	2	13	0	15,626	16,174	548	2,937,375.48	176,116.24	4,091,491.72
	2	12	1	15,503	16,174	671	2,914,253.94	215,645.98	4,095,899.92
	2	11	1	14,952	16,174	1,222	2,810,676.96	392,726.36	4,105,683.32
	2	13	1	15,834	16,174	340	2,976,475.32	109,269.20	4,115,464.52
10%	2	13	0	16,428	17,140	712	3,088,135.44	228,822.56	4,294,958.00
	2	12	0	15,930	17,140	1,210	2,994,521.40	388,869.80	4,297,671.20
	2	12	1	16,264	17,140	876	3,057,306.72	281,528.88	4,304,835.60
	2	14	0	16,766	17,140	374	3,151,672.68	120,196.12	4,313,588.80
	2	13	1	16,665	17,140	475	3,132,686.70	152,655.50	4,315,062.20
20%	2	14	0	17,840	18,697	857	3,353,563.20	275,422.66	4,670,705.86
	2	13	1	17,655	18,697	1,042	3,318,786.90	334,877.96	4,683,384.86
	2	14	1	18,106	18,697	591	3,403,565.88	189,935.58	4,686,941.46
	2	13	0	17,240	18,697	1,457	3,240,775.20	468,250.66	4,687,025.86
	2	15	0	18,193	18,697	504	3,419,920.14	161,975.52	4,687,335.66
30%	2	15	0	19,230	20,255	1,025	3,614,855.40	329,414.50	5,049,709.90
	2	14	1	19,037	20,255	1,218	3,578,575.26	391,440.84	5,063,456.10
	2	15	1	19,514	20,255	741	3,668,241.72	238,142.58	5,063,544.30
	2	16	0	19,602	20,255	653	3,684,783.96	209,861.14	5,063,805.10
	2	14	0	18,603	20,255	1,652	3,496,991.94	530,919.76	5,069,631.70
40%	3	16	0	20,694	21,781	1,087	3,890,058.12	349,340.06	5,483,378.18
	3	17	0	21,145	21,781	636	3,974,837.10	204,397.68	5,486,934.78
	3	15	1	20,567	21,781	1,214	3,866,184.66	390,155.32	5,488,319.98
	3	16	1	21,027	21,781	754	3,952,655.46	242,320.52	5,490,675.98
	3	15	0	20,086	21,781	1,695	3,775,766.28	544,739.10	5,500,765.38
50%	3	18	0	22,627	23,229	602	4,253,423.46	193,470.76	5,818,314.22
	3	17	0	22,117	23,229	1,112	4,157,553.66	357,374.56	5,822,628.22
	3	17	1	22,451	23,229	778	4,220,338.98	250,033.64	5,829,792.62
	3	16	1	21,890	23,229	1,339	4,114,882.20	430,327.82	5,840,910.02
	3	18	1	22,821	23,229	408	4,289,891.58	131,123.04	5,844,154.62

REMARK: [ ] stand for optimal solution in each demand volume.

For example, this warehouse currently have resource (2,12,0), which is optimal solution for current demand; the combination stands for 2 forklift, 12 10-wheel truck, and non 6-wheel truck. The information given by sale office informs that the sale volume will be stable and increase 10% each year for the next 2 years. Without any external factor, management should follow investment plan A, which is rent one more truck each year [(2,12,0), (2,13,0), (2,14,0)](Table 11). Plan A give 34,866.40 baht saving instead of choosing Plan B , which is investing 2 trucks simultaneously in year 2. However, if the truck company offer discount of 50,000 baht for 2-truck purchasing, the plan B will be more preferable choice. This table of sensitivity (

Table 10) will provide some room for management to adapt itself if any possible opportunity is given.

Table 11 Alternative investment plan

Timeline	Incremental sale volume	Resource			total cost	Plan A	Plan B
		FL	10w	6w			
Year1	0	2	12	0	4,090,869.92	4,090,869.92	4,090,869.92
		2	13	0	4,091,491.72		
		2	12	1	4,095,899.92		
		2	11	1	4,105,683.32		
		2	13	1	4,115,464.52		
Year2	10%	2	13	0	4,294,958.00	4,294,958.00	
		2	12	0	4,297,671.20		
		2	12	1	4,304,835.60		
		2	14	0	4,313,588.80		4,313,588.80
		2	13	1	4,315,062.20		
Year3	20%	2	14	0	4,670,705.86	4,670,705.86	
		2	13	1	4,683,384.86		
		2	14	1	4,686,941.46		4,686,941.46
		2	13	0	4,687,025.86		
		2	15	0	4,687,335.66		
		Total cost				**13,056,533.78**	**13,091,400.18**
		Different of total cost					**34,866.40**

10. SUPPLY CHAIN IMPROVEMENT

All previous studies were designed based on internal controllable factors within organization. However, overall operation needs to be operated based on required daily demand of external customers, which are wholesalers. Even though, manipulating demand of customer is not practically applied to every business, it is still possible happen with some support from marketing campaign, promotion and discount policy. Still, these marketing tactics and strategies will come with their own expenses. The company needs to consider on saving from manipulating demand of customer to the expense, if it is worth to apply it or not.

The studies can not predict the expense of any marketing tools, still it can predict saving from alternative demand pattern. The chosen patterns are flat month pattern (Figure 43) and flat week pattern (Figure 44)

Flat month pattern was designed based on equally distributed daily demand in each month, while still have same monthly sale volume compared to orginal daily order. Not only Flat week apply to the same assumption of flat month pattern, but it also have additional weekly distributed pattern as showen in Figure 45.

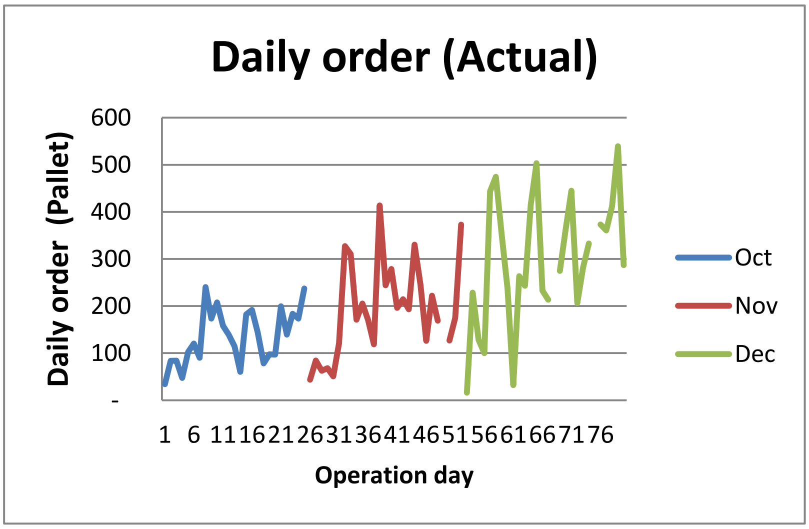

Figure 43 Actual daily order

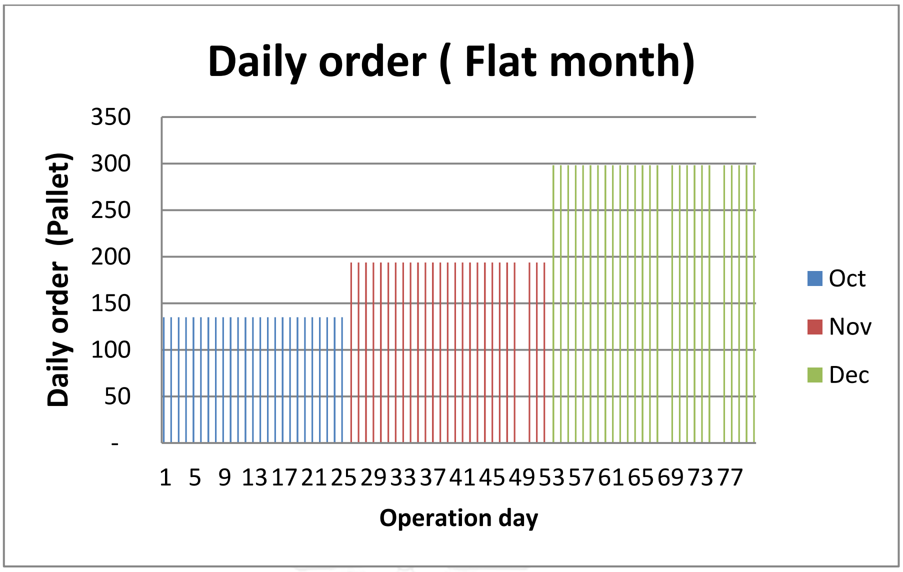

Figure 44 Daily order in flat month pattern

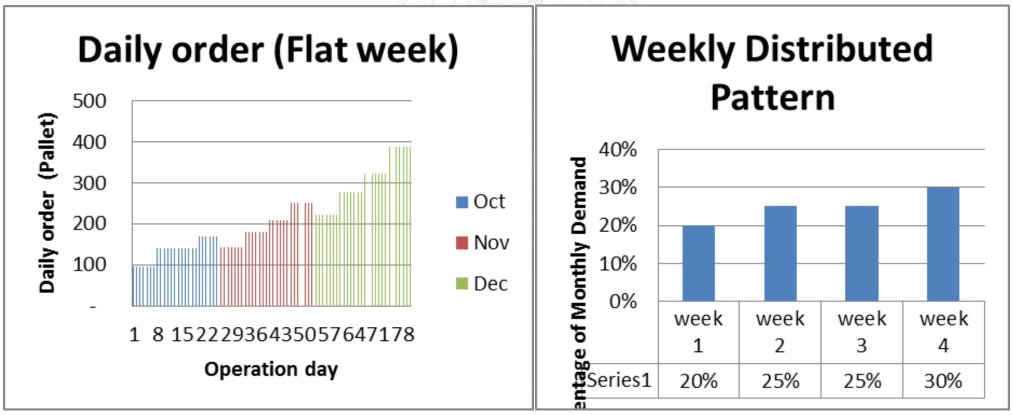

Figure 45 Daily order in flat week pattern and Weekly distributed pattern

After simulating model by using daily order with adjusted pattern, solution of model can be input and total cost also can be further improved. By adjusting demand in to flat month pattern, additional saving are 243,625.40 Baht, equal to 5.17% of total actual cost. The second option, flat week pattern, can also reduce some expense at 2.62% (Figure 47). Even though flat week pattern can generate saving at lower amount compared to flat month pattern, in practical situation, flat week pattern is more potential option and much easier to implement to current business, which result in lower marketing cost spending.

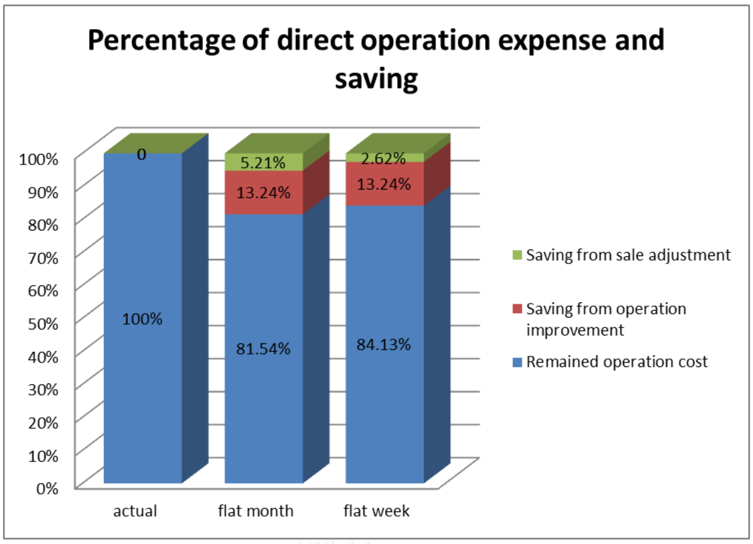

Figure 46 Percentage of direct operation expense and saving

Table 12 Table of cost related to flat month pattern

List	Flat month	
	Value	Percentage
operation cost	3,847,244.52	81.59%
opt adjustment	624,532.60	13.24%
Sale adjustment	243,625.40	5.17%

Table 13 Table of cost related to flat week pattern

List	Flat week	
	Value	Percentage
operation cost	3,967,265.52	84.13%
opt adjustment	624,532.60	13.24%
Sale adjustment	123,604.40	2.62%

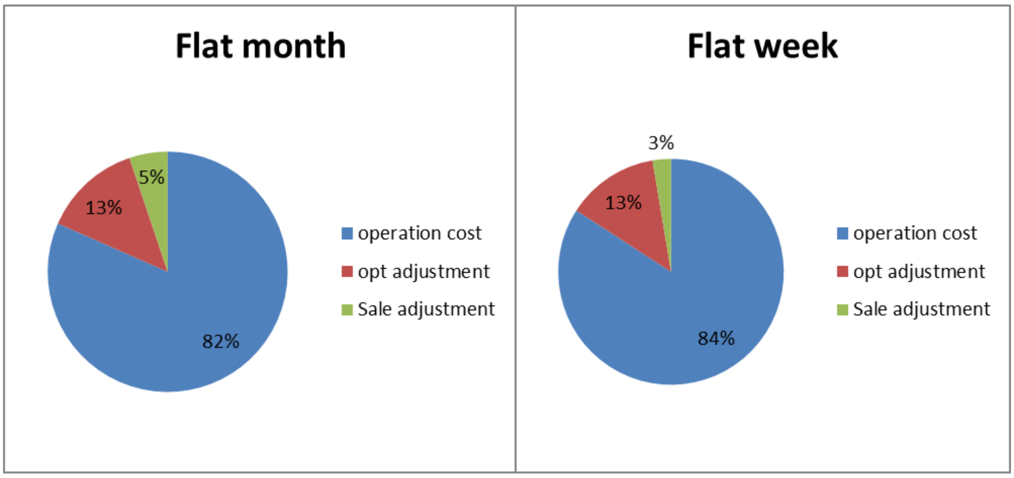

Figure 47 Saving from demand adjustment

11. SUMMARY AND SUGGESTION

The thesis approaches case study by simulation model to simulate expected delivery performance in variable factors of 3 main warehouse equipments, which are forklift, 10-wheel truck and 6-wheel truck. The model can be classified into 3 main parts, which are inbound, output and inventory. These main parts are combination of 8 minor process of Unloading, put away, pick up, loading, delivery time, returnable of inbound, returnable of outbound, and stamping. The result from model can be calculated and it provides optimal solution in term of cost and performance.

This thesis has achieved both objectives set to study about resource planning and cost optimization, while maintaining high quality of service level for distribution centre in beverage business. This study provides more understanding of warehouse management in term of equipment utilization and cost management refer to actual operation.

This study did not concern all condition that might indirectly effect to the operation, or some specific criteria, such as geographical traffic route, local regulation of truck-banning hour, and some specific requirements of customer; some customers have small warehouses which cannot deliver product only by 6-wheel truck. However, the study will give some directions and solutions for management, and also provide alternative options, in case the optimal option cannot be applied.

Suggestion

The simulation model applying in this study can be implemented to other warehouses of the company due to there are similar conditions and operational procedures in each warehouse. If the simulation model generates optimal and cost effective result in the Buriram warehouse, there is high possibility to implement in other warehouses.

Furthermore, the simulation model scopes only on local distribution centre, the regional and national distribution level might apply this simulation as a tool to study overall impact on the supply chain line.

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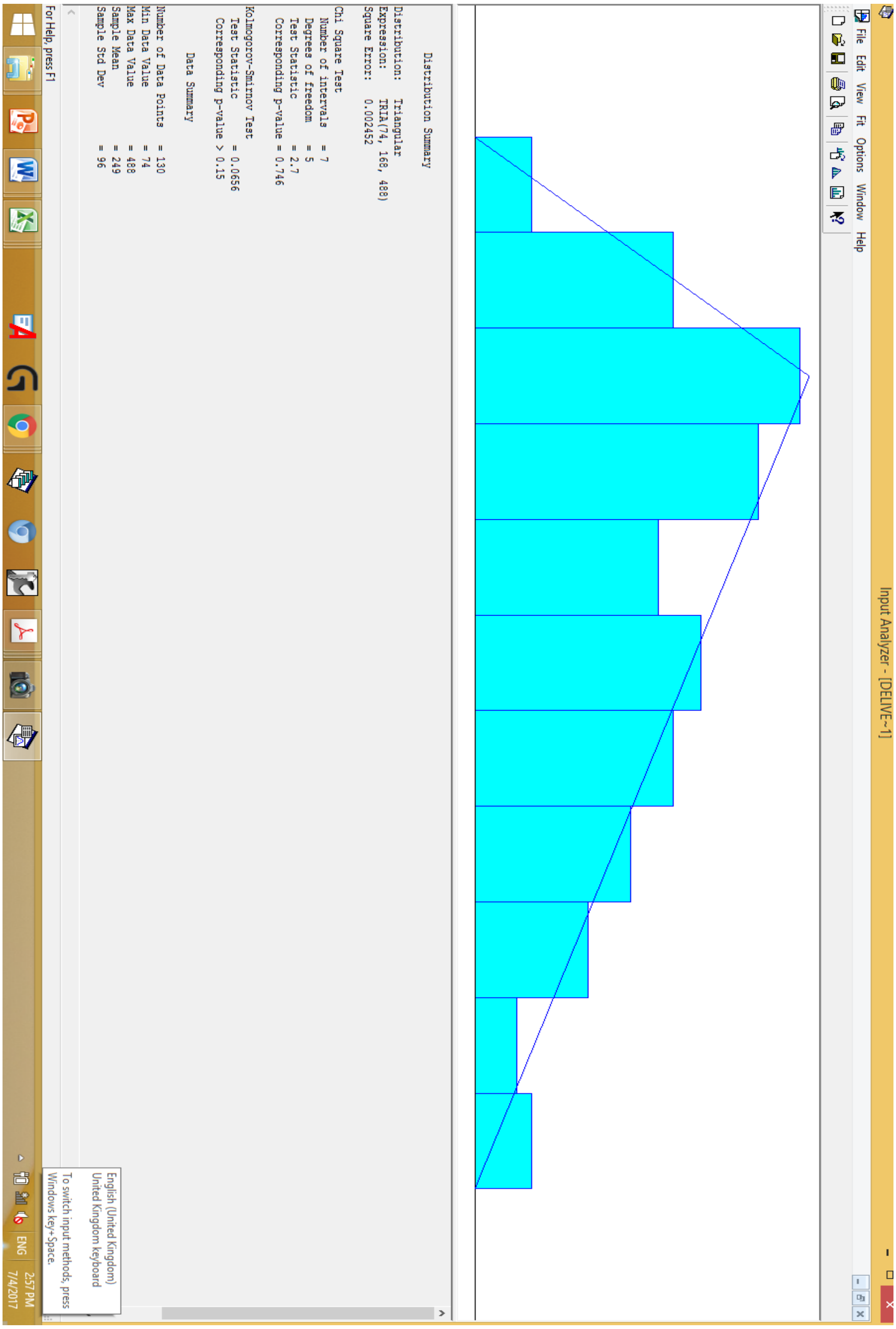
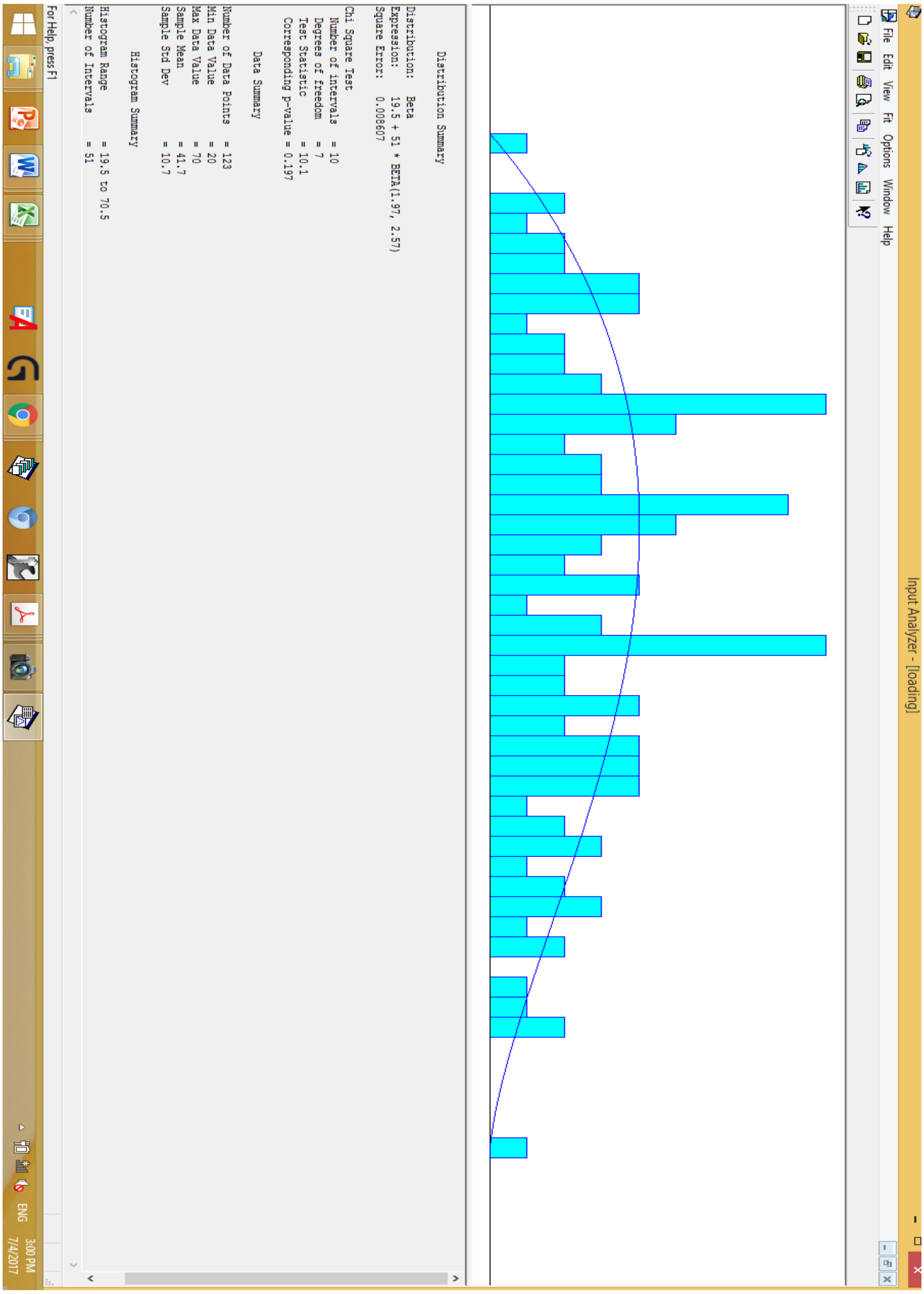
APPENDIX

Day	InBound			Outbound			Day	InBound			Outbound		
	Oct	Nov	Dec	Oct	Nov	Dec		Oct	Nov	Dec	Oct	Nov	Dec
1	36			34	0	0	41		240		0	196	0
2	47			84	0	0	42		220		0	215	0
3	100			84	0	0	43		216		0	193	0
4	157			47	0	0	44		218		0	330	0
5	83			102	0	0	45		215		0	245	0
6	70			120	0	0	46		136		0	126	0
7	118			90	0	0	47		71		0	222	0
8	108			240	0	0	48		187		0	169	0
9	106			173	0	0	49		0				0
10	117			208	0	0	50		180		0	127	0
11	131			158	0	0	51		227		0	175	0
12	103			139	0	0	52		148		0	373	0
13	71			115	0	0	53			235	0	0	16
14	160			60	0	0	54			316	0	0	228
15	174			182	0	0	55			122	0	0	128
16	183			192	0	0	56			127	0	0	100
17	155			144	0	0	57			207	0	0	444
18	143			78	0	0	58			337	0	0	475
19	48			98	0	0	59			176	0	0	350
20	195			97	0	0	60			341	0	0	237
21	270			200	0	0	61			200	0	0	32
22	230			139	0	0	62			235	0	0	263
23	222			184	0	0	63			297	0	0	243
24	59			173	0	0	64			253	0	0	415
25	135			237	0	0	65			263	0	0	503
26		121		0	43	0	66			155	0	0	233
27		131		0	84	0	67			389	0	0	214
28		103		0	62	0	68			131			-
29		122		0	68	0	69			239	0	0	275
30		162		0	51	0	70			327	0	0	362
31		92		0	121	0	71			407	0	0	445
32		304		0	327	0	72			288	0	0	206
33		252		0	310	0	73			377	0	0	282
34		248		0	171	0	74			249	0	0	333
35		275		0	205	0	75			264			-
36		168		0	170	0	76			438	0	0	373
37		162		0	119	0	77			311	0	0	361
38		218		0	414	0	78			93	0	0	412
39		189		0	244	0	79			120	0	0	540
40		236		0	279	0	80			12	0	0	287

Volume of inbound and outbound



Delivery time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File Edit View Fit Options Window Help
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Distribution: Beta
Expression: 19.5 + 51 * BETA(1.97, 2.57)
Square Error: 0.008607
Chi Square Test
Number of intervals = 10
Degrees of freedom = 7
Test Statistic = 10.1
Corresponding p-value = 0.197
Data Summary
Number of Data Points = 123
Min Data Value = 20
Max Data Value = 70
Sample Mean = 41.7
Sample Std Dev = 10.7
Histogram Summary
Histogram Range = 19.5 to 70.5
Number of Intervals = 51
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ENG
3:00 PM
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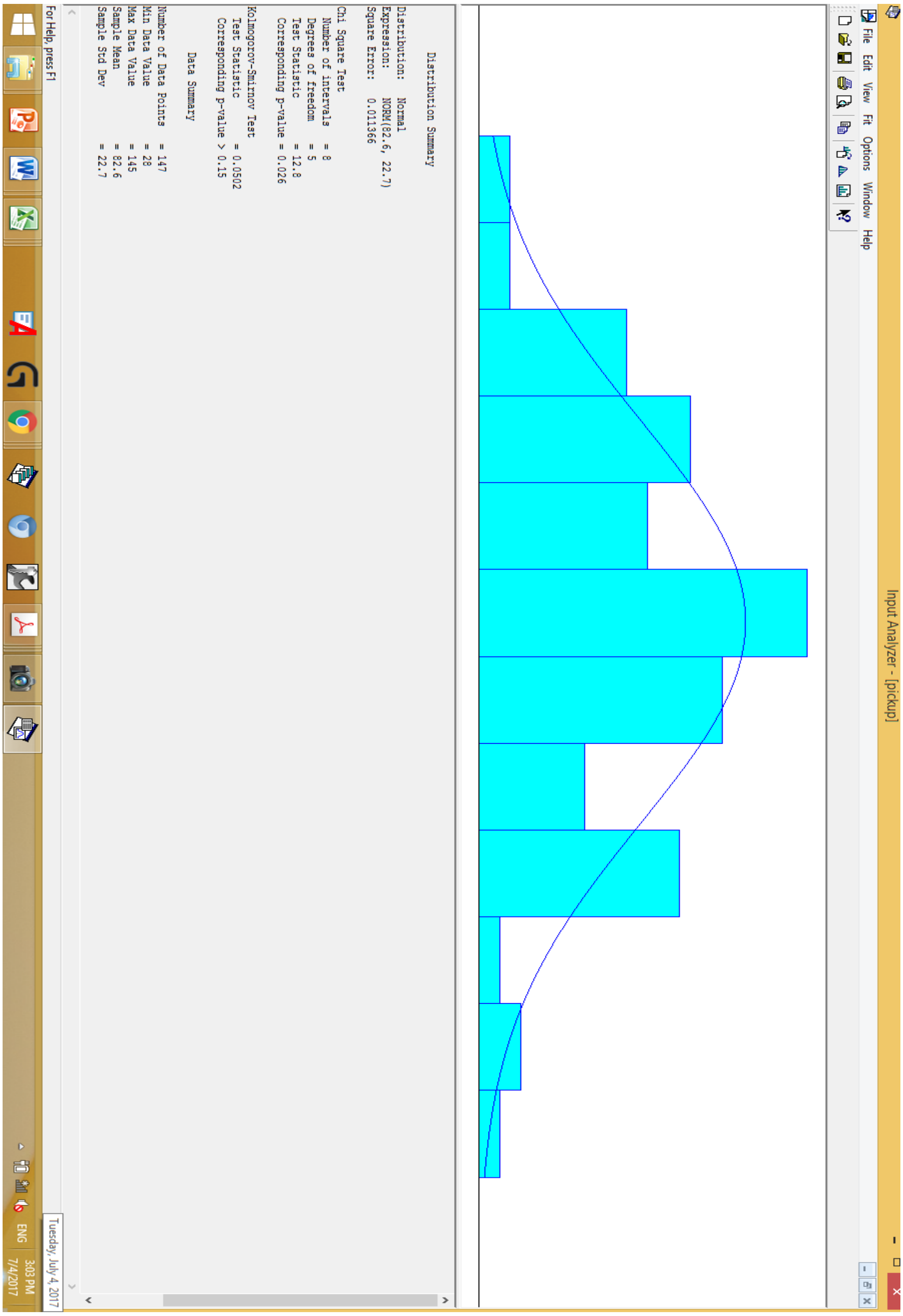
Loading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Distribution Summary
Distribution: Normal
Expression: NORM(82.6, 22.7)
Square Error: 0.011366
Chi Square Test
Number of intervals = 8
Degrees of freedom = 5
Test Statistic = 12.8
Corresponding p-value = 0.026
Kolmogorov-Smirnov Test
Test Statistic = 0.0502
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 147
Min Data Value = 28
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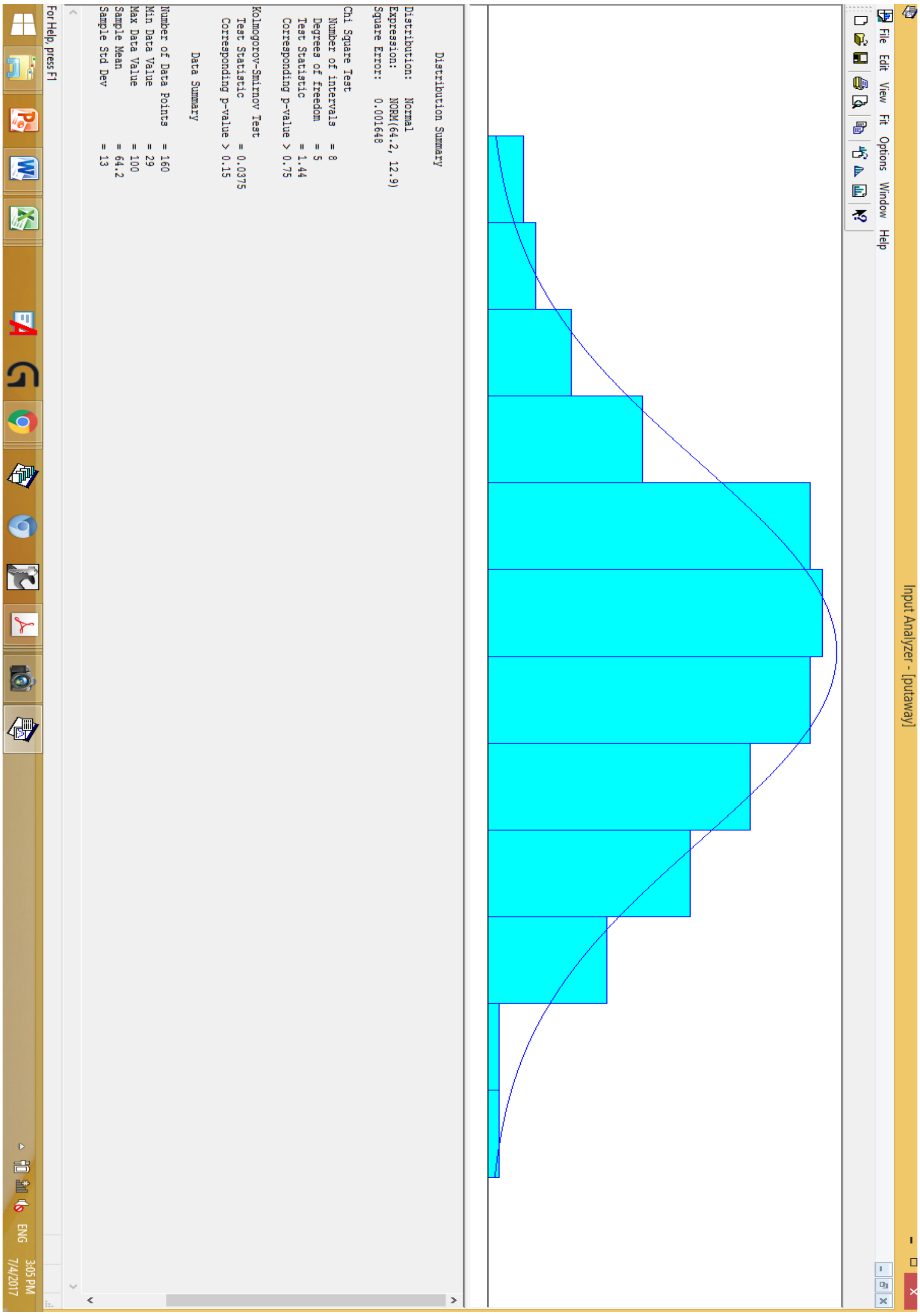
Sample Mean = 82.6
Sample Std Dev = 22.7
For Help, press F1

Pick up


Input Analyzer - [putaway]
File Edit View Fit Options Window Help
Distribution Summary
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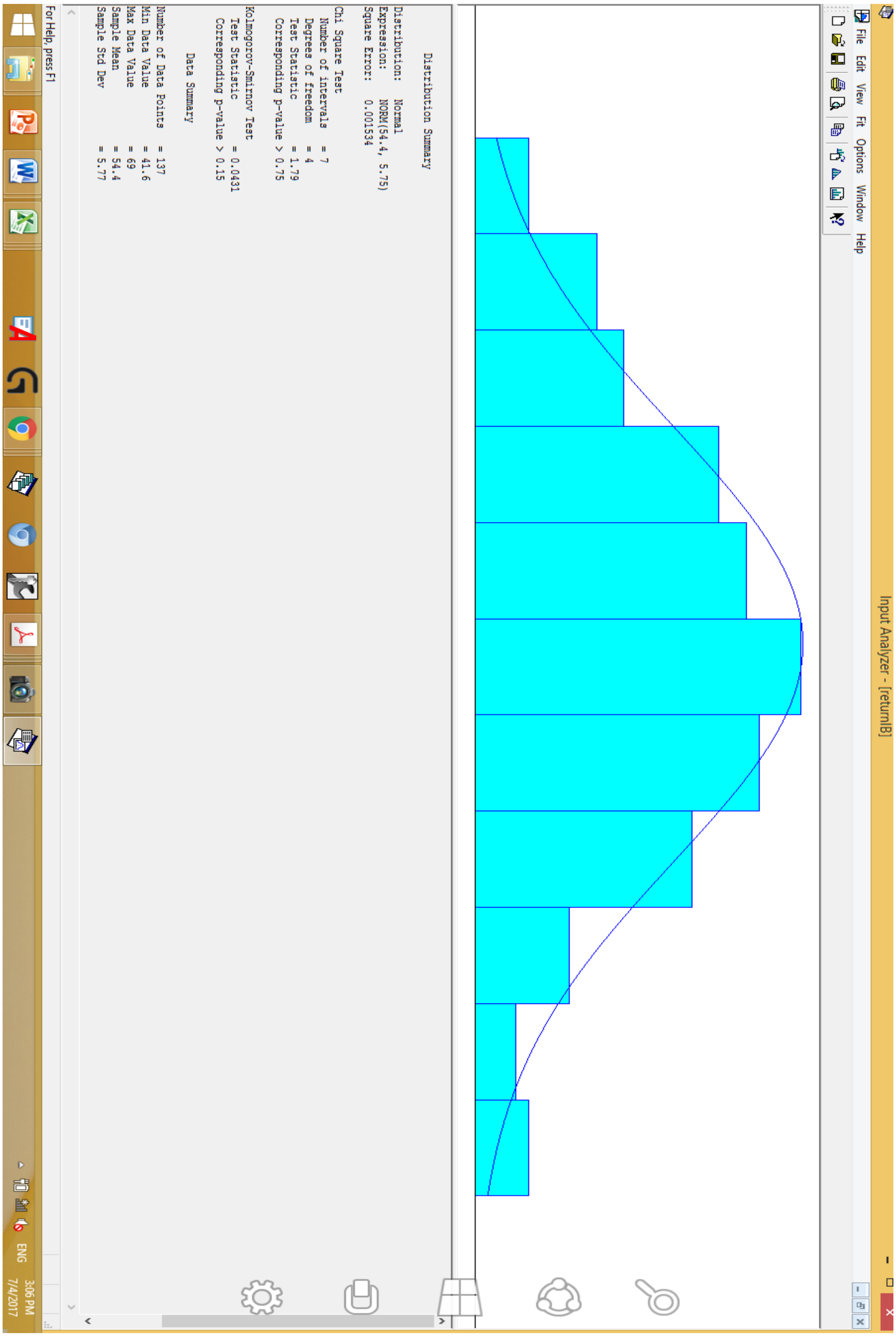
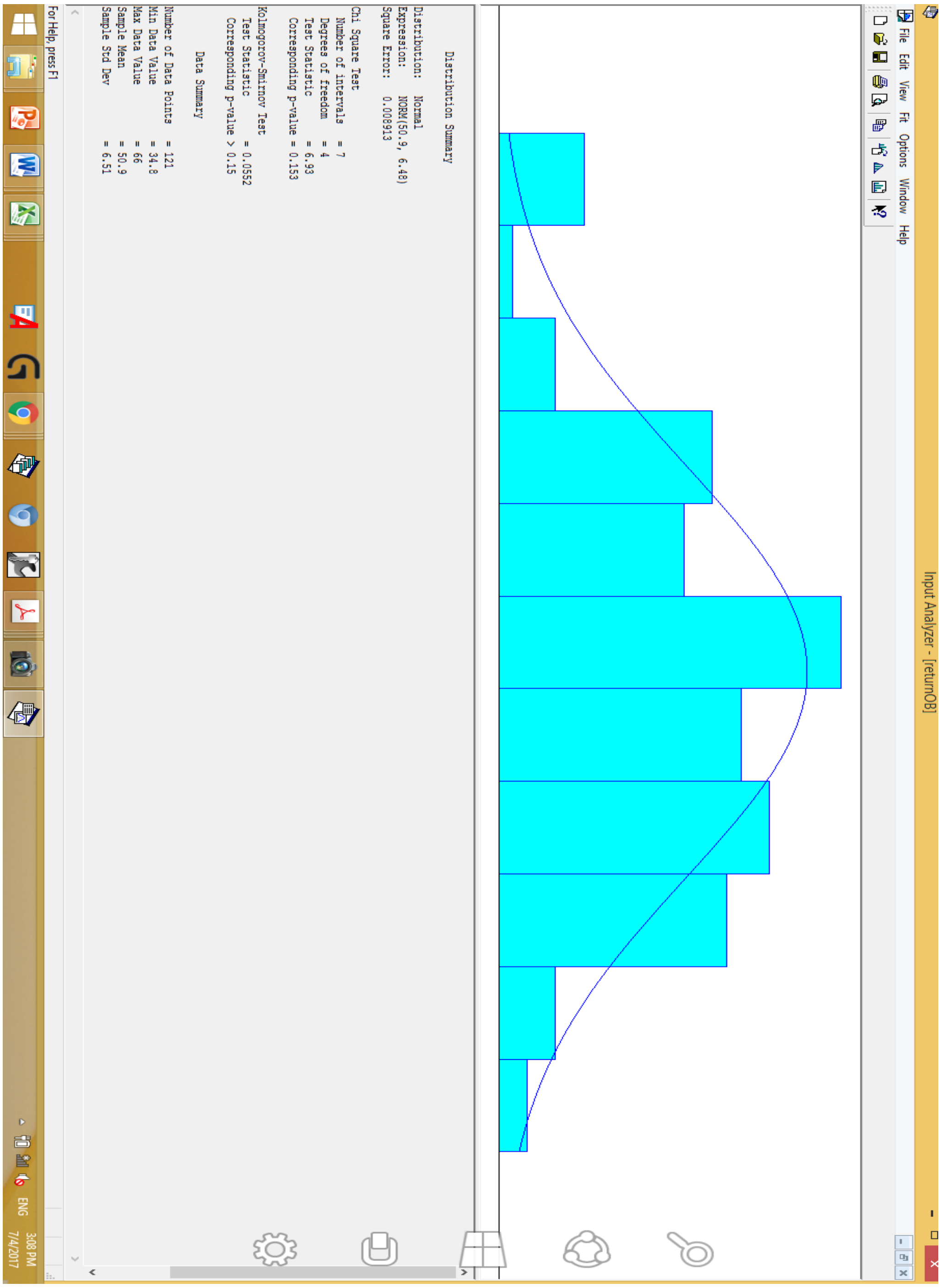
Expression: NORM(64.2, 12.9)
Square Error: 0.001648
Chi Square Test
Number of intervals = 8
Degrees of freedom = 5
Test Statistic = 1.44
Corresponding p-value > 0.75
Kolmogorov-Smirnov Test
Test Statistic = 0.0375
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 160
Min Data Value = 29
Max Data Value = 100
Sample Mean = 64.2
Sample Std Dev = 13
For Help, press F1
ENG
3:05 PM
7/4/2017

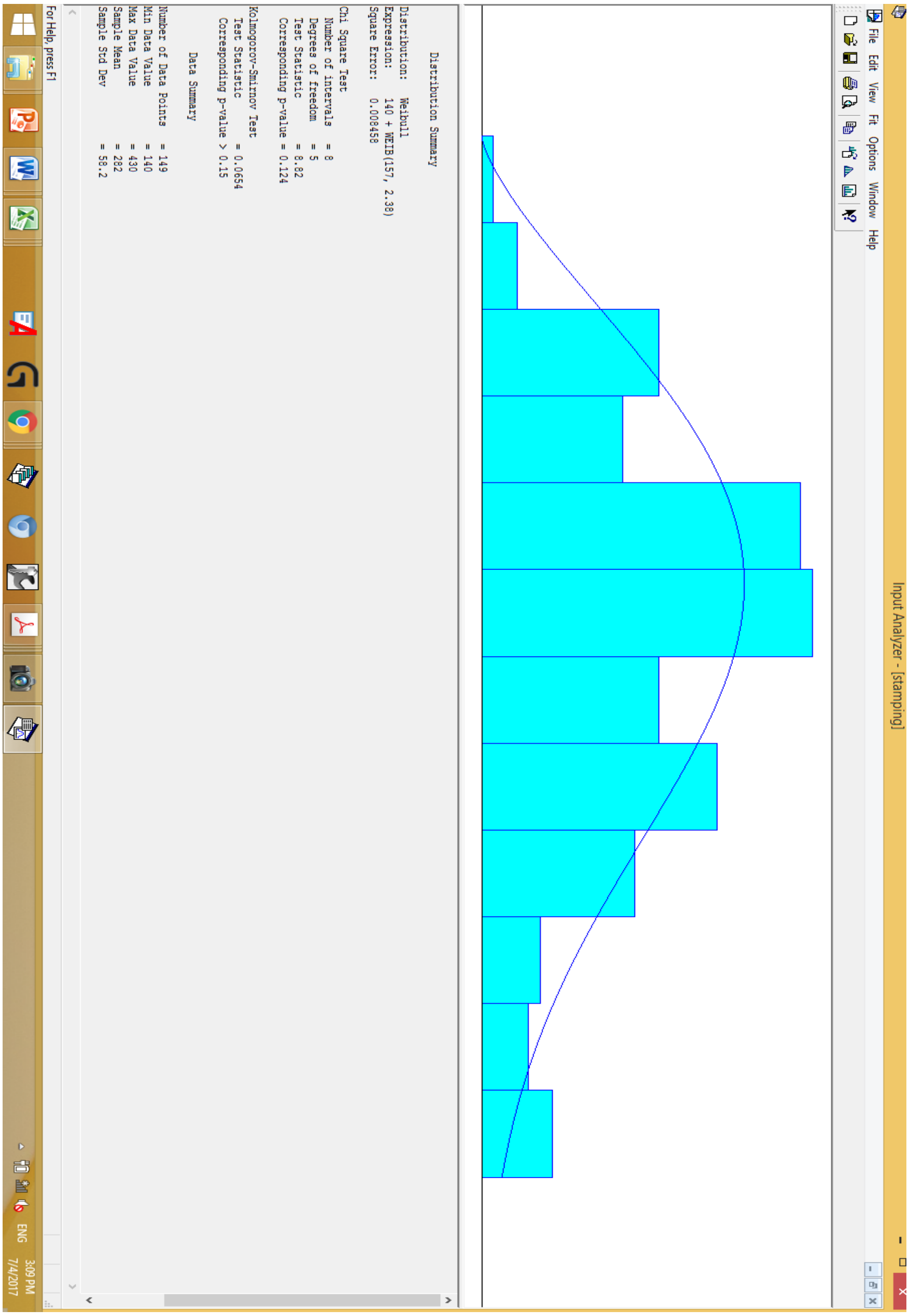
Putaway



Return Inbound

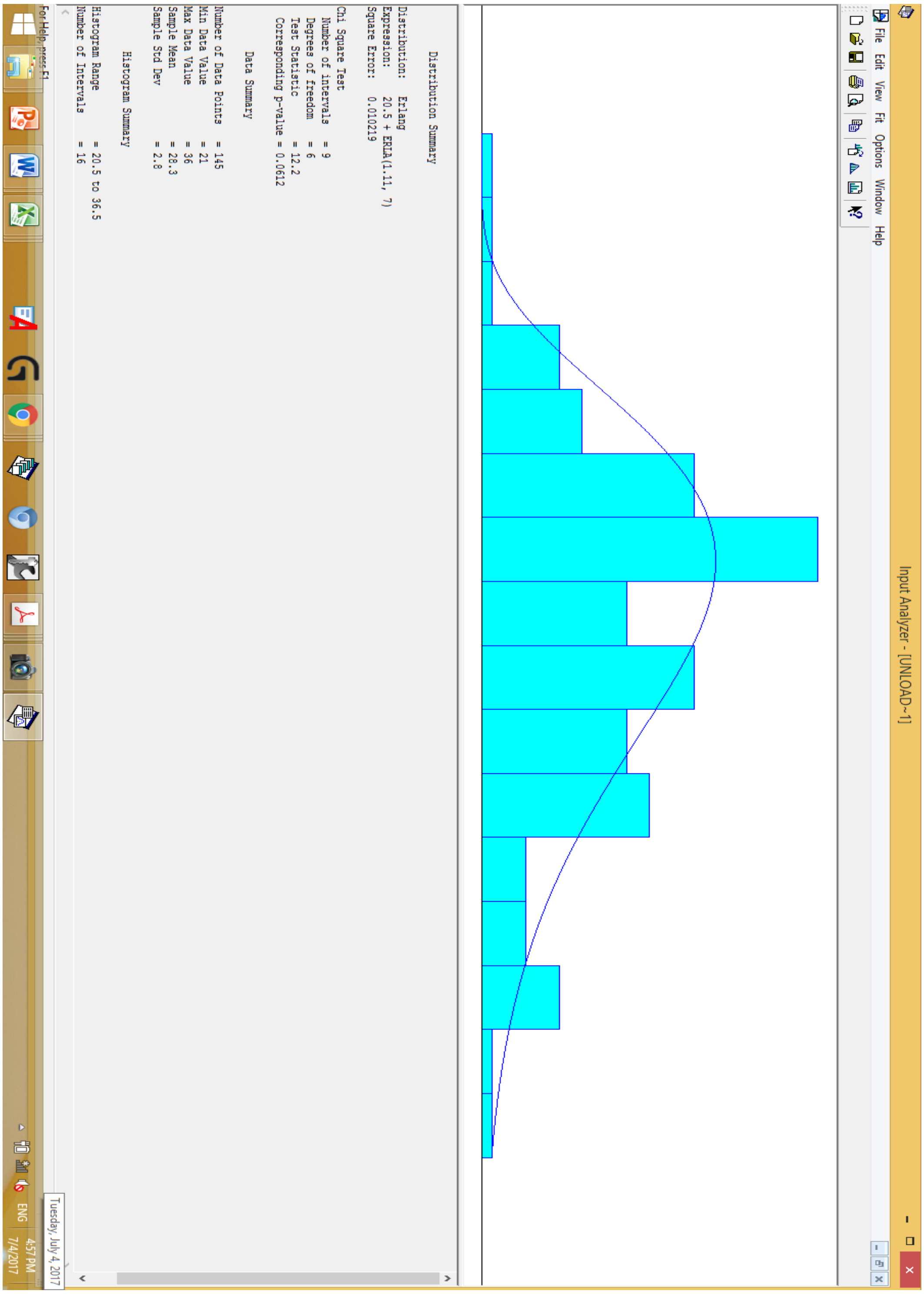


Return Outbound



Input Analyzer - [stamping]
File Edit View Fit Options Window Help
Distribution Summary
Distribution: Weibull
Expression: 140 + WEIB(157, 2.38)
Square Error: 0.008458
Chi Square Test
Number of intervals = 8
Degrees of freedom = 5
Test Statistic = 8.82
Corresponding p-value = 0.124
Kolmogorov-Smirnov Test
Test Statistic = 0.0654
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 149
Min Data Value = 140
Max Data Value = 430
Sample Mean = 282
Sample Std Dev = 58.2
For Help, press F1

Stamping


Input Analyzer - [UNLOAD~1]
File Edit View Fit Options Window Help
Distribution Summary
Distribution: Erlang
Expression: 20.5 + ERLA(1.11, 7)
Square Error: 0.010219
Chi Square Test
Number of intervals = 9
Degrees of freedom = 6
Test Statistic = 12.2
Corresponding p-value = 0.0612
Data Summary
Number of Data Points = 145
Min Data Value = 21
Max Data Value = 36
Sample Mean = 28.3
Sample Std Dev = 2.8
Histogram Summary
Histogram Range = 20.5 to 36.5
Number of Intervals = 16

Unloading

Date	Daily sale order (PL)
11/11/2016	312.70
11/12/2016	318.28
11/13/2016	-
11/14/2016	270.47
11/15/2016	291.57
11/16/2016	402.16
11/17/2016	228.96
11/18/2016	335.93
11/19/2016	377.57
11/20/2016	-
11/21/2016	250.39
11/22/2016	390.68
11/23/2016	314.84
11/24/2016	188.07
11/25/2016	170.42
11/26/2016	183.57
11/27/2016	-
11/28/2016	215.47
11/29/2016	463.01
11/30/2016	434.26
12/1/2016	70.06
12/2/2016	231.54
12/3/2016	309.04
12/4/2016	-
12/5/2016	-
12/6/2016	95.01
12/7/2016	486.66
12/8/2016	514.04
12/9/2016	384.02
12/10/2016	322.14

Daily order

Day	Folk lift 1	Folk lift 2	Folk lift 3	Folk lift 4	หน่วย ชั่วโมง
11/11/2016	4.1	3.0	4.2	3.5	14.8
11/12/2016	4.1	4.5	4.1	3.7	16.4
11/13/2016	0.0	0.0	0.0	0.0	0.0
11/14/2016	5.4	4.0	4.5	5.4	19.3
11/15/2016	4.9	3.7	4.4	4.3	17.3
11/16/2016	4.8	4.9	5.5	5.1	20.3
11/17/2016	4.2	3.3	5.4	5.0	17.9
11/18/2016	5.1	4.4	5.5	5.2	20.2
11/19/2016	4.8	4.4	5.0	4.0	18.2
11/20/2016	0.0	0.0	0.0	0.0	0.0
11/21/2016	4.5	4.2	5.1	4.6	18.4
11/22/2016	4.6	4.9	5.6	5.0	20.1
11/23/2016	4.6	3.4	2.5	3.9	14.4
11/24/2016	3.3	0.0	3.7	0.9	7.9
11/25/2016	3.6	2.6	4.5	0.9	11.6
11/26/2016	1.7	3.3	3.0	3.1	11.1
11/27/2016	0.0	0.5	0.0	0.8	1.3
11/28/2016	0.6	3.5	3.3	2.6	10.0
11/29/2016	0.0	5.2	6.3	0.0	11.5
11/30/2016	4.2	5.7	6.0	5.7	21.6
12/1/2016	4.4	2.1	3.9	4.8	15.2
12/2/2016	3.3	4.3	4.3	2.6	14.5
12/3/2016	3.6	4.3	0.0	4.0	11.9
12/4/2016	0.0	0.0	0.0	0.0	0.0
12/5/2016	0.0	0.0	0.0	0.0	0.0
12/6/2016	3.2	2.7	4.2	3.9	14.0
12/7/2016	6.2	4.4	5.1	3.8	19.5
12/8/2016	4.1	4.7	5.7	4.2	18.7
12/9/2016	3.4	3.2	4.4	4.2	15.2
12/10/2016	4.3	3.0	4.8	3.4	15.5

Operation hour of forklift