WAREHOUSE LAYOUT DESIGN FOR A METAL CONDUIT MANUFACTURER

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WAREHOUSE LAYOUT DESIGN FOR A METAL CONDUIT MANUFACTURER
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Nowadays, warehouse layout problems become a common problem for every organization, especially in conduit businesses. Finding an appropriate space to store the products, transporting the products in and out of the warehouse or even an effective way of using material-handling, for example, an overhead crane, is the most relevant topics that can cause a lot of costs and time for the organizations. To resolve these problems, the simulation is built to see the consequences of altering the position of conduit in the warehouse. For each layout design in the simulation is built based on the information provided by the conduit producer organization in Thailand. The results of the simulation are the layouts that provide the less distance involved and time usage for transporting the conduits in and out of the warehouse which leads directly to reduce the costs in the organization.

Field of Study:	Engineering Management	Student's Signature ....
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Chapter 1 Introduction

Warehousing plays an important role in the manufacturing and retail industries as stock pre-positioning. To keep enough products and inventories for selling becomes one of the important issues for every company. Warehouse management is considered as a tool for managing a warehouse both efficient and effective.

Ziga Innovation Public Co., Ltd., is a company who is the US standard conduit producer. Their main customers are the companies who construct the buildings or infrastructures. There also expand their business into white conduits and accessories for electrical use. Ziga products are mainly galvanized steel conduits with the same length but different diameters as shown in figure 1. The company stocks its materials and conduits in the warehouse which they have 4 warehouses.

Figure 1 galvanized steel conduits

Problem statement

Currently, the first three warehouses are used to stock raw materials and the other products from another company which is not in this research scope. While another warehouse, which considers in this research, is used to stock end-products. In this ladder warehouse, whenever the conduits are produced, the warehouse workers have no plan where to store. They only find the space to stock them. This creates a lot of problem such as waste more time to mobilize the product to the shipping point. In the worst scenarios, the production department stills produce products even if there is no space to stock them anymore. Doing such an operation has resulted in the company to encounter the low space of utilization, time-consuming for loading the stocks, no place to stock more conduits, hard to access and mobilize the stock.

In summary, there have not been any good warehouse layout where they can put the conduits in order to use the space in an efficient and effective way.

Research objective.

The objective of the research is to design the warehouse layout which provides the benefits for the company in term of less time consuming and distance travel. In order to achieve this objective, these are the following tasks to be made.

1. Measure the current utilization of the area in the warehouse.
2. Analyse the problem and design the appropriate warehouse layout.
3. Evaluate the results and revise the design plan to minimizing travel distance and time usage.

Research question.

1. What are the optimal warehouse layouts that suitable for storing the conduits with different diameter but the same length and provide the most efficiency?
2. How should SKUs be assigned to the warehouse in order to gain maximum benefits in term of less distance and time usage?

Hypothesis development

According to the above research questions, below are the hypothesis development based on the related research and existing knowledge.

1. The optimal warehouse layout can be achieved by using the class-based storage model that determines the storage layout of each SKUs based on characteristics.
2. The position of each SKU will be classified into the categories and stored in the assigned area.

The scope of the Research

This research will focus on how to increase the area utilization in the warehouse to maximize the benefit in term of less distance travel and time usage. Although there are four warehouses, only one of them (warehouse 3) are taken into account because the areas of this warehouse store the most of the conduits as an end product that ready to be sold. The other warehouses are used to store raw materials and machine parts for production or the products that do not belong to Ziga company and are considered out of the scope of this research.

Expected outcome

The warehouse design layout will provide these three outcomes which can be measured. Those three outcomes are shown below.

1. Design the appropriate warehouse layout for each SKUs.
2. Decrease travel distance and time for transporting SKUs.
3. Reducing the handling costs such as labour costs and electrical costs due to the decreasing travel distance and time usage.

Chapter 2 Review of Literature

Literature review

This section is intended to discuss key finding and related knowledge that relate to the objective of this research. Utilizing the space in the warehouse has been the issues that are attracted by many academic researchers to study and analysis. Various studied show that optimizing the space in the warehouse, it needs to investigate the layout of the warehouse (Derhami, et al., 2016). The several researchers pinpoint the important considerations for designing the warehouse such as cost of maintenance (Marco, et al., 2009), facility usage (Tompkins, et al., 2010), facility management (Ling, et al., 2008), security issues (Gunasekaran, et al., 1999), operational policies (Ramtin & Pazour, 2015) and product allocation (Ramtin & Pazour, 2015).

Warehouse layout problem

The objective of the warehouse is storing or buffering the products (Marco, et al., 2009). It is an essential function for mass production to store the product, especially in logistics players. Therefore, the decision to design the layout of the warehouse should benefit the organization the most. In the decision phase, there are two types of problem that need to be concerned (Koster, et al., 2007). The first problem refers to the facility layout problem which related to the receiving process, shipping process, picking, sorting, etc. This problem concerns how to configure the facility to minimize the travel distance between relative location, cost of internal transporting, cost of material handling. (Koster, et al., 2007), (Drira, et al., 2007). Furthermore, Shayan and Chittilappilly (2004) defined the facility layout problem as the optimization of the layout to gain the maximum profit in term of facility utilization. Another problem is the internal layout design or aisle design problem. It concerns about aisle configuration (length and width), storage area and order-picking or shipping area (Dukic & Opetuk, 2012) (Koster, et al., 2007) (Drira, et al., 2007). In the end, the objective to solve this problem is less travel distance the same as facility layout problem (Koster, et al., 2007).

Unit load storage model and storage policy

According to Goetschalckx (2012), the unit load storage model is referring to the items that bunch into units of the same dimension. These units can be moved or transported freely in the warehouse. The unit load storage model can help storekeepers transport the numerous amount of product from warehouse to shipping area or docking areas by using the overhead crane. There is also other factors to consider which is a storage policy (Fumi, et al., 2013) (Goetschalckx, 2012). This is similar to Derhami et al. (2016), they examined the policy for managing the space in a warehouse. In their researches, they found that dedicated and shared policies give different results. For the dedicated policy, the assigned stock keeping units (SKUs) are positioned in the defined area. If the area is empty, it cannot be stored any other SKUs except the assigned SKUs. On the other hand, the shared policy allows the SKUs to be stored in an empty area or wherever the SKUs can be stored. These showed that the shared policy had a good efficiency for managing numerous SKUs in the limited space. While the dedicated need much more space to store the SKUs. However, when considers the SKUs in this research, each unit of the conduits are heavy and not easy to move. The conduits need to be divided into group and stored in a different location based on product turnover rate or product characteristic (Goetschalckx, 2012) (Derickx, 2012). Therefore, it is appropriate to assign the SKUs by using the dedicated policy for managing the space in this research.

ABC Classification

According to Ravinder and Misra (2014), the inventory in the warehouse can be classified into 3 classes by applying Pareto's principle. Pareto's principle or 80/20 rules are used to prioritise the product to know which one is more important (Reh, 2017). The Pareto's principle focuses on 20 per cent of causes and 80 per cent of effects. In the ABC classification, Rank A is the most work involved or high value of price/volume. While rank C is the less work involved or low value of price/volume (Karthick, et al., 2014). Rank B is in-between.

Order picking method

It is well known that the process of picking inventory is the most important function in the warehouse. According to Tompkins et al. (2010), this process costs almost 55 per cent of the annual operating costs. This process defined as the activities that retrieve, sort, pick or transport any item from one location to another location in response to internal processes or customer requests (Dukic, et al., 2010). It is important to find some measures that reduce the distance travel and time to improve the order picking efficiency. By using an appropriate policy, it is possible to reduce the time and distance involved. One of the methods is the single order picking method. This method is generally used to pick one by one (in batches or by-product) at the time and then transports them to the shipping area or depot (Habazin, et al., 2017). In this research, we will focus on how to use this method in an effective way due to the characteristic of the warehouse and the policy.

Warehouse activities profiling

According to Bartholdi and Hackman (2014), the warehouse activities profiling is the measurement for understanding patterns, nature, trends, relation and material flow in each SKUs. The statistical information such as SKUs detail, warehouse layout, historical data on sale record, production etc. are needed to analyse which SKUs are matter and need to be focused. All of this information and more deep analysis, it can identify the potential improvement in the warehouse (Wessman & Bärring, 2014).

Storage and space allocation

Many types of research have been conducted on the mathematic model or optimization which aim to solve the warehouse layout problems (Tan, et al., 2017). There are 2 main benefits for solving the warehouse problems as shown in table 1.

Benefits	Descriptions
1. More profitability (Koster, et al., 2017)	The activity in warehouse related directly to costs and these costs affect the company profitability. In several companies, warehouses have different activities involved in assembly, storing, picking, packaging and shipping operation. These operations cause a lot of costs in the company such as labour cost and electricity cost for moving SKUs all over the warehouse, handling costs for picking and

	shipping. With the appropriate storage allocation, it will help in saving time which lead to saving costs for the company.
2. Reduce travel distance and times (Jaimes , et al., 2012)	The appropriate allocation of each product will be arranged in the appropriate amount, stacks and positions which will easily to access and transport. These will help the storekeepers to easily move product in and out which decrease the time and travel distance. It can be applied with the automation system which helps increase efficiency, flexibility and space utilization (Koster, et al., 2017).

Table 1 The benefits

When considering the characteristic of the Ziga warehouse for storing conduits, it consists of several things that similar to the terminal ports as shown in table 2 below.

Characteristic	Ziga warehouse	Terminal port
Equipment for transportation	Overhead crane	Overhead crane
Product	Conduits	Container
Depot area	Use trucks	Use ship and trucks
Movement of products	Move from the top	Move from the top

Type of storage yard	Block of conduits	Stack of containers

Table 2 Comparison between Ziga warehouse and Terminal ports.

Therefore, in this thesis, space and storage allocation will be applied from the terminal ports researches. In this section, a review of the studies from several types of research is provided below. Here are the lists.

Authors	Description
Zhen et al. (2013)	Zhen's (2013) research provides a strategy for improving the internal activity on terminal ports instead of changing the allocation layout by developing the storage yard management which mainly considers three resource activities such as ☐ Crane management ☐ Storage space management ☐ Vehicle schedules
Roy and Koster (2012)	Roy and Koster (2012) research consider the optimal design for storage allocation which focuses on how many stacks, bays, height should have and how to synchronized crane schedule and vehicle transport together.
Sun et al. (2013)	Sun (2013) research conducted the simulation for finding the optimal storage allocation for terminal ports. The simulation concern about crane schedules, the amount of depot area,

	transportation system planning and truck schedules.
Kim and Kim (1999)	Kim and KIM (1999) research provided the mathematical model and solution for container inventories in each storage allocation. The research focuses on how to choose the appropriate height stacks which would reduce the amount of re-handling operation.
Bish et al. (2001)	Bish's (2001) research analysis the vehicle scheduling and location problem. His research focuses on how to build the optimal storage location based on the routed in the terminal and vehicle scheduling.

Table 3 the literature review from other research

Performance measurement

Estimated travel distance for warehouse overhead crane

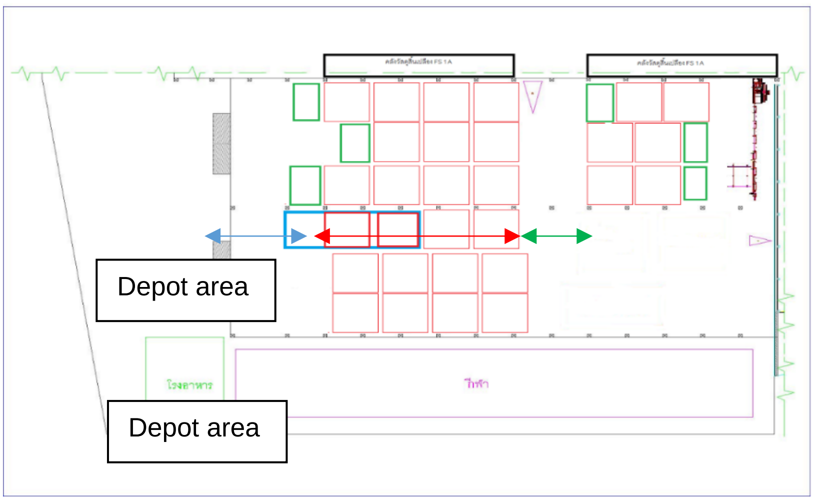


Figure 2 Estimated crane travel distance in the warehouse.

The estimated travel distance for picking n items (S_n) is the sum of the distance that involves with the basic distance (S_B) (the blue arrow), within-aisle distance (S_W) (the red arrow) and across-aisle distance (S_A) (the green arrow) as shown in figure 2 (Sadowsky & Hompel, 2011). The formulation is shown in the following:

Total distance Sn = within-aisle distance + basic distance + truck area

The following constraints for calculating the distance are shown below.

1. Each location for storing SKUs in the warehouse contains only 1 SKUs.
2. All locations for storing each product have the same length and width.
3. Ignoring the height of each SKUs.
4. It is assumed that the basic distance (S_b) is known by measuring the warehouse layout.
5. The within-aisle distance (S_W) and across-aisle distance (S_A) are calculated between centroids by measuring the aisle distance in the warehouse.
6. It is assumed that crane only brings back three batches of SKUs to the shipping areas.
7. It is assumed that crane only brings two batched of SKUs into the warehouse.
8. In the warehouse, we can use only two overhead cranes for the transport SKUs to each depot area.

Estimated travel time usage

According to Le-Duc and Koster (2005), the estimated time usage for picking the item I from can be calculated by the following formula.

$$TTU = TR_{WAT}+TR_{CAT}+OT_{BD}$$

There are some notations to be measured before the calculation. Below are the following notations.

1. TTU = Estimated total travel time usage
2. TR_{WA} = Estimated within aisle time
3. TR_{AA} = Estimated across aisle time
4. OT_{BD} = Other time (estimated time for travelling in the basic distance)
5. The order picking will be three SKUs at the time and will always bring back the SKUs from the destination to depot point.

Chapter 3 A Justification of the Research Methods Used

In this chapter, the methodology will be illustrated into the steps which focus on the model analysis, activity profiling, building a simulation model for each SKUs based on the information given, applied the involving theory in the simulation and verify and validate the current model for warehouse layout. Below are the summarized steps and data required for this research as shown in table 4.

Step	Data required
1. Model analysis.	- Blueprint of warehouse - Dimension of warehouse - Required on-site inspection (Ziga employees and author) - Position of each SKUs in the warehouse - Time usage for each SKUs when transport in and out of the warehouse - Truck size
2. Analysing the activity profiling by the following details: □ Inventory record in warehouse 3 □ Daily production plan in 2017 for each SKUs	- Inventory record in each warehouse - Daily production plan in 2017 for each SKUs - Daily sale record in 2017 for each SKUs - The diameter of each SKU - The picking frequency.

☐ Daily sale record in 2017 for each SKUs ☐ The diameter of each SKU ☐ Frequency of order Then classify each SKUs in rank A (fast moving), B (moderate moving) and C (slow moving).	
3. Design layout, define assumptions and constraints for building simulation.	- Blueprint of warehouse - Dimension of warehouse - Required on-site inspection (Ziga employees and author) - Position of each SKUs in warehouse - Time usage for each SKUs when transport in the warehouse - Truck size - Inventory flow - Limitations and constraints
4. Model simulation	- Flowchart that shows the internal process in the warehouse - Arrival rate for productions.

	- Arrival rate for sales and order.
5. Validation and verification.	- Results from Arena simulation - Production plan in 2018 for each SKUs - Sale record in 2018 for each SKUs - Handling costs - Operation administration costs

Table 4 Five steps of methodology for this research.

Step 1 : Model analysis.

This step required on-site inspection with Ziga employees to truly understand the space allocation in each warehouse. This step requires the interview with Ziga employees to confirm the dimension of the warehouse, a position of each SKUs, facility design, time usage for transport conduits and internal process in the warehouse. It is also required the understanding of the relation. For better understanding, the name of each position needs to be defined. Therefore, it will easy to understand and easy to put in the simulation.

As shown in table 5, this table intends to illustrate the present information in the warehouse.

Category	**Warehouse 3 information**
Area of the warehouse	2,609.568 m^2
Material handling equipment	Overhead crane
Amount of SKUs	17 different SKUs

Length of the SKUs	6 meters
Average picking per year	1330 times
Maximum sale volumes	275,977 EA
Minimum sale volumes	0 EA
Average sale volumes	12,520 EA
Deadstock policy	270 days to decide what to do next.
Depot area	2 areas

Table 5 The information on the current situation in warehouse 3.

The inventory popularity distribution based on the per cent of sale volume is shown in figure 3. The horizontal axis presents the name of the product and the vertical axis presents per cent of sale volume. This figure shows that the first twelve products cover most of the picking in the warehouse.

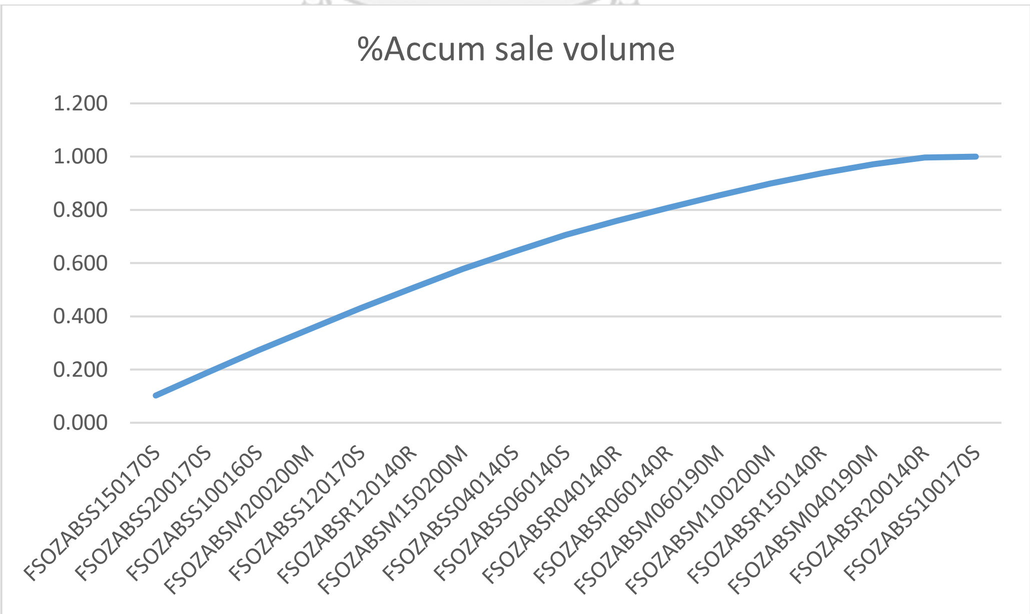


Figure 3 The inventory popularity distribution based on the sell volume

Product	Pieces/Batch	Volume	Total Batch sell	Frequency of order	%Accum P
FSOZABSS150170S	44	139832	3178	126	0.102
FSOZABSS200170S	37	98716	2668	124	0.188
FSOZABSS100160S	91	235144	2584	127	0.272
FSOZABSM200200M	37	91871	2483	112	0.352
FSOZABSS120170S	61	148840	2440	101	0.430
FSOZABSR120140R	61	142251	2332	83	0.505
FSOZABSM150200M	44	99789	2268	86	0.578
FSOZABSS040140S	169	343408	2032	99	0.644
FSOZABSS060140S	127	245999	1937	100	0.706
FSOZABSR040140R	169	275977	1633	82	0.759
FSOZABSR060140R	127	192532	1516	76	0.808
FSOZABSM060190M	127	187893	1480	84	0.855
FSOZABSM100200M	91	124852	1372	76	0.899
FSOZABSR150140R	44	52623	1196	56	0.938
FSOZABSM040190M	169	172211	1019	66	0.971
FSOZABSR200140R	37	30155	815	43	0.997
FSOZABSS100170S	91	8281	91	5	1

Table 6 the detail of each SKUs in warehouse 3.

Table 6 presents the detail of inventory in warehouse 3. It is clearly seen that the product name “FSOZABSS150170S” has the most sale volume even though this product does not have a highest frequency of orders. The last two products have a little sale volume since January 2017. According to the policy of Ziga company, when some SKUs reach to 270 days of staying in the warehouse without sale volumeม the sales team will need to consider what to do next such as cutting loss by dumping the price or boosting up the volume with promotions.

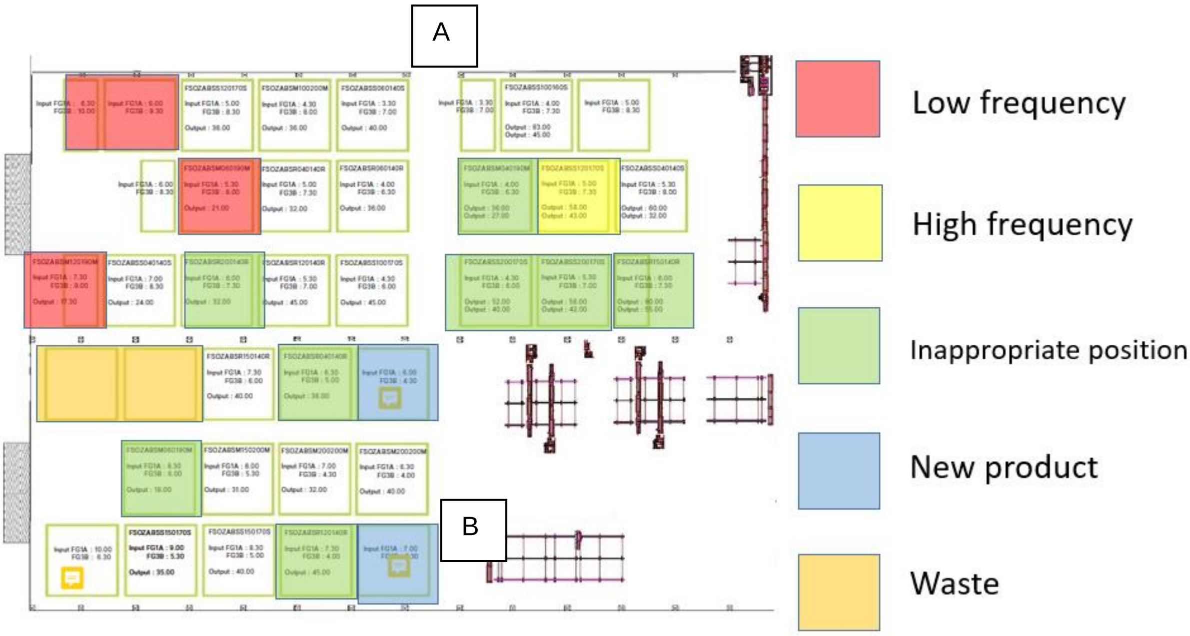


Figure 4 The position of SKUs in the warehouse based on the frequency

Figure 4 presents the position of each SKUs based on the frequency of picking. The yellow colour presents a high frequency picking SKUs. The blue colour presents the new products while the red one presents the low frequency. The orange colour presents the SKUs that are off-spec which define as waste stocks. The green areas in the first three row are the inappropriate positions to store the SKUs which produced from production point B. On the other hand, the green areas in the four to six row are the inappropriate positions to store the SKUs which produced from production point A.

Inventory flow

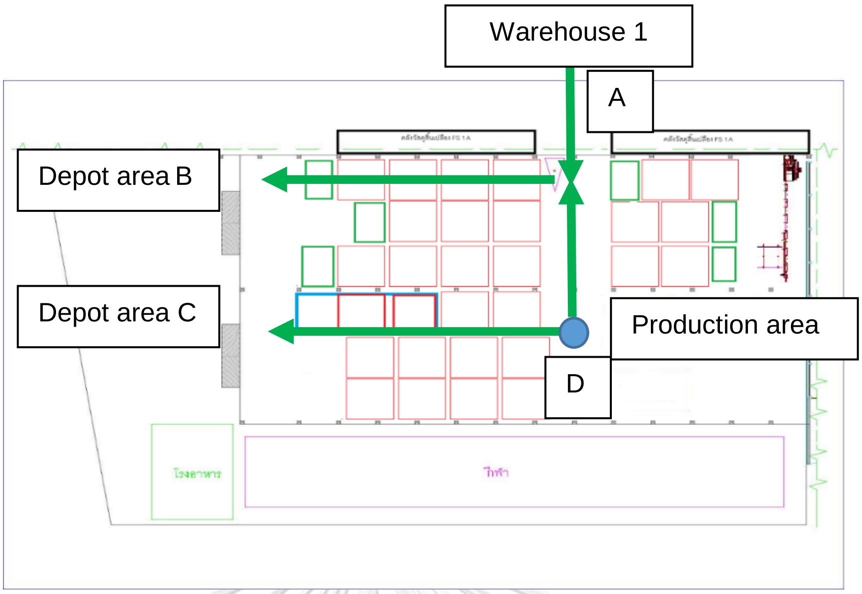


Figure 5 Inventory flow in warehouse 3.

According to figure 5, some SKUs in warehouse 3 are produced and bunched in warehouse 1 and transfer through A position. The other SKUs are produced and bunched in D position. Therefore, the high-frequency picking SKUs which come from warehouse 1 should be placed on area A as shown in figure 6. While the high-frequency picking SKUs which is produced from warehouse 3 should be placed on area B as shown in figure 6.

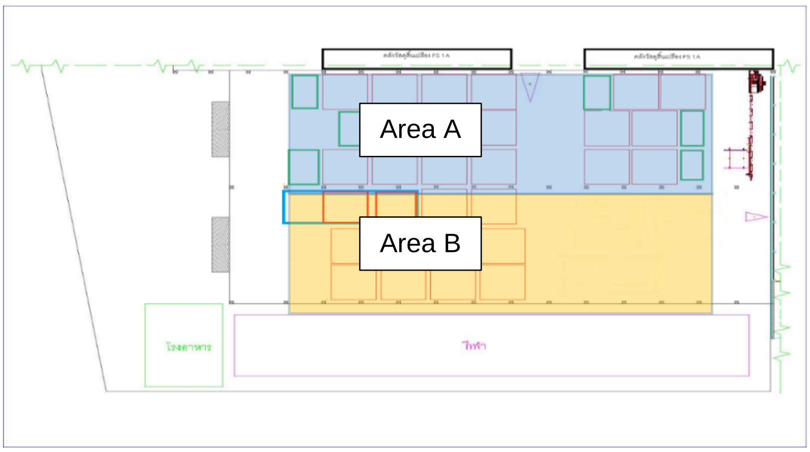


Figure 6 The position of high frequency picking SKUs

As shown in Figure 7, the number for each position will start from left to right and top to bottom. These numbers are used in the simulation to define every position for each SKUS. The areas will be divided into 2 parts which consist of area A and area B.

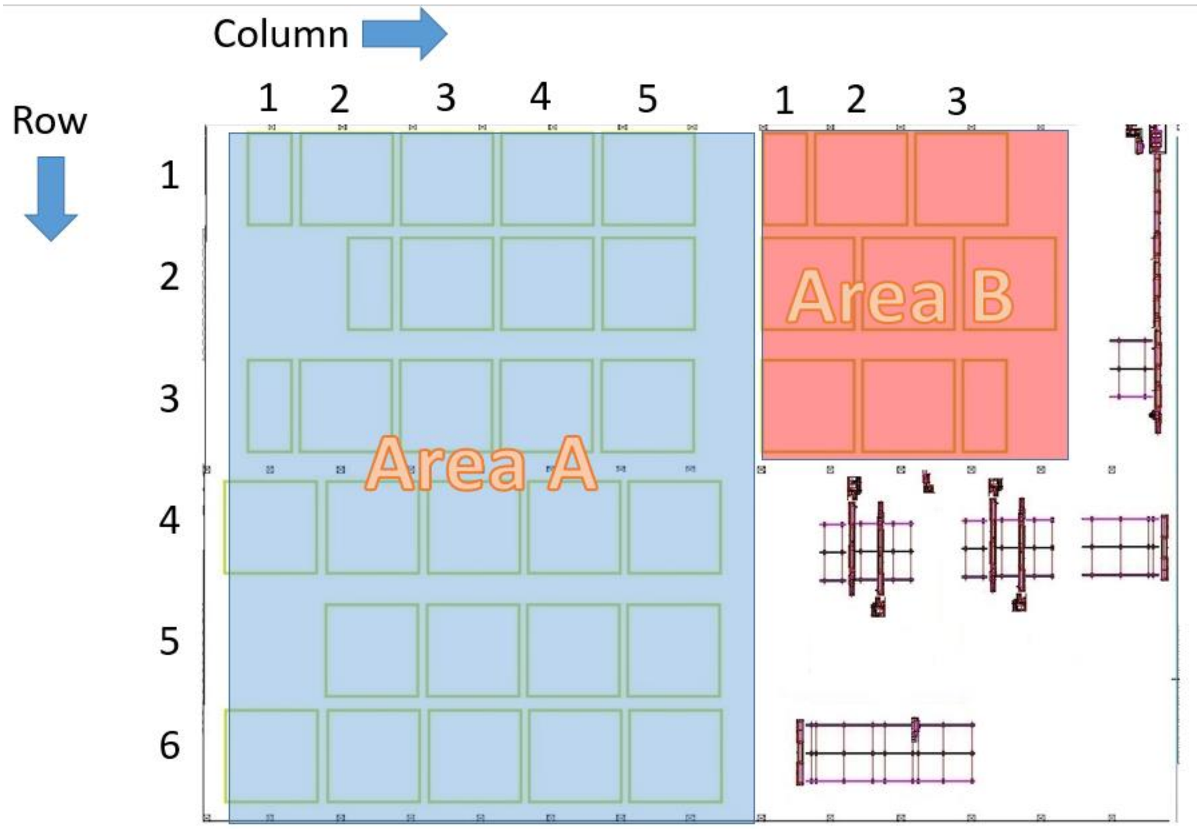


Figure 7 The name of each position

The space allocation name can be described as shown in table 7.

Area	Column	Row	Attribute	Set index	Product name
A	1	1	Position A11	1	-
A	2	1	Position A21	2	-
A	3	1	Position A31	3	FSOZABSS120170S
A	4	1	Position A41	4	FSOZABSM100200M
A	5	1	Position A51	5	FSOZABSS060140S
A	1	2	Position A12	6	-
A	2	2	Position A22	7	-
A	3	2	Position A32	8	FSOZABSM060190M
A	4	2	Position A42	9	FSOZABSR040140R
A	5	2	Position A52	10	FSOZABSR060140R
A	1	3	Position A13	11	FSOZABSM120190M
A	2	3	Position A23	12	FSOZABSS040140S
A	3	3	Position A33	13	FSOZABSR200140R
A	4	3	Position A43	14	FSOZABSR120140R
A	5	3	Position A53	15	FSOZABSS100170S
A	1	4	Position A14	16	Waste
A	2	4	Position A24	17	Waste
A	3	4	Position A34	18	FSOZABSR150140R
A	4	4	Position A44	19	FSOZABSR040140R
A	5	4	Position A54	20	New Product
A	1	5	Position A15	21	-
A	2	5	Position A25	22	FSOZABSM060190M
A	3	5	Position A35	23	FSOZABSM150200M
A	4	5	Position A45	24	FSOZABSM200200M
A	5	5	Position A55	25	FSOZABSM200200M
A	1	6	Position A16	26	FSOZABSM200200M
A	2	6	Position A26	27	FSOZABSS150170S
A	3	6	Position A36	28	FSOZABSS150170S
A	4	6	Position A46	29	FSOZABSR120140R
A	5	6	Position A56	30	New Product
B	1	1	Position B11	31	-
B	2	1	Position B21	32	FSOZABSS100160S
B	3	1	Position B31	33	-
B	1	2	Position B12	34	FSOZABSM040190M
B	2	2	Position B22	35	FSOZABSS120170S
B	3	2	Position B32	36	FSOZABSS040140S
B	1	3	Position B13	37	FSOZABSS200170S
B	2	3	Position B23	38	FSOZABSS200170S
B	3	3	Position B33	39	FSOZABSR150140R

Table 7 The allocation name in the warehouse for each SKUs.

The dimension of each SKUs can be defined as 6 metres * 6 metres in a square shape. To measure the distance between the production point to the position where SKUs will be stored, we have to define the starting point as shown in figure 8. The product that comes from production area A will start measure at point A. On the other hand, when the product come from production area B, it will start to measure at point B. In each position, we measure by using the measuring tape and the results can be shown in table 8.

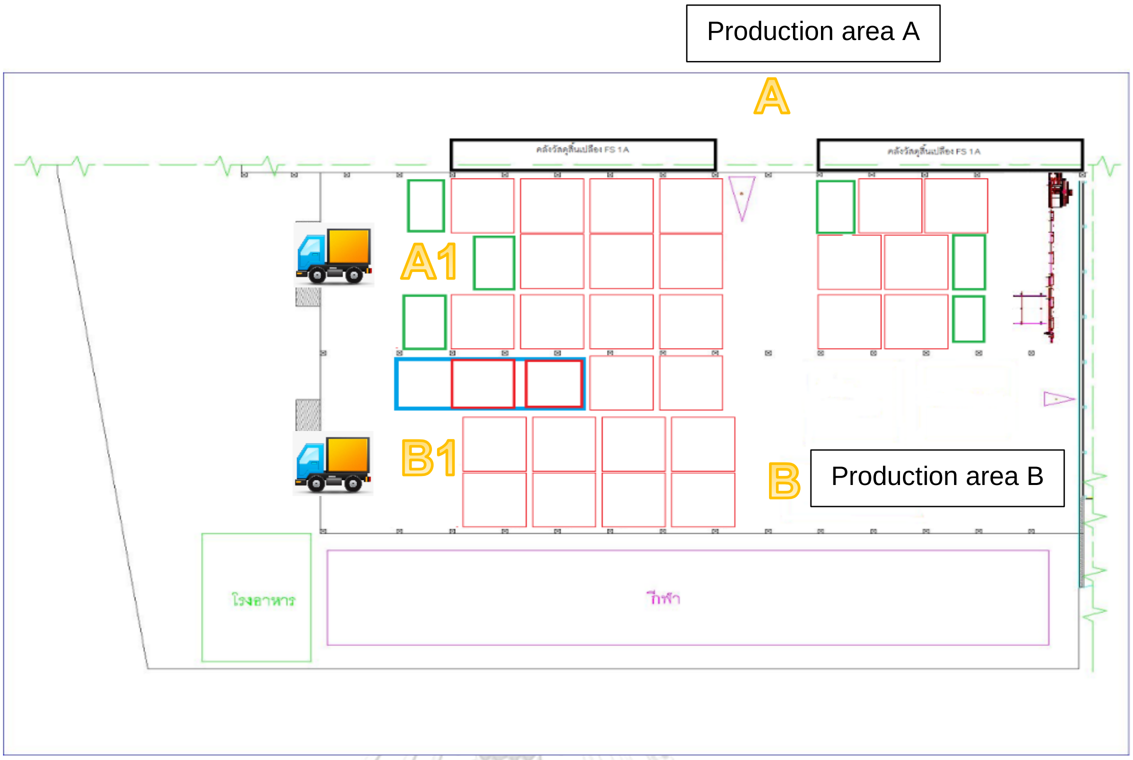


Figure 8 The starting point from production for measuring the distance.

Area	Column	Row	Attribute	Set index	Product name	Distance metre(A Input to warehouse)	Distance metre (B Input to warehouse)
A	1	1	Position A11	1	-	45.1	67.4
A	2	1	Position A21	2	-	38.6	60.9
A	3	1	Position A31	3	FSOZABSS120170S	32.1	54.4
A	4	1	Position A41	4	FSOZABSM100200M	25.2	47.5
A	5	1	Position A51	5	FSOZABSS060140S	18.6	40.9
A	1	2	Position A12	6	-	-	-
A	2	2	Position A22	7	-	44.1	53.6
A	3	2	Position A32	8	FSOZABSM060190M	38.3	47.8
A	4	2	Position A42	9	FSOZABSR040140R	31.3	40.8
A	5	2	Position A52	10	FSOZABSR060140R	25	34.5
A	1	3	Position A13	11	FSOZABSM120190M	56.3	51
A	2	3	Position A23	12	FSOZABSS040140S	51.8	46.5
A	3	3	Position A33	13	FSOZABSR200140R	45.11	39.9
A	4	3	Position A43	14	FSOZABSR120140R	38.9	33.6
A	5	3	Position A53	15	FSOZABSS100170S	32.4	27.1
A	1	4	Position A14	16	Waste	66.28	46.38
A	2	4	Position A24	17	Waste	60.28	40.38
A	3	4	Position A34	18	FSOZABSR150140R	54.28	34.38
A	4	4	Position A44	19	FSOZABSR040140R	48.18	28.28
A	5	4	Position A54	20	New Product	41	21.1
A	1	5	Position A15	21	-	-	-
A	2	5	Position A25	22	FSOZABSM060190M	65.4	32.5
A	3	5	Position A35	23	FSOZABSM150200M	59.4	26.5
A	4	5	Position A45	24	FSOZABSM200200M	53.2	20.3
A	5	5	Position A55	25	FSOZABSM200200M	46.6	13.7
A	1	6	Position A16	26	FSOZABSM200200M	78.7	32
A	2	6	Position A26	27	FSOZABSS150170S	72.6	25.9
A	3	6	Position A36	28	FSOZABSS150170S	66.5	19.8
A	4	6	Position A46	29	FSOZABSR120140R	60.1	13.4
A	5	6	Position A56	30	New Product	53.5	6.8
B	1	1	Position B11	31	-	15.7	38
B	2	1	Position B21	32	FSOZABSS100160S	20.2	42.5
B	3	1	Position B31	33	-	26.5	48.8
B	1	2	Position B12	34	FSOZABSM040190M	23.4	33.3
B	2	2	Position B22	35	FSOZABSS120170S	29.8	39.7
B	3	2	Position B32	36	FSOZABSS040140S	36	45.9
B	1	3	Position B13	37	FSOZABSS200170S	30.6	26.1
B	2	3	Position B23	38	FSOZABSS200170S	37.1	32.6
B	3	3	Position B33	39	FSOZABSR150140R	43.1	38.6

Table 8 The distance between production point A and B and each position of SKUs

In the depot area, according to the Thailand's department of land transport, the truck size that Ziga company uses to transport the conduits are shown in figure 9.

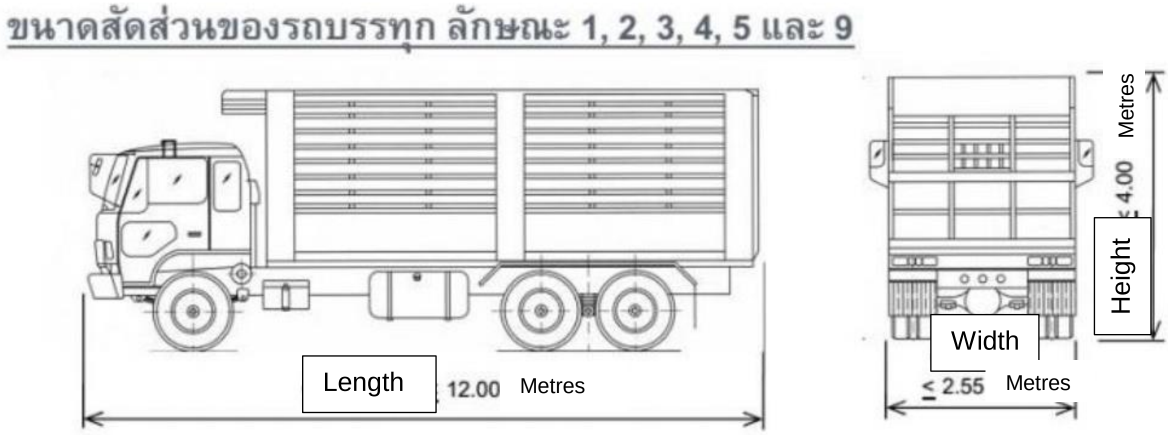


Figure 9 The track size (cited from http://Isuzu-truck.blogspot.com/2018/05/blog-post.html)

For measuring the distance from each SKUs to depots area, we will measure the centric of each position to the centric of the depot area (truck). The results are shown in table 9.

Area	Column	Row	Attribute	Set index	Product name	Distance metre (Warehouse to Truck A)	Distance metre (Warehouse to Truck B)
A	1	1	Position A11	1	-	7.95	-
A	2	1	Position A21	2	-	12.35	-
A	3	1	Position A31	3	FSOZABSS120170S	18.85	-
A	4	1	Position A41	4	FSOZABSM100200M	25.75	-
A	5	1	Position A51	5	FSOZABSS060140S	32.35	-
A	1	2	Position A12	6	-	-	-
A	2	2	Position A22	7	-	6.85	-
A	3	2	Position A32	8	FSOZABSM060190M	12.65	-
A	4	2	Position A42	9	FSOZABSR040140R	19.65	-
A	5	2	Position A52	10	FSOZABSR060140R	25.95	-
A	1	3	Position A13	11	FSOZABSM120190M	8.45	-
A	2	3	Position A23	12	FSOZABSS040140S	12.95	-
A	3	3	Position A33	13	FSOZABSR200140R	19.55	-
A	4	3	Position A43	14	FSOZABSR120140R	25.85	-
A	5	3	Position A53	15	FSOZABSS100170S	32.35	-
A	1	4	Position A14	16	Waste	-	8.52
A	2	4	Position A24	17	Waste	-	14.52
A	3	4	Position A34	18	FSOZABSR150140R	-	20.52
A	4	4	Position A44	19	FSOZABSR040140R	-	26.62
A	5	4	Position A54	20	New Product	-	33.8
A	1	5	Position A15	21	-	-	-
A	2	5	Position A25	22	FSOZABSM060190M	-	8.1
A	3	5	Position A35	23	FSOZABSM150200M	-	14.1
A	4	5	Position A45	24	FSOZABSM200200M	-	20.3
A	5	5	Position A55	25	FSOZABSM200200M	-	26.9
A	1	6	Position A16	26	FSOZABSM200200M	-	8.6
A	2	6	Position A26	27	FSOZABSS150170S	-	14.7
A	3	6	Position A36	28	FSOZABSS150170S	-	20.8
A	4	6	Position A46	29	FSOZABSR120140R	-	27.2
A	5	6	Position A56	30	New Product	-	33.8
B	1	1	Position B11	31	-	40.25	-
B	2	1	Position B21	32	FSOZABSS100160S	44.75	-
B	3	1	Position B31	33	-	51.05	-
B	1	2	Position B12	34	FSOZABSM040190M	35.55	-
B	2	2	Position B22	35	FSOZABSS120170S	41.95	-
B	3	2	Position B32	36	FSOZABSS040140S	48.15	-
B	1	3	Position B13	37	FSOZABSS200170S	41.35	-
B	2	3	Position B23	38	FSOZABSS200170S	47.85	-
B	3	3	Position B33	39	FSOZABSR150140R	53.85	-

Table 9 The distance between depot area and each position of SKUs.

Time usage

For measuring time usage for transporting conduits from production area to warehouse and from the warehouse to the depot area. We measure the time by using the average time for transporting the products from each position to the depot area. The results are shown in table 10 and table 11.

Area	Column	Row	Attribute	Set index	Product name	Time minute/batch (A Input to warehouse)	Time minute/batch(B Input to warehouse)
A	1	1	Position A11	1	-	6.5	10
A	2	1	Position A21	2	-	6	9.5
A	3	1	Position A31	3	FSOZABSS120170S	5	8.5
A	4	1	Position A41	4	FSOZABSM100200M	4.5	8
A	5	1	Position A51	5	FSOZABSS060140S	3.5	7
A	1	2	Position A12	6	-	-	-
A	2	2	Position A22	7	-	6	8.5
A	3	2	Position A32	8	FSOZABSM060190M	5.5	8
A	4	2	Position A42	9	FSOZABSR040140R	5	7.5
A	5	2	Position A52	10	FSOZABSR060140R	4	6.5
A	1	3	Position A13	11	FSOZABSM120190M	7.5	9
A	2	3	Position A23	12	FSOZABSS040140S	7	8.5
A	3	3	Position A33	13	FSOZABSR200140R	6	7.5
A	4	3	Position A43	14	FSOZABSR120140R	5.5	7
A	5	3	Position A53	15	FSOZABSS100170S	4.5	6
A	1	4	Position A14	16	Waste	-	-
A	2	4	Position A24	17	Waste	-	-
A	3	4	Position A34	18	FSOZABSR150140R	7.5	6
A	4	4	Position A44	19	FSOZABSR040140R	6.5	5
A	5	4	Position A54	20	New Product	6	4.5
A	1	5	Position A15	21	-	-	-
A	2	5	Position A25	22	FSOZABSM060190M	8.5	6
A	3	5	Position A35	23	FSOZABSM150200M	8	5.5
A	4	5	Position A45	24	FSOZABSM200200M	7	4.5
A	5	5	Position A55	25	FSOZABSM200200M	6.5	4
A	1	6	Position A16	26	FSOZABSM200200M	10	6.5
A	2	6	Position A26	27	FSOZABSS150170S	9	5.5
A	3	6	Position A36	28	FSOZABSS150170S	8.5	5
A	4	6	Position A46	29	FSOZABSR120140R	7.5	4
A	5	6	Position A56	30	New Product	7	3.5
B	1	1	Position B11	31	-	3.5	7
B	2	1	Position B21	32	FSOZABSS100160S	4	7.5
B	3	1	Position B31	33	-	5	8.5
B	1	2	Position B12	34	FSOZABSM040190M	4	6.5
B	2	2	Position B22	35	FSOZABSS120170S	5	7.5
B	3	2	Position B32	36	FSOZABSS040140S	5.5	8
B	1	3	Position B13	37	FSOZABSS200170S	4.5	6
B	2	3	Position B23	38	FSOZABSS200170S	5.5	7
B	3	3	Position B33	39	FSOZABSR150140R	6	7.5

Table 10 time usage for transporting the product to the warehouse

Area	Column	Row	Attribute	Set index	Product name	Time per batch to depot area A	Time per batch to depot area B
A	1	1	Position A11	1	-		
A	2	1	Position A21	2	-		
A	3	1	Position A31	3	FSOZABSS120170S	4	
A	4	1	Position A41	4	FSOZABSM100200M	4.5	
A	5	1	Position A51	5	FSOZABSS060140S	5	
A	1	2	Position A12	6	-		
A	2	2	Position A22	7	-		
A	3	2	Position A32	8	FSOZABSM060190M	3.5	
A	4	2	Position A42	9	FSOZABSR040140R	4	
A	5	2	Position A52	10	FSOZABSR060140R	4.5	
A	1	3	Position A13	11	FSOZABSM120190M	2.5	
A	2	3	Position A23	12	FSOZABSS040140S	3	
A	3	3	Position A33	13	FSOZABSR200140R	4	
A	4	3	Position A43	14	FSOZABSR120140R	4.5	
A	5	3	Position A53	15	FSOZABSS100170S	5	
A	1	4	Position A14	16	Waste		
A	2	4	Position A24	17	Waste		
A	3	4	Position A34	18	FSOZABSR150140R		4
A	4	4	Position A44	19	FSOZABSR040140R		4.5
A	5	4	Position A54	20	New Product		
A	1	5	Position A15	21	-		
A	2	5	Position A25	22	FSOZABSM060190M		3
A	3	5	Position A35	23	FSOZABSM150200M		3.5
A	4	5	Position A45	24	FSOZABSM200200M		4
A	5	5	Position A55	25	FSOZABSM200200M		5
A	1	6	Position A16	26	FSOZABSM200200M		2.5
A	2	6	Position A26	27	FSOZABSS150170S		3.5
A	3	6	Position A36	28	FSOZABSS150170S		4
A	4	6	Position A46	29	FSOZABSR120140R		4.5
A	5	6	Position A56	30	New Product		
B	1	1	Position B11	31	-		
B	2	1	Position B21	32	FSOZABSS100160S	7	
B	3	1	Position B31	33	-		
B	1	2	Position B12	34	FSOZABSM040190M	6	
B	2	2	Position B22	35	FSOZABSS120170S	6.5	
B	3	2	Position B32	36	FSOZABSS040140S	7.5	
B	1	3	Position B13	37	FSOZABSS200170S	6.5	
B	2	3	Position B23	38	FSOZABSS200170S	7	
B	3	3	Position B33	39	FSOZABSR150140R	8	

Table 11 time usage for transporting the product to the depot area from warehouse.

Step 2 : Analysing the activity profiling by the following details:

This step aims for analyzing the activity profiling in warehouse 3 (from high-frequency picking product to low-frequency picking product) based on the following information.

- ☐ Daily production plan in 2017 for each SKUs
- ☐ Daily sale record in 2017 for each SKUs
- ☐ The diameter of each SKU
- ☐ Frequency of order

- Frequency of picking

To get the above information for each SKUs, the author asks Ziga personnel to provide historical daily production, sale record, size and inventory record. This information will be disclosed under the terms and conditions that Ziga company defined. For building the simulation in this thesis, we use the daily production plan for calculating the amount of picking when transport from the production area to the warehouse. While we use the daily sale record to calculate the amount of picking from warehouse to depot area. The amount of picking for transporting products into the warehouse will be calculated by using the batch producing number divided by the number of batch per picking which is two batch per picking while the number of batch per picking for transporting product out will be three. Table 12 and Table 13 shows that amount of picking for each SKUs from productions and sales.

	Pieces/Batch	Production volume	Batch produce	Pick
FSOZABSS150170S	44	150131	3412	1706
FSOZABSS120170S	61	172165	2822	1411
FSOZABSS100160S	91	252954	2780	1390
FSOZABSM200200M	37	91165	2464	1232
FSOZABSR120140R	61	147510	2418	1209
FSOZABSS200170S	37	88781	2399	1200
FSOZABSM150200M	44	99179	2254	1127
FSOZABSS060140S	127	269866	2125	1062
FSOZABSS040170S	169	289047	1710	855
FSOZABSM060190M	127	199955	1574	787
FSOZABSM040190M	169	221424	1310	655
FSOZABSR060140R	127	165968	1307	653
FSOZABSR040140R	169	217394	1286	643
FSOZABSM100200M	91	116836	1284	642
FSOZABSR150140R	44	54392	1236	618
FSOZABSR200140R	37	29530	798	399
FSOZABSS100170S	91	22566	248	124

Table 12 The amount of picking for production volume.

Product	Pieces/Batch	Volume	Total Batch sell	Pick
FSOZABSS150170S	44	139832	3178	1059
FSOZABSS200170S	37	98716	2668	889
FSOZABSS100160S	91	235144	2584	861
FSOZABSM200200M	37	91871	2483	828
FSOZABSS120170S	61	148840	2440	813
FSOZABSR120140R	61	142251	2332	777
FSOZABSM150200M	44	99789	2268	756
FSOZABSS040140S	169	343408	2032	677
FSOZABSS060140S	127	245999	1937	646
FSOZABSR040140R	169	275977	1633	544
FSOZABSR060140R	127	192532	1516	505
FSOZABSM060190M	127	187893	1480	493
FSOZABSM100200M	91	124852	1372	457
FSOZABSR150140R	44	52623	1196	399
FSOZABSM040190M	169	172211	1019	340
FSOZABSR200140R	37	30155	815	272
FSOZABSS100170S	91	8281	91	30

Table 13 The amount of picking for sale volume.

Step 3 : Design layout, define assumptions and constraints for building simulation.

In this step, the area in each warehouse will divide into 2 zones which consist of zone A and zone B. Zone A will store the SKUs near each depot area in the warehouse. While zone B will be the farthest location from the depot area as shown in figure 10. In this simulation, the SKUs in zone B and the SKUs in row 1-3 in zone A will transport directly to depot area A1 while the SKUs in row 4-6 in zone A will transport to depot area A2 as shown in figure 10.

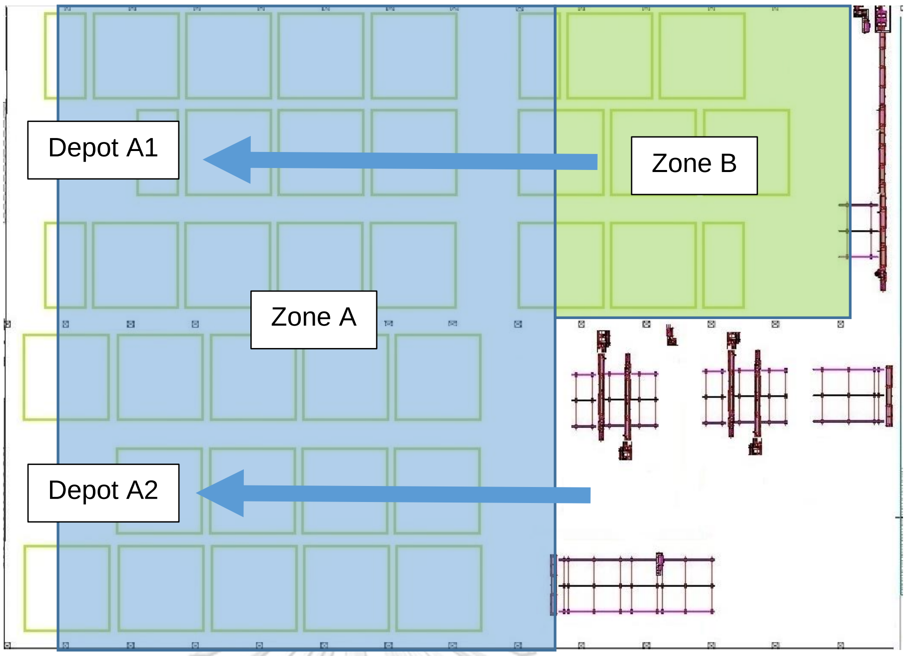


Figure 10 Classification area of the warehouse

Next is to define the operational assumptions and constraints that are used throughout this thesis. Some assumptions are the limitations that come from the current layouts. Some are the limitation of the Ziga company. Some constraints have to be defined in order to build the model more easily. Here are the consumptions that are used in the simulation.

1. The weight of SKUs does not affect the speed of the cranes.
2. A number of batch for transporting SKUs from the production area to each position in the warehouse are two batches per picking.
3. A number of batch for transporting SKUs from to each position in the warehouse to depot area are three batches per picking.
4. When SKUs are stored in row 1-3, the crane will transport the SKUs to depot area A1.
5. When SKUs are stored in row 4-6, the crane will transport the SKUs to depot area A2.

6. If there are the same SKUs are stored in different positions, the possibility of transporting to each position are equal.
7. If there are the same SKUs are stored in different positions, the possibility of picking from each position to the depot area are equal.
8. There is exclude the time for setting the batch for the crane to transport.
9. Assume that there is no different ability for crane controllers to control the crane.
10. The time and distance are calculated by using the centre of area truck and the centre of each position.
11. The Ziga company prefers not to invest in a warehouse system. Therefore, they are looking for a solution that does not require any budget.
12. There are six overhead cranes in warehouse 3. Three overhead cranes are currently used in area A and the other three are currently used in area B as shown in figure 6.
13. We assume that we can use only two overhead crane in area A and B to transport the SKUs in warehouse 3. The main reason why we can use only two overhead crane in each area because the other cranes have to transport the SKUs from the production area or use to transport SKUs from warehouse 1.
14. There are the off-specification SKUs that do not meet the Ziga standard quality. Therefore, the Ziga company have to spare some area to store these off-specification SKUs. Ziga company have a routine policy to dispose of the off-specification SKUs every month.

15. Ziga company have the policy to deal with the dead stock. When the SKUs cannot be sold in 270 days, the storekeepers will inform the sale manager to think about how to deal with the dead stock such as boost the sale volume by promotion or reduce the prices.
16. We only focus on the inventory that store in warehouse 3.
17. There are 2 available of crane for each row 1-3 and row 4-6.
18. The capacity in each position is infinite.

Table 14 are the position and lists of SKUs for the original layout.

Area	Column	Row	Attribute	Set index	Product name
A	1	1	Position A11	1	-
A	2	1	Position A21	2	-
A	3	1	Position A31	3	FSOZABSS120170S
A	4	1	Position A41	4	FSOZABSM100200M
A	5	1	Position A51	5	FSOZABSS060140S
A	1	2	Position A12	6	-
A	2	2	Position A22	7	-
A	3	2	Position A32	8	FSOZABSM060190M
A	4	2	Position A42	9	FSOZABSR040140R
A	5	2	Position A52	10	FSOZABSR060140R
A	1	3	Position A13	11	FSOZABSM120190M
A	2	3	Position A23	12	FSOZABSS040140S
A	3	3	Position A33	13	FSOZABSR200140R
A	4	3	Position A43	14	FSOZABSR120140R
A	5	3	Position A53	15	FSOZABSS100170S
A	1	4	Position A14	16	Waste
A	2	4	Position A24	17	Waste
A	3	4	Position A34	18	FSOZABSR150140R
A	4	4	Position A44	19	FSOZABSR040140R
A	5	4	Position A54	20	New Product
A	1	5	Position A15	21	-
A	2	5	Position A25	22	FSOZABSM060190M
A	3	5	Position A35	23	FSOZABSM150200M
A	4	5	Position A45	24	FSOZABSM200200M
A	5	5	Position A55	25	FSOZABSM200200M
A	1	6	Position A16	26	FSOZABSM200200M
A	2	6	Position A26	27	FSOZABSS150170S
A	3	6	Position A36	28	FSOZABSS150170S
A	4	6	Position A46	29	FSOZABSR120140R
A	5	6	Position A56	30	New Product
B	1	1	Position B11	31	-
B	2	1	Position B21	32	FSOZABSS100160S
B	3	1	Position B31	33	-
B	1	2	Position B12	34	FSOZABSM040190M
B	2	2	Position B22	35	FSOZABSS120170S
B	3	2	Position B32	36	FSOZABSS040140S
B	1	3	Position B13	37	FSOZABSS200170S
B	2	3	Position B23	38	FSOZABSS200170S
B	3	3	Position B33	39	FSOZABSR150140R

Table 14 The original warehouse layout

Step 4 : model simulation

To be able to build a model in arena simulation, analysing the process is a mandatory action. Each action or process in the warehouse leads to the act of handling products into the warehouse or transport to the depot area. Therefore, this action or process that involve in the warehouse will transform into a model in arena simulation. Below is the flowchart as shown in figure 11 that illustrates the process in the warehouse.

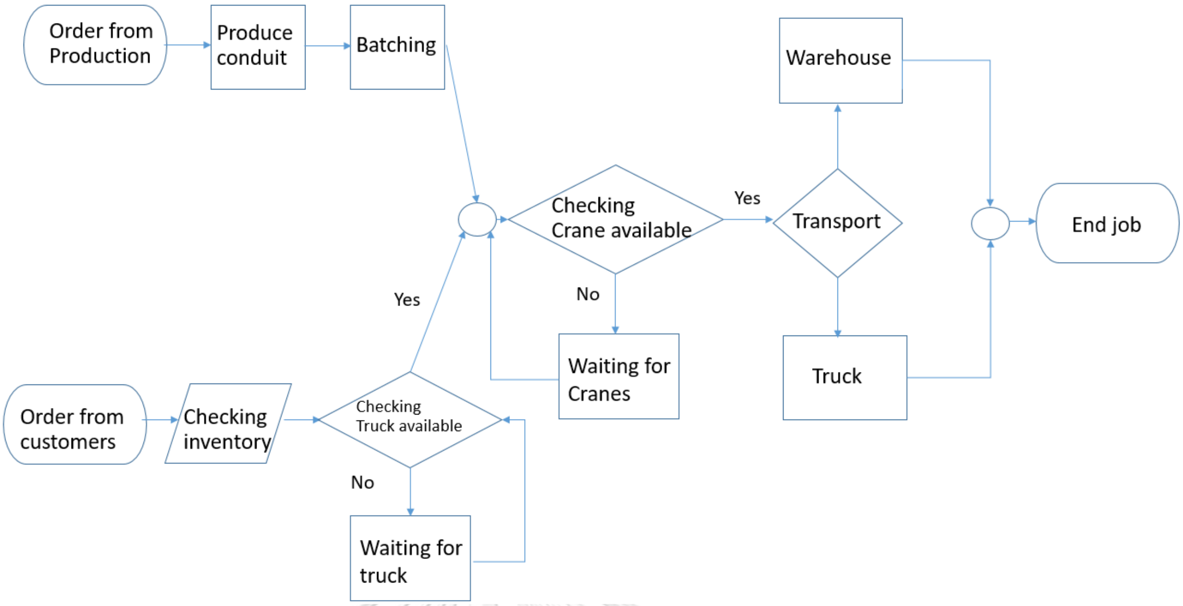


Figure 11 The flowchart process in the warehouse

The current operation.

According to figure 11, the current operation in this warehouse will start from either production point A or production point B as shown in figure 10. The product will be produced according to the order from the production plan. The production will produce the conduits and these conduits will be batched into bundles and wait until the overhead cranes are available. When the overhead cranes are available, the warehouse keeper will load the bundle of products up by crane and transport to the position in the warehouse. On the other hand, the customer orders will be managed by the sale team. When the orders come. the sale teams will check the amount of inventory in the warehouse, confirm the truck schedule and inform the delivery date to the customers. When the trucks arrive to transport the customer orders, the warehouse keepers will check the overhead cranes are available or not, if available, they will begin loading the product to the truck.

The Arena simulation program for modelling and simulating the results.

A modelling program will be developed through the arena simulation program in order to simulate the results for comparing each layout. Building the model and configuration will be created in the Arena program and made into processes which duplicate the processes in the warehouse. In this model, it consists of four processes which are the production processes, the warehouse operation processes, the sale processes and the free space processes as shown in figure 12.

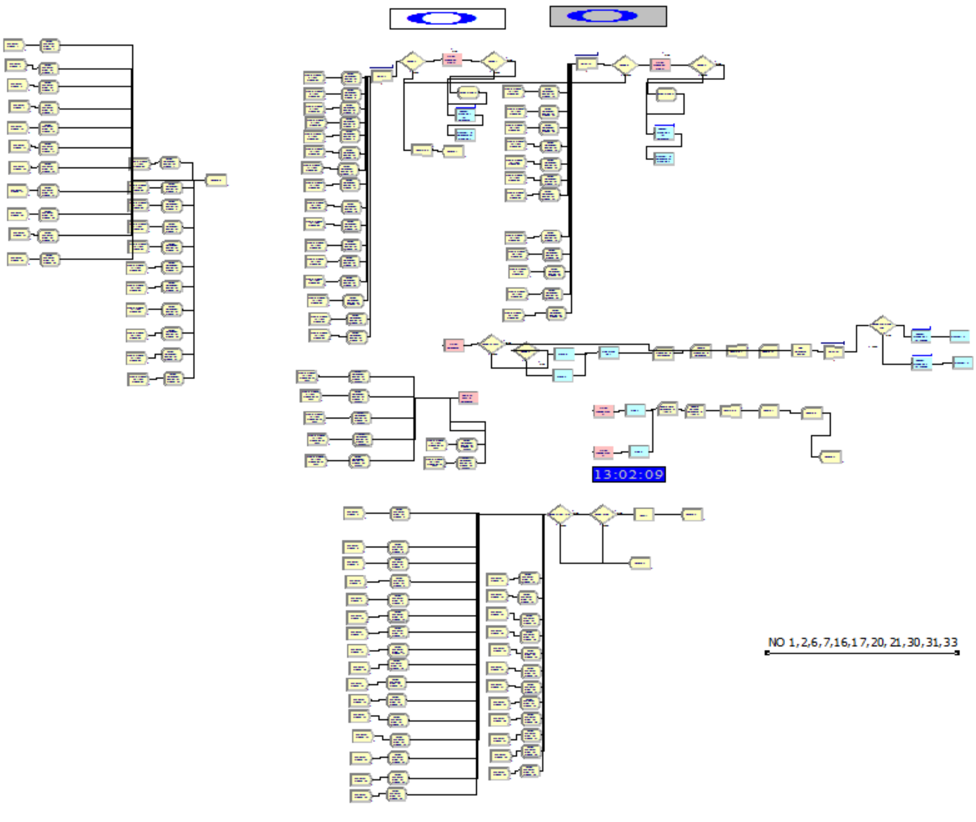


Figure 12 The arena model simulation

The production process will generate the products into the warehouse and the warehouse operation processes calculate the distance and time for transporting the product into the warehouse. On the other hand, the sale process will generate the amount of sale volume for each product and waiting for the warehouse operation process to calculate the distance and time for transporting out of the warehouse. The free space process does not generate the amount of product or uses to calculate the distance and time. It is only the reminder that which spaces are not occupied. These models, configurations and process will be used to calculate the results from different layouts based on the different criteria (as illustrated in chapter 5).

The goodness of fit test

In arena simulation, there is a program name "arena input analyser". This program will generate the hypothesized distribution based on the information given. In this thesis, the information given is the production plan and order from customers. These information will be used to find the arrival rate distribution for each product. The way to test the hypothesized distribution is called the goodness of fit test (Adekpedjou & Zamba, 2012). This test is used to verify the distribution that we get from input analyser. There are two types of testing hypothesized distribution in arena input analyser which are consists of

1. Chi-square test

In case of the information given are large (much more than 50 information), the chi-square test is used (Guizani, et al., 2010). The hypothesized distribution will be accepted when the p-value is higher than significant level (0.05).

2. Kolmogorov – Smirnov Test

In case of the information given are small (less than 50 information), the Kolmogorov – Smirnov Test is used (Guizani, et al., 2010). The hypothesized distribution will be accepted when the p-value is higher than significant level (0.05).

Arrival rate

In order to find the arrival rate distribution from the production plan and orders, we will use the arena input analyser to generate the distribution and verify the p-value of each distribution. When the p-value is higher than the significant level (0.05), that distributions will be used in the arena simulation. Here is the arrival rate for productions for each SKUs in each position as shown in table 15.

Area	Column	Row	Attribute	Set index	Product name	Input A input Analyzer
A	1	1	Position A11	1	-	-
A	2	1	Position A21	2	-	-
A	3	1	Position A31	3	FSOZABSS120170S	(TRIA(427, 1.63e+003, 7.69e+003))/(61*2)
A	4	1	Position A41	4	FSOZABSM100200M	(57 + WEIB(3.02e+003, 1.11))/91
A	5	1	Position A51	5	FSOZABSS060140S	(762 + 9.4e+003 * BETA(1.14, 1.33))/127
A	1	2	Position A12	6	-	-
A	2	2	Position A22	7	-	-
A	3	2	Position A32	8	FSOZABSM060190M	(313 + 9.85e+003 * BETA(0.626, 1.19))/(127*2)
A	4	2	Position A42	9	FSOZABSR040140R	(1.01e+003 + 7.1e+003 * BETA(0.931, 1.03))/(169*2)
A	5	2	Position A52	10	FSOZABSR060140R	NORM(3.01e+003, 1.59e+003)/127
A	1	3	Position A13	11	FSOZABSM120190M	ไม่มีการผลิตในปี 2017
A	2	3	Position A23	12	FSOZABSS040140S	(338 + WEIB(3.68e+003, 1.28))/169*2
A	3	3	Position A33	13	FSOZABSR200140R	(592 + 2.91e+003 * BETA(0.856, 0.952))/37
A	4	3	Position A43	14	FSOZABSR120140R	(424 + 7.51e+003 * BETA(0.858, 1.22))/61*2
A	5	3	Position A53	15	FSOZABSS100170S	(364 + 4.58e+003 * BETA(0.631, 0.716))/91
A	1	4	Position A14	16	Waste	-
A	2	4	Position A24	17	Waste	-
A	3	4	Position A34	18	FSOZABSR150140R	(TRIA(85, 1.22e+003, 4.97e+003))/(44*2)
A	4	4	Position A44	19	FSOZABSR040140R	(1.01e+003 + 7.1e+003 * BETA(0.931, 1.03))/(169*2)
A	5	4	Position A54	20	New Product	-
A	1	5	Position A15	21	-	-
A	2	5	Position A25	22	FSOZABSM060190M	(313 + 9.85e+003 * BETA(0.626, 1.19))/127*2
A	3	5	Position A35	23	FSOZABSM150200M	(440 + 9.02e+003 * BETA(0.918, 2.66))/44
A	4	5	Position A45	24	FSOZABSM200200M	(64 + 5.19e+003 * BETA(1.89, 2.84))/(37*3)
A	5	5	Position A55	25	FSOZABSM200200M	(64 + 5.19e+003 * BETA(1.89, 2.84))/(37*3)
A	1	6	Position A16	26	FSOZABSM200200M	(64 + 5.19e+003 * BETA(1.89, 2.84))/(37*3)
A	2	6	Position A26	27	FSOZABSS150170S	(TRIA(32, 1.34e+003, 6.12e+003))/44
A	3	6	Position A36	28	FSOZABSS150170S	(TRIA(32, 1.34e+003, 6.12e+003))/44
A	4	6	Position A46	29	FSOZABSR120140R	(424 + 7.51e+003 * BETA(0.858, 1.22))/(61*2)
A	5	6	Position A56	30	New Product	-
B	1	1	Position B11	31	-	-
B	2	1	Position B21	32	FSOZABSS100160S	(261 + 9.75e+003 * BETA(1.31, 2.03))/91
B	3	1	Position B31	33	-	-
B	1	2	Position B12	34	FSOZABSM040190M	(507 + 9.63e+003 * BETA(1.3, 2.11))/169
B	2	2	Position B22	35	FSOZABSS120170S	(TRIA(427, 1.63e+003, 7.69e+003))/(61*2)
B	3	2	Position B32	36	FSOZABSS040140S	(338 + WEIB(3.68e+003, 1.28))/(169*2)
B	1	3	Position B13	37	FSOZABSS200170S	(NORM(2.28e+003, 1.11e+003))/(37*2)
B	2	3	Position B23	38	FSOZABSS200170S	(NORM(2.28e+003, 1.11e+003))/(37*2)
B	3	3	Position B33	39	FSOZABSR150140R	(TRIA(85, 1.22e+003, 4.97e+003))/(44*2)

Table 15 arrival rate from the productions

Then, we verify the p-value for each hypothesized distribution. The results as shown in table 16 show that every distribution has p-value more than 0.05. Therefore, we can use these distributions as the arrival rate for each product.

Area	Column	Row	Attribute	Set index	Product name	Input A input Analyzer	P-value	number of data
A	1	1	Position A11	1	-	-		-
A	2	1	Position A21	2	-	-		-
A	3	1	Position A31	3	FSOZABSS120170S	(TRIA(427, 1.63e+003, 7.69e+003))/(61*2)	0.272	53
A	4	1	Position A41	4	FSOZABSM100200M	(57 + WEIB(3.02e+003, 1.11))/91	>0.15	39
A	5	1	Position A51	5	FSOZABSS060140S	(762 + 9.4e+003 * BETA(1.14, 1.33))/127	0.06	53
A	1	2	Position A12	6	-	-		-
A	2	2	Position A22	7	-	-		-
A	3	2	Position A32	8	FSOZABSM060190M	(313 + 9.85e+003 * BETA(0.626, 1.19))/(127*2)	0.46	54
A	4	2	Position A42	9	FSOZABSR040140R	(1.01e+003 + 7.1e+003 * BETA(0.931, 1.03))/(169*2)	0.12	66
A	5	2	Position A52	10	FSOZABSR060140R	NORM(3.01e+003, 1.59e+003)/127	0.09	68
A	1	3	Position A13	11	FSOZABSM120190M	Not produce in 2017	-	-
A	2	3	Position A23	12	FSOZABSS040140S	(338 + WEIB(3.68e+003, 1.28))/169*2	>0.15	76
A	3	3	Position A33	13	FSOZABSR200140R	(592 + 2.91e+003 * BETA(0.856, 0.952))/37	>0.15	15
A	4	3	Position A43	14	FSOZABSR120140R	(424 + 7.51e+003 * BETA(0.858, 1.22))/61*2	>0.15	44
A	5	3	Position A53	15	FSOZABSS100170S	(364 + 4.58e+003 * BETA(0.631, 0.716))/91	>0.15	9
A	1	4	Position A14	16	Waste	-	-	-
A	2	4	Position A24	17	Waste	-	-	-
A	3	4	Position A34	18	FSOZABSR150140R	(TRIA(85, 1.22e+003, 4.97e+003))/(44*2)	>0.15	26
A	4	4	Position A44	19	FSOZABSR040140R	(1.01e+003 + 7.1e+003 * BETA(0.931, 1.03))/(169*2)	0.12	66
A	5	4	Position A54	20	New product	-	-	-
A	1	5	Position A15	21	-	-	-	-
A	2	5	Position A25	22	FSOZABSM060190M	(313 + 9.85e+003 * BETA(0.626, 1.19))/127*2	0.46	54
A	3	5	Position A35	23	FSOZABSM150200M	(440 + 9.02e+003 * BETA(0.918, 2.66))/44	>0.15	36
A	4	5	Position A45	24	FSOZABSM200200M	(64 + 5.19e+003 * BETA(1.89, 2.84))/(37*3)	>0.15	48
A	5	5	Position A55	25	FSOZABSM200200M	(64 + 5.19e+003 * BETA(1.89, 2.84))/(37*3)	>0.15	48
A	1	6	Position A16	26	FSOZABSM200200M	(64 + 5.19e+003 * BETA(1.89, 2.84))/(37*3)	>0.15	48
A	2	6	Position A26	27	FSOZABSS150170S	(TRIA(32, 1.34e+003, 6.12e+003))/44	0.055	59
A	3	6	Position A36	28	FSOZABSS150170S	(TRIA(32, 1.34e+003, 6.12e+003))/44	0.055	59
A	4	6	Position A46	29	FSOZABSR120140R	(424 + 7.51e+003 * BETA(0.858, 1.22))/(61*2)	>0.15	44
A	5	6	Position A56	30	New product	-	-	-
B	1	1	Position B11	31	-	-	-	-
B	2	1	Position B21	32	FSOZABSS100160S	(261 + 9.75e+003 * BETA(1.31, 2.03))/91	0.4	62
B	3	1	Position B31	33	-	-		
B	1	2	Position B12	34	FSOZABSM040190M	(507 + 9.63e+003 * BETA(1.3, 2.11))/169	0.12	53
B	2	2	Position B22	35	FSOZABSS120170S	(TRIA(427, 1.63e+003, 7.69e+003))/(61*2)	0.272	53
B	3	2	Position B32	36	FSOZABSS040140S	(338 + WEIB(3.68e+003, 1.28))/(169*2)	>0.15	76
B	1	3	Position B13	37	FSOZABSS200170S	(NORM(2.28e+003, 1.11e+003))/(37*2)	>0.15	39
B	2	3	Position B23	38	FSOZABSS200170S	(NORM(2.28e+003, 1.11e+003))/(37*2)	>0.15	39
B	3	3	Position B33	39	FSOZABSR150140R	(TRIA(85, 1.22e+003, 4.97e+003))/(44*2)	>0.15	26

Table 16 the p-value for each product (production plan)

However, in the sale and order information, there are no distributions that have p-valve higher than the significant level (0.05). Therefore, we divided the information into 3 periods, starting with January – April, May – August and September – December. Due to the 3 period, the sale information will be spilt into 3 periods as well. The information for each period will be less than 50 information. Thus, we will use the Kolmogorov – Smirnov Test to verify the p-value. The distribution for sale and order will consist of three distributions for each period as shown in table 17.

Area	Column	Row	Attribute	Set index	Product name	Demand A (Input analyzer)		
						Month 1-4	Month 5-8	Month 9-12
A	1	1	Position A11	1	-			
A	2	1	Position A21	2	-			
A	3	1	Position A31	3	FSOZABSS120170S	(UNIF(183, 3.05e+003))/(61*3*2)	(NORM(1.33e+003, 853))/(61*3*2)	(61 + EXPO(1.74e+003))/(61*3*2)
A	4	1	Position A41	4	FSOZABSM100200M	(TRIA(91, 1.77e+003, 3.46e+003))/(91*3)	(TRIA(91, 1.62e+003, 5.19e+003))/(91*3)	(TRIA(273, 1.75e+003, 5.19e+003))/(91*3)
A	5	1	Position A51	5	FSOZABSS060140S	(UNIF(127, 5.84e+003))/(127*3)	(UNIF(254, 5.84e+003))/(127*3)	(NORM(2.55e+003, 2.3e+003))/(127*3)
A	1	2	Position A12	6	-	-	-	-
A	2	2	Position A22	7	-	-	-	-
A	3	2	Position A32	8	FSOZABSM060190M	(127 + 6.72e+003 * BETA(1.47, 3.14))/(127*3*2)	(TRIA(127, 2.15e+003, 6.86e+003))/(127*3*2)	(127 + EXPO(1.98e+003))/(127*3*2)
A	4	2	Position A42	9	FSOZABSR040140R	(TRIA(169, 3.8e+003, 7.44e+003))/(169*3*2)	(TRIA(338, 3.58e+003, 1.12e+004))/(169*3*2)	(UNIF(169, 7.44e+003))/(169*3*2)
A	5	2	Position A52	10	FSOZABSR060140R	(NORM(2.55e+003, 1.33e+003))/(127*3)	(TRIA(762, 3.3e+003, 5.84e+003))/(127*3)	(NORM(2.13e+003, 1.38e+003))/(127*3)
A	1	3	Position A13	11	FSOZABSM120190M		Cannot generate distribution due to less information	
A	2	3	Position A23	12	FSOZABSS040140S	(NORM(3.43e+003, 2.55e+003))/(169*3*2)	(TRIA(169, 2.92e+003, 1.12e+004))/(169*3*2)	(NORM(3.32e+003, 2.43e+003))/(169*3*2)
A	3	3	Position A33	13	FSOZABSR200140R	(TRIA(37, 833, 1.63e+003))/(37*3)	(37 + EXPO(728))/(37*3*2)	(74 + WEIB(517, 0.823))/(37*3*2)
A	4	3	Position A43	14	FSOZABSR120140R	(NORM(1.29e+003, 603))/(61*3*2)	(22 + EXPO(1.54e+003))/(61*3*2)	(61 + 6.28e+003 * BETA(0.916, 1.98))/(61*3*2)
A	5	3	Position A53	15	FSOZABSS100170S	-	-	(273 + EXPO(1.38e+003))/(91*3)
A	1	4	Position A14	16	Waste	-	-	-
A	2	4	Position A24	17	Waste	-	-	-
A	3	4	Position A34	18	FSOZABSR150140R	(UNIF(44, 1.23e+003))/(44*3*2)	(TRIA(88, 695, 6.16e+003))/(44*3*2)	(44 + WEIB(734, 0.782))/(44*3*2)
A	4	4	Position A44	19	FSOZABSR040140R	(TRIA(169, 3.8e+003, 7.44e+003))/(169*3)	(TRIA(338, 3.58e+003, 1.12e+004))/(169*3)	(UNIF(169, 7.44e+003))/(169*3)
A	5	4	Position A54	20	New Product			
A	1	5	Position A15	21	-			
A	2	5	Position A25	22	FSOZABSM060190M	(127 + 6.72e+003 * BETA(1.47, 3.14))/(127*3)	(TRIA(127, 2.15e+003, 6.86e+003))/(127*3)	(127 + EXPO(1.98e+003))/(127*3)
A	3	5	Position A35	23	FSOZABSM150200M	(TRIA(44, 1.17e+003, 2.29e+003))/(44*3)	(44 + 5.68e+003 * BETA(0.677, 3.12))/(44*3)	(44 + 5.68e+003 * BETA(0.277, 0.631))/(44*3)
A	4	5	Position A45	24	FSOZABSM200200M	(NORM(765, 429))/(37*3*3)	(37 + EXPO(965))/(37*3*3)	(37 + EXPO(829))/(37*3*3)
A	5	5	Position A55	25	FSOZABSM200200M	(NORM(765, 429))/(37*3*3)	(37 + EXPO(965))/(37*3*3)	(37 + EXPO(829))/(37*3*3)
A	1	6	Position A16	26	FSOZABSM200200M	(NORM(765, 429))/(37*3*3)	(37 + EXPO(965))/(37*3*3)	(37 + EXPO(829))/(37*3*3)
A	2	6	Position A26	27	FSOZABSS150170S	(UNIF(44, 2.46e+003))/(44*3*2)	(NORM(1.17e+003, 875))/(44*3*2)	(88 + 4.84e+003 * BETA(0.549, 2.55))/(44*3*2)
A	3	6	Position A36	28	FSOZABSS150170S	(UNIF(44, 2.46e+003))/(44*3*2)	(NORM(1.17e+003, 875))/(44*3*2)	(88 + 4.84e+003 * BETA(0.549, 2.55))/(44*3*2)
A	4	6	Position A46	29	FSOZABSR120140R	(NORM(1.29e+003, 603))/(61*3*2)	(22 + EXPO(1.54e+003))/(61*3*2)	(61 + 6.28e+003 * BETA(0.916, 1.98))/(61*3*2)
A	5	6	Position A56	30	New Product			
B	1	1	Position B11	31	-			
B	2	1	Position B21	32	FSOZABSS100160S	(UNIF(91, 4e+003))/(3*91)	(NORM(2.21e+003, 1.33e+003))/(3*91)	(TRIA(91, 1.57e+003, 6.01e+003))/(3*91)
B	3	1	Position B31	33	-			
B	1	2	Position B12	34	FSOZABSM040190M	(TRIA(169, 2.96e+003, 5.75e+003))/(169*3)	(NORM(2.97e+003, 2.23e+003))/(169*3)	(169 + EXPO(1.71e+003))/(169*3)
B	2	2	Position B22	35	FSOZABSS120170S	(UNIF(183, 3.05e+003))/(61*3*2)	(NORM(1.33e+003, 853))/(61*3*2)	(61 + EXPO(1.74e+003))/(61*3*2)
B	3	2	Position B32	36	FSOZABSS040140S	(NORM(3.43e+003, 2.55e+003))/(169*3*2)	(TRIA(169, 2.92e+003, 1.12e+004))/(169*3*2)	(NORM(3.32e+003, 2.43e+003))/(169*3*2)
B	1	3	Position B13	37	FSOZABSS200170S	(NORM(937, 430))/(37*3*2)	(TRIA(37, 638, 2.44e+003))/(37*3*2)	(NORM(605, 344))/(37*3*2)
B	2	3	Position B23	38	FSOZABSS200170S	(NORM(937, 430))/(37*3*2)	(TRIA(37, 638, 2.44e+003))/(37*3*2)	(NORM(605, 344))/(37*3*2)
B	3	3	Position B33	39	FSOZABSR150140R	(UNIF(44, 1.23e+003))/(44*3*2)	(TRIA(88, 695, 6.16e+003))/(44*3*2)	(44 + WEIB(734, 0.782))/(44*3*2)

Table 17 arrival rate from the sales and orders.

The p-value for each distribution are more than 0.05 as shown in table 18. Therefore, we can use these hypothesized distributions for configuration in the model.

Area	Column	Row	Attribute	Set index	Product name	Demand A (Input analyzer)					
						Month 1-4	P-value	Month 5-8	P-value	Month 9-12	P-value
A	1	1	Position A11	1	-						
A	2	1	Position A21	2	-						
A	3	1	Position A31	3	FSOZABSS120170S	(UNIF(183, 3.05e+003))/(61*3*2)	>0.15	(NORM(1.33e+003, 853))/(61*3*2)	0.12	(61 + EXPO(1.74e+003))/(61*3*2)	0.08
A	4	1	Position A41	4	FSOZABSM100200M	(TRIA(91, 1.77e+003, 3.46e+003))/(91*3)	>0.15	(TRIA(91, 1.62e+003, 5.19e+003))/(91*3)	>0.15	(TRIA(273, 1.75e+003, 5.19e+003))/(91*3)	>0.15
A	5	1	Position A51	5	FSOZABSS060140S	(UNIF(127, 5.84e+003))/(127*3)	>0.15	(UNIF(254, 5.84e+003))/(127*3)	0.05	(NORM(2.55e+003, 2.3e+003))/(127*3)	>0.15
A	1	2	Position A12	6	-	-		-		-	
A	2	2	Position A22	7	-	-		-		-	
A	3	2	Position A32	8	FSOZABSM060190M	(127 + 6.72e+003 * BETA(1.47, 3.14))/(127*3*2)	0.05	(TRIA(127, 2.15e+003, 6.86e+003))/(127*3*2)	>0.15	(127 + EXPO(1.98e+003))/(127*3*2)	0.06
A	4	2	Position A42	9	FSOZABSR040140R	(TRIA(169, 3.8e+003, 7.44e+003))/(169*3*2)	>0.15	(TRIA(338, 3.58e+003, 1.12e+004))/(169*3*2)	>0.15	(UNIF(169, 7.44e+003))/(169*3*2)	>0.15
A	5	2	Position A52	10	FSOZABSR060140R	(NORM(2.55e+003, 1.33e+003))/(127*3)	>0.15	(TRIA(762, 3.3e+003, 5.84e+003))/(127*3)	>0.15	(NORM(2.13e+003, 1.38e+003))/(127*3)	0.05
A	1	3	Position A13	11	FSOZABSM120190M			Cannot generate distribution due to less information			
A	2	3	Position A23	12	FSOZABSS040140S	(NORM(3.43e+003, 2.55e+003))/(169*3*2)	>0.15	(TRIA(169, 2.92e+003, 1.12e+004))/(169*3*2)	>0.15	(NORM(3.32e+003, 2.43e+003))/(169*3*2)	>0.15
A	3	3	Position A33	13	FSOZABSR200140R	(TRIA(37, 833, 1.63e+003))/(37*3)	>0.15	(37 + EXPO(728))/(37*3*2)	0.05	(74 + WEIB(517, 0.823))/(37*3*2)	0.09
A	4	3	Position A43	14	FSOZABSR120140R	(NORM(1.29e+003, 603))/(61*3*2)	0.13	(22 + EXPO(1.54e+003))/(61*3*2)	0.06	(61 + 6.28e+003 * BETA(0.916, 1.98))/(61*3*2)	0.05
A	5	3	Position A53	15	FSOZABSS100170S	No sale record	-	No sale record	-	(273 + EXPO(1.38e+003))/(91*3)	0.09
A	1	4	Position A14	16	Waste	-		-		-	
A	2	4	Position A24	17	Waste	-		-		-	
A	3	4	Position A34	18	FSOZABSR150140R	(UNIF(44, 1.23e+003))/(44*3*2)	0.05	(TRIA(88, 695, 6.16e+003))/(44*3*2)	>0.15	(44 + WEIB(734, 0.782))/(44*3*2)	>0.15
A	4	4	Position A44	19	FSOZABSR040140R	(TRIA(169, 3.8e+003, 7.44e+003))/(169*3)	>0.15	(TRIA(338, 3.58e+003, 1.12e+004))/(169*3)	>0.15	(UNIF(169, 7.44e+003))/(169*3)	>0.15
A	5	4	Position A54	20	New product						
A	1	5	Position A15	21	-						
A	2	5	Position A25	22	FSOZABSM060190M	(127 + 6.72e+003 * BETA(1.47, 3.14))/(127*3)	0.05	(TRIA(127, 2.15e+003, 6.86e+003))/(127*3)	>0.15	(127 + EXPO(1.98e+003))/(127*3)	0.06
A	3	5	Position A35	23	FSOZABSM150200M	(TRIA(44, 1.17e+003, 2.29e+003))/(44*3)	>0.15	(44 + 5.68e+003 * BETA(0.677, 3.12))/(44*3)	0.05	(44 + 5.68e+003 * BETA(0.277, 0.631))/(44*3)	>0.15
A	4	5	Position A45	24	FSOZABSM200200M	(NORM(765, 429))/(37*3*3)	0.05	(37 + EXPO(965))/(37*3*3)	0.05	(37 + EXPO(829))/(37*3*3)	0.08
A	5	5	Position A55	25	FSOZABSM200200M	(NORM(765, 429))/(37*3*3)	0.05	(37 + EXPO(965))/(37*3*3)	0.05	(37 + EXPO(829))/(37*3*3)	0.08
A	1	6	Position A16	26	FSOZABSM200200M	(NORM(765, 429))/(37*3*3)	0.05	(37 + EXPO(965))/(37*3*3)	0.05	(37 + EXPO(829))/(37*3*3)	0.08
A	2	6	Position A26	27	FSOZABSS150170S	(UNIF(44, 2.46e+003))/(44*3*2)	0.09	(NORM(1.17e+003, 875))/(44*3*2)	0.13	(88 + 4.84e+003 * BETA(0.549, 2.55))/(44*3*2)	0.05
A	3	6	Position A36	28	FSOZABSS150170S	(UNIF(44, 2.46e+003))/(44*3*2)	0.09	(NORM(1.17e+003, 875))/(44*3*2)	0.13	(88 + 4.84e+003 * BETA(0.549, 2.55))/(44*3*2)	0.05
A	4	6	Position A46	29	FSOZABSR120140R	(NORM(1.29e+003, 603))/(61*3*2)	0.13	(22 + EXPO(1.54e+003))/(61*3*2)	0.06	(61 + 6.28e+003 * BETA(0.916, 1.98))/(61*3*2)	0.05
A	5	6	Position A56	30	New product						
B	1	1	Position B11	31	-						
B	2	1	Position B21	32	FSOZABSS100160S	(UNIF(91, 4e+003))/(3*91)	>0.15	(NORM(2.21e+003, 1.33e+003))/(3*91)	0.12	(TRIA(91, 1.57e+003, 6.01e+003))/(3*91)	>0.15
B	3	1	Position B31	33	-						
B	1	2	Position B12	34	FSOZABSM040190M	(TRIA(169, 2.96e+003, 5.75e+003))/(169*3)		(NORM(2.97e+003, 2.23e+003))/(169*3)		(169 + EXPO(1.71e+003))/(169*3)	
B	2	2	Position B22	35	FSOZABSS120170S	(UNIF(183, 3.05e+003))/(61*3*2)	>0.15	(NORM(1.33e+003, 853))/(61*3*2)	0.12	(61 + EXPO(1.74e+003))/(61*3*2)	0.08
B	3	2	Position B32	36	FSOZABSS040140S	(NORM(3.43e+003, 2.55e+003))/(169*3*2)	>0.15	(TRIA(169, 2.92e+003, 1.12e+004))/(169*3*2)	>0.15	(NORM(3.32e+003, 2.43e+003))/(169*3*2)	>0.15
B	1	3	Position B13	37	FSOZABSS200170S	(NORM(937, 430))/(37*3*2)	0.05	(TRIA(37, 638, 2.44e+003))/(37*3*2)	0.05	(NORM(605, 344))/(37*3*2)	0.05
B	2	3	Position B23	38	FSOZABSS200170S	(NORM(937, 430))/(37*3*2)	0.05	(TRIA(37, 638, 2.44e+003))/(37*3*2)	0.05	(NORM(605, 344))/(37*3*2)	0.05
B	3	3	Position B33	39	FSOZABSR150140R	(UNIF(44, 1.23e+003))/(44*3*2)	0.05	(TRIA(88, 695, 6.16e+003))/(44*3*2)	>0.15	(44 + WEIB(734, 0.782))/(44*3*2)	>0.15

Table 18 The p-value for each product (sales)

Step 5 : Validation and verification

The objective of this step is to validate and verify the model and results from arena simulation. In the validation, we will compare the results from arena simulation and the real value from Ziga report. If the model is right, the results should be similar to the Ziga reports collected by Ziga company. Then, we can apply the change in the simulation to be able to see the consequences before implement. Below are the results of arena simulation. On the other hand, the verification will be the results from specific value and compare with the results that did not calculate by the program which will be demonstrated below in table 19.

Area	Column	Row	Attribute	Set index	Product name	Real producing product	Valve from simulation	% Error
A	1	1	Position A11	1	-			
A	2	1	Position A21	2	-			
A	3	1	Position A31	3	FSOZABSS120170S	1412	1375	-2.6
A	4	1	Position A41	4	FSOZABSM100200M	1284	1268	-1.25
A	5	1	Position A51	5	FSOZABSS060140S	2125	2108	-0.8
A	1	2	Position A12	6	-	-		
A	2	2	Position A22	7	-	-		
A	3	2	Position A32	8	FSOZABSM060190M	788	778	-1.3
A	4	2	Position A42	9	FSOZABSR040140R	644	620	-3.7
A	5	2	Position A52	10	FSOZABSR060140R	1307	1291	-1.2
A	1	3	Position A13	11	FSOZABSM120190M	-	-	
A	2	3	Position A23	12	FSOZABSS040140S	856	818	-4.4
A	3	3	Position A33	13	FSOZABSR200140R	799	804	0.6
A	4	3	Position A43	14	FSOZABSR120140R	1210	1274	5.3
A	5	3	Position A53	15	FSOZABSS100170S	248	242	-2.4
A	1	4	Position A14	16	Waste			
A	2	4	Position A24	17	Waste			
A	3	4	Position A34	18	FSOZABSR150140R	619	613	-1.0
A	4	4	Position A44	19	FSOZABSR040140R	644	654	1.6
A	5	4	Position A54	20	New product			
A	1	5	Position A15	21	-			
A	2	5	Position A25	22	FSOZABSM060190M	788	803	1.9
A	3	5	Position A35	23	FSOZABSM150200M	2255	2242	-0.6
A	4	5	Position A45	24	FSOZABSM200200M	822	817	-0.6
A	5	5	Position A55	25	FSOZABSM200200M	822	808	-1.7
A	1	6	Position A16	26	FSOZABSM200200M	822	846	2.9
A	2	6	Position A26	27	FSOZABSS150170S	1707	1611	-5.6
A	3	6	Position A36	28	FSOZABSS150170S	1707	1635	-4.2
A	4	6	Position A46	29	FSOZABSR120140R	1210	1260	4.1
A	5	6	Position A56	30	New product			
B	1	1	Position B11	31	-			
B	2	1	Position B21	32	FSOZABSS100160S	2780	2748	-1.2
B	3	1	Position B31	33	-			
B	1	2	Position B12	34	FSOZABSM040190M	1311	1289	-1.7
B	2	2	Position B22	35	FSOZABSS120170S	1412	1416	0.3
B	3	2	Position B32	36	FSOZABSS040140S	856	845	-1.3
B	1	3	Position B13	37	FSOZABSS200170S	1200	1203	0.3
B	2	3	Position B23	38	FSOZABSS200170S	1200	1194	-0.5
B	3	3	Position B33	39	FSOZABSR150140R	619	611	-1.3

Table 19 results for production from arena simulation

According to table 19, the results for production generated by arena simulation are similar to the real value. The total product producing from the ziga reports are 31,447 batches while the simulation results are 31,173 batches. It is very close to the real results. The average per cent error for production error, when compared the results with the real production, is 0.9 per cent. Moreover, the results from each distribution showed that the per cent error for each distribution compared to the real results are mostly not more than 5 per cent. Therefore, the production distributions for each SKUs calculated from arena input analyser are acceptable and can be used throughout this thesis.

Area	Column	Row	Attribute	Set index	Product name	Real orders and sales	Valve from simulation	% Error
A	1	1	Position A11	1	-			
A	2	1	Position A21	2	-			
A	3	1	Position A31	3	FSOZABSS120170S	1220	1176	-3.6
A	4	1	Position A41	4	FSOZABSM100200M	1372	1313	-4.3
A	5	1	Position A51	5	FSOZABSS060140S	1937	1942	0.3
A	1	2	Position A12	6	-			
A	2	2	Position A22	7	-			
A	3	2	Position A32	8	FSOZABSM060190M	740	773	4.5
A	4	2	Position A42	9	FSOZABSR040140R	817	789	-3.4
A	5	2	Position A52	10	FSOZABSR060140R	1516	1462	-3.6
A	1	3	Position A13	11	FSOZABSM120190M	-	-	-
A	2	3	Position A23	12	FSOZABSS040140S	1016	1052	3.5
A	3	3	Position A33	13	FSOZABSR200140R	815	827	1.5
A	4	3	Position A43	14	FSOZABSR120140R	1166	1208	3.6
A	5	3	Position A53	15	FSOZABSS100170S	91	90	-1.1
A	1	4	Position A14	16	Waste			
A	2	4	Position A24	17	Waste			
A	3	4	Position A34	18	FSOZABSR150140R	598	571	-4.5
A	4	4	Position A44	19	FSOZABSR040140R	817	825	1.0
A	5	4	Position A54	20	New product			
A	1	5	Position A15	21	-			
A	2	5	Position A25	22	FSOZABSM060190M	740	792	7.0
A	3	5	Position A35	23	FSOZABSM150200M	2268	2303	1.5
A	4	5	Position A45	24	FSOZABSM200200M	828	866	4.6
A	5	5	Position A55	25	FSOZABSM200200M	828	829	0.1
A	1	6	Position A16	26	FSOZABSM200200M	828	825	-0.4
A	2	6	Position A26	27	FSOZABSS150170S	1589	1629	2.5
A	3	6	Position A36	28	FSOZABSS150170S	1589	1662	4.6
A	4	6	Position A46	29	FSOZABSR120140R	1166	1091	-6.4
A	5	6	Position A56	30	New product			
B	1	1	Position B11	31	-			
B	2	1	Position B21	32	FSOZABSS100160S	2584	2553	-1.2
B	3	1	Position B31	33	-			
B	1	2	Position B12	34	FSOZABSM040190M	1019	1015	-0.4
B	2	2	Position B22	35	FSOZABSS120170S	1220	1263	3.5
B	3	2	Position B32	36	FSOZABSS040140S	1016	955	-6.0
B	1	3	Position B13	37	FSOZABSS200170S	1334	1396	4.6
B	2	3	Position B23	38	FSOZABSS200170S	1334	1385	3.8
B	3	3	Position B33	39	FSOZABSR150140R	598	621	3.8

Table 20 Results for orders and sales from arena simulation

According to table 20, the results for orders and sales generated by arena simulation are similar to the real value. The total product sale from Ziga reports are 31,046 batches while the simulation results are 31,213 batches. The average per cent for sale error, when compared the results from the simulation and the real results, is 0.6 per cent. When looking closely, the table 20 shows that each distribution generates the sale volume similar to the real value from Ziga report with the per cent error mostly not more than 5 per cent. Therefore, the orders and sales distributions for each SKUs calculated from arena input analyser are acceptable and can be used throughout this thesis.

In the verification, we can test the model by defining some values in the model and see the results from arena simulation. Then, calculate the results again but not using arena simulation and compared the results. In this section, we will define some conditions below.

1. Define the entities per arrival for production (that has SKUs) in each position equal 1.
2. Define the max arrivals equal 12
3. Batch for transport to the warehouse from production equal 2
4. Define the number of replication equal 1
5. Warm-up period equal to 10
6. Define the entities per arrival for orders and sales (that has SKUs) in each position equal

The results from arena simulation compared with the results calculate by hand as shown in table 21 and table 22 is equal. Thus, the model in the simulation is correct.

Index position	Arena simulation		Calculate by hand	
	Production Results	Picking	Production results	Picking
1	2	1	2	1
2	2	1	2	1
3	2	1	2	1
4	2	1	2	1
5	2	1	2	1
6	2	1	2	1
7	2	1	2	1
8	2	1	2	1
9	2	1	2	1
10	2	1	2	1
11	2	1	2	1
12	2	1	2	1
13	2	1	2	1
14	2	1	2	1
15	2	1	2	1
16	2	1	2	1
17	2	1	2	1
18	2	1	2	1
19	2	1	2	1
20	2	1	2	1
21	2	1	2	1
22	2	1	2	1
23	2	1	2	1
24	2	1	2	1
25	2	1	2	1
26	2	1	2	1
27	2	1	2	1

28	2	1	2	1
29	2	1	2	1
30	2	1	2	1
31	2	1	2	1
32	2	1	2	1
33	2	1	2	1
34	2	1	2	1
35	2	1	2	1
36	2	1	2	1
37	2	1	2	1
38	2	1	2	1
39	2	1	2	1

Table 21 The production results from simulation and results from calculated by hand

Index position	Arena simulation		Calculate by hand	
	Order and sales Results	Picking	Order and sales results	Picking
1	3	1	3	1
2	3	1	3	1
3	3	1	3	1
4	3	1	3	1
5	3	1	3	1
6	3	1	3	1
7	3	1	3	1
8	3	1	3	1
9	3	1	3	1
10	3	1	3	1
11	3	1	3	1
12	3	1	3	1
13	3	1	3	1

14	3	1	3	1
15	3	1	3	1
16	3	1	3	1
17	3	1	3	1
18	3	1	3	1
19	3	1	3	1
20	3	1	3	1
21	3	1	3	1
22	3	1	3	1
23	3	1	3	1
24	3	1	3	1
25	3	1	3	1
26	3	1	3	1
27	3	1	3	1
28	3	1	3	1
29	3	1	3	1
30	3	1	3	1
31	3	1	3	1
32	3	1	3	1
33	3	1	3	1
34	3	1	3	1
35	3	1	3	1
36	3	1	3	1
37	3	1	3	1
38	3	1	3	1
39	3	1	3	1

Table 22 The sales and orders results from simulation and results from calculated by hand

Distance involved and time usage

After validate and verify the model in arena simulation, we confirm that the model is correct and can be used to simulate distance involved and time usage. The distance and time calculated by arena simulation are shown in table 23. The results come from the average number calculated by arena with the value number of replication which equals 15.

Name	Results from Arena (average)
Overall distance from production to warehouse	474,466 metres.
Overall distance from the warehouse to truck	280,126 metres.
Time usage for transport the product from production point to each position in the warehouse.	80,408 minute
Time usage for transport the product from each position in the warehouse to truck.	47,899 minute

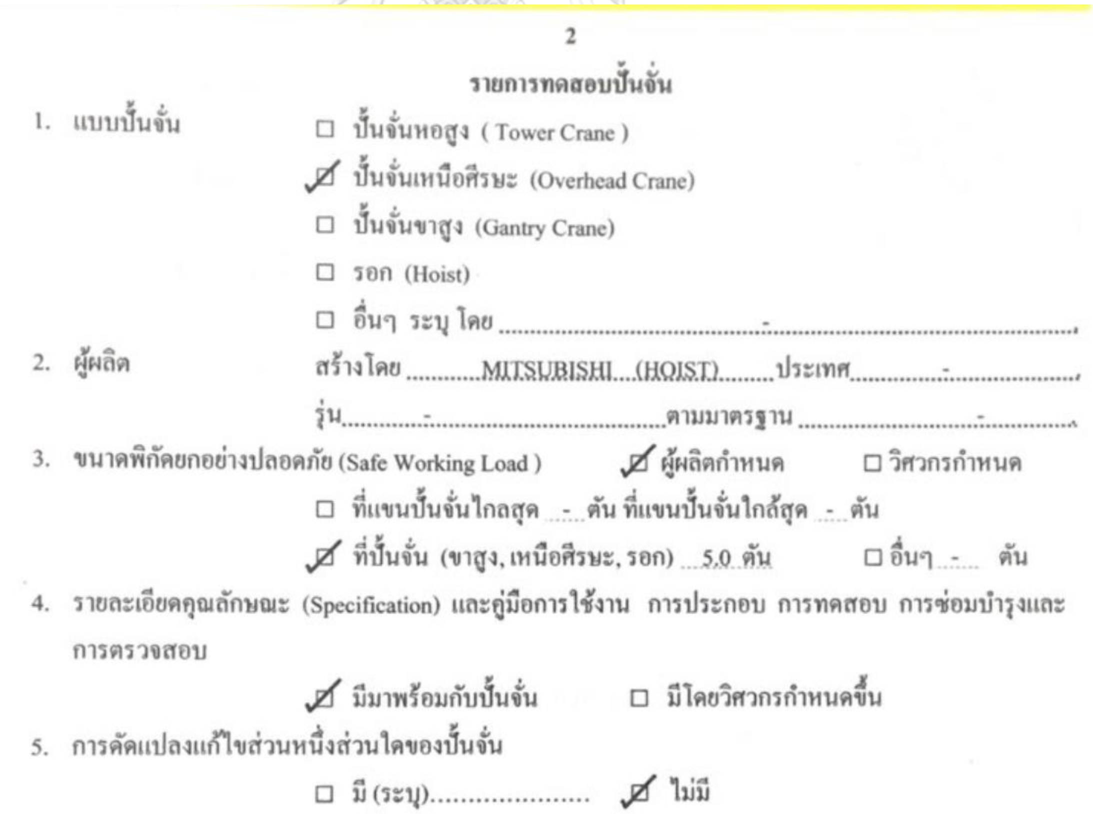
Table 23 The results from arena

Handling costs

There are many costs involving in warehouse operations. Most of them are handling costs such as human labour including transporting the product, receiving, loading and storing. In this thesis, the handling costs will consist of crane operation and human labour wage. When transporting the products in the warehouse, the Ziga labour will use the cranes to transport the products. Therefore, most of the costs will depend on how much time you will use the crane. One of the costs that relate directly to the time spent on using crane is electricity costs. Moreover, the more time labours spent on the cranes, the more money that Ziga has to pay for labours. The hourly wage and the price per unit of electricity for calculating the labour cost and the electricity costs for using crane need to be collected by asking the Ziga comapny to provide the information. Below as shown in table 24 are the values that will use to calculate the costs.

Costs	Price
Electricity costs per unit	3 baht per unit
Labour cost	100 baht per hour

Table 24 cost calculation



2

รายการทดสอบปั้นจั่น

1. แบบปั้นจั่น
   - ☐ ปั้นจั่นหอสูง (Tower Crane)
   - ☑ ปั้นจั่นเหนือศีรษะ (Overhead Crane)
   - ☐ ปั้นจั่นขาสูง (Gantry Crane)
   - ☐ รอก (Hoist)
   - ☐ อื่นๆ ระบุ โดย ....-........,
2. ผู้ผลิต สร้างโดย ....MITSUBISHI (HOIST)........ ประเทศ ....-........, รุ่น ....-........ ตามมาตรฐาน ....-........
3. ขนาดพิกัดยกอย่างปลอดภัย (Safe Working Load) ☑ ผู้ผลิตกำหนด ☐ วิศวกรกำหนด
   - ☐ ที่แขนปั้นจั่นไกลสุด - ตัน ที่แขนปั้นจั่นใกล้สุด - ตัน
   - ☑ ที่ปั้นจั่น (ขาสูง, เหนือศีรษะ, รอก) 5.0 ตัน ☐ อื่นๆ - ตัน
4. รายละเอียดคุณลักษณะ (Specification) และคู่มือการใช้งาน การประกอบ การทดสอบ การซ่อมบำรุงและการตรวจสอบ
   - ☑ มีมาพร้อมกับปั้นจั่น ☐ มีโดยวิศวกรกำหนดขึ้น
5. การดัดแปลงแก้ไขส่วนหนึ่งส่วนใดของปั้นจั่น
   - ☐ มี (ระบุ).................... ☑ ไม่มี

Figure 13 The certificate of Ziga's crane.

For calculating the electricity costs for crane, we need to find the consumption of the crane. According to figure 13, the certification certificated by the authorized company indicates that the manufacturer is Mitsubishi and the safe working load is 5 tons. The specification of the crane can be found in the Mitsubishi website as shown in figure 14.

Specifications

Type	Capacity(t)	Lift(m) Low	Lift(m) High	Wire Rope Monorail type 2falls	Wire Rope Monorail type 4falls	Wire Rope Lowhead type 4falls	Wire Rope Double railtype 4falls	Rope specification	Hoisting Inverter Operation speed m/min On-load Low speed	Hoisting speed m/min On-load High speed	Hoisting speed m/min Light load high speed	Hoisting Motor Out put (kW)	Hoisting Motor Rated Current (A)	Hoisting Poles	Traversing Monorail·Low-head type speed m/min Magnetic contactor operation 50 Hz	Monorail·Low-head speed Magnetic contactor operation 60 Hz	Monorail·Low-head speed INV Operation Low speed	Monorail·Low-head speed INV Operation High speed	Monorail·Low-head Motor (Magnetic contactor operation) Out put (kW) 50 Hz	Monorail·Low-head Motor Out put (kW) 60 Hz	Monorail·Low-head Motor Rated Current (A) 50 Hz	Monorail·Low-head Motor Rated Current (A) 60 Hz	Monorail·Low-head Poles	Double rail type speed m/min Magnetic contactor operation 50 Hz	Double rail speed Magnetic contactor operation 60 Hz	Double rail speed INV Operation Low speed	Double rail speed INV Operation High speed	Double rail Motor (Magnetic contactor operation) Out put (kW) 50 Hz	Double rail Motor Out put (kW) 60 Hz	Double rail Motor Rated Current (A) 50 Hz	Double rail Motor Rated Current (A) 60 Hz	Double rail Poles
	1/2			ϕ6.3	—	ϕ4	—	6XW(19) B Class JISG3525	0.0233 (1.4)	0.217 (13)	0.325 (19.5)	1.2	8						0.22	0.26	1.6	1.5		—	—	—	—	—	—	—	—	—
	1			ϕ8 ※3	—	ϕ6.3	—					2.4	17											—	—	—	—	—	—	—	—	—
	2	6		ϕ10	—	ϕ8	—					3.5	26		0.35 (21)	0.417 (25)	0.0417 (2.5)	0.417 (25)						—	—	—	—	—	—	—	—	—
	2.8			ϕ12.5	—	ϕ9	ϕ9		0.0183 (1.1)	0.167 (10)	0.25 (15)	4.9	32	4					0.5	0.6	3.2	3.1										
	3			ϕ12.5	—	ϕ9	ϕ9					5.3	34											0.35 (21)	0.417 (25)	0.0417 (2.5)	0.417 (25)	0.5	0.6	3.2	3.1	
	5		12	—	ϕ11.2	ϕ11.2	ϕ11.2	6XFi(29) B Class JISG3525	0.015 (0.9)	0.133 (8)	0.2 (12)	7.5	40						0.85	1.0	4.8	4.7										
	7.5			—	ϕ14	ϕ14	ϕ14		0.0117 (0.7)	0.117 (7)	0.175 (10.5)	10	54															0.85	1.0	4.8	4.7	
U2	10	8		—	ϕ16	ϕ16	ϕ16		0.01 (0.6)	0.1 (6)	0.2 (12)	12	58		0.2 (12)	0.25 (15)	0.025 (1.5)	0.25 (15)	1.5	1.8	8.5	8.1	4									
	15			—	ϕ20	—	ϕ20					20	89						0.85×2	1.0×2	4.8×2	4.7×2						1.5	1.8	8.5	8.1	4
	20	—		—	ϕ22.4	—	ϕ22.4		0.00833 (0.5)	0.0833 (5)	0.167 (10)	20	89						1.5×2	1.8×2	8.5×2	8.1×2										

Figure 14 the specification of crane (cited from http://www.mitsubishi-hoists.com)

There are two types of operations in the crane that involve in the calculation. It is consist of hoisting operation and traversing operation. In the hoisting operation, the consumption of motor will be 7.5 kW. While the traversing operation, the consumption of motor will be 0.85 kW.

The number of labour use for transporting the product to the warehouse and warehouse to truck can be shown in table 25.

Process	The number of people use.
Transporting product to warehouse	2 people
Transporting product to truck	3 people

Table 25 The number of people use in the process

The cost of labour and crane operation are shown in table 26.

	Labour costs	Electricity costs
Transporting the products to warehouse	268,027 Baht	134,281 Baht
Transporting the products to truck	239,495 Baht	79,991 Baht
Total cost	507,522 Baht	214,273 Baht

Table 26 Total costs

The total distance involved is shown in table 27.

	Distance cover
Transporting the product to warehouse	474,466 metre
Transporting the product to truck	280,126 metre
Total distance	754,592 metre

Table 27 The total distance

In the next chapter, we will try to reduce the costs by using the different criteria for switching the products within the warehouse.

Chapter 4 Implement Results

Criteria, implemented and results for layout 1

In the implementation phase, we have already discussed with the Ziga company and confirm that we will use simulation to see the trend of the results. Therefore, in this thesis, we create 3 different criteria which will be illustrated in the next section below. The first criteria will consider 2 important points based on the most picking product from sale volume and where the SKUs are produced using the sale information shown in table 28.

Criteria

1. The most picking product (from sale volume) will be stored near the depot area which has less time usage and less distance to transport the product to the depot area.
2. If the area of position has equal time usage, then consider the distance between the depot area and position in the warehouse.
3. The products which store in row 1-3 will transport to depot area A1 while the products stored in row 4-6 will transport to depot area A2.
4. When the products are produced from entrance A, the products will be stored in row 1-3.
5. When the products are produced from entrance B, the products will be stored in row 4-6.

Product	Pieces/Batch	Volume	Total Batch sell	Pick	Produce from warehouse
FSOZABSS150170S	44	139832	3178	1059	3
FSOZABSS200170S	37	98716	2668	889	3
FSOZABSS100160S	91	235144	2584	861	1
FSOZABSM200200M	37	91871	2483	828	3
FSOZABSS120170S	61	148840	2440	813	1
FSOZABSR120140R	61	142251	2332	777	1
FSOZABSM150200M	44	99789	2268	756	3
FSOZABSS040140S	169	343408	2032	677	1
FSOZABSS060140S	127	245999	1937	646	1
FSOZABSR040140R	169	275977	1633	544	1
FSOZABSR060140R	127	192532	1516	505	1
FSOZABSM060190M	127	187893	1480	493	1
FSOZABSM100200M	91	124852	1372	457	3
FSOZABSR150140R	44	52623	1196	399	3
FSOZABSM040190M	169	172211	1019	340	3
FSOZABSR200140R	37	30155	815	272	1
FSOZABSS100170S	91	8281	91	30	1

Table 28 The amount of picking for sale volume.

For example, the product name "FSOZABSS150170S" has been picked 1059 times (which are the most picking product) as shown in table 28 and has been produced at entrance B (warehouse 3). Therefore, this product should have been stored near the depot area between row 4-6 (in this case row 4 column 1 which has the least time usage and distance) because these three rows are near the entrance B and also have distance input and time usage less than row 1- row 3. Table 29 shown below are the list for each product when considering the amount of picking and the production area.

Column	Row	Attribute	Set index	Product name
1	1	Position 11	1	
2	1	Position 21	2	FSOZABSS100160S
3	1	Position 31	3	FSOZABSR120140R
4	1	Position 41	4	FSOZABSS040140S
5	1	Position 51	5	FSOZABSR040140R
1	2	Position 12	6	
2	2	Position 22	7	
3	2	Position 32	8	FSOZABSS120170S
4	2	Position 42	9	FSOZABSS040140S
5	2	Position 52	10	FSOZABSR040140R
1	3	Position 13	11	
2	3	Position 23	12	FSOZABSS120170S
3	3	Position 33	13	FSOZABSR120140R
4	3	Position 43	14	FSOZABSS060140S
5	3	Position 53	15	FSOZABSR060140R
1	4	Position 14	16	FSOZABSS150170S
2	4	Position 24	17	FSOZABSS200170S
3	4	Position 34	18	FSOZABSM200200M
4	4	Position 44	19	FSOZABSR150140R
5	4	Position 54	20	New product
1	5	Position 15	21	-
2	5	Position 25	22	FSOZABSS200170S
3	5	Position 35	23	FSOZABSM200200M
4	5	Position 45	24	FSOZABSR150140R
5	5	Position 55	25	FSOZABSR200140R
1	6	Position 16	26	FSOZABSS150170S
2	6	Position 26	27	FSOZABSM200200M
3	6	Position 36	28	FSOZABSM150200M
4	6	Position 46	29	FSOZABSM040190M
5	6	Position 56	30	New product
1	1	Position 11	31	-
2	1	Position 21	32	FSOZABSS100170S
3	1	Position 31	33	Waste
1	2	Position 12	34	FSOZABSM100200M
2	2	Position 22	35	FSOZABSM060190M
3	2	Position 32	36	Waste
1	3	Position 13	37	FSOZABSM060190M
2	3	Position 23	38	New product
3	3	Position 33	39	-

Table 29 The modified warehouse layout 1.

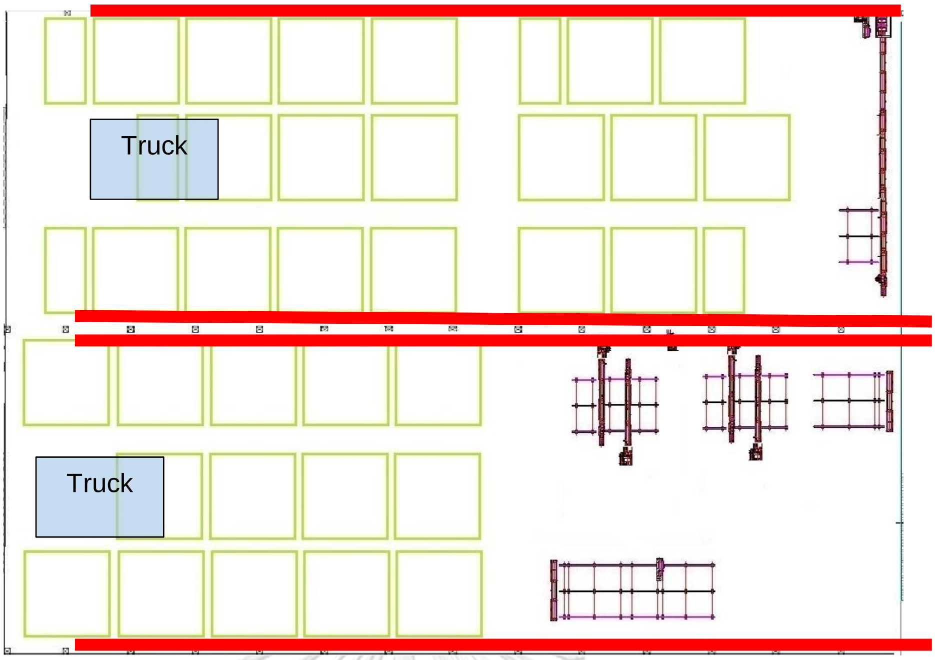


Figure 15 Truck area

When considering the truck area, we should not store the product at the position column 1 row 2, column 2 row 2 and column 1 row 5 as shown in figure 15. Even though three positions cannot store the product, it will not affect the performance at all. Firstly, if we store the product in three positions, there will have a chance that we cannot use the crane because of the end way of the rail as shown in figure 15 (the red line). Therefore, the time for transport the product will increase significantly if we continue to store the product in these three positions. Secondly, to utilize the crane effectively, the crane should be able to transport the product directly to the trucks. With these, it will help the storekeeper easily use the crane to put the conduits into the truck.

For the table 30 as shown below, the production distributions from input analyser are the same as the original one but in the different positions. As well as the order and sale distributions as shown in table 30 and table 31 are also the same but also different positions based on the criteria mentioned above.

Column	Row	Attribute	Set index	Product name	Distribution from input Analyzer
1	1	Position 11	1		
2	1	Position 21	2	FSOZABSS100160S	(261 + 9.75e+003 * BETA(1.31, 2.03))/91
3	1	Position 31	3	FSOZABSR120140R	(424 + 7.51e+003 * BETA(0.858, 1.22))/(61*2)
4	1	Position 41	4	FSOZABSS040140S	(338 + WEIB(3.68e+003, 1.28))/(169*2)
5	1	Position 51	5	FSOZABSR040140R	(1.01e+003 + 7.1e+003 * BETA(0.931, 1.03))/(169*2)
1	2	Position 12	6		
2	2	Position 22	7		
3	2	Position 32	8	FSOZABSS120170S	(TRIA(427, 1.63e+003, 7.69e+003))/(61*2)
4	2	Position 42	9	FSOZABSS040140S	(338 + WEIB(3.68e+003, 1.28))/(169*2)
5	2	Position 52	10	FSOZABSR040140R	(1.01e+003 + 7.1e+003 * BETA(0.931, 1.03))/(169*2)
1	3	Position 13	11		
2	3	Position 23	12	FSOZABSS120170S	(TRIA(427, 1.63e+003, 7.69e+003))/(61*2)
3	3	Position 33	13	FSOZABSR120140R	(424 + 7.51e+003 * BETA(0.858, 1.22))/(61*2)
4	3	Position 43	14	FSOZABSS060140S	(762 + 9.4e+003 * BETA(1.14, 1.33))/127
5	3	Position 53	15	FSOZABSR060140R	NORM(3.01e+003, 1.59e+003)/127
1	4	Position 14	16	FSOZABSS150170S	(TRIA(32, 1.34e+003, 6.12e+003))/(44*2)
2	4	Position 24	17	FSOZABSS200170S	(NORM(2.28e+003, 1.11e+003))/(37*2)
3	4	Position 34	18	FSOZABSM200200M	(64 + 5.19e+003 * BETA(1.89, 2.84))/(37*3)
4	4	Position 44	19	FSOZABSR150140R	(TRIA(85, 1.22e+003, 4.97e+003))/(44*2)
5	4	Position 54	20	New product	
1	5	Position 15	21	-	
2	5	Position 25	22	FSOZABSS200170S	(NORM(2.28e+003, 1.11e+003))/(37*2)
3	5	Position 35	23	FSOZABSM200200M	(64 + 5.19e+003 * BETA(1.89, 2.84))/(37*3)
4	5	Position 45	24	FSOZABSR150140R	(TRIA(85, 1.22e+003, 4.97e+003))/(44*2)
5	5	Position 55	25	FSOZABSR200140R	(592 + 2.91e+003 * BETA(0.856, 0.952))/37
1	6	Position 16	26	FSOZABSS150170S	(TRIA(32, 1.34e+003, 6.12e+003))/(44*2)
2	6	Position 26	27	FSOZABSM200200M	(64 + 5.19e+003 * BETA(1.89, 2.84))/(37*3)
3	6	Position 36	28	FSOZABSM150200M	(440 + 9.02e+003 * BETA(0.918, 2.66))/44
4	6	Position 46	29	FSOZABSM040190M	(507 + 9.63e+003 * BETA(1.3, 2.11))/169
5	6	Position 56	30	New product	
1	1	Position 11	31	-	
2	1	Position 21	32	FSOZABSS100170S	(364 + 4.58e+003 * BETA(0.631, 0.716))/91
3	1	Position 31	33	Waste	
1	2	Position 12	34	FSOZABSM100200M	(57 + WEIB(3.02e+003, 1.11))/91
2	2	Position 22	35	FSOZABSM060190M	(313 + 9.85e+003 * BETA(0.626, 1.19))/(127*2)
3	2	Position 32	36	Waste	
1	3	Position 13	37	FSOZABSM060190M	(313 + 9.85e+003 * BETA(0.626, 1.19))/(127*2)
2	3	Position 23	38	-	
3	3	Position 33	39	-	

Table 30 The production distributions for the warehouse layout 1.

Column	Row	Attribute	Set index	Product name	Order and sale A (Input analyzer)		
					Month 1-4	Month 5-8	Month 9-12
1	1	Position 11	1				
2	1	Position 21	2	FSOZABSS100160S	(UNIF(91, 4e+003))/(3*91)	(NORM(2.21e+003, 1.33e+003))/(3*91)	(TRIA(91, 1.57e+003, 6.01e+003))/(3*91)
3	1	Position 31	3	FSOZABSR120140R	(NORM(1.29e+003, 603))/(61*3*2)	(22 + EXPO(1.54e+003))/(61*3*2)	(61 + 6.28e+003 * BETA(0.916, 1.98))/(61*3*2)
4	1	Position 41	4	FSOZABSS040140S	(NORM(3.43e+003, 2.55e+003))/(169*3*2)	(TRIA(169, 2.92e+003, 1.12e+004))/(169*3*2)	(NORM(3.32e+003, 2.43e+003))/(169*3*2)
5	1	Position 51	5	FSOZABSR040140R	(TRIA(169, 3.8e+003, 7.44e+003))/(169*3*2)	(TRIA(338, 3.58e+003, 1.12e+004))/(169*3*2)	(UNIF(169, 7.44e+003))/(169*3*2)
1	2	Position 12	6				
2	2	Position 22	7				
3	2	Position 32	8	FSOZABSS120170S	(UNIF(183, 3.05e+003))/(61*3*2)	(NORM(1.33e+003, 853))/(61*3*2)	(61 + EXPO(1.74e+003))/(61*3*2)
4	2	Position 42	9	FSOZABSS040140S	(NORM(3.43e+003, 2.55e+003))/(169*3*2)	(TRIA(169, 2.92e+003, 1.12e+004))/(169*3*2)	(NORM(3.32e+003, 2.43e+003))/(169*3*2)
5	2	Position 52	10	FSOZABSR040140R	(TRIA(169, 3.8e+003, 7.44e+003))/(169*3*2)	(TRIA(338, 3.58e+003, 1.12e+004))/(169*3*2)	(UNIF(169, 7.44e+003))/(169*3*2)
1	3	Position 13	11				
2	3	Position 23	12	FSOZABSS120170S	(UNIF(183, 3.05e+003))/(61*3*2)	(NORM(1.33e+003, 853))/(61*3*2)	(61 + EXPO(1.74e+003))/(61*3*2)
3	3	Position 33	13	FSOZABSR120140R	(NORM(1.29e+003, 603))/(61*3*2)	(22 + EXPO(1.54e+003))/(61*3*2)	(61 + 6.28e+003 * BETA(0.916, 1.98))/(61*3*2)
4	3	Position 43	14	FSOZABSS060140S	(UNIF(127, 5.84e+003))/(127*3)	(UNIF(254, 5.84e+003))/(127*3)	(NORM(2.55e+003, 2.3e+003))/(127*3)
5	3	Position 53	15	FSOZABSR060140R	(NORM(2.55e+003, 1.33e+003))/(127*3)	(TRIA(762, 3.3e+003, 5.84e+003))/(127*3)	(NORM(2.13e+003, 1.38e+003))/(127*3)
1	4	Position 14	16	FSOZABSS150170S	(UNIF(44, 2.46e+003))/(44*3*2)	(NORM(1.17e+003, 875))/(44*3*2)	(88 + 4.84e+003 * BETA(0.549, 2.55))/(44*3*2)
2	4	Position 24	17	FSOZABSS200170S	(NORM(937, 430))/(37*3*2)	(TRIA(37, 638, 2.44e+003))/(37*3*2)	(NORM(605, 344))/(37*3*2)
3	4	Position 34	18	FSOZABSM200200M	(NORM(765, 429))/(37*3*3)	(37 + EXPO(965))/(37*3*3)	(37 + EXPO(829))/(37*3*3)
4	4	Position 44	19	FSOZABSR150140R	(UNIF(44, 1.23e+003))/(44*3*2)	(TRIA(88, 695, 6.16e+003))/(44*3*2)	(44 + WEIB(734, 0.782))/(44*3*2)
5	4	Position 54	20	New product			
1	5	Position 15	21	-			
2	5	Position 25	22	FSOZABSS200170S	(NORM(937, 430))/(37*3*2)	(TRIA(37, 638, 2.44e+003))/(37*3*2)	(NORM(605, 344))/(37*3*2)
3	5	Position 35	23	FSOZABSM200200M	(NORM(765, 429))/(37*3*3)	(37 + EXPO(965))/(37*3*3)	(37 + EXPO(829))/(37*3*3)
4	5	Position 45	24	FSOZABSR150140R	(UNIF(44, 1.23e+003))/(44*3*2)	(TRIA(88, 695, 6.16e+003))/(44*3*2)	(44 + WEIB(734, 0.782))/(44*3*2)
5	5	Position 55	25	FSOZABSR200140R	(TRIA(37, 833, 1.63e+003))/(37*3)	(37 + EXPO(728))/(37*3)	(74 + WEIB(517, 0.823))/(37*3)
1	6	Position 16	26	FSOZABSS150170S	(UNIF(44, 2.46e+003))/(44*3*2)	(NORM(1.17e+003, 875))/(44*3*2)	(88 + 4.84e+003 * BETA(0.549, 2.55))/(44*3*2)
2	6	Position 26	27	FSOZABSM200200M	(NORM(765, 429))/(37*3*3)	(37 + EXPO(965))/(37*3*3)	(37 + EXPO(829))/(37*3*3)
3	6	Position 36	28	FSOZABSM150200M	(TRIA(44, 1.17e+003, 2.29e+003))/(44*3)	(44 + 5.68e+003 * BETA(0.677, 3.12))/(44*3)	(44 + 5.68e+003 * BETA(0.277, 0.631))/(44*3)
4	6	Position 46	29	FSOZABSM040190M	(TRIA(169, 2.96e+003, 5.75e+003))/(169*3)	(NORM(2.97e+003, 2.23e+003))/(169*3)	(169 + EXPO(1.71e+003))/(169*3)
5	6	Position 56	30	New product			
1	1	Position 11	31	-			
2	1	Position 21	32	FSOZABSS100170S	-	-	(273 + EXPO(1.38e+003))/(91*3)
3	1	Position 31	33	Waste			
1	2	Position 12	34	FSOZABSM100200M	(TRIA(91, 1.77e+003, 3.46e+003))/(91*3)	(TRIA(91, 1.62e+003, 5.19e+003))/(91*3)	(TRIA(273, 1.75e+003, 5.19e+003))/(91*3)
2	2	Position 22	35	FSOZABSM060190M	(127 + 6.72e+003 * BETA(1.47, 3.14))/(127*3*2)	(TRIA(127, 2.15e+003, 6.86e+003))/(127*3*2)	(127 + EXPO(1.98e+003))/(127*3*2)
3	2	Position 32	36	Waste			
1	3	Position 13	37	FSOZABSM060190M	(127 + 6.72e+003 * BETA(1.47, 3.14))/(127*3*2)	(TRIA(127, 2.15e+003, 6.86e+003))/(127*3*2)	(127 + EXPO(1.98e+003))/(127*3*2)
2	3	Position 23	38	-			
3	3	Position 33	39	-			

Table 31 The order and sale distribution for the warehouse layout 1.

The results from arena simulation shown in table 32.

Column	Row	Attribute	Set index	Product name	Real producing product	Valve from simulation	% Error
1	1	Position 11	1				
2	1	Position 21	2	FSOZABSS100160S	2780	2692	-3.2
3	1	Position 31	3	FSOZABSR120140R	1210	1264	4.5
4	1	Position 41	4	FSOZABSS040140S	856	860	0.47
5	1	Position 51	5	FSOZABSR040140R	644	662	2.8
1	2	Position 12	6		-		
2	2	Position 22	7		-		
3	2	Position 32	8	FSOZABSS120170S	1412	1357	-3.9
4	2	Position 42	9	FSOZABSS040140S	856	808	-5.6
5	2	Position 52	10	FSOZABSR040140R	644	667	3.6
1	3	Position 13	11		-		
2	3	Position 23	12	FSOZABSS120170S	1412	1389	-1.6
3	3	Position 33	13	FSOZABSR120140R	1210	1244	2.8
4	3	Position 43	14	FSOZABSS060140S	2125	2113	-0.6
5	3	Position 53	15	FSOZABSR060140R	1307	1322	1.1
1	4	Position 14	16	FSOZABSS150170S	1707	1580	-7.4
2	4	Position 24	17	FSOZABSS200170S	1200	1159	-3.4
3	4	Position 34	18	FSOZABSM200200M	822	830	1.0
4	4	Position 44	19	FSOZABSR150140R	619	597	-3.6
5	4	Position 54	20	New product			
1	5	Position 15	21	-			
2	5	Position 25	22	FSOZABSS200170S	1200	1209	0.8
3	5	Position 35	23	FSOZABSM200200M	822	808	-1.7
4	5	Position 45	24	FSOZABSR150140R	619	616	-0.5
5	5	Position 55	25	FSOZABSR200140R	799	784	-1.9
1	6	Position 16	26	FSOZABSS150170S	1707	1699	-0.5
2	6	Position 26	27	FSOZABSM200200M	822	848	3.2
3	6	Position 36	28	FSOZABSM150200M	2255	2206	-2.2
4	6	Position 46	29	FSOZABSM040190M	1311	1294	-1.3
5	6	Position 56	30	New product			
1	1	Position 11	31	-			
2	1	Position 21	32	FSOZABSS100170S	248	244	-1.6
3	1	Position 31	33	Waste			
1	2	Position 12	34	FSOZABSM100200M	1284	1335	4.0
2	2	Position 22	35	FSOZABSM060190M	788	774	-1.8
3	2	Position 32	36	Waste			
1	3	Position 13	37	FSOZABSM060190M	788	772	-2.0
2	3	Position 23	38	-			
3	3	Position 33	39	-			

Table 32 Production results from arena simulation compared with the real one.

According to table 32, the production results from arena are similar to the real production value from Ziga reports. The per cent errors for each product are almost less than 5 per cents. It is acceptable that these results can be compared to the original one. Next is to validate the orders and sales results as shown in table 33.

Column	Row	Attribute	Set index	Product name	Real orders and sales	Valve from simulation	% Error
1	1	Position 11	1				
2	1	Position 21	2	FSOZABSS100160S	2584	2483	-3.9
3	1	Position 31	3	FSOZABSR120140R	1166	1121	-3.9
4	1	Position 41	4	FSOZABSS040140S	1016	1046	3.0
5	1	Position 51	5	FSOZABSR040140R	817	826	1.1
1	2	Position 12	6				
2	2	Position 22	7				
3	2	Position 32	8	FSOZABSS120170S	1220	1244	2.0
4	2	Position 42	9	FSOZABSS040140S	1016	978	-3.7
5	2	Position 52	10	FSOZABSR040140R	817	839	2.7
1	3	Position 13	11				
2	3	Position 23	12	FSOZABSS120170S	1220	1258	3.1
3	3	Position 33	13	FSOZABSR120140R	1166	1136	-2.6
4	3	Position 43	14	FSOZABSS060140S	1937	1934	-0.2
5	3	Position 53	15	FSOZABSR060140R	1516	1560	2.9
1	4	Position 14	16	FSOZABSS150170S	1589	1576	-0.8
2	4	Position 24	17	FSOZABSS200170S	1334	1340	0.4
3	4	Position 34	18	FSOZABSM200200M	828	841	1.6
4	4	Position 44	19	FSOZABSR150140R	598	608	1.7
5	4	Position 54	20	New product			
1	5	Position 15	21	-			
2	5	Position 25	22	FSOZABSS200170S	1334	1404	5.2
3	5	Position 35	23	FSOZABSM200200M	828	834	0.7
4	5	Position 45	24	FSOZABSR150140R	598	631	5.5
5	5	Position 55	25	FSOZABSR200140R	815	811	-0.5
1	6	Position 16	26	FSOZABSS150170S	1589	1681	5.8
2	6	Position 26	27	FSOZABSM200200M	828	865	4.5
3	6	Position 36	28	FSOZABSM150200M	2268	2228	-1.8
4	6	Position 46	29	FSOZABSM040190M	1019	1045	2.6
5	6	Position 56	30	New product			
1	1	Position 11	31	-			
2	1	Position 21	32	FSOZABSS100170S	91	96	5.5
3	1	Position 31	33	Waste			
1	2	Position 12	34	FSOZABSM100200M	1372	1386	1.0
2	2	Position 22	35	FSOZABSM060190M	740	779	5.3
3	2	Position 32	36	Waste			
1	3	Position 13	37	FSOZABSM060190M	740	793	7.2
2	3	Position 23	38	-			
3	3	Position 33	39	-			

Table 33 Orders and sales results from arena simulation compared with the real one

The simulation model have the same condition as the original one and the number of replication are 15 times. The orders and sales results are similar to the reports from Ziga company. The errors are almost less than 5 per cents. Thus, it is acceptable results.

The total time usage is shown below in table 34.

Process	Time usage
Time usage for transporting the product to warehouse	80,410 minutes
Time usage for transporting the product to truck	39,531 minutes

Table 34 The total time usage

Then, the results of labour costs and electricity costs are shown in table 35.

	Labour costs	Electricity costs
Transporting the product to warehouse	268,643 Baht	134,590 Baht
Transporting the product to truck	198,005 Baht	66,134 Baht
Total cost	466,648 Baht	200,724 Baht

Table 35 The results of labour costs and electricity costs

The total distance involved is shown in table 36.

	Distance cover
Transporting the product to warehouse	490,176 metres
Transporting the product to truck	209,321 metres
Total distance	699,497 metres

Table 36 The distance cover.

Criteria, implemented and results for layout 2

For the next modified warehouse layout, the criteria have changed in some points. Below are the lists of criteria for this modified warehouse layout.

1. We will mainly focus on the sale volume and the positions to be stored.
2. If there are some SKUs that have more than 2 positions to be stored, the total sale volume of that SKUs will be divided by the number of positions that has the same SKUs. For example, as shown in table 37, if the company sell product A 3,000 batches per year and has 2 positions to be stored, the amount of volume for each position to be picked will be 1,500 batches per position. When compared to product B and C that has only one position to be picked, product A has the lower amount of volume per position. Therefore, we need to move product B and C in front of product A.

Product	Sale volume (batch)	The number of position	Sale volume per position
A	3000	2	1500
B	2000	1	2000
C	1800	1	1800

Table 37 Criteria for sorting

3. The number of replication will be 15 times same as previous layout.

4. The products which store in row 1-3 will transport to depot area A1 while the products stored in row 4-6 will transport to depot area A2.

5. When the products are produced from entrance A, the products will be stored in row 1-3.

6. When the products are produced from entrance B, the products will be stored in row 4-6.

When considering the above criteria, the warehouse layout will change as shown in table 38.

Column	Row	Attribute	Set index	Product name
1	1	Position 11	1	-
2	1	Position 21	2	FSOZABSS100160S
3	1	Position 31	3	FSOZABSM100200M
4	1	Position 41	4	FSOZABSR120140R
5	1	Position 51	5	FSOZABSS040140S
1	2	Position 12	6	-
2	2	Position 22	7	-
3	2	Position 32	8	FSOZABSS060140S
4	2	Position 42	9	FSOZABSS120170S
5	2	Position 52	10	FSOZABSS040140S
1	3	Position 13	11	-
2	3	Position 23	12	FSOZABSR060140R
3	3	Position 33	13	FSOZABSS120170S
4	3	Position 43	14	FSOZABSR120140R
5	3	Position 53	15	FSOZABSR040140R
1	4	Position 14	16	FSOZABSS150170S
2	4	Position 24	17	FSOZABSS200170S
3	4	Position 34	18	FSOZABSM200200M
4	4	Position 44	19	FSOZABSR200140R
5	4	Position 54	20	New product
1	5	Position 15	21	-
2	5	Position 25	22	FSOZABSM150200M
3	5	Position 35	23	FSOZABSS200170S
4	5	Position 45	24	FSOZABSM200200M
5	5	Position 55	25	FSOZABSR150140R
1	6	Position 16	26	FSOZABSS150170S
2	6	Position 26	27	FSOZABSM040190M
3	6	Position 36	28	FSOZABSM200200M
4	6	Position 46	29	FSOZABSR150140R
5	6	Position 56	30	New product
1	1	Position 11	31	-
2	1	Position 21	32	FSOZABSS100170S
3	1	Position 31	33	Waste
1	2	Position 12	34	FSOZABSR040140R
2	2	Position 22	35	FSOZABSM060190M
3	2	Position 32	36	Waste
1	3	Position 13	37	FSOZABSM060190M
2	3	Position 23	38	New product
3	3	Position 33	39	

Table 38 The modified warehouse layout 2.

The production-distribution for each position are shown in table 39 and the orders and sales distribution are shown in table 40. All of the distributions are the same as the original one.

Column	Row	Attribute	Set index	Product name	Input A input Analyzer
1	1	Position 11	1	-	-
2	1	Position 21	2	FSOZABSS100160S	(261 + 9.75e+003 * BETA(1.31, 2.03))/91
3	1	Position 31	3	FSOZABSM100200M	(57 + WEIB(3.02e+003, 1.11))/91
4	1	Position 41	4	FSOZABSR120140R	(424 + 7.51e+003 * BETA(0.858, 1.22))/(61*2)
5	1	Position 51	5	FSOZABSS040140S	(338 + WEIB(3.68e+003, 1.28))/(169*2)
1	2	Position 12	6	-	-
2	2	Position 22	7	-	-
3	2	Position 32	8	FSOZABSS060140S	(762 + 9.4e+003 * BETA(1.14, 1.33))/127
4	2	Position 42	9	FSOZABSS120170S	(TRIA(427, 1.63e+003, 7.69e+003))/(61*2)
5	2	Position 52	10	FSOZABSS040140S	(338 + WEIB(3.68e+003, 1.28))/(169*2)
1	3	Position 13	11	-	-
2	3	Position 23	12	FSOZABSR060140R	NORM(3.01e+003, 1.59e+003)/127
3	3	Position 33	13	FSOZABSS120170S	(TRIA(427, 1.63e+003, 7.69e+003))/(61*2)
4	3	Position 43	14	FSOZABSR120140R	(424 + 7.51e+003 * BETA(0.858, 1.22))/(61*2)
5	3	Position 53	15	FSOZABSR040140R	(1.01e+003 + 7.1e+003 * BETA(0.931, 1.03))/(169*2)
1	4	Position 14	16	FSOZABSS150170S	(TRIA(32, 1.34e+003, 6.12e+003))/(44*2)
2	4	Position 24	17	FSOZABSS200170S	(NORM(2.28e+003, 1.11e+003))/(37*2)
3	4	Position 34	18	FSOZABSM200200M	(64 + 5.19e+003 * BETA(1.89, 2.84))/(37*3)
4	4	Position 44	19	FSOZABSR200140R	(592 + 2.91e+003 * BETA(0.856, 0.952))/37
5	4	Position 54	20	New product	-
1	5	Position 15	21	-	-
2	5	Position 25	22	FSOZABSM150200M	(440 + 9.02e+003 * BETA(0.918, 2.66))/44
3	5	Position 35	23	FSOZABSS200170S	(NORM(2.28e+003, 1.11e+003))/(37*2)
4	5	Position 45	24	FSOZABSM200200M	(64 + 5.19e+003 * BETA(1.89, 2.84))/(37*3)
5	5	Position 55	25	FSOZABSR150140R	(TRIA(85, 1.22e+003, 4.97e+003))/(44*2)
1	6	Position 16	26	FSOZABSS150170S	(TRIA(32, 1.34e+003, 6.12e+003))/(44*2)
2	6	Position 26	27	FSOZABSM040190M	(507 + 9.63e+003 * BETA(1.3, 2.11))/169
3	6	Position 36	28	FSOZABSM200200M	(64 + 5.19e+003 * BETA(1.89, 2.84))/(37*3)
4	6	Position 46	29	FSOZABSR150140R	(TRIA(85, 1.22e+003, 4.97e+003))/(44*2)
5	6	Position 56	30	New product	-
1	1	Position 11	31	-	-
2	1	Position 21	32	FSOZABSS100170S	(364 + 4.58e+003 * BETA(0.631, 0.716))/91
3	1	Position 31	33	Waste	-
1	2	Position 12	34	FSOZABSR040140R	(1.01e+003 + 7.1e+003 * BETA(0.931, 1.03))/(169*2)
2	2	Position 22	35	FSOZABSM060190M	(313 + 9.85e+003 * BETA(0.626, 1.19))/(127*2)
3	2	Position 32	36	Waste	-
1	3	Position 13	37	FSOZABSM060190M	(313 + 9.85e+003 * BETA(0.626, 1.19))/(127*2)
2	3	Position 23	38		-
3	3	Position 33	39		-

Table 39 The production-distributions for the warehouse layout 2.

Column	Row	Attribute	Set index	Order and sale A (Input analyzer)		
				Month 1-4	Month 5-8	Month 9-12
1	1	Position 11	1			
2	1	Position 21	2	(UNIF(91, 4e+003))/(3*91)	(NORM(2.21e+003, 1.33e+003))/(3*91)	(TRIA(91, 1.57e+003, 6.01e+003))/(3*91)
3	1	Position 31	3	(TRIA(91, 1.77e+003, 3.46e+003))/(91*3)	(TRIA(91, 1.62e+003, 5.19e+003))/(91*3)	(TRIA(273, 1.75e+003, 5.19e+003))/(91*3)
4	1	Position 41	4	(NORM(1.29e+003, 603))/(61*3*2)	(22 + EXPO(1.54e+003))/(61*3*2)	(61 + 6.28e+003 * BETA(0.916, 1.98))/(61*3*2)
5	1	Position 51	5	(NORM(3.43e+003, 2.55e+003))/(169*3*2)	(TRIA(169, 2.92e+003, 1.12e+004))/(169*3*2)	(NORM(3.32e+003, 2.43e+003))/(169*3*2)
1	2	Position 12	6	-	-	-
2	2	Position 22	7	-	-	-
3	2	Position 32	8	(UNIF(127, 5.84e+003))/(127*3)	(UNIF(254, 5.84e+003))/(127*3)	(NORM(2.55e+003, 2.3e+003))/(127*3)
4	2	Position 42	9	(UNIF(183, 3.05e+003))/(61*3*2)	(NORM(1.33e+003, 853))/(61*3*2)	(61 + EXPO(1.74e+003))/(61*3*2)
5	2	Position 52	10	(NORM(3.43e+003, 2.55e+003))/(169*3*2)	(TRIA(169, 2.92e+003, 1.12e+004))/(169*3*2)	(NORM(3.32e+003, 2.43e+003))/(169*3*2)
1	3	Position 13	11			
2	3	Position 23	12	(NORM(2.55e+003, 1.33e+003))/(127*3)	(TRIA(762, 3.3e+003, 5.84e+003))/(127*3)	(NORM(2.13e+003, 1.38e+003))/(127*3)
3	3	Position 33	13	(UNIF(183, 3.05e+003))/(61*3*2)	(NORM(1.33e+003, 853))/(61*3*2)	(61 + EXPO(1.74e+003))/(61*3*2)
4	3	Position 43	14	(NORM(1.29e+003, 603))/(61*3*2)	(22 + EXPO(1.54e+003))/(61*3*2)	(61 + 6.28e+003 * BETA(0.916, 1.98))/(61*3*2)
5	3	Position 53	15	(TRIA(169, 3.8e+003, 7.44e+003))/(169*3*2)	(TRIA(338, 3.58e+003, 1.12e+004))/(169*3*2)	(UNIF(169, 7.44e+003))/(169*3*2)
1	4	Position 14	16	(UNIF(44, 2.46e+003))/(44*3*2)	(NORM(1.17e+003, 875))/(44*3*2)	(88 + 4.84e+003 * BETA(0.549, 2.55))/(44*3*2)
2	4	Position 24	17	(NORM(937, 430))/(37*3*2)	(TRIA(37, 638, 2.44e+003))/(37*3*2)	(NORM(605, 344))/(37*3*2)
3	4	Position 34	18	(NORM(765, 429))/(37*3*3)	(37 + EXPO(965))/(37*3*3)	(37 + EXPO(829))/(37*3*3)
4	4	Position 44	19	(TRIA(37, 833, 1.63e+003))/(37*3)	(37 + EXPO(728))/(37*3)	(74 + WEIB(517, 0.823))/(37*3)
5	4	Position 54	20	-	-	-
1	5	Position 15	21	-	-	-
2	5	Position 25	22	(TRIA(44, 1.17e+003, 2.29e+003))/(44*3)	(44 + 5.68e+003 * BETA(0.677, 3.12))/(44*3)	(44 + 5.68e+003 * BETA(0.277, 0.631))/(44*3)
3	5	Position 35	23	(NORM(937, 430))/(37*3*2)	(TRIA(37, 638, 2.44e+003))/(37*3*2)	(NORM(605, 344))/(37*3*2)
4	5	Position 45	24	(NORM(765, 429))/(37*3*3)	(37 + EXPO(965))/(37*3*3)	(37 + EXPO(829))/(37*3*3)
5	5	Position 55	25	(UNIF(44, 1.23e+003))/(44*3*2)	(TRIA(88, 695, 6.16e+003))/(44*3*2)	(44 + WEIB(734, 0.782))/(44*3*2)
1	6	Position 16	26	(UNIF(44, 2.46e+003))/(44*3*2)	(NORM(1.17e+003, 875))/(44*3*2)	(88 + 4.84e+003 * BETA(0.549, 2.55))/(44*3*2)
2	6	Position 26	27	(TRIA(169, 2.96e+003, 5.75e+003))/(169*3)	(NORM(2.97e+003, 2.23e+003))/(169*3)	(169 + EXPO(1.71e+003))/(169*3)
3	6	Position 36	28	(NORM(765, 429))/(37*3*3)	(37 + EXPO(965))/(37*3*3)	(37 + EXPO(829))/(37*3*3)
4	6	Position 46	29	(UNIF(44, 1.23e+003))/(44*3*2)	(TRIA(88, 695, 6.16e+003))/(44*3*2)	(44 + WEIB(734, 0.782))/(44*3*2)
5	6	Position 56	30	-	-	-
1	1	Position 11	31	-	-	-
2	1	Position 21	32	-	-	(273 + EXPO(1.38e+003))/(91*3)
3	1	Position 31	33	-	-	-
1	2	Position 12	34	(TRIA(169, 3.8e+003, 7.44e+003))/(169*3*2)	(TRIA(338, 3.58e+003, 1.12e+004))/(169*3*2)	(UNIF(169, 7.44e+003))/(169*3*2)
2	2	Position 22	35	(127 + 6.72e+003 * BETA(1.47, 3.14))/(127*3*2)	(TRIA(127, 2.15e+003, 6.86e+003))/(127*3*2)	(127 + EXPO(1.98e+003))/(127*3*2)
3	2	Position 32	36	-	-	-
1	3	Position 13	37	(127 + 6.72e+003 * BETA(1.47, 3.14))/(127*3*2)	(TRIA(127, 2.15e+003, 6.86e+003))/(127*3*2)	(127 + EXPO(1.98e+003))/(127*3*2)
2	3	Position 23	38			
3	3	Position 33	39			

Table 40 The production distributions for the warehouse layout 2.

The production results as shown in table 41 and orders and sales results as shown in table 42 are similar to the Ziga reports. The errors for each product are almost less than 5 per cents. It is acceptable results.

Column	Row	Attribute	Set index	Product name	Real producing product	Valve from simulation	% Error
1	1	Position 11	1	-			
2	1	Position 21	2	FSOZABSS100160S	2780	2803	0.8
3	1	Position 31	3	FSOZABSM100200M	1284	1265	-1.5
4	1	Position 41	4	FSOZABSR120140R	1210	1233	1.9
5	1	Position 51	5	FSOZABSS040140S	856	873	2.0
1	2	Position 12	6	-			
2	2	Position 22	7	-			
3	2	Position 32	8	FSOZABSS060140S	2125	2117	-0.4
4	2	Position 42	9	FSOZABSS120170S	1412	1347	-4.6
5	2	Position 52	10	FSOZABSS040140S	856	806	-5.8
1	3	Position 13	11	-			
2	3	Position 23	12	FSOZABSR060140R	1307	1320	1.0
3	3	Position 33	13	FSOZABSS120170S	1412	1369	-3.0
4	3	Position 43	14	FSOZABSR120140R	1210	1256	3.8
5	3	Position 53	15	FSOZABSR040140R	644	643	-0.2
1	4	Position 14	16	FSOZABSS150170S	1707	1702	-0.3
2	4	Position 24	17	FSOZABSS200170S	1200	1162	-3.2
3	4	Position 34	18	FSOZABSM200200M	822	799	-2.8
4	4	Position 44	19	FSOZABSR200140R	799	798	-0.1
5	4	Position 54	20	New product			
1	5	Position 15	21	-			
2	5	Position 25	22	FSOZABSM150200M	2255	2222	-1.5
3	5	Position 35	23	FSOZABSS200170S	1200	1160	-3.3
4	5	Position 45	24	FSOZABSM200200M	822	818	-0.5
5	5	Position 55	25	FSOZABSR150140R	619	614	-0.8
1	6	Position 16	26	FSOZABSS150170S	1707	1668	-2.3
2	6	Position 26	27	FSOZABSM040190M	1311	1288	-1.8
3	6	Position 36	28	FSOZABSM200200M	822	817	-0.6
4	6	Position 46	29	FSOZABSR150140R	619	612	-1.1
5	6	Position 56	30	New product			
1	1	Position 11	31	-			
2	1	Position 21	32	FSOZABSS100170S	248	243	-2.0
3	1	Position 31	33	Waste			
1	2	Position 12	34	FSOZABSR040140R	644	636	-1.2
2	2	Position 22	35	FSOZABSM060190M	788	768	-2.5
3	2	Position 32	36	Waste			
1	3	Position 13	37	FSOZABSM060190M	788	782	-0.8
2	3	Position 23	38				
3	3	Position 33	39				

Table 41 Production results from arena simulation compared with the real one.

Column	Row	Attribute	Set index	Product name	Real orders and sales	Valve from simulation	% Error
1	1	Position 11	1	-			
2	1	Position 21	2	FSOZABSS100160S	2584	2543	-1.6
3	1	Position 31	3	FSOZABSM100200M	1372	1305	-4.9
4	1	Position 41	4	FSOZABSR120140R	1166	1158	-0.7
5	1	Position 51	5	FSOZABSS040140S	1016	1028	1.2
1	2	Position 12	6	-			
2	2	Position 22	7	-			
3	2	Position 32	8	FSOZABSS060140S	1937	1900	-1.9
4	2	Position 42	9	FSOZABSS120170S	1220	1222	0.2
5	2	Position 52	10	FSOZABSS040140S	1016	1024	0.8
1	3	Position 13	11	-			
2	3	Position 23	12	FSOZABSR060140R	1516	1575	3.9
3	3	Position 33	13	FSOZABSS120170S	1220	1182	-3.1
4	3	Position 43	14	FSOZABSR120140R	1166	1183	1.5
5	3	Position 53	15	FSOZABSR040140R	817	811	-0.7
1	4	Position 14	16	FSOZABSS150170S	1589	1608	1.2
2	4	Position 24	17	FSOZABSS200170S	1334	1342	0.6
3	4	Position 34	18	FSOZABSM200200M	828	808	-2.4
4	4	Position 44	19	FSOZABSR200140R	815	830	1.8
5	4	Position 54	20	New product			
1	5	Position 15	21	-			
2	5	Position 25	22	FSOZABSM150200M	2268	2243	-1.1
3	5	Position 35	23	FSOZABSS200170S	1334	1348	1.0
4	5	Position 45	24	FSOZABSM200200M	828	820	-1.0
5	5	Position 55	25	FSOZABSR150140R	598	624	4.3
1	6	Position 16	26	FSOZABSS150170S	1589	1669	5.0
2	6	Position 26	27	FSOZABSM040190M	1019	1051	3.1
3	6	Position 36	28	FSOZABSM200200M	828	831	0.4
4	6	Position 46	29	FSOZABSR150140R	598	605	1.2
5	6	Position 56	30	New product			
1	1	Position 11	31	-			
2	1	Position 21	32	FSOZABSS100170S	91	95	4.4
3	1	Position 31	33	Waste			
1	2	Position 12	34	FSOZABSR040140R	817	804	-1.6
2	2	Position 22	35	FSOZABSM060190M	740	778	5.1
3	2	Position 32	36	Waste			
1	3	Position 13	37	FSOZABSM060190M	740	794	7.3
2	3	Position 23	38				
3	3	Position 33	39				

Table 42 Orders and sales results from arena simulation compared with the real one

The total time usage is shown in table 43.

Process	Time usage
Time usage for transporting product to warehouse	81,742 minute
Time usage for transporting product to truck	37,878 minute

Table 43 The total time usage

Then, the results of labour costs and electricity costs are shown in Table 44.

	Labour costs	Electricity costs
transporting product to warehouse	340,592 Baht	170,636 Baht

transporting product to truck	236,738 Baht	79,070 Baht
Total cost	577,329 Baht	249,707 Baht

Table 44 the results of labour costs and electricity costs

The total distance involved is shown in table 45.

	Distance cover
transporting product to warehouse	503,474 metre
transporting product to truck	193,594 metre
Total distance	697,068 metre

Table 45 The distance cover.

Criteria, implemented and results for layout 3

For the last modified warehouse layout, the criteria have changed by using the requirements from Ziga. The author, Ziga employees and Ziga manager had arranged the meeting to discuss pros and cons for the requirements. The conclusion from the meeting are shown below.

1. There are two positions that store the waste conduits which the storekeepers are called off-spec products. The meeting concluded that these two positions had to be stored in position 14 and position 24. The rationale behind this requirement is that the off-spec products cannot use the overhead crane. Due to the small size of the batch, the off-spec products can only lift by Ziga labour. If we store the waste conduits too far away from the depot area, the time for transporting waste out will increase significantly and will affect the picking performance.

Therefore, the last layout warehouse will be displayed in table 46.

Column	Row	Attribute	Set index	Product name
1	1	Position 11	1	-
2	1	Position 21	2	FSOZABSS100160S
3	1	Position 31	3	FSOZABSM100200M
4	1	Position 41	4	FSOZABSR120140R
5	1	Position 51	5	FSOZABSS040140S
1	2	Position 12	6	-
2	2	Position 22	7	-
3	2	Position 32	8	FSOZABSS060140S
4	2	Position 42	9	FSOZABSS120170S
5	2	Position 52	10	FSOZABSS040140S
1	3	Position 13	11	-
2	3	Position 23	12	FSOZABSR060140R
3	3	Position 33	13	FSOZABSS120170S
4	3	Position 43	14	FSOZABSR120140R
5	3	Position 53	15	FSOZABSR040140R
1	4	Position 14	16	Waste
2	4	Position 24	17	Waste
3	4	Position 34	18	FSOZABSS200170S
4	4	Position 44	19	FSOZABSM200200M
5	4	Position 54	20	FSOZABSR150140R
1	5	Position 15	21	-
2	5	Position 25	22	FSOZABSM150200M
3	5	Position 35	23	FSOZABSS200170S
4	5	Position 45	24	FSOZABSM200200M
5	5	Position 55	25	FSOZABSM200200M
1	6	Position 16	26	FSOZABSS150170S
2	6	Position 26	27	FSOZABSS150170S
3	6	Position 36	28	FSOZABSM040190M
4	6	Position 46	29	FSOZABSR200140R
5	6	Position 56	30	FSOZABSR150140R
1	1	Position 11	31	-
2	1	Position 21	32	FSOZABSS100170S
3	1	Position 31	33	สินค้าใหม่
1	2	Position 12	34	FSOZABSR040140R
2	2	Position 22	35	FSOZABSM060190M
3	2	Position 32	36	สินค้าใหม่
1	3	Position 13	37	FSOZABSM060190M
2	3	Position 23	38	
3	3	Position 33	39	

Table 46 The modified warehouse layout 3.

The production-distribution for each position are shown in table 47 and the orders and sales distribution are shown in table 48. All of the distributions are the same as the original one.

Column	Row	Attribute	Set index	Input A input Analyzer
1	1	Position 11	1	
2	1	Position 21	2	(261 + 9.75e+003 * BETA(1.31, 2.03))/91
3	1	Position 31	3	(57 + WEIB(3.02e+003, 1.11))/91
4	1	Position 41	4	(424 + 7.51e+003 * BETA(0.858, 1.22))/(61*2)
5	1	Position 51	5	(338 + WEIB(3.68e+003, 1.28))/(169*2)
1	2	Position 12	6	-
2	2	Position 22	7	-
3	2	Position 32	8	(762 + 9.4e+003 * BETA(1.14, 1.33))/127
4	2	Position 42	9	(TRIA(427, 1.63e+003, 7.69e+003))/(61*2)
5	2	Position 52	10	(338 + WEIB(3.68e+003, 1.28))/(169*2)
1	3	Position 13	11	
2	3	Position 23	12	NORM(3.01e+003, 1.59e+003)/127
3	3	Position 33	13	(TRIA(427, 1.63e+003, 7.69e+003))/(61*2)
4	3	Position 43	14	(424 + 7.51e+003 * BETA(0.858, 1.22))/(61*2)
5	3	Position 53	15	(1.01e+003 + 7.1e+003 * BETA(0.931, 1.03))/(169*2)
1	4	Position 14	16	-
2	4	Position 24	17	-
3	4	Position 34	18	(NORM(2.28e+003, 1.11e+003))/(37*2)
4	4	Position 44	19	(64 + 5.19e+003 * BETA(1.89, 2.84))/(37*3)
5	4	Position 54	20	(TRIA(85, 1.22e+003, 4.97e+003))/(44*2)
1	5	Position 15	21	
2	5	Position 25	22	(440 + 9.02e+003 * BETA(0.918, 2.66))/44
3	5	Position 35	23	(NORM(2.28e+003, 1.11e+003))/(37*2)
4	5	Position 45	24	(64 + 5.19e+003 * BETA(1.89, 2.84))/(37*3)
5	5	Position 55	25	(64 + 5.19e+003 * BETA(1.89, 2.84))/(37*3)
1	6	Position 16	26	(TRIA(32, 1.34e+003, 6.12e+003))/(44*2)
2	6	Position 26	27	(TRIA(32, 1.34e+003, 6.12e+003))/(44*2)
3	6	Position 36	28	(507 + 9.63e+003 * BETA(1.3, 2.11))/169
4	6	Position 46	29	(592 + 2.91e+003 * BETA(0.856, 0.952))/37
5	6	Position 56	30	(TRIA(85, 1.22e+003, 4.97e+003))/(44*2)
1	1	Position 11	31	-
2	1	Position 21	32	(364 + 4.58e+003 * BETA(0.631, 0.716))/91
3	1	Position 31	33	-
1	2	Position 12	34	(1.01e+003 + 7.1e+003 * BETA(0.931, 1.03))/(169*2)
2	2	Position 22	35	(313 + 9.85e+003 * BETA(0.626, 1.19))/(127*2)
3	2	Position 32	36	-
1	3	Position 13	37	(313 + 9.85e+003 * BETA(0.626, 1.19))/(127*2)
2	3	Position 23	38	
3	3	Position 33	39	

Table 47 The production distributions for the warehouse layout 3.

Column	Row	Attribute	Set index	Order and sale A (Input analyzer)		
				Month 1-4	Month 5-8	Month 9-12
1	1	Position 11	1			
2	1	Position 21	2	(UNIF(91, 4e+003))/(3*91)	(NORM(2.21e+003, 1.33e+003))/(3*91)	(TRIA(91, 1.57e+003, 6.01e+003))/(3*91)
3	1	Position 31	3	(TRIA(91, 1.77e+003, 3.46e+003))/(91*3)	(TRIA(91, 1.62e+003, 5.19e+003))/(91*3)	(TRIA(273, 1.75e+003, 5.19e+003))/(91*3)
4	1	Position 41	4	(NORM(1.29e+003, 603))/(61*3*2)	(22 + EXPO(1.54e+003))/(61*3*2)	(61 + 6.28e+003 * BETA(0.916, 1.98))/(61*3*2)
5	1	Position 51	5	(NORM(3.43e+003, 2.55e+003))/(169*3*2)	(TRIA(169, 2.92e+003, 1.12e+004))/(169*3*2)	(NORM(3.32e+003, 2.43e+003))/(169*3*2)
1	2	Position 12	6	-	-	-
2	2	Position 22	7	-	-	-
3	2	Position 32	8	(UNIF(127, 5.84e+003))/(127*3)	(UNIF(254, 5.84e+003))/(127*3)	(NORM(2.55e+003, 2.3e+003))/(127*3)
4	2	Position 42	9	(UNIF(183, 3.05e+003))/(61*3*2)	(NORM(1.33e+003, 853))/(61*3*2)	(61 + EXPO(1.74e+003))/(61*3*2)
5	2	Position 52	10	(NORM(3.43e+003, 2.55e+003))/(169*3*2)	(TRIA(169, 2.92e+003, 1.12e+004))/(169*3*2)	(NORM(3.32e+003, 2.43e+003))/(169*3*2)
1	3	Position 13	11			
2	3	Position 23	12	(NORM(2.55e+003, 1.33e+003))/(127*3)	(TRIA(762, 3.3e+003, 5.84e+003))/(127*3)	(NORM(2.13e+003, 1.38e+003))/(127*3)
3	3	Position 33	13	(UNIF(183, 3.05e+003))/(61*3*2)	(NORM(1.33e+003, 853))/(61*3*2)	(61 + EXPO(1.74e+003))/(61*3*2)
4	3	Position 43	14	(NORM(1.29e+003, 603))/(61*3*2)	(22 + EXPO(1.54e+003))/(61*3*2)	(61 + 6.28e+003 * BETA(0.916, 1.98))/(61*3*2)
5	3	Position 53	15	(TRIA(169, 3.8e+003, 7.44e+003))/(169*3*2)	(TRIA(338, 3.58e+003, 1.12e+004))/(169*3*2)	(UNIF(169, 7.44e+003))/(169*3*2)
1	4	Position 14	16	-	-	-
2	4	Position 24	17	-	-	-
3	4	Position 34	18	(NORM(937, 430))/(37*3*2)	(TRIA(37, 638, 2.44e+003))/(37*3*2)	(NORM(605, 344))/(37*3*2)
4	4	Position 44	19	(NORM(765, 429))/(37*3*3)	(37 + EXPO(965))/(37*3*3)	(37 + EXPO(829))/(37*3*3)
5	4	Position 54	20	(UNIF(44, 1.23e+003))/(44*3*2)	(TRIA(88, 695, 6.16e+003))/(44*3*2)	(44 + WEIB(734, 0.782))/(44*3*2)
1	5	Position 15	21			
2	5	Position 25	22	(TRIA(44, 1.17e+003, 2.29e+003))/(44*3)	(44 + 5.68e+003 * BETA(0.677, 3.12))/(44*3)	(44 + 5.68e+003 * BETA(0.277, 0.631))/(44*3)
3	5	Position 35	23	(NORM(937, 430))/(37*3*2)	(TRIA(37, 638, 2.44e+003))/(37*3*2)	(NORM(605, 344))/(37*3*2)
4	5	Position 45	24	(NORM(765, 429))/(37*3*3)	(37 + EXPO(965))/(37*3*3)	(37 + EXPO(829))/(37*3*3)
5	5	Position 55	25	(NORM(765, 429))/(37*3*3)	(37 + EXPO(965))/(37*3*3)	(37 + EXPO(829))/(37*3*3)
1	6	Position 16	26	(UNIF(44, 2.46e+003))/(44*3*2)	(NORM(1.17e+003, 875))/(44*3*2)	(88 + 4.84e+003 * BETA(0.549, 2.55))/(44*3*2)
2	6	Position 26	27	(UNIF(44, 2.46e+003))/(44*3*2)	(NORM(1.17e+003, 875))/(44*3*2)	(88 + 4.84e+003 * BETA(0.549, 2.55))/(44*3*2)
3	6	Position 36	28	(TRIA(169, 2.96e+003, 5.75e+003))/(169*3)	(NORM(2.97e+003, 2.23e+003))/(169*3)	(169 + EXPO(1.71e+003))/(169*3)
4	6	Position 46	29	(TRIA(37, 833, 1.63e+003))/(37*3)	(37 + EXPO(728))/(37*3)	(74 + WEIB(517, 0.823))/(37*3)
5	6	Position 56	30	(UNIF(44, 1.23e+003))/(44*3*2)	(TRIA(88, 695, 6.16e+003))/(44*3*2)	(44 + WEIB(734, 0.782))/(44*3*2)
1	1	Position 11	31	-	-	-
2	1	Position 21	32	-	-	(273 + EXPO(1.38e+003))/(91*3)
3	1	Position 31	33	-	-	-
1	2	Position 12	34	(TRIA(169, 3.8e+003, 7.44e+003))/(169*3*2)	(TRIA(338, 3.58e+003, 1.12e+004))/(169*3*2)	(UNIF(169, 7.44e+003))/(169*3*2)
2	2	Position 22	35	(127 + 6.72e+003 * BETA(1.47, 3.14))/(127*3*2)	(TRIA(127, 2.15e+003, 6.86e+003))/(127*3*2)	(127 + EXPO(1.98e+003))/(127*3*2)
3	2	Position 32	36			
1	3	Position 13	37	(127 + 6.72e+003 * BETA(1.47, 3.14))/(127*3*2)	(TRIA(127, 2.15e+003, 6.86e+003))/(127*3*2)	(127 + EXPO(1.98e+003))/(127*3*2)
2	3	Position 23	38	-	-	-
3	3	Position 33	39	-	-	-

Table 48 The orders and sales distributions for the warehouse layout 3.

The production results as shown in table 49 and orders and sales as shown in table 50 are similar to the Ziga reports. The errors are almost less than 5 per cents. It is acceptable results.

Column	Row	Attribute	Set index	Product name	Real producing product	Valve from simulation	% Error
1	1	Position 11	1	-			
2	1	Position 21	2	FSOZABSS100160S	2780	2686	-3.4
3	1	Position 31	3	FSOZABSM100200M	1284	1280	-0.3
4	1	Position 41	4	FSOZABSR120140R	1210	1281	5.87
5	1	Position 51	5	FSOZABSS040140S	856	819	-4.3
1	2	Position 12	6	-			
2	2	Position 22	7	-			
3	2	Position 32	8	FSOZABSS060140S	2125	2116	-0.4
4	2	Position 42	9	FSOZABSS120170S	1412	1419	0.5
5	2	Position 52	10	FSOZABSS040140S	856	806	-5.8
1	3	Position 13	11	-			
2	3	Position 23	12	FSOZABSR060140R	1307	1252	-4.2
3	3	Position 33	13	FSOZABSS120170S	1412	1411	-0.1
4	3	Position 43	14	FSOZABSR120140R	1210	1292	6.8
5	3	Position 53	15	FSOZABSR040140R	644	649	0.8
1	4	Position 14	16	Waste			
2	4	Position 24	17	Waste			
3	4	Position 34	18	FSOZABSS200170S	1200	1202	0.2
4	4	Position 44	19	FSOZABSM200200M	822	839	2.1
5	4	Position 54	20	FSOZABSR150140R	619	610	-1.5
1	5	Position 15	21	-			
2	5	Position 25	22	FSOZABSM150200M	2255	2227	-1.2
3	5	Position 35	23	FSOZABSS200170S	1200	1204	0.3
4	5	Position 45	24	FSOZABSM200200M	822	869	5.7
5	5	Position 55	25	FSOZABSM200200M	822	797	-3.0
1	6	Position 16	26	FSOZABSS150170S	1707	1679	-1.6
2	6	Position 26	27	FSOZABSS150170S	1707	1681	-1.5
3	6	Position 36	28	FSOZABSM040190M	1311	1325	1.1
4	6	Position 46	29	FSOZABSR200140R	799	781	-2.3
5	6	Position 56	30	FSOZABSR150140R	619	627	1.3
1	1	Position 11	31	-			
2	1	Position 21	32	FSOZABSS100170S	248	237	-4.4
3	1	Position 31	33	สินค้าใหม่			
1	2	Position 12	34	FSOZABSR040140R	644	653	1.4
2	2	Position 22	35	FSOZABSM060190M	788	791	0.4
3	2	Position 32	36	สินค้าใหม่			
1	3	Position 13	37	FSOZABSM060190M	788	776	-1.5
2	3	Position 23	38				
3	3	Position 33	39				

Table 49 Production results from arena simulation compared with the real one.

Column	Row	Attribute	Set index	Product name	Real orders and sales	Valve from simulation	% Error
1	1	Position 11	1	-			
2	1	Position 21	2	FSOZABSS100160S	2584	2498	-3.3
3	1	Position 31	3	FSOZABSM100200M	1372	1325	-3.4
4	1	Position 41	4	FSOZABSR120140R	1166	1186	1.7
5	1	Position 51	5	FSOZABSS040140S	1016	1054	3.7
1	2	Position 12	6	-			
2	2	Position 22	7	-			
3	2	Position 32	8	FSOZABSS060140S	1937	1961	1.2
4	2	Position 42	9	FSOZABSS120170S	1220	1236	1.3
5	2	Position 52	10	FSOZABSS040140S	1016	1048	3.1
1	3	Position 13	11	-			
2	3	Position 23	12	FSOZABSR060140R	1516	1526	0.7
3	3	Position 33	13	FSOZABSS120170S	1220	1197	-1.9
4	3	Position 43	14	FSOZABSR120140R	1166	1206	3.4
5	3	Position 53	15	FSOZABSR040140R	817	817	0.0
1	4	Position 14	16	Waste			
2	4	Position 24	17	Waste			
3	4	Position 34	18	FSOZABSS200170S	1334	1371	2.8
4	4	Position 44	19	FSOZABSM200200M	828	843	1.8
5	4	Position 54	20	FSOZABSR150140R	598	627	4.8
1	5	Position 15	21	-			
2	5	Position 25	22	FSOZABSM150200M	2268	2274	0.3
3	5	Position 35	23	FSOZABSS200170S	1334	1356	1.6
4	5	Position 45	24	FSOZABSM200200M	828	884	6.8
5	5	Position 55	25	FSOZABSM200200M	828	806	-2.7
1	6	Position 16	26	FSOZABSS150170S	1589	1637	3.0
2	6	Position 26	27	FSOZABSS150170S	1589	1635	2.9
3	6	Position 36	28	FSOZABSM040190M	1019	1018	-0.1
4	6	Position 46	29	FSOZABSR200140R	815	803	-1.5
5	6	Position 56	30	FSOZABSR150140R	598	628	5.0
1	1	Position 11	31	-			
2	1	Position 21	32	FSOZABSS100170S	91	93	2.2
3	1	Position 31	33	สินค้าใหม่			
1	2	Position 12	34	FSOZABSR040140R	817	825	1.0
2	2	Position 22	35	FSOZABSM060190M	740	789	6.6
3	2	Position 32	36	สินค้าใหม่			
1	3	Position 13	37	FSOZABSM060190M	740	777	5.0
2	3	Position 23	38				
3	3	Position 33	39				

Table 50 Orders and sales results from arena simulation compared with the real one

The total time usage is shown in table 51.

Process	Time usage
Time usage for transporting the product to warehouse	78,935 minutes
Time usage for transporting the product to truck	40,042 minutes

Table 51 The total time usage

The results of labour costs and electricity costs are shown in Table 52.

	Labour costs	Electricity costs
Transporting the product to warehouse	263,117 Baht	131,821 Baht
Transporting the product to truck	200,210 Baht	66,870 Baht
Total cost	463,327 Baht	198,692 Baht

Table 52 The results of labour costs and electricity costs

The total distance involved is shown in table 53.

	Distance cover
Transporting the products to warehouse	469,829 metres
Transporting the products to truck	209,800 metres
Total distance	679,629 metres

Table 53 The distance cover.

Chapter 5 Result Analysis and Discussion

As performed in above, the warehouse layout 2 with the condition based on the amount of sale volume and the number of position has the most cost saving when compared to the original one. However, the warehouse layout 3 with the Ziga preferred is also has second results with a slightly different. Based on the results from simulation, the following analysis can be realized.

1. When considering only the transporting SKUs out of the warehouse, the warehouse layout 2 has the most advantage in term of distance involve and time usage. The rationale behind these is that the most picking SKUs in each position are stored near the depot areas. When exporting the SKUs, the warehouse keeper can easily mobilize the SKUs to trucks or depot areas. Therefore, the distance from the warehouse to truck will be reduced significantly and also in the same way of time usage.

2. For layout 2, the labour cost, electricity cost, time and distance for inputting SKUs to the warehouse are higher than the original one but not much. On the contrary, these costs, time and distance decreased significantly when transporting out of the warehouse. The overall cost is lower than the original one and the others. It can be described that if we want to save the costs, we need to consider the process of transporting SKUs out of the warehouse. This process involved more human resources, which means Ziga will have to pay more labour costs than transporting SKU into the warehouse when the process has the same time usage.

3. We also can conclude that the areas which store the same product have an effect on the results from the simulation. Due to the equal possibility of picking product in each area, if the most picking products have two areas to be stored, the amount of picking and sale volume of each area has to be divided into the same amount. Therefore, when we used the criteria to sort the most picking product from high to low or high sale volume to low volume, the sequence to put in the simulation will change. For further researches, we recommend finding the appropriate criteria to design which SKUs need more than one area to be stored.
4. For layout 3, the Ziga's storekeepers request to move the waste positions from the back into the front. The rationale behind this action is that they want the contractors to dispose of the wastes every month and they did not want the contractors to use the overhead crane. The wastes are not in the form of batch. Therefore, it will not be easy to transport by overhead cranes. The results show that when slightly move SKUs away from their appropriate positions that use in layout 2. The costs of transporting SKUs in the warehouse decreased. However, when SKUs are far away from the depot area, the storekeepers need more time to transport SKUs and distances that involved also increase. These cause more costs of transporting SKUs out of the warehouse than layout 2.
5. In layout 1, the labour cost, electricity cost and distance for transporting SKUs in the warehouse are almost the same as the original one. It can be inferred that if Ziga implements this layout, the storekeepers will spend the same amount of time transporting

SKUs into the warehouse as they spend time in the warehouse now. However, they will save time when transport products out of the warehouse. The most picking SKUs are far away from the production point but near the depot point. These increase the time and distance to transport the SKUs to the warehouse but reduce time when transport out. However, this layout is not the best one with the cost saving, time and distance.

6. With the change in position of SKUs, the operational cost decreased integrally both labour cost and electricity cost. Then, for each layout, layout 1, layout 2, layout 3 shown an average decreased of 7.5 per cent, 8.33 per cent and 8.28 per cent. Layout 2 had the most cost saving when compared to the other layout.
7. It can be observed that the total distance depends on the position of SKUs. The total distance includes the distance from production point to warehouse and warehouse to depot area. The results in simulation show that each layout has distance involved from 679,629 metres to 699,497 metres or decreased 7.3 per cent to 9.9 per cent when compared to the original one. The simulation results show that the layout 3 had the least distance involved.
8. Obviously, no matter what kind of formats used in this thesis in order to adjust the position of SKUs still improving the performance in term of time, distance and reduce the costs.
9. When considering the resource utilization in this thesis which is labour, the decreasing time for transporting SKUs also has pros and cons for the company. The benefit of

reducing the time for transportation in the warehouse is that the labours have more time to do another task such as administrative tasks. However, it is a two sided coin, if the company doesn’t mobilize their labours to do anything, your labour will be wasting their time because they have no tasks to work on.

Chapter 6 Conclusions and future work

This thesis addressed the different layouts based on the criteria in order to improve the performance in Ziga's warehouse. The simulation considers changing the positions in the warehouse which are different depending on the frequency of picking or the best-selling products and the amount of position for each SKUs. These changing position in the layouts point out the different consequences which included the time and distance that involved with the activity in the warehouse. These consequences lead directly to the costs which are the most important subjects that Ziga company concern. For conclusion, the following finding as shown below can be concluded from this thesis.

1. There are some trade-off issues that need to be concerned. Firstly, the cost of transport in and out seem to directly relate with position changing. If we move all of the best-selling products to the position where are near the depot area, it will reduce the cost and time for transport SKUs out. However, it obviously causes more the workload in the transport SKUs into the warehouse because the distances are far away from the production point and it will need more time to move the SKUs.
2. The human resources that use for transporting SKUs into the warehouse are 2 person but the human resources for transporting products out is 3 person. These are the big difference in activities in the warehouse. If we want to save costs for the company, we have to focus on the activities related to transporting the SKUs out.

3. According to the figure 16, the warehouse layout 2 has 8.33 per cent of the cost saving. When compare to the other results, this layout tends to have the best results when implemented in the Ziga warehouse. However, these results are based on the equal possibility of picking the product in each position. In the realistic, the possibility to pick the SKUs in each position are not equal, therefore, the results will change. Layout 3 has 8.28 per cent of cost saving because of the waste position located near the depot position. Because of the request from Ziga to put the waste near the depot area, thus, this layout shifts the most picking product to the position that far away from the depot area which means more time to transport SKUs out of the warehouse. However, the benefit of moving the waste near the depot area is that the contractors can move out the waste easily and do not need to use the overhead crane. These will reduce the costs from electricity and time for waiting overhead crane to finish their tasks.

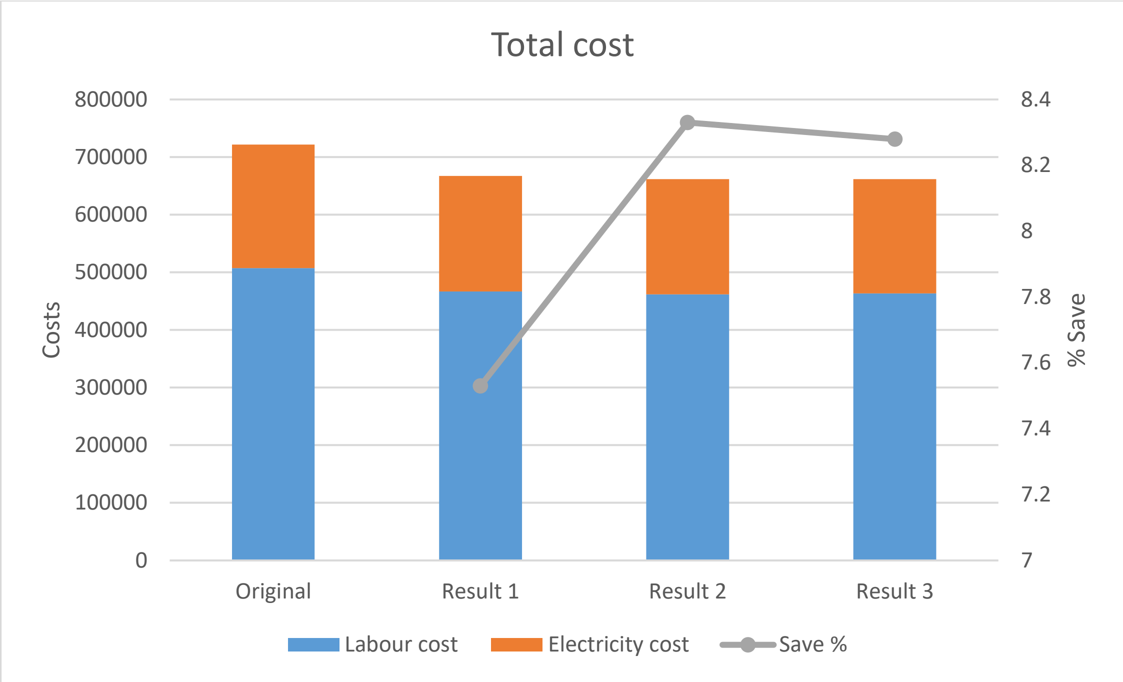


Figure 16 Comparing the results.

4. When Ziga wants to implement the new layout for each SKUs, they need to consider the costs that they need to spend such as the cost of moving SKUs. Moreover, the empty space to temporarily store the old or previous SKUs before moving to the new positions is also important. These are the additional costs for consideration.

5. Due to deadlock time which is hard to measure, therefore the deadlock issues are also excluded from the simulation. This delay time could possibly increase the difficulty of the layout design, therefore, the upgrade of the simulation and model is needed to solve the problem effectively.

6. It can be seen that there is no free space in any layouts. With no free space, it is not easy to move the first or previous products unless moving out the top products which recently produced of each position out. It is a disadvantage topic which needs to be fixed.

7. Although we defined that the weight of SKUs does not affect the speed and time for transporting the SKUs in and out, it is needed to be considered in the future work of research.

Limitation and suggestion (Future work)

Limitation	Suggestion (future work)
1. Deadlock issues	The deadlock issues also increase the delay time for transporting the SKUs. These issues need a plan for compensating the waiting time. For example, when the first crane is transporting the SKUs from production point to warehouse, the second crane cannot transport SKUs from warehouse to depot area and have to wait for the first crane to finish the tasks. Therefore, the second crane should instead do a different job as transport SKUs into the warehouse.
2. First in first out policy	It is a common issue for every warehouse to move the first or previous products out of the warehouse. However, because of the characteristic of conduits, the first one will be on the floor and the newest one will be on the top. The only way to move the first one out is to move the product on the top to another area. This activity needs space and time to shuffle the SKUs. The possible way for doing this is that Ziga warehouse needs to

	provide free space. This free space will provide an opportunity for storekeepers to arrange the position of the SKUs in each position. On the other hand, it will definitely increase the waiting time for other activities which directly related to labour costs and electricity costs. It is also the tradeoff that needs to be concerned.
3. Indirect cost	The indirect cost such as the administration costs, IT costs, supplier costs or overhead costs are not included in the simulation. However, these cost needs to be put in the simulation one way or another to make the simulation more realistic.
4. Synchronized plan	To avoid deadlock issues, the production plans, track schedules and crane activities needs to synchronize with each other. To reduce the possibility of the deadlock, the plan need to consider the amount of time that has been spent on every activity in the warehouse.
5. Time sharing with the waste transportation	The position of the waste SKUs are also important. If these positions are near the depot area. It means that when the contractors want to transport the waste to the trucks they will not affect the activity in the warehouse. On the other hand,

	when the wastes are located at the back or far away from depot area, the contractors will need to use the overhead crane which will delay the time for activity in the warehouse. These issues need to clarify with the contractors to use overhead cranes when they are free from the internal process in the warehouse.
6. The weight of SKUS	The weight of the SKUs can affect the time for transportation. In the simulation, we excluded this effect in order to make the simulation easy to construct. However, the more weight of SKUs, the time spend for transporting the SKUs in or out will increase. This consequence may be outperformed the criteria we used in layout 2. For further researches, the weight of SKUs needs to be considered as a criterion along with the most picking product criteria or sale volume criteria.
7. Same product at the different area.	To reduce the time used for transporting the most picking product out and reduce the costs, you can store the products at the other warehouses. However, when looking at the whole business, this issue needs to be considered as one of the criteria for the simulation.

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