CHAPTER IV

DESIGN ANALYSIS

4.1 Study methods

In this study, the methods used to analyze the data depend on criteria. There are three criterions for determining the warehouse design, including storage requirement, layout and physical design, warehouse operation and material handling resources.

4.1.1 Storage requirement, layout and physical design

Stock keeping units or SKUs to be stored in the warehouse is the major factor determined by calculations tables. The data of material categories in the existing warehouse still applied in the design development. Then, the ergonomic and smooth material flow processes are considered at the designing stage.

4.1.2 Warehouse operation

Base on three operation processes, the unloading/receiving, inspection and put-away. The time study and excel spread sheet are the basic tools to gather the data. And historical data is the baseline in order to develop the warehouse operation design by assessing bottle neck and wastes.

4.1.3 Material handling resource

The material handling resource relies on existing resources and design. Weighted techniques and comparison table are applied for analyzing the proper resources in the design warehouse.

4.2 Data collection

4.2.1 Storage requirement, layout and physical design - Historical and forecasting data

Existing SKUs stored in the warehouse and additional SKUs are calculated based on the part proliferation of new model by specialist in the functional area. These SKUs data is collected by grouping the material category to sort out material zones, therefore storage requirement is calculated.

For the design of the storage system, the data of container or packaging specification which existing warehouse handle including packaging type, pallet load, dimension, weight, etc. are use to indicate the storage system.

4.2.2 Warehouse operation - Sample collection

There are separated into 2 terms, overall warehousing process and process steps element time. The unloading/receiving, inspection and operation design are the daily occurrence activities. So, the time study will be record in sampling 4 times per day in each working time period (regular working time is Monday – Friday, time 7.30 – 16.40, this product is produced in day shift only) as detailed below:

Time A: 7.30 – 9.30 (120 min.)
Time B: 9.40 – 11.30 (110 min.)
Time C: 12.10 – 14.30 (140 min.)
Time D: 14.40 – 16.40 (120 min.)

4.2.3 Material handling resource – Utilization rate

The material handling resource is concerned with human resource or workforce and mobile equipment. Utilization of each function is recorded and calculated by part per resource ratio. Measurement tables are established to fill in the data.

The 3 criterions are the focused points in order to analyze data therefore, data collection plan is developed to record, analyze and evaluate the warehouse criterion.

The data collection plan is shown in **Table 4.1, Table 4.1:** Data collection plan.

Table 4.1: Data collection plan

Criterion	Indicator	Data collection technique	Analyzing Tool
Layout and physical design	• SKUs	• Storage requirement • Packaging • Supply operation	• Selection metric / each category
Warehouse operation	• Box & Pallet	• Time study	• Process steps and element times
Material handling resource	• Utilization (Production rate)	• Consumption rate	• Data calculation

4.3 Analysis techniques and evaluation

Information output of the warehouse is summarized in order to consider its design. It includes physical design, warehouse operation and material handling resource.

1) Physical design

Key features	**Description**
Storage requirement	- Calculate the warehouse requirement based on the existing and forecasting data
Warehouse zones	- Place the expandable warehouse requirement on the existing 3 zones location basis
Aisle way	- Considering via the mobile equipment requirement - Blending with the building post and existing infrastructure system
Traffic flow	- Acquire safety transportation and good visibility
Storage type	- Define the packaging/container type, dimension and unit load to be store in the warehouse and match with the racking system capability - Ergonomic considering on human operation - FIFO process support

2) Warehouse operation

Key features	**Description**
Unloading/Receiving	- Define the time consumption each operation step
Inspection	- Manual and automatic system comparison
Put-away	- Specify physical location and travel time into travel route

3) Material handling resource

Key features	**Description**
Workforce	- Organize workforce in appropriate area and balance
Mobile equipment	- Align with the warehouse design structure, racking system and material characteristic

4.3.1 Storage requirement, layout and physical design

The warehouse data scheme is different depending on the operation plant, vehicle type and productivity. In order to fine tune the analysis, there are various tools to analyze the warehouse patterns. First, develop the existing and forecasting data of SKUs, from 'plan for every part' database, to be stored in the warehouse which is shown in **Table 4.2:** Material storage area for each category. The required area is calculated from the existing and forecast data.

Table 4.2: Material storage area for each category

Area	Model I (Existing)		Model II (Exiting)		Model III (Forecasting)		Total SKU	Total require area (g) = (b+d+f)	Available area (h)	Diff (h)-(g)
	SKU (a)	Area (b)	SKU (c)	Area (d)	SKU (e)	Area (f)				
ZONE 1	1,038.00	248.04	867.00	207.18	1,100.00	262.86	3,005.00	718.08	937.56	219.49
ZONE 2	500.00	1,373.32	260.00	714.13	847.00	2,326.40	1,607.00	4,413.85	1,580.04	- 2,833.81
ZONE 3	238.00	1454.93	33.00	201.73	10.00	61.13	281.00	1,717.79	2,299.86	582.06
TOTAL	1,776.00	3,076.29	1,160.00	1,123.04	1,957.00	2,650.39	4,893.00	6,849.72	4,817.46	- 2,032.26

From the above data, storage requirement area is calculated by including new product model. The negative available area shows that the floor area is not enough and shows that the storage area requires more space around

2,032.26 sq.m. Then the additional storage area is considered. In this case, 3 main alternatives are generated to determine each criterion to rate output in positive (+, for preferred) and negative (-, for not preferred) sign and the result is shown in **Table 4.3**, **Table 4.3:** Addition warehouse pattern selection metric.

Table 4.3: Addition warehouse pattern selection metric

Alternative/Criteria:	Investment	Space utilize	Delivery	Range
1. Install storage rack	+	+	+	1st
2. Construct second floor	+	+	-	2nd
3. Build new warehouse	-	-	+	3rd

From these results, the type 'install storage rack' is first due to its lower investment needs, good space utilization, and smooth delivery by allowing material handling team maximum selectivity with accessibility to any pallet at each storage location and providing the movement in the vertical direction instead horizontal direction which causes the density traffic flow. And also the requirements of expendable area can be served by installing racking.

With reference to the many types of high racks, the final step is developed to select the storage module. Base on the difference in material characteristic, the consideration is separated by material zoning. Selection metrics are developed to determine to suitable storage module in each zone. And 11 criterions are the factors to be considered. X is applicable, O is not preferred. The data gathered here referred to in **Table 2.1** and chapter II.

Zone 1, pull card materials, totally 3,005 SKU. No pallet load except overflow which is currently stored on the top shelves. The part packages are small box and tote, weight limited per container at 15 kg. Material in and out is the whole container picking, no-repacking or pieces picking. Therefore, storage module choices recommended for storage are bin shelving, gravity flow rack and bin drawer. In **Table 4.4:** Storage module selection metric for zone 1, two alternatives, shelves and flow rack are considered.

Table 4.4: Storage module selection metric for zone 1

Storage type / Criteria	Shelves	Flow rack	Bin drawer
Align with container/packaging	O	X	O
Load capacity	O	X	O
FIFO ability	X	X	O
Support ergonomic/picking process	X	X	X
Productivity/Traffic flow	X	X	O
Space utilization/Align with existing design	X	X	X
Easy to control material/visualization	X	X	X
Investment	O	X	O
Align with current mobile equipment	X	X	X
Flexible design	O	X	O
Safe work environment	X	X	X
Total score	X = 7 O = 4	X = 11 O = 0	X = 5 O = 6

From above data, it shows the significant result that the flow rack is the preferable storage module for zone 1.

Zone 2, Internal sequencing part, SKU amount is 1,607. This zone is occupied both pallet and box. With reference to flow racks already installed in the existing area for box container and still available so, only the pallet storage module is desired. **Table 4.5:** Storage module selection metric for zone 2, there are 4 alternatives, selective racks, double deep rack, selective flow rack and drive-in rack to be considered.

Table 4.5: Storage module selection metric for zone 2

Storage type / Criteria	Single Selective rack	Double deep rack	Selective flow rack	Drive-In rack
Align with container/packaging	X	X	X	X
Load capacity	X	X	X	X
FIFO ability	X	O	X	O
Support ergonomic/picking process	O	O	X	O
Productivity/Traffic flow	X	X	X	X
Space utilization/Align with existing design	X	X	X	X
Easy to control material/visualization	X	X	X	X
Investment	X	X	O	O
Align with current mobile equipment	X	O	X	X
Flexible design	X	X	O	O
Safe work environment	X	X	X	O
Total score	X = 10 O = 1	X = 8 O = 3	X = 9 O = 2	X = 6 O = 5

Table 4.5 shows the result for the first 3 modules. The last module is not considered due to it not compiling with 5 criteria, and especially not suitable for safety work environment. Those 3 modules are considered to apply based on the warehouse foot print.

Zone 3, call for material tool part, bulky rack, dolly, pallet and wooden/steel case container and totally 281 SKU, is mainly operated by fork lift truck. **Table 4.6:** Storage module selection metric for zone 3, there are 4 alternatives similar to zone 2, single selective racks, double deep rack, selective flow rack and drive-in rack.

Table 4.6: Storage module selection metric for zone 3

Criteria \ Storage type	Single Selective rack	Double deep rack	Selective flow rack	Drive-In rack
Align with container/packaging	X	X	O	O
Load capacity	X	X	O	X
FIFO ability	X	O	X	O
Support ergonomic/picking process	X	O	O	O
Productivity/Traffic flow	X	X	O	X
Space utilization/Align with existing design	X	X	X	X
Easy to control material/visualization	X	X	X	X
Investment	X	X	O	O
Align with current mobile equipment	X	O	X	X
Flexible design	X	X	X	O
Safe work environment	X	X	X	O
Total score	X = 11 O = 0	X = 8 O = 3	X = 6 O = 5	X = 5 O = 6

The storage module selection for zone 3 shows that the single selective rack is the most effective and double deep rack may also apply.

Racking system to be installed is based on the existing rack and the warehouse operation support. The consideration factors are developed to match with the material characteristic and warehouse operation base on the specification requirement from specialist and management team, and also as the basic requirements for warehousing design. For these 3 zones, factors to be considered in designing the warehouse are aisle way width, storage depth and storage height as detailed below:

- Aisle width; normally, aisle way should be as narrow as possible but it can be depend on the mobile equipment which is used and material container dimensions. Also the warehouse blueprint post or columns can not be obstructed by the aisle way.
- Storage depth; the depth of storage can be aligned with the standard pallet and min-max control of material. The inventory data is used to check and level the appropriate racking depth.
- Storage height; it depends on the height of the warehouse building and providing allowance for water sprinkles and ventilation systems under the roof. The material stack height could be measured for contingencies.
- Existing layout pattern of warehouse including loading dock, store area, receiving area and group area are maintained to save the cost of relocating facilities and not have high impact to the part supply operation route. By the way, it can be applied to the inspection area which is empty at the moment.

Base on the customer (supply operation team) and user requirement, the requirement data are gathered as following.

- It can support the packaging which store in the warehouse.
- In order to support FIFO process, racking system shall indicate in term of in and out direction.
- In term of internal sequencing material, racking system can serve the picking activities including ergonomic issues.
- Align with the existing rack and relocate or adjust flexibility to support the changing of container type, dimension and layout.
- Racking layout could be avoiding build post and column on the aisle way, means the post is blended in racking construction.
- User friendly, free maintenance and simple construction shall be considers.

Therefore the design of racking and layout is developed from both specification and user requirement data.

4.3.2 Warehouse operation/Information flow

The time study data is recorded and averaged. Then, information is filled in the table for each process. **Table 4.7** below shows the average material arriving density per day. **Table 4.7:** Data collection from warehousing process and **Table 4.8:** Data collection from process steps and element times, show the base line data in warehousing process. By executing operation detailed investigations of each process, problems or wastes are identified. To improve warehouse operation and material flow process.

Table 4.7: Data collection from warehousing process

Warehousing Process			
Item		**amount**	**Remark**
1	total available working time per shift (min)	2,907.00	considers 5% down time
1.1	actual number of team members per shift	6	Receiving
1.2	available working time per head per shift	510	exclude break times, relief times, etc
2	number of RDC routes per day (*)	8	
3	number of Milk Runs per day (*)	18	unload by driver
4	number of direct routes per day (*)	6	
5	number of trucks (delivery document) per shift	21	
6	number of trailer per shift	9	
7	average number of package units per shift (Box)	200	mixed pallet = 1 package unit
8	average number of package units per shift (Pallet)	60	
9	average number of additional labels per shift	2	
10	average number of delivery document per week (*)	100	
10.1	- regular delivery document	60	
10.2	- supplementary delivery document	10	
10.3	- amended deliver document	30	
11	average number of mixed pallets per shift	48	
12	average number of trucks with empties per shift	20	

Table 4.8 Data collection from process steps and element times

	Process steps and element times	Time per item (min)	Repetition per shift (x times)	Time per Step/action (min)	Remark
	Process start point: Truck / Trailer arrived for unloading				
1	Check paperwork on correctness	1.00	24	24.00	
2	Visual check of trailer, seals, safety	1.00	30	30.00	
3	Open truck/trailer				
3.1	Open truck	0.00	21	-	done by driver
3.2	Open trailer	0.00	9	-	done by driver
4	Unload material and place it to "check off area" for checking Check area could be shop floor, dolly, fork truck, etc.				
4.1	Unload Trailer	15.00	5.25	78.75	
4.2	Unload Milk run	8.00	11.8125	94.50	
4.3	Unload Direct Route	8.00	3.9375	31.50	
5	Check material vs. Documents (Pick-up sheets, delivery note).			-	
5.1	Box	0.01	2601	30.00	
5.2	Pallet	0.01	2342	30.00	
6	Handle additional labeling	20.00	2	40.00	avoid additional label
7	Sign/stamp Pick-up sheets/delivery note	1.00	6.67	6.67	
8	Hand over documents for Booking	10.00	24	240.00	
9	Separation of mixed pallets, if applicable	45.00	48	2,160.00	
10	Loading empties, if applicable				
10.1	Truck	10.00	20	200.00	
10.2	Trailer	0.00	0	-	
11	Close truck/trailer				
11.1	Close truck	0.00	21	-	done by driver
11.2	Close trailer	0.00	9	-	done by driver
12	Update unloading schedule (board)	5.00	21	105.00	
13	Call next truck/trailer	5.00	24	120.00	
	Required time for regular Receiving activities per shift			2,960.42	
	Exceptions				
a)	handling of deviations (Mislabeling/wrong content)	20.00	16.67	333.40	
b)	handling of transport damages/damaged containers	30.00	3	90.00	
c)	perform quality spot checks	20.00	4.55	91.00	
d)	perform quantity spot checks	20.00	8.89	177.80	
e)	dangerous / hazardous material	10.00		-	
f)	Report of discrepancies found on labeling, Report different error codes.	10.00	0	-	
g)	repack material in original containers	20.00	87.3	1,746.00	
h)	move material to marshalling area	10.00	0	-	considered part of "Parts to Store&Storage" process
	Required time for exceptional Receiving activities per			2,438.20	
	One time actions				
a)	Battery changes / fuel trucks	5.00	1	5.00	consider # of fork lifts and frequency of battery changes per shift
b)	Safety Checks	5.00	1	5.00	consider # of fork lifts
c)	Prepare unloading schedule (effort per shift)	5.00		5.00	
	Total Receiving process time per shift (min)			5,413.62	
	Heads Required to Run			11.37	
	Utilization/efficiency in %			186%	
(*):	value pro shift varies excessively and does not give an accurate image of the effort/shift (1 route/shift can be equal to 3 trucks/shift in early and late shift and 1 truck during night shift only)				

To increase the work performance related to information flow, base line of the warehouse operation is considered. The unloading/receiving process is related to information flow term by the documentary operation. It could be consider that the existing documentary on average is 60 documents for 9 containers and 21 trucks. The historical record base line supports the existing number of parts. It is a tight schedule for various shipments or high mix SKUs load which may need overtime work.

In order to serve this warehouse operation for the new model plan, the forecast number for the new model SKUs is increasing 1,957 units. By the way, while the number of SKU is increasing, shipment trips are related to the production rate which is still the same at 10 JPH. Therefore, to serve the variety of increasing part numbers and documents, the information movement improvement is required. Even though the operation process can be reduced by improving the other areas such as relocating the loading area. This will be effect the warehouse facility investment with high costs.

To support this, the number of increasing document related to these new SKUs is growing up from 60 to 100 documents; it means the number of document is increased by 40 documents. To support this activity, the same workforce team (per shift working day) is used. By considering the information flow in the process the flow process is developed to present the movement of the information and the time consumption. In **Figure 4.1** shows the information flow chart.

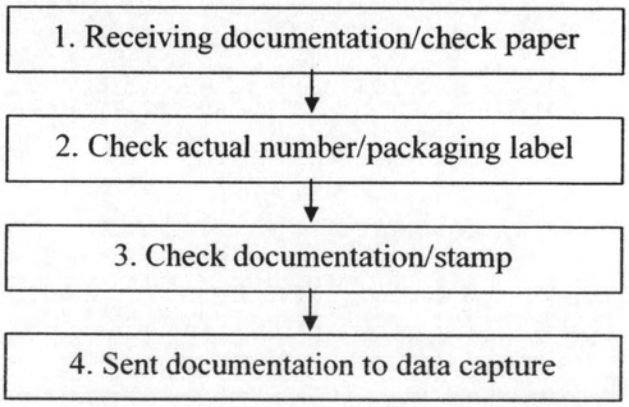

Figure 4.1: Information flow chart

The process is manually operated and from the **Table 4.8** it shows the operation time consumption for the first 3 processes accumulation per day is equal to

24 + 60 + 6.67 = 90.67 minutes. And the last process is 2 times per day which consumes 10 min. per time so, totally 20 minutes per day (by feet). Therefore, the total usage time for this activity is 110.67 minutes which is the number of the base line and could be reduce to serve the increasing of documentation.

Base on the information checking and transferring ineffectiveness, this can be introduced by the real-time connectivity and technology tool to reduce the information transfer time and checking process system to match the actual data, documentation and order information.

Many types of information are currently being used and the investment depends on the size of information, complexity of the data and customization. Therefore, the useful tools are considered which bar coding and RFID (Radio Frequency Identification). These types of techniques increase the speed and accuracy of picking and putting away of items which is useful in terms of warehouse management. By the way, the comparison between barcode and RFID is shown in **Table 4.9** (+ is preferred, - is not preferred), **Table 4.9:** Comparison between barcode and RFID. The result shows the positive in Barcode.

Table 4.9: Comparison between barcode and RFID

Criterion	Barcode	RFID
Supplier support	+ Easy to implement with current label	- Require investment for all suppliers
User friendly	- Tracking by scanner, operate by employee	+ Automatic tracking by installing tag reader
Data capability (part number 8-9 digit)	+ Can serve the user requirement	+ Can serve the user requirement
Speed	- Manually check with automatic data transfer	+ Automatic both check data transfer
Interface with the existing system	+ Can develop the software to interface with the existing system	+ Can develop the software to interface with the existing system
Align with the packaging	+ Serve all type in existing packaging label by printing	- Can not serve in some packaging material or require more special type of RFID
Serve existing environment condition	+ Yes, can use in existing condition	+ Yes, can use in existing condition
Investment	+ Low	- High
Total	+ 6, -2	+ 5,- 3

4.3.3 Material handling resource

Material handling resource includes workforce and mobile equipment. The production line rate is the useful data to plan workforce. In this case production line rate is constancy at 12 jobs per hour. The existing number of workforce is grouped with material zones. Therefore, the material handling resource is related to the number of SKUs in each zone and production rate.

Mobile equipment requires aisle width of a minimum of 3.5 m. and 4.0 m. for reach truck and forklift truck, respectively. Mobile equipment shall be designed to match with the warehouse storage system, aisle and operation.