CHAPTER V

NEW WAREHOUSE DESIGN

Along with the data collection and analysis, the warehouse improving efforts are able to be performed subsequently. In accordance to the solutions proposed in chapter 2, the design of new warehouse layout, material storage equipments and handling system are required. In the meanwhile, formulation of the new operation procedure and the corresponding safety and security plan are demanded. In an attempt to achieve the warehouse improvement, all of these activities aim to develop the new warehouse. Therefore, this chapter will discuss the new warehouse design process for the Company.

5.1 Concept

On account of issues in the warehouse solutions noted in section 3.1.3 and the objective of warehouse design mentioned in section 3.2.1, the concept of warehouse design in this case is defined as ***reconciling the people, space and equipment to realize the efficient and flexible operation, better space utilization and raw material easy store, pick and move as well as guarantee the employees safety and material security. It also aims to realize cost-efficient, avoid the loss of inventory in future operation, and satisfy the internal production line through good quality control.*** The concept is bearing in mind at each stage across design process.

5.2 Strategy Choice

Four alternative warehouse design strategies in terms of frequency of picking and storage activities have been discussed in section 3.2.2. In light of the Company's characteristic and historical data, it operates as a make-to-order business unit and the picking and storage activities do not appear to be so high. For this reason, the design strategy ideally falls into the low picking and low storage quadrant.

According to implication of this quadrant, the warehouse is simple and small. Neither automation nor sophisticated equipment is required. In another word, only simple storage equipments such as racks and shelves are sufficient to fulfill the operational requirement. Additionally, manual handling is adequately satisfactory.

5.3 Detail Design

Under the direction of design concept and strategy, the new warehouse detail design is carried on. This includes the material storage equipments design; new operation procedure formulation; material handling system development; warehouse layout setup; safety and security plan establishment.

5.3.1 Material Storage Equipment

Material storage equipment, one of the most critical elements within the warehouse, to a large extent, determines the warehouse performance. Since the storage equipment in this case has been identified as a serious root cause to warehouse problems, aiming to realize the warehouse ultimate improvement, it deserves significant concerns.

1) Principles of design

In order to realize optimum results, the principles of storage equipment design are set down first of all. For easily observing and understanding, the design principles are listed below. The explanations will be given in succession.

- Fully utilizing the vertical space and condensing the horizontal space
- Easy make
- Constructive material is accessible
- Sufficient capacity
- Less materials utilization and rational structure

- Safe

The core principle of material storage equipment design is taking full advantage of the vertical space and condensing the horizontal space. Due to the weight constraint, steel bars are imperative to be moved by the overhead crane within the current stock area. For this reason, the storage equipments are impelled to be restricted in the overhead working region and the size of warehouse is confined to be expanded. As a result, the vertical space requires adequate utilization and horizontal space calls for thrifty consumption.

For other principles, the storage equipments require easily making. The constructive materials are ought to be available across the country so as to avoid long time-consuming on complicated material manufacturing. The capacity of the equipment is ensure to be sufficient to sustain the items and materials utilization is desired as less as possible. The structure demands compact, but rational, for the benefit of easy operations. Above all, safety deserves the highest attentions and safety considerations are enforced to be recalled at any stage across the design process.

2) **Equipment model selection**

To cope with different items to be stored in the warehouse, the suitable equipment models are selected in light of the item characteristics at the very beginning. As noted in section 3.4.2, the open shelf is most suitable for the small items. For this reason, it is applied to keep the remnants. In the meanwhile, section 3.4.3 generalized that the rack has been widely used in the warehouse and, among so many different kinds of racks, the selective pallet rack is the most universal selection and the cantilever rack is optimally suitable for holding long beams due to its advantage. Therefore, the selective pallet rack and the cantilever rack are under consideration for holding the round steel bars and flat steel bars.

Thus, the equipment profile design is primarily erected on the general structure and characteristic of the ***selective pallet racks***, ***cantilever rack*** and ***shelf*** illustrated in the figure 3.2, 3.3 and 3.4. The modifications are made according to the actual request.

3) Round steel bars classification with proposed equipment

In section 4.1.2, aside from the remnants, the to-be-stored items are generally classified into round steel bar and flat steel bar. In order to rationalize material arrangement and optimize storage equipment design, each one is wise to be further classified into sub-categories. Therefore, this section and next one will respectively discuss the classification of round bar and flat bar with proposed equipment.

On the basis of the existing raw material statistics, the round steel bars are determined to be divided into three sub-categories in light of factors of ***Diameter*** and ***Length***. The division is based on the considerations of material quantity, characteristic, safety issue. Meanwhile, the corresponding storage equipment for each category is proposed as well. (See figure 5.1)

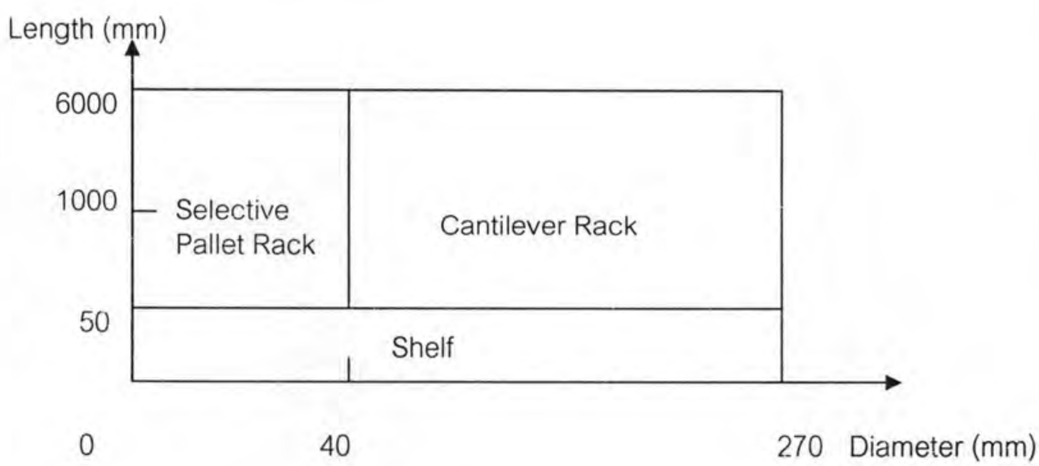

Figure 5.1: Round steel bars classification with proposed storage equipments

By interpreting figure 5.1 above, it is assumed that three independent storage equipments, selective pallet rack, cantilever rack, and shelf, are employed to hold the total round steel bars. Selective pallet rack and cantilever rack are together responsible to the steel bars whose length are more than 50mm, but selective pallet rack deals with those whose diameters are less than 40mm whereas cantilever rack is for those whose diameters are greater than 40 mm. For any round bar whose length is less than 50mm, the shelf is its destination.

4) **Flat steel bars classification with proposed equipment**

Similar to round steel bar, the flat steel bar is classified into three sub-categories as well. (see figure 5.2)

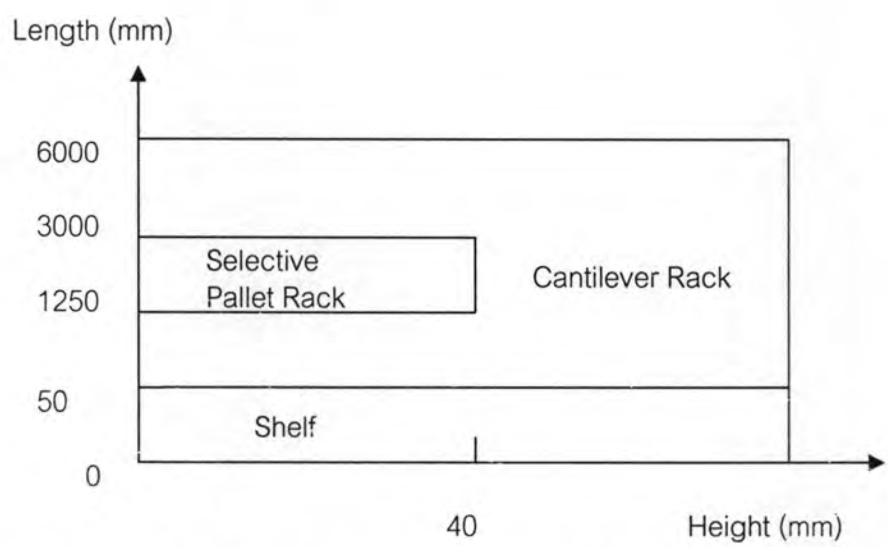

Figure 5.2: Flat steel bars classification with proposed storage equipments

Principally, regardless of the height factor, over 50 millimeters long flat steel bar is designate to the cantilever rack. However, with reference of the statistics of current steel stock and estimation of the load capacity of selective pallet rack, it is assumed the selective pallet rack will have much more residual space after the designated round steel bars being placed. For this reason, some flat steel bars are transferred to selective pallet rack so as to reduce the workload of cantilever rack. Thus, figure 5.2 above depicts that if the length of flat bar is located between 1250mm and 3000mm as well as the height is less than 40mm, the selective pallet rack will take in charge. For those whose lengths are lower than 50mm, the shelf is responsible.

5) **Selective pallet rack**

After the steel bars being classified and storage equipment being proposed, the detail design for equipments is going forward. The selective pallet rack becomes the first target. With regard to the design principle, material characteristic and general structure illustrated in figure 3.3, the selective pallet rack to be used in the Company's warehouse is drafted. Figure 5.3 and figure 5.4 below exhibit its 3D model and 2D specification respectively.

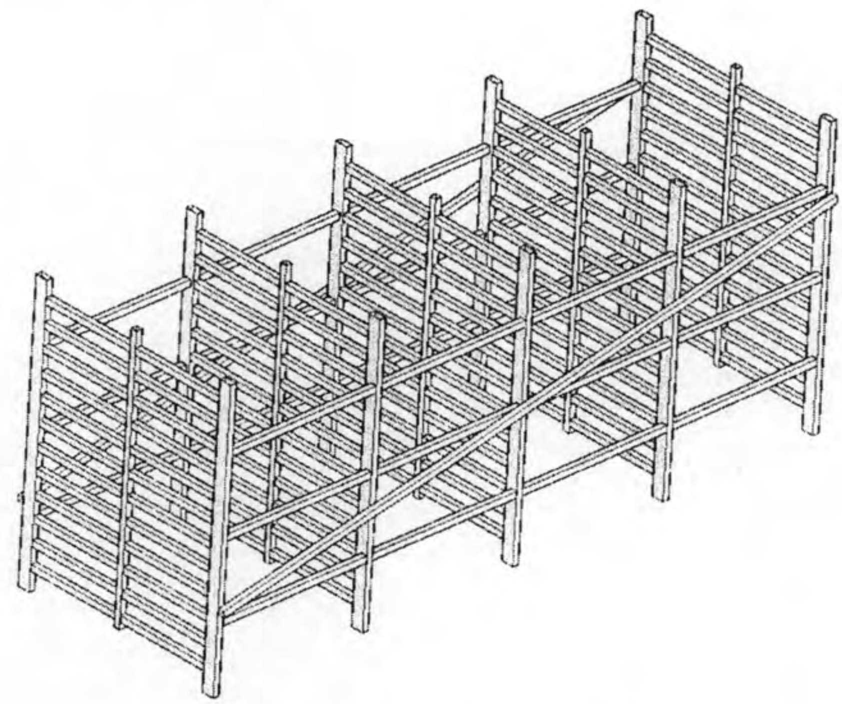

Figure 5.3: 3D model of selective pallet rack

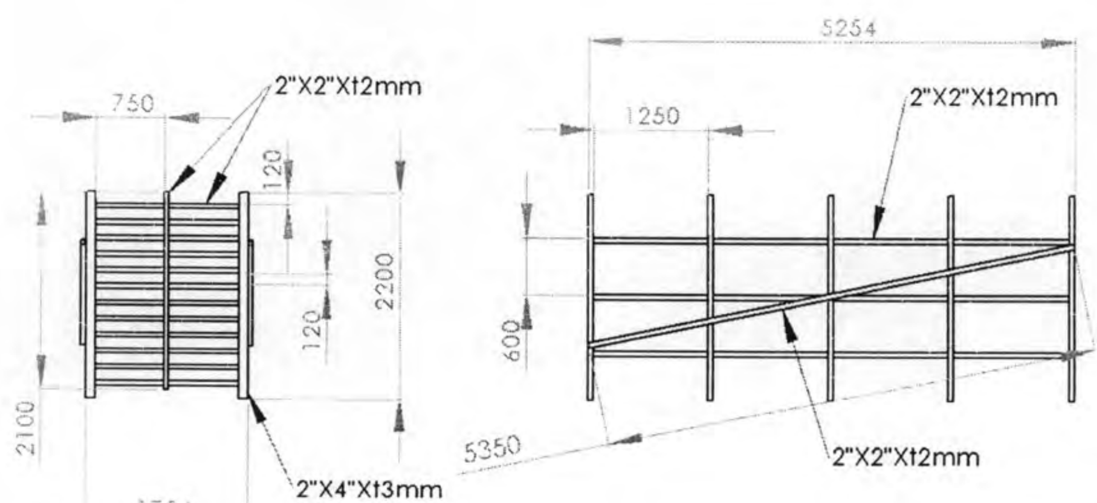

Figure 5.4: 2D specification of selective pallet rack

The selective pallet rack is constructed by 2"X 2" X t2mm and 2"X 4" X t3mm constructive close square bar noted in the section 3.3.3. Except the side posts which use 2"X 4" X t3mm square bar for the sake of consolidating the structure, the rest parts utilize 2"X 2" X t2mm square bar.

Seen from figure 5.4, the width, height and length are designed 1754mm, 2200mm and 5245mm for the corresponding reasons of material quantity, human capability to reach the maximum height, 6 meters long steel bars. Since noted in the design principle that the vertical space shall be fully taken advantage, 12 intervals, including the top side, between two adjacent horizontal bars are set up and the distance is distributed 120mm by considering the maximum size of the steel bar diameter to be located. To ensure the safety, two 5330 millimeters long square bars are fasted on the sides.

- Safety check

In order to guarantee the equipment safety, the structure is undertaken theoretical risk test on the assumption of maximum workload being imposed on the equipment.

Since the width of one interval is set as 750mm and height as 120mm and round bar which the diameter is below 40mm will be located on this rack, after calculation, 18 steel bars are able to be maximally placed on the horizontal orientation and 2 steel bars on the vertical orientation. Thus, the maximum amount for each interval is 36 steel bars. At the same time, the side distance between two posts is designed as 1250mm. Based on these, the weight of one round steel bar with diameter 40mm and length 1250mmm is computing as

$$Weight = Density \times \pi \times \left(\frac{Diameter}{2}\right)^2 \times Length = 7850 \times \left(\frac{40}{2}\right)^2 \times 1250 = 12.325Kg$$

Therefore, maximum load along 1250mm on one horizontal bar of selective pallet rack is calculated as $36 \times 12.325 = 444Kg$

According to the materials mechanics theory, the ***Bending Stress*** and ***Compress Stress*** must be checked against its permitted value to ensure whether the structure is rational and safe. Thus, this case will conduct both tests and the formula for each one is shown as follows. The permitted bending stress and compress stress for the square bar used on this rack are 300-400 N/mm^2 and 20-30 N/mm^2 respectively.

$$Bending\ Stress = \frac{\text{Moment} \times e}{\text{Inertia}}$$

$$Compress\ Stress = \frac{F}{A}$$

In this case, each intermediate parameter is calculated as

$$Moment = \left(Mg \times \frac{L}{2} \right) = (444 \times 10) \times \left(\frac{0.75}{2} \right) = 1665 N.m$$

$$e = 0.025m$$

$$I = 1.477 \times 10^{-7}$$

$$Compress\ Force = Mg = 444 \times 10 = 4440N$$

With the results above, the bending stress and compress stress are computed as

$$Bending\ Stress = \frac{\text{Moment} \times e}{\text{Inertia}} = \frac{1665 \times 0.025}{1.477 \times 10^{-7}} = 281.82 N/mm^2 < 300 - 400 N/mm^2$$

$$Compress\ Stress = \frac{F}{A} = \frac{4440}{384} = 11.56 N/mm^2 < 20 - 30 N/mm^2$$

The results imply that the structure is capable to hold the maximum workload.

- **Quantity required**

Since total 24 intervals are setup at the front and 4 intervals on the sides, with the capacity 444Kg calculated previously on the basis of length 1250mm and 1 interval, the minimum capacity of select pallet rack is obtained by the formula

$$Capacity = 444kg \times 24 \times 4 = 42624Kg$$

It means that the rack is able to hold at least 42624 Kg workload. Comparing with the summation of round steel bar weight 24992 Kg and flat steel bar weight 2448Kg, this numeral is at least one-folder bigger. Thus, one selective pallet rack is enough to satisfy the requirement even the new steel bars arrive.

6) Cantilever rack

Analogous to the selective pallet rack, the cantilever rack is also designed to hold both big round and flat steel bar. Figure 5.5 and figure 5.6 below respectively present the 3D model and 2D specification of cantilever rack.

With the intent of holding large size steel bar, the cantilever rack is fabricated with close square bar of 2"X 4" X t3mm and 4"X 6" X t4mm. Apart from the middle post which uses 4"X 6" X t4mm square bar in order to consolidate the structure, the rest parts are constructed with 2"X 4" X t3mm square bar.

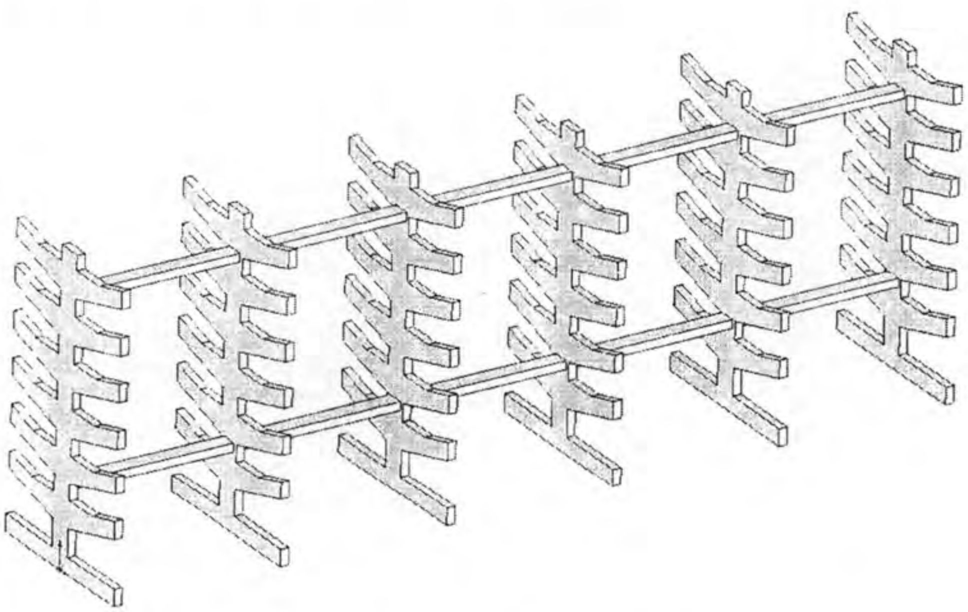

Figure 5.5: 3D model of cantilever rack

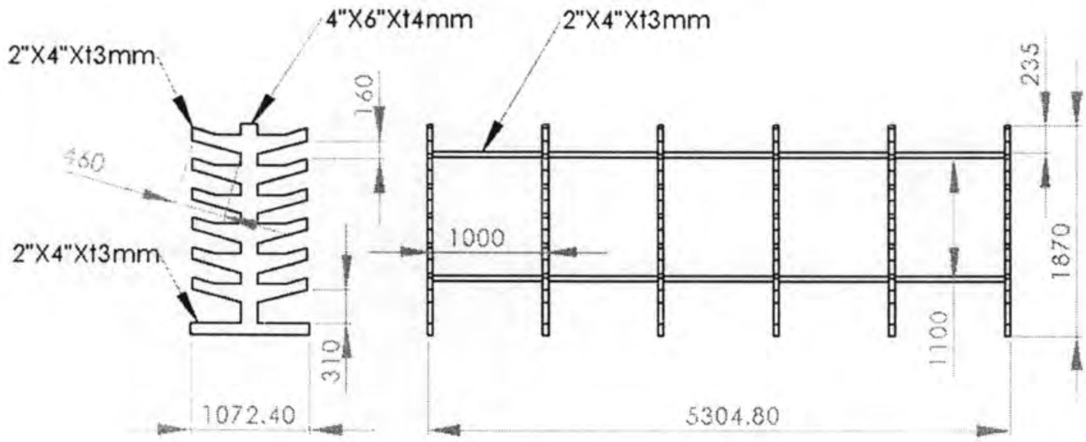

Figure 5.6: 2D specification of cantilever rack

Viewed from figure 5.6, the width, height and length of the cantilever rack are designed 1072.4mm, 1870mm and 5304.8mm for the corresponding considerations of structure, potential risk, and the longest steel bar of 6000mm. So as to take full advantage of vertical space, 7 arms on each side with different interval space size are weld. The space between two arms, except the bottom one, is assigned 160mm by considering that the diameters of most steel bars are less than this figure. The bottom interval space is set as 310mm regarding to the largest diameter 270mm. The length of each arm is built as 460mm.

- Safety check

Same as selective pallet rack, cantilever rack is also subject to the theoretical safety test on the assumption of maximum workload.

In view of the fact that the bottom interval is larger than the others and will hold much bigger steel bars, which might erect extra impact on the structure, so the safety check is conducted separately on ***normal arm basis*** and ***bottom arm basis***. Since the cantilever rack uses the thicker close square bar in comparison to the selective pallet rack, the permitted value of bending stress and compress stress are adjusted to 500-600 N/mm^2 and 30-40 N/mm^2 respectively.

On the side of normal arm, since the interval space is established as 160mm and length of one arm is 460mm, nearly 3 steel bars can be maximally placed on. Also, the space between two side arms is designed 1000mm. Thus, the weight of one round steel bar with diameter of 160mm and length of 1000mm is computing as

$$Weight = Density \times \pi \times \left(\frac{Diameter}{2}\right)^2 \times Length = 7850 \times \left(\frac{160}{2}\right)^2 \times 1000 = 157.7Kg$$

Therefore, maximum load along 1000mm on one arm is calculated as $3 \times 157.7 = 473Kg$

In this case, each parameter in the equation of bending stress and compress stress is calculated as

$$Moment_1 = \left(Mg \times \frac{L}{2}\right) = (473 \times 10) \times \left(\frac{0.46}{2}\right) = 1088.5N.m$$

$$e = 0.05m$$

$$I = 1.121 \times 10^{-6}$$

$$Compress\ Force = Mg = 473 \times 10 = 4730N$$

With the results above, the bending stress and compress stress are calculated as

$$Bending\ Stress = \frac{\text{Moment} \times e}{\text{Inertia}} = \frac{1088.5 \times 0.05}{1.121 \times 10^{-6}} = 60.96N/mm^2 < 500 - 600N/mm^2$$

$$Compress\ Stress = \frac{F}{A} = \frac{4730}{864} = 5.47N/mm^2 < 30 - 40N/mm^2$$

Judging from the results above, the normal arms are capable to sustain the maximum load.

For the aspect of the bottom arm, the computing process is described as follows.

$$Moment_2 = \left(Mg \times \frac{L}{2} \right) = (1347.68 \times 10) \times \left(\frac{0.46}{2} \right) = 3099.6 N.m$$

$$e = 0.05m$$

$$I = 1.121 \times 10^{-6}$$

$$Compress\ Force = Mg = 1347.68 \times 10 = 13476.8N$$

$$Bending\ Stress = \frac{\text{Moment} \times e}{\text{Inertia}} = \frac{3099.6 \times 0.05}{1.121 \times 10^{-6}} = 173.58 N / mm^2 < 500 - 600 N / mm^2$$

$$Compress\ Stress = \frac{F}{A} = \frac{13476.8}{864} = 16 N / mm^2 < 30 - 40 N / mm^2$$

The results also imply that the structure of bottom arm is capable to hold the maximum materials load.

In conclusion, two results obtained jointly give convincible reason that the cantilever rack designed is fully capable to hold the maximum load.

- **Quantity required**

On 1000mm basis, one normal arm is able to hold 473Kg whereas one bottom arm can sustain 1347.68Kg. Since there are totally 12 normal arms and 2 bottom arms and the length of the rack is designed as 5304mm, the minimum capacity of this rack is calculated

$$Capacity = (473Kg \times 12 + 1348 \times 2) \times 5304 = 44418Kg$$

It means that cantilever rack is able to hold at least 44418 Kg workload. Although this rack is able to hold all of the existing steel bars, with regard to the historical order data, 2 cantilever racks are required on the safe side.

7) **Shelf**

Shelf is primarily made to conserve a large amount of the remnants. As described above, it is also responsible to hold certain steel bars which are unable to be placed on the racks. For these reasons, two different shelves are designed by considering the characteristics of the small items. Figure 5.7 and Figure 5.8 below illustrates the 3D models.

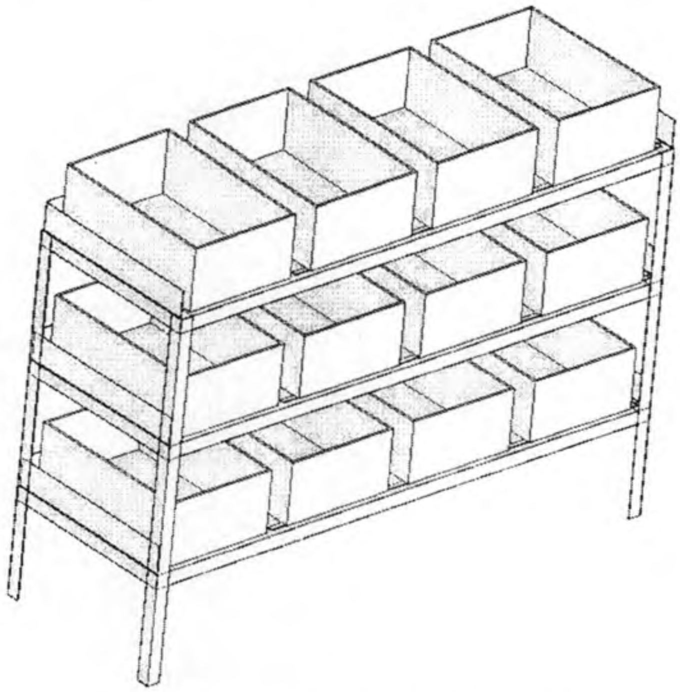

Figure 5.7: 3D model of shelf 1

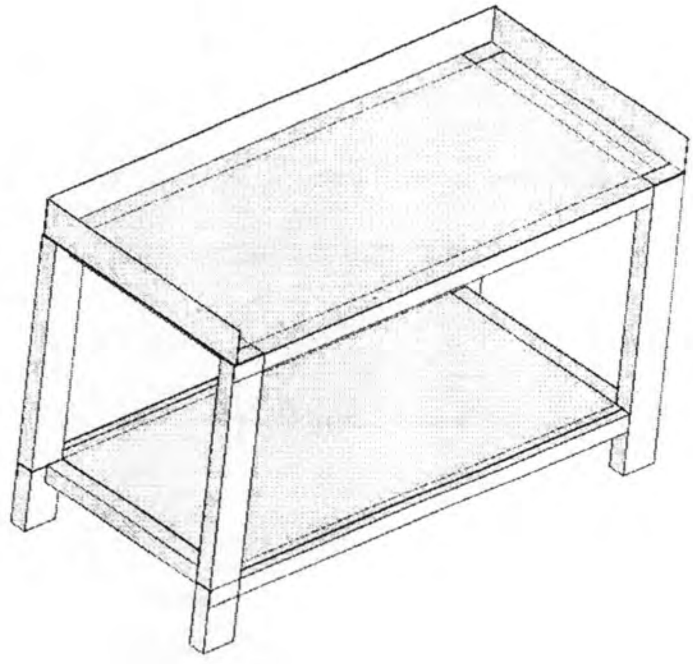

Figure 5.8: 3D model of shelf 2

The shelf structures are general follow the model illustrated in the figure 3.2. Thus, no complicated configuration is required. The shelf displayed in figure 5.7 is constructed by using 2"X 2" X t2mm open square bar and is mainly employed to keep the tiny remnants. Thus, plastic containers are required to put on the shelf to hold the items. The shelf in figure 5.8 is designed to hold those relative big steel bars which can not be placed on the rack. Thus, the plastic container is unnecessary.

Due to the lighter weight of the components in comparison to the steel bars, the shelf safety check can be ignored. The size and quantity of the shelf could be adjusted, depending on the item amount and warehouse size. However, by judging the current remnants within the warehouse, it is estimated that at least 5 shelves in figure 5.7 and 3 shelves in figure 5.8 are necessary.

5.3.2 New Warehouse Operations

It has been identified in the chapter 2 that the Company's poor warehouse operations contributed itself to be one of root causes to the problems, so the operation improvement is required. It is for this reason that the new operation procedure is re-formulated, aiming to not only primarily eliminate the warehouse problems, but also enhance the operational efficiency.

Section 3.8.1 has introduced the operating policy and section 3.8.2 and 3.8.3 have illustrated the fundamental and essential activities happening in a typical warehouse. As a reference, the new warehouse operational policy and procedures will be developed.

Section 3.8.4 has introduced an efficiency improvement model with cooperation of JIT and TQM. In the fact that the Company operates as a make-to-order business unit, its operation is obviously reflected as a demand pull system which is triggered by customers and flows back to the suppliers along the supply chain. Thus, the efficiency of its operation partly depends on the JIT system. Fortunately, since the Company has long been keeping good relationship with its suppliers who ensure the timely delivery, it makes the JIT possible. According to the model, what the Company should emphasize is the TQM aspect. As a consequence, more considerations of TQM will be put in the operation procedure.

Additionally, it has been strongly argued that information erected a deep impact on warehouse operation efficiency, so the analysis of information flow and raw materials monitoring and measurement will be processed.

1) Establishment of operating policy

The warehouse operating policy should be established in order to guide the procedure formulation. According to the suggestions in section 3.8.1, the warehouse in the case prefer the volume based storage which means the high volume raw materials is placed nearest to the I/O point. Among the volume based storage, the within-aisle policy is applied for its advantage of reducing traveling time and distance. On the side of routing policy, composite routing policy is used to picking items due to its good and fast solution.

2) New inbound procedure

As being analyzed in the chapter 3, three underlying problematic activities occurred in the present inbound operation: no sortation and arrangement activities being done before raw materials storage which straightly led to the warehouse untidy condition, too many waiting activities aggregating the operation time and no information track activities. To improve the inbound operation, thus, the waste should be eliminated firstly and the essential operation is ought to be included.

Similar to the approach being used to describe the present inbound operation, the flow-processing chart is deployed again. The table 5.1 below illustrates the proposed new inbound operation procedure.

On the assumption of the suppliers timely-delivering the raw materials to the warehouse, the assigned warehouse working staffs are required to shoulder the

Summary	No.	Min.	Operation Raw materials inbound
○	3	5	Department Warehouse
⇨	1	0	Sheet 1 of 1
□	1	2	Charted by:
D	0	0	Data:
△	1	5	Present method
Total	6	12	Proposed method X
Feet of travel			

No.	Dist. Moved (mm)	Worker Time (Min.)	Symbols	Description
1				Material incoming
2		2		Inspection
3		1		Sign invoice
4		3		Material sortation, assignment and printing
5		5		Material Storage
6		1		Information update

Table 5.1: Flow-processing chart for proposed inbound operation

responsibility to check up the quantity according to the supplier's invoice. In addition to quantity, most attentions should be drawn on the quality inspect on the basis of TQM concept. This requires the warehouse employees to identify the defective item in the first place for the sake of avoiding the possible scrap in future. To prevent poor quality, thus, standard of acceptability has to be established in advance. In case that the quality fail to meet the requirement, the raw materials must be refund. If both the quality and quantity are satisfactory, the warehouse workers, rather than the purchasing department staff, are ought to be given the privilege to sign the invoice in order to save operation time. Afterwards, the raw materials need sortation in terms of materials type and geometric dimension and different steel bars call for different color printing for easy identification. Simultaneously, according to the material type and quantity, each type of raw materials has to been assigned to the proper storage position. On the completion of all these activities, warehouse staffs have to use overhead crane to move the raw materials into individual assigned position on the racks. In term of the storage policy, the high volume steel bars, Machinery Steel, Cold Work Steel and Carbon Steel, should be located nearest to the I/O point. Finally, the materials information in the warehouse must be updated.

According to the proposed inbound procedure, the operation is condensed from 8 stages to 6 stages and is estimated to take up 12 minutes which is around 10 minutes shorter than the present operation. This is the result of eliminating three waiting activities and involving the sorting action and information track activities. Additionally, the warehouse employees are given more rights to deal with the raw materials.

3) **New outbound procedure**

The outbound operation is also required improvement in order to eliminate the waste and inventory loss. Similar to the presentation approach of current outbound operation, the block-diagram flowchart is utilized again. The figure 5.9 below proposes the new outbound operation.

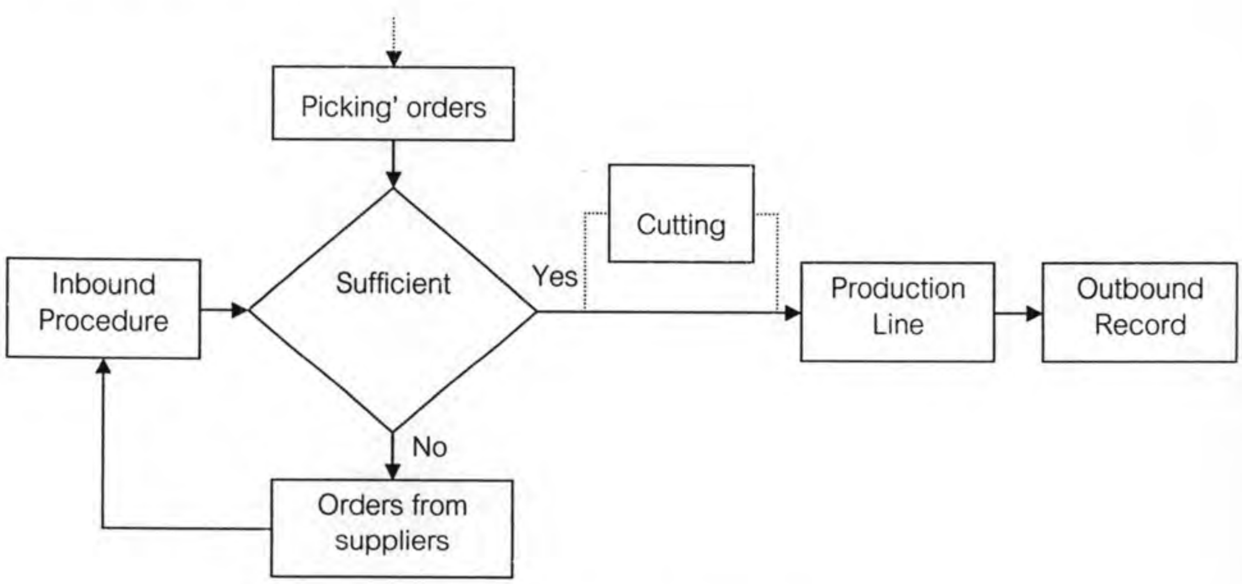

Figure 5.9: New outbound operation

While the picking orders from the production line arrive, the warehouse workers are originally responsible to check the available steel bars in the stock area with respect to the demand quantity. In the case of insufficient steels bars being at hand, they as fast as possible have to report back to the purchasing function where will place the new order to the supplies. After the new raw materials being delivered, the new inbound operation above should take action. If the raw materials are in service, inspection is required before any further activities. This is to avoid the possible defective item and guarantee the quality of final product. On the condition that the raw materials quality is fulfilled, the requested steel bars have to be transferred to the cutting machine for cutting operation, and then the residual part is moved back to the shelf or rack. In the case that item exactly meets the specification, these two steps can be skipped and they are directly shipped to the production line. Finally, information of raw materials being withdrawn should be updated.

4) Analysis of information flow

The inbound and outbound procedure proposed above is only dealing with the materials flow. Due to the importance of information in the management and control of the inventory which, to a large extent, affects the operation efficiency, it is necessary to analyze and understand the information flow throughout the operation proposed.

Figure 5.10 below demonstrates how raw materials information passes through the inbound operation. It originates from the contents of the total suppliers' invoices, forwards through quantity and quality check, goes across the steel bar sortation and movement, and terminates at the filed document. At the end of each step, the information of raw materials is traced and updated, and then the final record is documented.

For the outbound information flow, figure 5.11 describes its process. It starts from the picking sheet of production line, undertakes the quality and quantity check, goes head through the movement and cutting of the steel bars, and ends at the filed documents. Same as the inbound operation, the information is caught up at the completion of each stage.

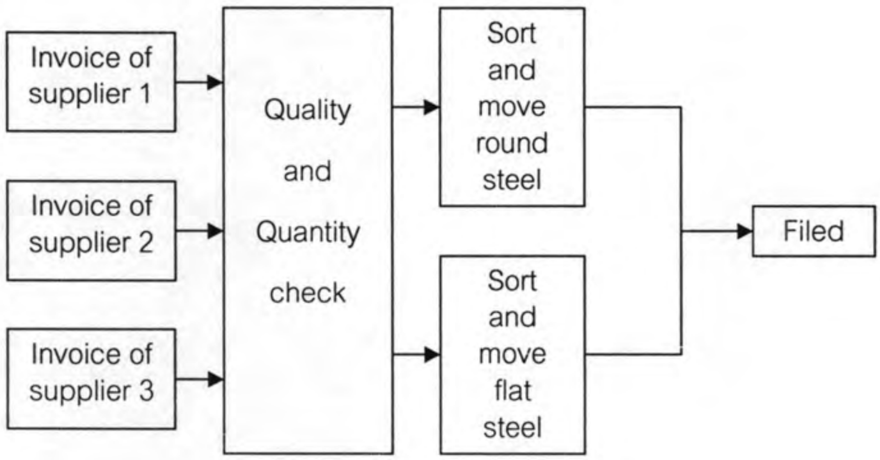

Figure 5.10: Inbound information flow

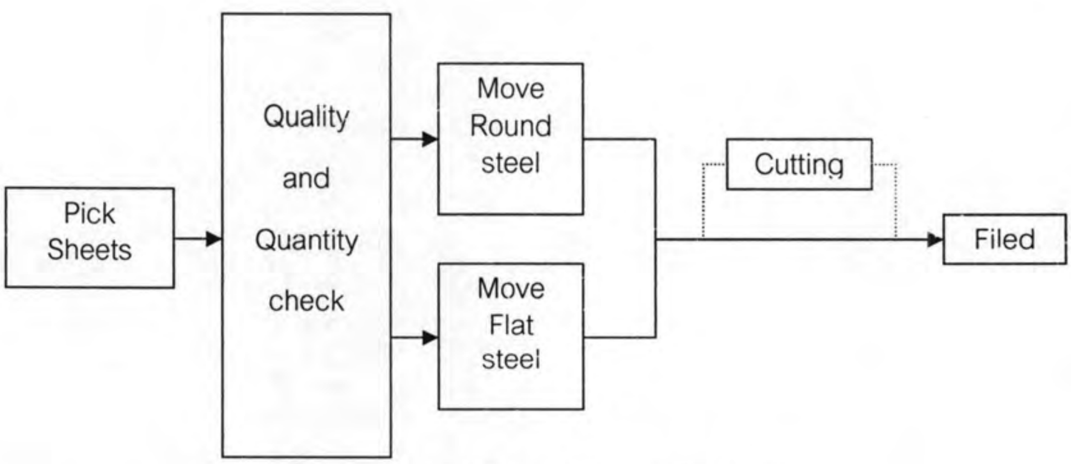

Figure 5.11: Outbound information flow

5) **Steel bars monitor and measurement**

The monitor and measurement of the raw materials information at the terminal of each operational step is able to help highlight and eliminate errors and improve the operation efficiency. Thus, it is necessary to understand what information should be traced. It once again appeals to the inbound and outbound information flow being analyzed above.

For the inbound information flow, since a wide range of vendors supply the Company, relevant information, such as supplier name, product code, materials type etc., of raw materials being delivered should be recorded by manual. If the quality and quantity of certain items fail to pass the inspection, the note must be done and the information is updated immediately. Otherwise, round steel and flat steel are sorted and moved to the assigned position in the warehouse and the results, such as storage position and quantity, are updated. Finally, the information document of inbound operation is filed.

For the outbound information flow, on the other hand, while the picking order from the production line arrives, the information such as amount demand and name of department are required to be recorded. Then, the inspection of raw materials is conducted and the corresponding information is updated accordingly. In additional, information like the dimension and material type of steel bars being picked is required to be traced. Finally, the information result is filed.

In light of the discussion above, indicators required measuring and monitoring in the inbound and outbound activities are displayed in Table 5.2. The record table is formulated on the basis of material type. In another word, the table is for each type of material. Since there are 10 different types of material being used in the Company, 10 sheets representing each material type are necessary.

Product code	Quantity	Diameter	Width	Height	Length	Supplier ☐ Picker ☐	Remark

Table 5.2: Inbound and outbound record

The information should be updated as quickly as possible after each step is over for the purpose of controlling and managing the ultimate information of raw materials. For this reason, the sheet containing the total characteristics of raw materials should also be schemed. Table 5.3 illustrates what information of steel bar should be involved in the documents. It includes the steel bar fixed information, variable information and derived information introduced in section 3.8.4. The table is also erected on the material type basis.

No.	Product code	Diameter (Width and Height)	Length	Weight	Storage equipment	Location address	Space utilization	Load status

Table 5.3: Required information for steel bars

The table 5.2 and table 5.3 are able to jointly deduce the information of total steel bar within the warehouse. The logic is depicted in the figure 5.12. It firstly uses the data of each material type to add the inbound data, and then reduce the outbound data. Afterwards, the data of 10 different material types is put together and the total balance is obtained.

Knowing the information of raw materials, the Company is able to easily control and manage amount level of inventory, which in return, increases the operation efficiency.

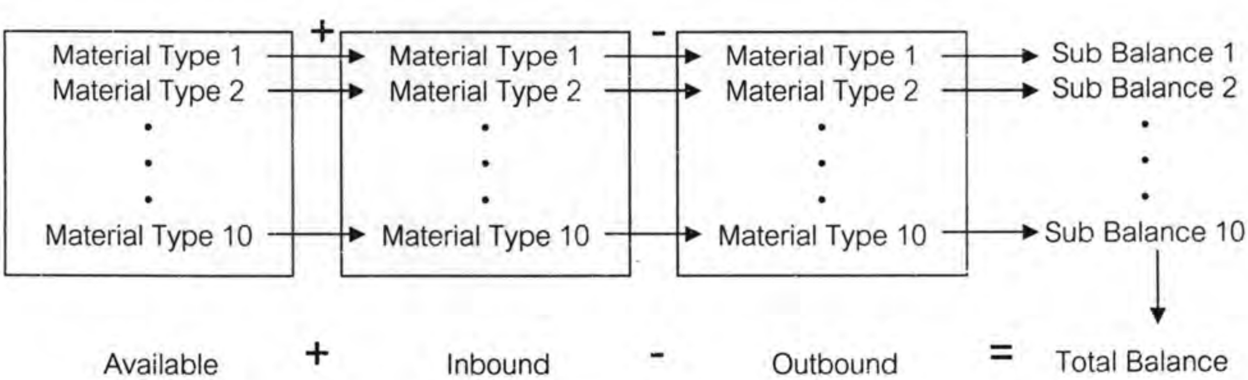

Figure 5.12: Logic of total balance of raw materials

5.3.3 Material Handling System

As indicated in chapter 4, material handling acts as a major role in the warehouse by influencing the movement of goods, which, in return, affects the operation efficiency. As a response of the formulation of new operation, the material handling system is enforced to be developed in order to guide steel bars movement and right equipments selection.

Two frameworks have been introduced in section 3.5.4. Judging from them, each one develops the handling system from different perspectives. Thus, the development of material handling system for this case will refer to combination of both models. Since a large amount necessary data and information associating to two frameworks have been generated previously, this section only deals with the system concept, criteria and objective, on which the development of inbound and outbound handling system will be based.

1) **Concept**

The system concept for this case is defined as simplifying the handling and reducing cost as possible as can. As noted previously, the focused warehouse is distinguished as simple and small, the manual handling is sufficient to meet the requirements. Due to the less complicated structure of the raw materials being operated, on the other hand, general ready-made, not special, handling equipments are adequate. Additionally, since the Company has already possessed certain well-maintained equipments, such as overhead crane and cutting machine, only the other required handling equipments are necessary to be selected in order to avoid the extra cost.

2) **Criteria**

In response to the system concept, the system criteria demand the less time-consuming and shorter distance coverage. In another word, the movement of steel bars should be completed in minimum time and shortest distance as possible as can.

3) **Objective**

The objective of the handling system is defined to enhance the efficiency of steel bar movement. This is the common goal any handling systems aim to achieve. Thus, this case is not an exception.

- **Inbound system**

With the identification of material flow and activities in the operation procedure as well as the analysis of steel bars characteristics, the inbound and outbound handling systems are developed. The figure 5.13 below expresses the raw materials inbound handling system.

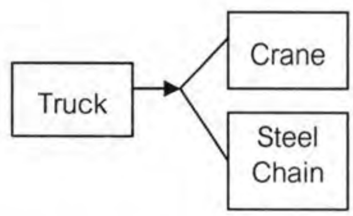

Figure 5.13: Inbound handling system

In the inbound procedure, the activities are not so complex and only two handling equipments, crane and steel chain are required. After the supplier's truck delivers the raw materials, the warehouse employees only use the crane and steel chain to move the steel bars to its assigned position after being sorted.

- **Outbound system**

Figure 5.14 below describes the outbound handling system. On the side of outbound operation, while the picking order arrives, the warehouse workers principally have to identify the length of the steel bar to be moved. If the length is less than 250mm, combination of crane and magnet is applied. Otherwise, steel chain and crane take in charge. Subsequently, if the dimension of steel bar exactly meets the requirement, it is straightly moved to the tray. In the case that the cutting is compulsory, the steel bar is transferred to the cutting machine before delivering to the tray. Afterwards, if the total weight of the steel bar to be shipped is less than 200Kg, the manual trolley is employed to speed up the movement and reduce the operation cost. Otherwise, forklift is used to complete the shipment.

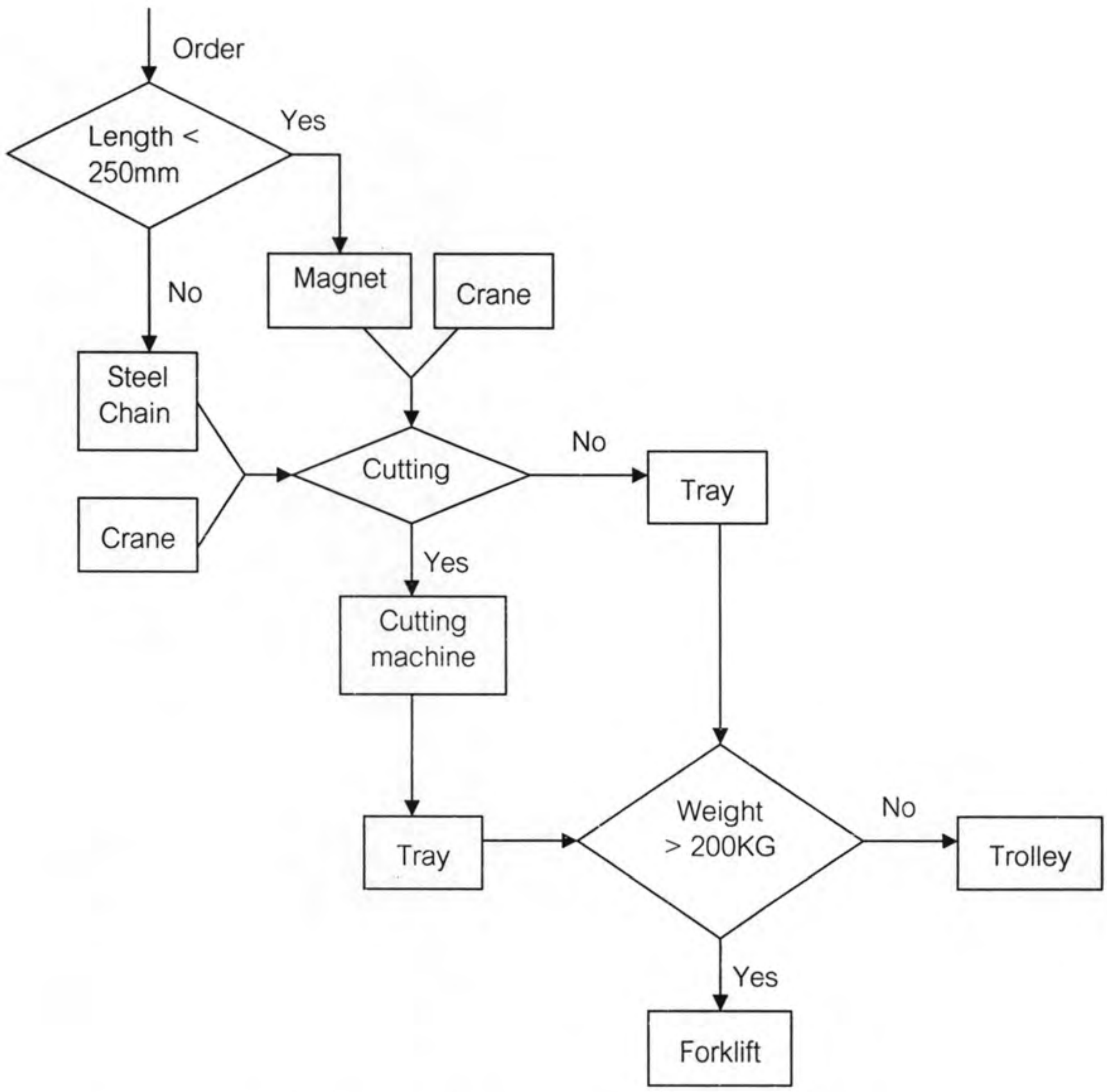

Figure 5.14: Outbound materials handling system

4) Illustration of required equipments

After defining the handling system, the required handling equipments are selected with the exception of available overhead crane and cutting machine.

- **Steel chain**

As analyzed in the chapter 3, the worn rubber elastic rope which commits to fasten the steel bars with the crane during the movement turned up to be the potential safety problem. To eliminate this possible danger, thus, the connection equipment is replaced by the steel chain. (See Figure 5.15) Due to advantage of the mechanical characteristic, steel chain is the ideal tool to carry out this task.

Figure 5.15: Steel chain

- Magnet

The magnet is used to handling the steel bar with large diameter and short length. (See figure 5.16) Although it is possible to use the steel chain to perform all steel bar movement, it perceives that using the steel chain to fasten the short steel bar may cause inconvenience for workers, which consumes much time. In addition, the steel chain is estimated to be unable to tightly fasten the steel bar, so the danger might arise during the movement. For these two reasons, the magnet takes in charge if the length of steel bar to be moved is less than 250mm.

Figure 5.16: Magnet

- Tray

Tray (figure 5.17) is expected to be responsible to hold the steel bar pieces after the long steel bars being cut. Due to the simple profile of the steel bar, the structure of tray is not required so complex. The normal one is capable enough to carry out this task.

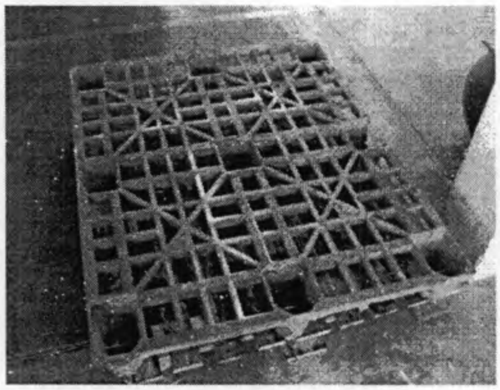

Figure 5.17: Tray

- **Trolley**

Trolley (figure 5.18) is ready for action when the steel bars are being cut. After the steel bars pieces are loaded on the tray, the trolley is used to ship the tray to the production line.

Figure 5.18: Trolley

- **Forklift**

Besides the trolley, the forklift (figure 5.19) is also ready for action if the weight of the steel pieces is over than 200KG. Under this circumstance, the forklift is taking the responsibility to accelerate the shipment and reduce the manual working.

Figure 5.19: Forklift

5.3.4 Warehouse Layout

To ensure the systematical management and operations of the raw materials, appropriately designing warehouse layout is another important issue required supreme concerns. Section 3.3.2 has presented a framework of warehouse layout design. Judging from the procedure of this framework, it can be regarded that almost all required inputs to the warehouse layout have been covered. Thus, the warehouse layout design in this case largely follows this framework, but certain steps are skipped due to limitation of the current warehouse. On the other hand, since a large amount of required information and data relating to this framework have been discussed above, this section will only deal with general design analysis and present the final simulative solution.

1) General layout

In light of the framework, the quantity of department and their activities within the warehouse have to be identified in order to establish the general layout. In this case, the current warehouse has been serving as a raw material storage place since it was built. Therefore, only receiving, storage, picking, and shipping departments have been assigned at the very beginning, which basically form the present warehouse. Also, as proposed in the inbound operation, the sortation activity is requested in order to realize the raw materials good arrangement. Totally, therefore, 5 departments are necessary to perform the warehouse tasks.

On the basis of required departments, the general layout setup can be processed. However, it is agreed that different layouts generate different storage and picking performance which, to a large extent, affect the warehouse operation efficiency. For this reason, in order to obtain optimum results, three different general layouts are proposed, which are displayed in the following three figures. To decide which one is better than the others, a comparison based on the principle of ***reducing the travel distance of picking orders*** is made. Therefore, a simulative pick tour is conducted on the assumption that the picker attempts to pick items on each shelf as well as move one steel bar to the cutting machine since the crane is only able to handle one steel bar per tour. The maximum and minimum travel distance coverage to complete this tour is measured to determine the best layout. Suppose that the time consumed by picker to pick one item is identical during three different tours.

Since the remnants are manually picked, the shelf picking route is fixed. Thus, maximum and minimum routes are only drawn for picking one steel bar, which are marked in the figures. The maximum route is decided by pick one steel bar which is farthest from the cutting area whereas minimum route is the nearest.

For easy calculation, the size of each aisle between two adjacent storage equipments and the width of storage equipment is supposed to be 1 meter. The total size of the warehouse has been measured as 10 meters long and 10 meters wide previously. Since the cutting machine is unable to be moved due the constraint of the electricity location, it can only be suited in the left-bottom corner.

The total maximum travel distance is calculated by summing up the distance of picking remnants items and the maximum distance of picking a steel bar. The total minimum travel distance is summed by the distance of picking remnants and the minimum distance of picking a steel bar.

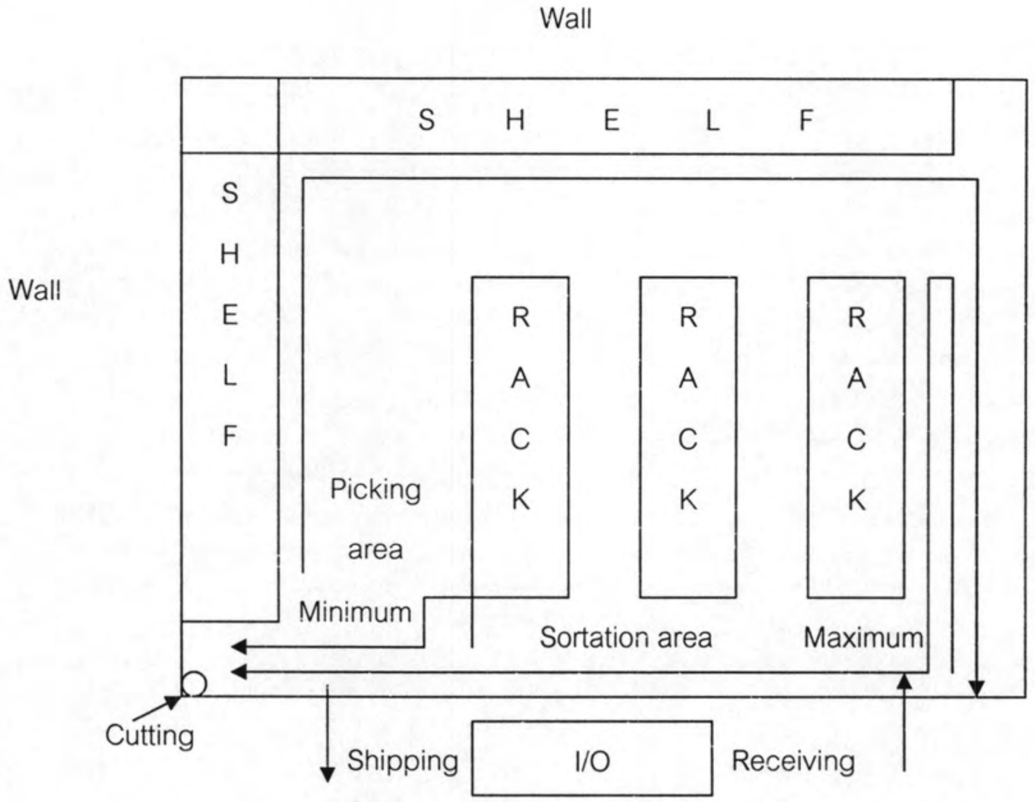

Figure 5.20: Warehouse general layout 1

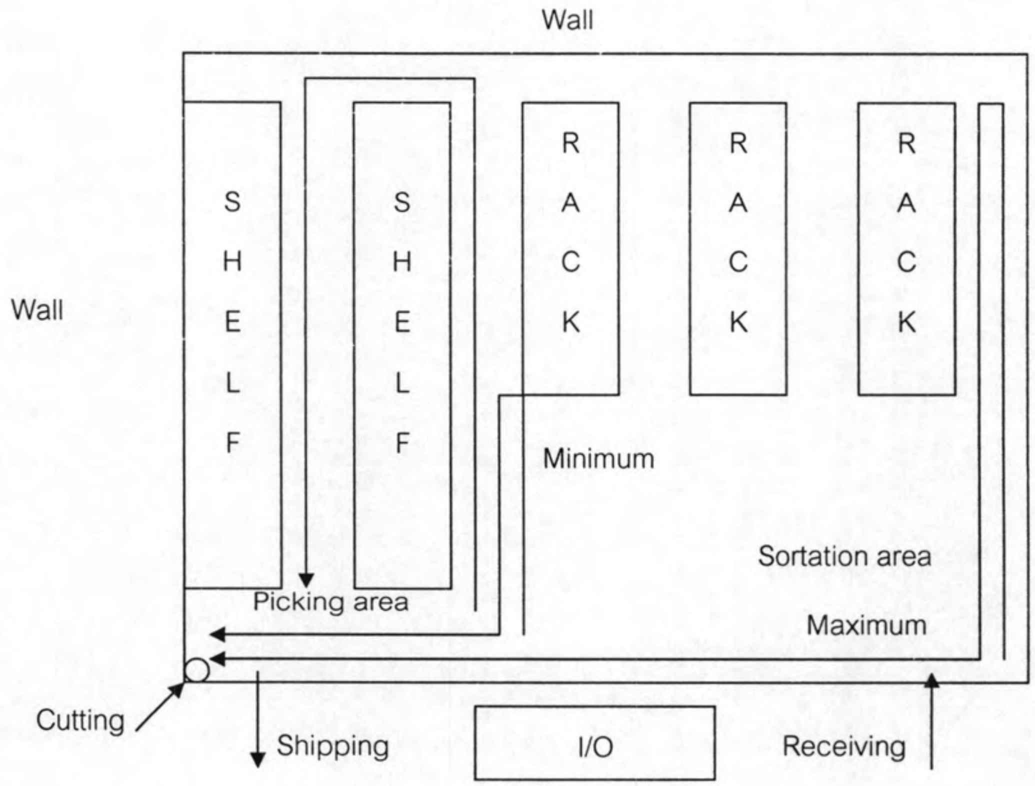

Figure 5.21: Warehouse general layout 2

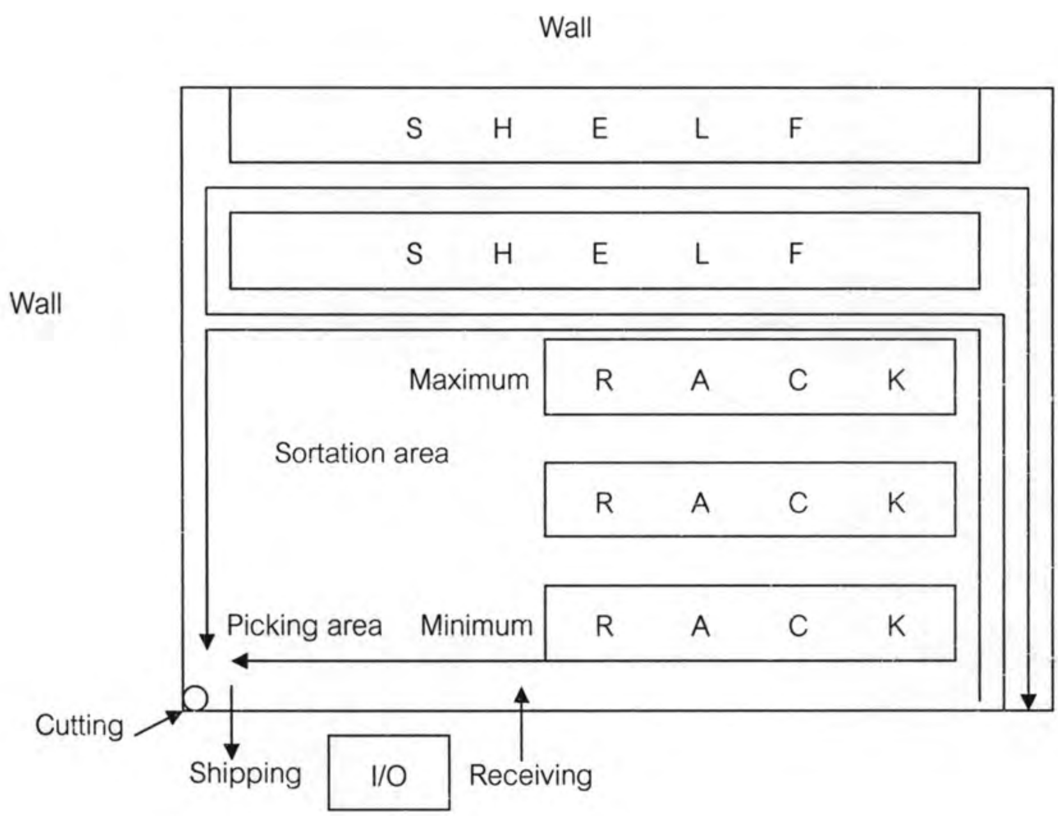

Figure 5.22: Warehouse general layout 3

With the hypothesis above, the results are obtained as below.

For layout 1, maximum distance: (9+8+9) + (6+6+9) = 47 and minimum distance: (9+8+9) + (1+1+3) = 31

For layout 2, maximum distance: (9+9+2) + (9+9+9) = 47 and minimum distance: (9+9+2) + (4+4+4) = 32.

For layout 3, Maximum distance: (7+8+2+8+9) + (4+9+4) = 51 Minimum distance: (7+8+2+8+9) + (4+1) = 39

The theoretic travel distance for layout 1 extends from 31 to 47, for layout 2 from 32 to 47 and for layout 3 from 39 to 51. By comparing and contrasting these results, the layout 3 is rejected firstly since it relatively consumes more distance than the other two layouts do. Although it is possible to move the steel bar over the other racks in the layout 3 to reduce the travel distance, it appears to be so dangerous. In addition to the factor of travel distance, layout 3 has smaller I/O point than the other two layouts do, which may originate the inconvenience for the future inbound and outbound operation. This is largely due to the constraint of the wall. Between layout 1 and layout 2, there is only slight difference in the travel distance. In principle, just according to the results, any of them can be selected. However, the racks in layout 1 are closer to the I/O point than the racks in layout 2, which is able to speed up the storage and picking of the steel bar. For this reason, the layout 1 is preferred eventually.

2) **Final layout**

After collecting necessary data for each step of the design framework, the final warehouse layout can be set up. Figure 5.23 and figure 5.24 respectively illustrate 3D and 2D detail final layout.

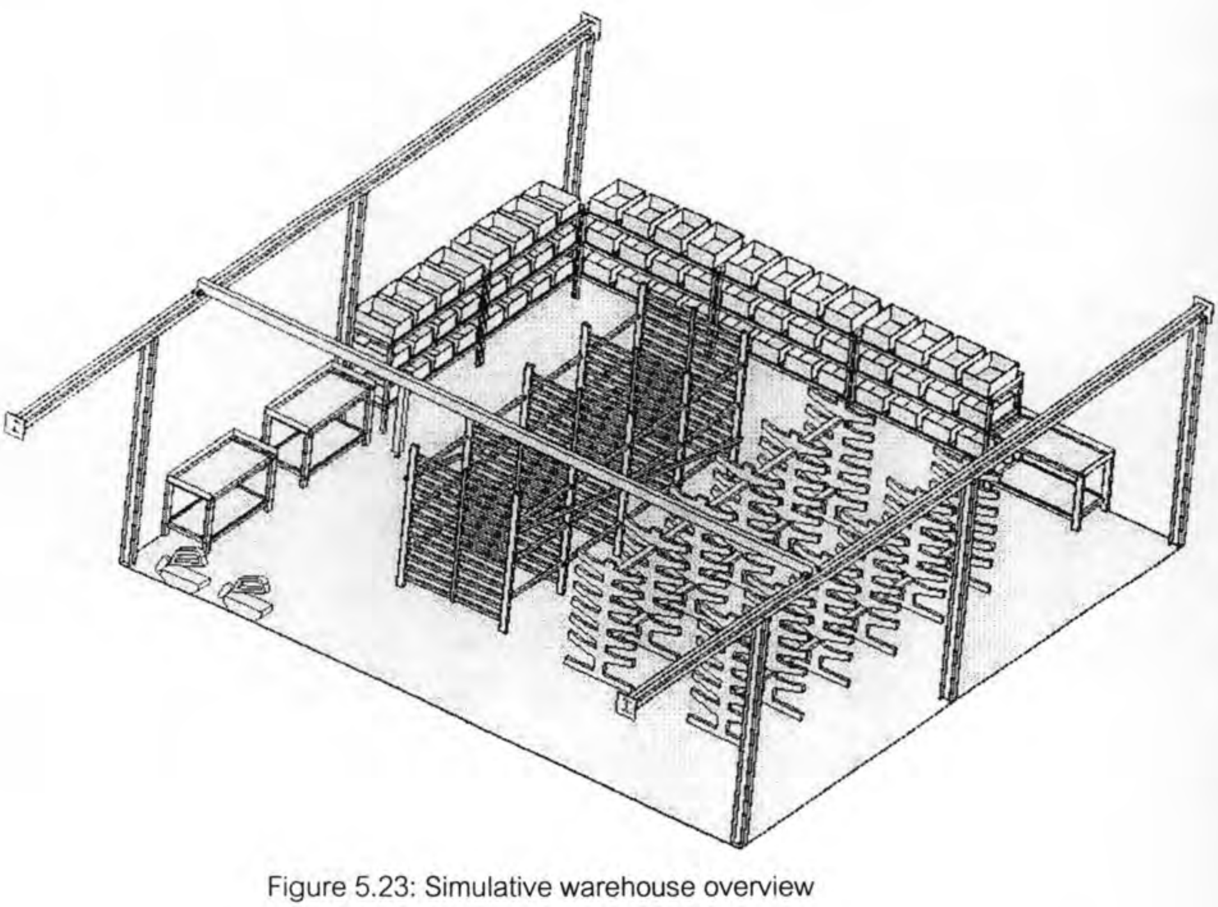

Figure 5.23: Simulative warehouse overview

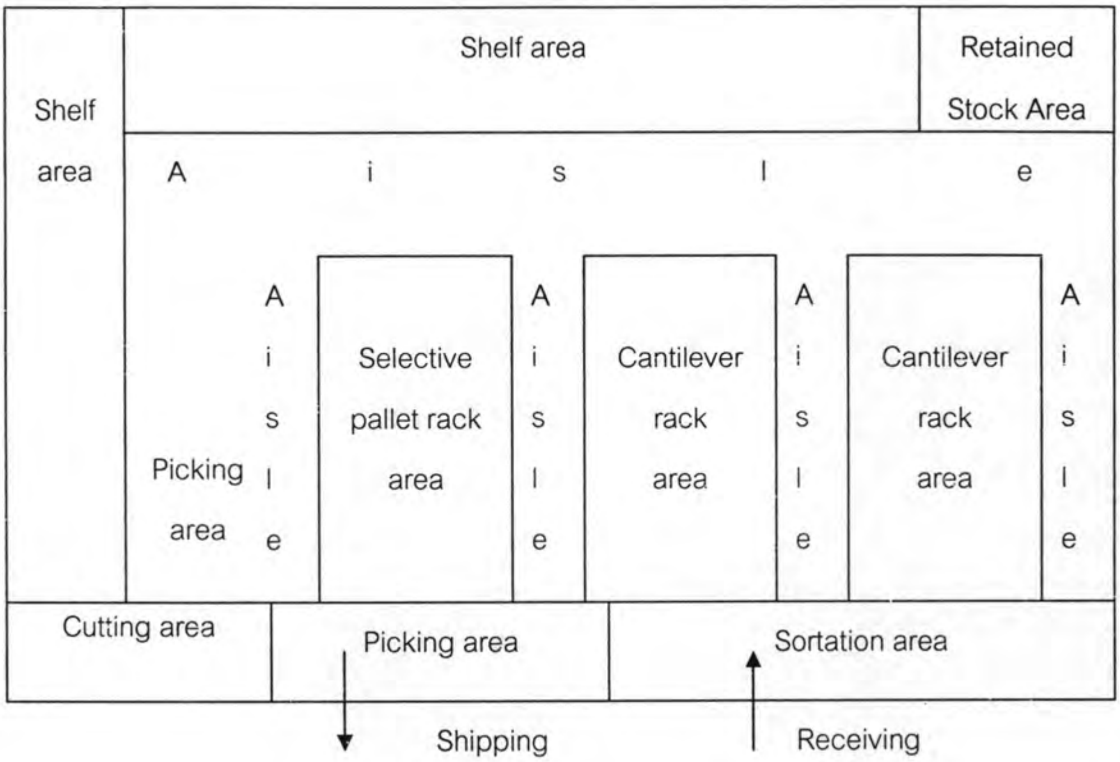

Figure 5.24: Warehouse layout

Seen from the figure 5.24, except the space being taken up by the storage materials and cutting machine, the rest is totally distributed to the aisles and the sorting and picking function. Due to the danger of the steel bar movement, at least two people are required to conduct the operation. In another word, one aisle between two racks has to minimally accommodate 2 employees. So, one meter is assigned to the aisles between two racks. On the other hand, in order to avoid the congestion of simultaneously picking items on the rack and shelf, 2 meters are distributed to the aisles between the shelf and racks. For the area in front of the racks, in principle, it is jointly consumed by receiving, sorting, picking and shipping functions for the purpose of integrating the usable space. However, the receiving and shipping districts are separated to avoid the conflicts and inconveniences if inbound and outbound operation happens simultaneously.

5.3.5 Safety Plan

Due to the potential dangers might be aroused by the raw materials, the safety plan is formulated to avoid the possible injury and accident and corresponding cost.

1) **Safety management approach**

The Boeing's world class safety management model illustrated in section 3.6.4 offers a comprehensive approach to achieve high safety performance. The model involves five main aspects --- the attentions of executive leadership, training program, communication skill, safety improvement processes and alternative work program. Although the warehouse is only a small case in comparison to the multinational organization, this model is still able to be used as a reference to guide the Company warehouse safety plan and management, but some modifications are made with reference to the actual resources and conditions.

2) **Safety policy**

Warehouse safety policy is firstly enforced to be carefully formulated and clearly declared to any employees involved. It includes the general statement of intent, people and their duties and system and procedure. As a result, commitments and responsibilities of relevant personnel are impelled to be identified. Safety rule and safe operating procedure are formulated as well. Each of them will be specifically discussed below.

After discussing with the managers of the Company, the warehouse overall safety philosophy is established and stated as follows. ***"The warehouse safety is to reduce the number of injuries and accidents as well as protect the employees' health and life. The manager, warehouse supervisors and personnel are all responsible for the warehouse safety."***

3) **Personnel and their duties**

Safety performance is the result of people awareness and attitude. Whether high performance could be realize largely rely on people's attentions. Thus, the most importance element has to be emphasized is the responsibilities and obligations of the personal, as part of the Boeing model describes. It requires attention of not only the warehouse employees, but the management level as well. And the latter should shoulder more responsibilities and commitments than the former deserves for the reason that they are planner and promoter of safety activities.

Given that the safety is the business of management and ordinary employees, the individual responsibilities and duties during the daily warehouse operation are ought to be defined unambiguously. After consulting with the managers and employees, thus, the corresponding responsibilities are generalized as follows. Additionally, documents showing the individual responsibility must be filed and delivered to the corresponding personnel.

For the manager and warehouse supervisor in this case, they shall:

- Fully understand the warehouse police and ensure it work properly.
- Provide the safety training and guarantee that the employees are qualified enough to operate.
- Give advice which is out of the policy range to employees
- Monitor the warehouse operation
- Inspect the potential accident.
- Ensure the employee correct operation
- Ensure that adequate first-aid equipment and device are on site and appropriately maintained.
- Audit the safety measures
- Analysis the hazard if occurs
- Develop the correct produces

For the ordinary warehouse staffs, they have to

- Inspect the storage and handling equipments regularly and keep the warehouse clean at any time

- Follow the correct operation procedure
- Report any potential problems they identify
- Obey the safety rule
- Participate the safety training
- Maintain the storage and handling equipment

4) **Safe operating procedure**

Since the weight of steel bars may initiate injuries and accidents during the operation and the most dangerous part of the operation process is its movement, the formulation of safe operating procedure is indispensable and listed blow. Detail explanation will be given subsequently.

- Decide the difficulty of operations
- Determine the number of necessary people and assign the appropriate persons.
- Prepare the necessary equipments
- Prepare the movement
- Check the safety before moving
- Conduct the moving (stop if find any problems)
- Check the safety after moving

Before preceding the operations, the complication and difficult level of operation must be measured. Based on the results of difficulty level measurement, the quantity of required employees has to determine and proper operators should be assigned. For the easy operation, ordinary staffs are capable enough to complete. In the case of extremely complicated and dangerous operations, the sophisticated operators must be assigned to conduct. After setting the staffs, the required moving equipments and safety prevention devices have to be selected. These include the overhead crane, fastening components, helmet and other related equipments. After being selected, all of them should stand by. For example, the overhead crane should be moved to the appropriate position and the operators have to wear the helmet. Prior to steel bar movement, the fastness must be checked up carefully and it should not start until all tangible and intangible problems are ensured to be eliminated. The movement of steel bar is ought to be conducted carefully and slowly. If any problems occur in the interim, the operation must be stopped immediately. After being transferred to its due location, the position of steel bar on the rack is enforced to be inspected in order to prevent it from dropping.

5) Safety rule

The safety rule must be formulated and delivered to the employees as well. In addition, training on safety rule is required to not only the new operators, but also sophisticated staffs. In order to ensure the safety rule take action, at the same time, some mandate measures must be taken. For example, fine or penalty is applied to the workers who violate the safety rule during the operations and the responsibilities are traced back to the supervisor if accident happened. Following is the safety rule being schemed for the Company.

- Helmet must be worn during the stock movement.
- Inflammable goods and smoking are strictly prohibited in the stock area.
- Without permission, no employee can change the configurations of storage equipments.
- No people are permitted to stand under the raw materials during its movement.
- The storage and handling equipments must be inspected periodically.
- During the operations, at least two staffs are required.
- Safety warning signs must be post up at the visible place.
- Non-warehouse employees are permitted to operate the raw materials.
- New employees must be trained before operating.

- Report the unsafe conditions to the supervisor as soon as possible.
- Conduct safety examination periodically.

6) Safety performance review

Even though there is not such an accident or injury case once being reported, the safety performance still need to be periodically measured and reviewed by management to assess and understand the safety condition and inadequacy during the specific period. The performance, at best, should be assessed by the measurable factors for easy comparison.

Checklist is a good technique widely used in the workplace to assess the safety condition during the given period. It uses the standard to measure the target performance which helps investigate the potential problems as well as aim to guarantee the ultimate safety. Appendix E describes the safety checklist formulated for this case.

Section 3.5.6 also has introduced four indicators which are commonly used in the workplace to help measure the safety performance. Thus, based on parameters involved in these indicators, four indexes, no. of injuries, no. of absent days, cost of injuries, and no. of employees are recorded on the basis of per million worker-hours. (See Table below)

Data	No. of injuries	No. of absent days	Cost of injuries	No. of employees
Total				

Table 5.4: Safety performance recorder (per million worker-hours)

With the results in the table 5.4, the frequency-severity indicated, cost factor, loss ratio and nonindustrial disabling injury rate are able to be calculated to interpret the safety performance in the past time interval. Numerically, the lower the result will be the better. However, at all events, injury-free are strongly and definitely expected.

5.3.6 Security Measures

Since the warehouse frequently receives the patronage of the greedy employees, the security plan should be formulated to prevent the raw materials from being stolen as a result. Section 3.6 has introduced some applicable measures to secure the stockyard. Under the guidance of these recommendations, the security rule is schemed as follows.

- At least assign one employee on the scene
- Lock the plant door before leaving
- Forbid non-warehouse employee
- Mark the raw materials with distinct colors

Principally, at least one warehouse staff has to be ensured to fix at the stockyard during the working time, even at the lunch time. This is because the loss largely results from no supervising. Also, the door of the plant should be ensured to be locked before leaving and the keys must be handed over to the office. Moreover, without permission, any non-warehouse employee is allowed to enter stock area at any time. For easily identifying the loss of materials, the distinctive marks should be printed on the steel bars.

In case that the rule above does not take effect in the future operation, other aided measures might be considered. For example, device such closed-circuit television (CCTV) or vision terminal is worth being installed to monitor the daytime and night activities. The ringing alarm could be installed to warn the security guard. In order to enhance the awareness of the relevant personnel, additionally, mandatory measure such as fine is enforced to apply on the warehouse supervisors and employees in the case of pilferage of raw materials happening. Aiming to reduce the extra cost, however, these activities are only applied if the security rule will not take action. Thus, they are only reserved choices.