

# **A Study on the Facility Layout and Design of Sugar Plants in the Philippines**

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## **Abstract**

A well-managed warehouse system with effective facility layout design is the key concept of modern supply chain system and has an important role in the success of a company (Baker and Canessa, 2009). According to Glock & Grosse (2012) several components must be considered when developing an efficient warehouse facility layout and design, one of which is the material placement and location, and one of the critical activities in material placement is order picking. Picking process have become an important part of the supply chain process and is seen as the most labor-intensive and costly activity for almost every warehouse, where the cost is estimated to be 55% of the total warehouse operating expense. That is why, the researchers aim to design facility layout focusing on material placement and location for warehouse system. The study covers two largest sugar milling warehouses in the Philippines that experience delay in material placement due to slow response time and long cycle time in its picking process. Techniques such as time study, ABC inventory analysis, quality function deployment (QFD) tool, systematic layout planning (SLP) and systems simulation were used in order to design and improve the current material placement layout of the companies. It is concluded that using ABC inventory analysis based on the order picking frequency of materials and implementation of “U” flow material warehouse layout design significantly reduces time and distance spent in searching and picking activities and improves the overall warehouse operation of the companies.

## **Keywords**

Facility layout and design, material placement, U flow material layout design, ABC inventory analysis, quality function deployment

## **1. Introduction**

Warehouse layout directly affects the day-to-day efficiency of any business operation, from manufacturing and assembly to order fulfillment and more. It is important that a warehouse has enough space to operate efficiently. However, it may be even more important that the space is laid out in a way that optimizes the warehouse’s abilities.

A well-managed warehouse system with effective facility layout design is the key concept of modern supply chain system and has an important role in the success of a company (Baker and Canessa, 2009). As levels of supply chain integration have increased and inventory levels have been reduced, reliable, on-time deliveries have become increasingly critical for success of the company.

According to Glock & Grosse (2012) several components must be considered in developing a warehouse facility layout design, and one of which is material placement and location. And one the most critical activities in material placement and location is order picking activity. Order picking can be defined as the activity by which a small number of goods are extracted from a warehousing system, to satisfy a number of independent customer orders. Order picking processes have become an important part of the supply chain process. It is seen as the most labor-intensive and costly activity for almost every warehouse, where the cost of order picking is estimated to be as much as 55% of the total warehouse operating expense. As the order picking process involves significant cost and can affect customer satisfaction levels, there have been increasing numbers of process improvements proposed to help companies with this supply chain issue (Murray, 2018).

Thus, warehouse facility layout design focusing on material placement is the main focus of this research study. Generally, multiple factors must be considered to maximize efficiencies when designing the layout of an area. Because of this, a systematic procedure can be highly useful.

There are numerous studies regarding warehouse layout and design focusing on material placement and location. However, most studies made use of group technology-based approach such as binary part-machine incidence matrix for layout design (Krishnan, et al., 2011). That is why the researchers propose to design a warehouse layout focusing on material placement incorporating the tools such as “U” flow material layout, ABC inventory analysis and Quality Function Deployment (QFD).

The researchers cover the two largest sugar milling warehouse in the Philippines that experience delay in material placement due to slow response time and long cycle time in its picking process. Based on interview and time study conducted, the researchers were able to identify causes for the delay in order picking process such as failure to follow storage requirements, wasted man-hours spent in walking from shelf to shelf and searching for materials, ineffective placement of materials throughout the warehouse and blocking of aisles and shelves that limit the activities and movement of warehouse personnel and materials.

## 2. Methodology

The researchers followed a framework shown in the figures below in order to provide structure and guidelines on how the output design was developed.

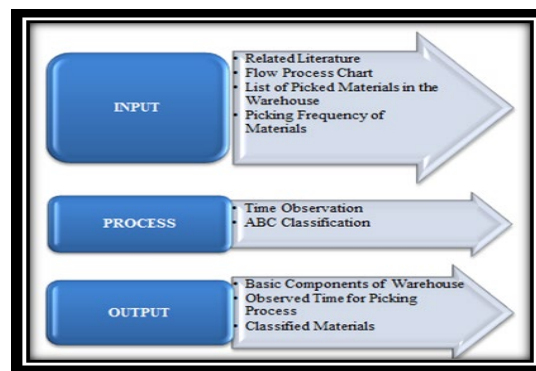


Figure 1. Conceptual Framework – Phase 1

In order to identify and assess the basic components that will be considered in designing warehouse facility layout, the researchers evaluated the current layout of the two sugar milling warehouses considered in the study. The researchers also identified the specific activities involved in order picking process that will be the focus of the study through process mapping and flowcharting. Motion and time study were developed in order to measure the standard time of all the activities involved in order picking. Data for picking frequency of materials was also obtained in order to develop an ABC inventory analysis that will be used for further analysis.

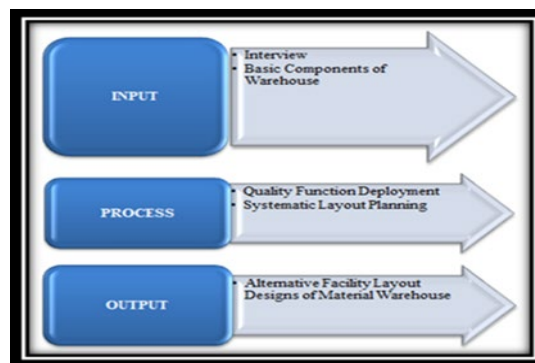


Figure 2. Conceptual Framework (Phase 2)

For the design facility layout for material placement and location, the researchers conducted interview and survey from warehouse personnel in order to gather information about the needs and requirements of personnel in the material placement layout. The data gathered are then for Quality Function Deployment (QFD) tool in order to translate the needs and requirements of personnel into specific plans in developing the material placement layout and design. The basic components of warehouse design based on review of related literature were also used by the researchers in developing a Systematic Layout Planning (SLP). This technique is used to determine the specific locations of receiving & shipping areas, receiving staging & shipping staging areas, storage areas, office, and equipment areas in the warehouse based on closeness relationship prioritization. The result generated different facility layout design alternatives for material placement and location.

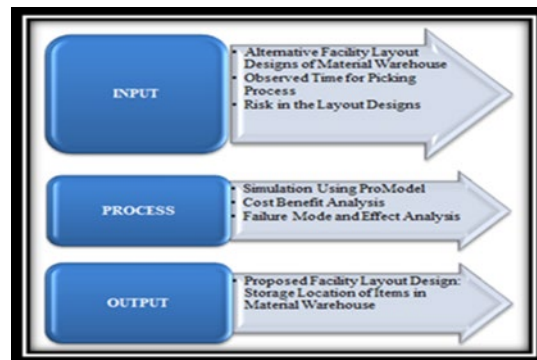


Figure 3. Conceptual Framework (Phase 3)

In order to evaluate the different facility layout design alternatives, the researchers used statistical analysis to analyze the standard time obtained from motion and time study of order picking process and transformed these data into a single distribution. The alternatives were then evaluated through systems simulation using ProModel software. Then afterwards, the most viable alternative based on simulation were then evaluated using cost-benefit analysis to estimate the overall cost of the new layout design and its benefits. The researchers also assess the measure the possible risks that will be encountered in implementing the new layout design using Failure Mode and Effect Analysis (FMEA). The result of the analysis will give the researchers the best facility layout design for material placement and location.

### 3. Results and Discussion

#### 3.1. Assessment of Current Facility Layout

The figures below show the current facility layout for both companies considered in the study: (a) Batangas Sugar Central Incorporated Material Warehouse (BSCI) and (b) Central Azucarera Don Pedro Incorporated (CADPI).

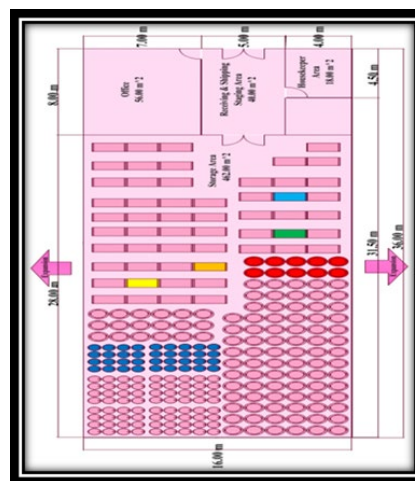


Figure 1. Current Layout of BSCI

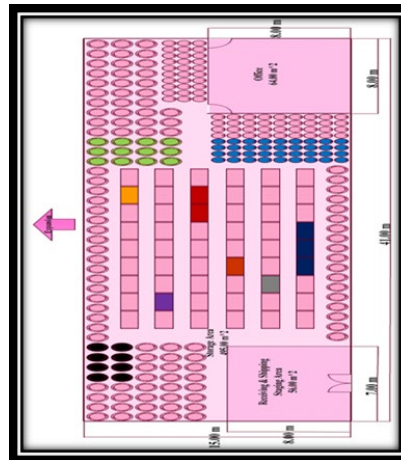


Figure 2. Current Layout of CADPI

Based on direct observation, survey, interview and conduct of motion and time study, the of slow response time and long cycle time of order picking in material placement and location area of the facilities are caused by the following factors:

Table 1: Analysis of Current Facility Layout of BSCI and CADPI

COMPONENTS OF FACILITY LAYOUT DESIGN	ANALYSIS AND FINDINGS
Input and Output Doors	Having separated doors for receiving area and shipping area is significant in order to reduce delays, confusion, loss of materials, mixed materials and damages of materials when incoming and outgoing materials happens at the same time.
Receiving Area, Receiving-Staging Area, Shipping Area, Shipping-Staging Area	Having one area for receiving area, receiving staging area, shipping area and shipping staging area is significant in order to reduce delays, confusion, loss of materials, mixed materials and damages of materials when incoming and outgoing materials happens at the same time.
Storage Requirement	70% of the total warehouse area should be considered for actual storage space. The remaining 30% is used in receiving staging area, shipping staging area, office, equipment area.
Aisles	Narrow aisle. These aisles have a measurement of 1.2 meters. With this aisle measurement, material warehouse will have more storage area and will ease the movement of warehouse personnel and materials.
Material Handling Equipment	BSCI and CADPI suitable material handling equipment to be used in the material warehouse are shelves, pallets, trolleys and leveler. Having this equipment in the material warehouse guarantees protection from damages and faster transferring of material in and out of the material warehouse.
Material Placement	ABC Classification as a material placement. It helps to determine the importance of each material in the warehouse and thus, the applicable positioning of the materials based on picking frequency. The result reduces time and distance of searching and picking of materials.
Movement of Warehouse Personnel	Concerned with the controlled and uninterrupted movement of warehouse personnel going in and going out of the warehouse

	with or without materials. “U” flow and “Through” flow contributes to a smooth flow of activities/processes with a minimum amount of movement and disruption.
Flow of Materials	Concerned with the controlled and uninterrupted movement of materials going in and going out of the warehouse. “U” flow and “Through” flow contributes to a smooth flow of activities/processes with a minimum amount of movement and disruption.
Accessibility	Not only about whether or not warehouse personnel can get to the materials but also can warehouse personnel get the required number of materials? The ABC classification, “U” flow and “Through” flow contributes to a smooth flow of activities/processes with a minimum amount of movement and disruption.
Space	When considering how to use the available space, the maximum should be allocated to operational storage and stock processing purposes. Increasing material warehouse size gives a separated receiving area, receiving staging area, shipping area, shipping staging area, storage area, equipment area and office.
Throughput	In the research study, the scope of the activity are from the searching of materials up to transporting of materials. Throughput is not only materials that part through the warehouse but also the nature of the materials and its velocity through the flow. Reducing cycle time gives positive impact in the manufacturing operations.
Health, Safety and Comfort	Considerations that involve in attention to possible hazards in warehouse. Focusing on this component improve warehouse personnel work performance and avoid possible injuries.
Environmental Considerations	Considerations in energy efficiency for environmental awareness, choices of roofs, walls electric light and temperature control. Focusing on this component improve warehouse personnel work performance.
Coding Location	Each possible storage location in the warehouse should be assigned a specific code, and materials are then located by these codes. The result reduces time from searching of materials.

### **3.2. ABC Inventory Analysis**

The tables below show the ABC inventory analysis for both companies based on picking frequency, material percentage and consumption percentage of materials stored in the facility layout. ABC inventory analysis is an inventory control used throughout materials and distribution management. The items stored in the layout for both companies are analyzed and categorized in three classes, Class A, Class B and Class C. Class A is the category for items that are outstandingly important, Class B is classification of items of average or middle importance and Class C is the designation for relatively unimportant items. The classification of items under ABC categorization is based on Pareto Analysis, under this rule in terms of material consumption, 80% of the value of inventory would be held in about 20% of the items. As such, categories B and C would make up the remaining 80% of the items, perhaps B with 30% and C with 50%.

However, in terms of their material consumption, Class B and C would make up on 20% of the value combined, with C the least, perhaps split at 15% and 5% respectively. The percentages vary based on company’s unique inventory control needs.

This means that ABC analysis conforms with the Pareto principle which states that items that account for a large proportion of the overall value are small in number and that items with a low overall value are high in number. It is

also worth remembering that the proportions of the ABC values, both in terms of their consumption value and their number of items, are not set in stone, so long as they add up to 100 percent.

As such, the result of the ABC analysis will be used by the authors in developing a new facility layout for material placement and location based on prioritization of materials.

Table 2. ABC Inventory Analysis of BSCI

Material	Picking Frequency Level	Highest Picking Frequency	Number of Material	Material Percentage	Consumption Percentage
Class A	High	1,629	260	22.39%	70.18%
Class B	Average	155	238	20.50%	20.02%
Class C	Low	60	663	57.11%	9.80%
Total			1,161	100%	100%

Table 3. ABC Inventory Analysis of CADPI

Material	Picking Frequency Level	Highest Picking Frequency	Number of Material	Material Percentage	Consumption Percentage
Class A	High	2,389	225	19.98%	70.12%
Class B	Average	168	234	20.78%	20.02%
Class C	Low	61	667	59.24%	9.85%
Total			1,126	100%	100%

### 3.3 Result of Quality Function Deployment (QFD)

The figure below shows the result of Quality Function Deployment, this tool is a structured approach to effectively determine the warehouse personnel's requirement and needs in terms of facility layout and design for material placement and location. Beginning with the initial matrix, the QFD focuses on the most important service attributes or qualities set by the warehouse personnel. Once the qualities and attributes are prioritized, the QFD deploys them to the appropriate organizational function or action. Thus, this methodology helped the researchers in understanding essential requirements, internal capabilities, and constraints in designing the ideal facility layout for material placement and location.

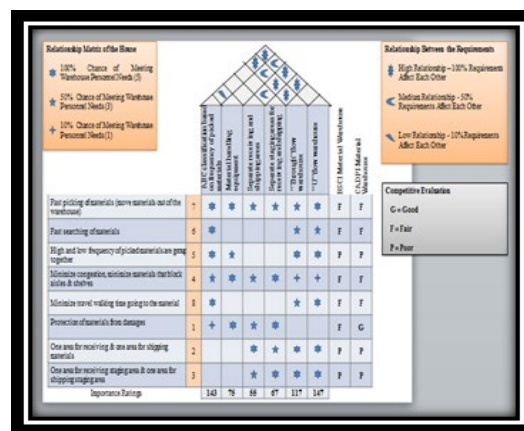


Figure 3. Result of QFD





In “Through” flow material warehouse design, there is separate area for shipping and receiving unlike in “U” flow. The areas are located at the opposing end of material warehouse. The flow of materials starts from receiving area, then storage area and then shipping area in a straight path. Materials are then stored in storage area in accordance with ABC inventory classification based also on picking frequency of materials. Materials that have higher picking frequency level are located at the center of the material warehouse since the total distance travelled would be shorter.

### 3.5. Result of Simulation

In order to evaluate the effectiveness and efficiency of two alternative layout designs for material placement and location, the researchers developed a simulation model using ProModel software. The model analyzes the two alternatives based on operational parameters such as material utilization, throughput, average distance travelled by personnel, and average order picking cycle time of materials under ABC inventory classification. The simulation model is presented in the figure below.

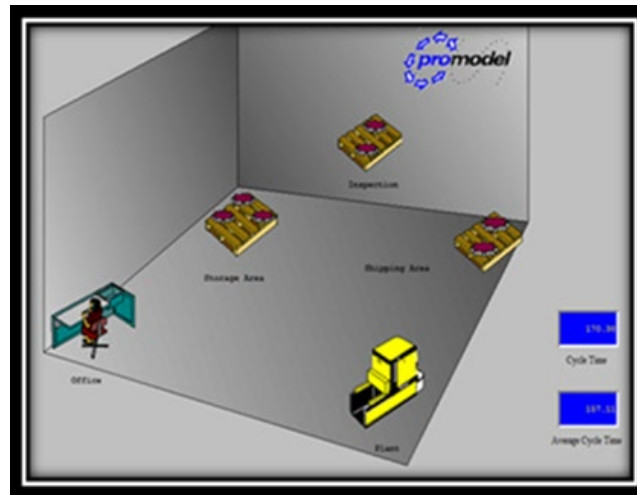


Figure 6. Simulation Model for “U” Flow and “Through” Flow Facility Layout Design

The result of the order picking cycle time and average distance travel for both design alternatives for BSCI is presented in the tables below. Based on simulation, the “U” flow material warehouse design significantly reduces the cycle time of order picking by 45.51% as oppose to “Through” flow material warehouse design. In terms of distance travelled, the “U” flow design also resulted in shorter distance by 4% compared to “Through” flow design. Therefore, it is proposed for BSCI to use the “U” flow layout design for material placement and location.

Table 4. BSCI Data Summary for Cycle Time and Travel Distance

	Current ProModel	“U” Flow ProModel	“Through” Flow ProModel
Class A	2,751.56s	966.15s	1,055.22s
Class B	240.03s	204.56s	207.30s
Class C	2,996.01s	2,609.58s	2,428.03s
Class AB	2,845.75s	1,084.90s	1,180.43s
Class AC	5,661.20s	3,482.85s	3,429.32s
Class BC	235.38s	188.98s	187.96s
Class ABC	2,837.65s	1,034.76s	1,138.10s
Total Cycle Time	17,567.58s	9,571.78s	9,626.38s

	Current	“U” Flow	“Through” Flow
Class A	132m	116m	120m
Class B	132m	122m	124m
Class C	174m	158m	152m
Class AB	176m	155m	166m
Class AC	230m	198m	196m
Class BC	144m	178m	176m
Class ABC	200m	218m	220m
Total Distance	1,188m	1,145m	1,154m



Similarly, the result of the order picking cycle time and average distance travel for both design alternatives for CAPDI is presented in the tables below. Based on simulation, the “U” flow material warehouse design significantly reduces the cycle time of order picking by 36% as oppose to “Through” flow material warehouse design. In terms of distance travelled, the “U” flow design also resulted in shorter distance by 7% compared to “Through” flow design. Therefore, it is proposed for BSCI to use the “U” flow layout design for material placement and location.

#### **4. Conclusion**

Material placement and warehouse facility layout design is the main core of this research study. The material warehouses of Batangas Sugar Central Incorporated (BSCI) and Central Azucarera de Don Pedro Incorporated (CADPI) have been considered in this research since the two largest sugar milling companies in the country experience delay due to slow response time and long cycle time in order picking activity. Techniques such as motion and time study, ABC inventory analysis, quality function deployment (QFD), systematic layout planning and system simulation were developed and used to design and improve the facility layout for material placement and location.

The researchers applied the ABC classification based on the picking frequency of the materials in the warehouse. Class A materials that have the highest picking frequency are therefore located in areas with the easiest, best access, and are stored closest to the input and output doors of the proposed layout. Class B materials that have a medium picking frequency are located in areas less desirable compared to class A material. And for class C materials that have the lowest picking frequency are located in the least desirable location in the material warehouse. The researchers concluded that using ABC inventory analysis significantly reduced the cycle time and distance travelled in searching and picking activities.

Using the quality function deployment, systematic layout planning and systems simulation showed that “U” flow material layout design is the best layout design alternative. The results showed that material warehouse performance based on minimized total travel distance and time can be improved for class A, B, C, AB, AC, BC and ABC materials using the “U” flow material layout design. Simulation results indicated that the combined techniques offer significant improvement to the existing layout design. The average reduction in cycle time for both companies resulted in 40.8% decrease and resulted in 5.5% decrease in average travel distance.

Finally, using Cost Benefit Analysis (CBA) and Failure Mode and Effects Analysis (FMEA) showed a significant improvement in the facility design by applying the “U” flow material layout. The estimated benefit for the proposed “U” flow based on cost benefit analysis amounts to PhP 622,711,852.10. The estimated benefits are greater than the estimated cost thus the proposed action is potentially advisable and should be further evaluated as a realistic opportunity. For FMEA, “U” flow material warehouse layout design shows that only congestion is the possible risk that may be encountered if the layout design is implemented while potential risks for “Through” flow material warehouse layout design are congestion, longer travel distance and security risk.

Therefore, the researchers recommend the “U” flow material warehouse layout design for BSCI and CAPDI companies. The layout design has two separate doors for incoming and outgoing materials, one designated receiving area, one designated shipping area, one designated receiving staging area, one designated shipping staging area, storage area, equipment area and office. Materials flow in at receiving area, move in to the storage area and then to the shipping area in a “U” line flow. The proposed layout design significantly reduced the cycle time and travel distance for order picking activity.

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