# Facility Layout Design and Optimization using Simulation and Time Study

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**Abstract -** This paper deals with the design of manufacturing facilities layout with the consideration of downtime of facilities and space utilization. Facility Layout alludes to the course of action of physical facilities, for example, machines, gear, devices, and so forth in such a way in order to have a quickest progression of material at most reduced expense and with minimal measure of taking care of the product from the receipt of crude material to the conveyance of the eventual outcome. Plant layout being the basic piece of any association needs legitimate thought and seeing in order to have no issue in the work cycle. Hence plant layout simulation is the initial move towards the creation of such plants in order to have the overview of most the factors i.e. cycle time, space, machinery requirement etc. Simulation also helps in making any changes in the plant layout and also the assembly line. For making changes in the Assembly line one needs to study the process going on the current Assembly line and what are the drawbacks of the layout. Time study is the main part of the assembly line so as to know how much time a particular process needs and how it can be reduced using different methods.

**Keywords:** Facility layout, simulation, Time Study, Optimization.

## 1. Introduction

The plant layout is very critical part of running an efficient and cost-effective business. All work areas, production lines, material storage facilities, etc. should be designed to perform the highest rate and the corresponding shortest cycle time. When designing a plant layout, it is necessary to take into account all functions within the business. The design must include not only the needs for the present business but should also have provisions for future expansions. This is included to avoid frequent and costly changes to the design as the demand increases.

For any efficient plant layout, various factors such as direct and indirect cost incurred, space utilization, operator efficiency, arrangement of various equipment, material handling, etc. are considered.

This has been one of the top most priority in the manufacturing and any other industry. Facility layout design deals with the optimal design of any plant, assembly line etc. based on the drawbacks of the current layout. Designing of such a layout requires various information such as cycle time of the processes, distance travelled, plant area, no of machinery, operator efficiency, takt time, process time etc. which are to be either calculated or obtained from the internal data.

Time Study is one of the key aspects that is to be used for recording and calculating cycle times. It is also used to analyze and interpret data in real life scenarios. This time study method comes under work measurement technique.

Simulation is technique where real life processes can be virtualized and understood. Through simulation, many problems can be eliminated before the application of any process is brought in to effect. It gives the information of the system being investigated and the system being implemented.

The amalgamations of these techniques to evaluate, study and interpret has modified a layout design that is effective in various ways such as minimizing of expenditure, reducing work load and increasing efficiency in working which will ultimately result in more production of the product.

## 2. Literature Review

Plant layout is the physical arrangement of equipment and facilities within a plant. i.e. the grouping of equipment and operations in the factory for the greatest degree of efficiency. The plant layout can be indicated in the shop floor plan showing the distances between of the different features of the plant. Optimizing the layout of the plant can improve productivity safety and quality of the products. Unnecessary efforts of material handling can be avoided when the plant layout is optimized. This is valid for:

1. Distances through which the material has to move.
2. Distances equipment has to move.
3. Types of handling equipment needed.
4. Distances operator has to move.
5. Energy required to move items against resistance (i.e. gravity).

### 2.1) Plant Layout

In any manufacturing facility, the layout is extremely important as it decides how the Assembly line will work and how the parts will flow. Plant layout is the essential part of any organization. Over the years, plant layouts have evolved into different types.

The types of layouts are listed below:

a. Product Type.
b. Process Type.
c. Fixed Position.
d. Combination Type.

a. Product Type Layout:
If all the processing equipment and machines are arranged according to the sequence of operations of the product, the layout is called product type of layout. In this type of layout, only one product of one type of products is produced in an operating area. This product must be standardized and produced in large quantities in order to justify the product layout. The raw material is supplied at one end of the line and goes from one operation to the next quite rapidly with a minimum work in process, storage and material handling.

Advantages offered by Product Layout:

I. Lowers total material handling cost.
II. There is less work in processes.
III. Better utilization of men and machines,
IV. Less floor area is occupied by material in transit and for temporary storages.

b. Process Type Layout
The process layout is particularly useful where low volume of production is needed. If the products are not standardized, the process layout is less desirable, because it has creator process flexibility than other. In this type of layout, the machines and not arranged according to the sequence of operations but are arranged according to the nature or type of the operations. This layout is commonly suitable for non-repetitive jobs. Same type of operation facilities are grouped together such as lathes will be placed at one place, all the drill machines are at another place and so on.

Advantages of Process Layout:

I. There will be less duplication of machines. Thus, total investment in equipment purchase will be reduced.
II. It offers better and more efficient supervision through specialization at various levels.
III. There is a greater flexibility in equipment and man power thus load distribution is easily controlled.
IV. Better utilization of equipment available is possible.
V. Break down of equipment can be easily handled by transferring work to another machine/work station.
VI. There will be better control of complicated or precision processes, especially where much inspection is required.

c. Fixed Position Layout:
This type of layout is the least important for today's manufacturing industries. In this type of layout, the major component remains in a fixed location, other materials, parts, tools, machinery, man power and other supporting equipment's are brought to this location.

The major component or body of the product remain in a fixed position because it is too heavy or too big and as such it is economical and convenient to bring the necessary tools and equipment's to work place along with the man power. This type of layout is used in the manufacture of boilers, hydraulic and steam turbines and ships etc.
Advantages Offered by Fixed Position Layout:

(i) Material movement is reduced
(ii) Capital investment is minimized.
(iii) The task is usually done by gang of operators, hence continuity of operations is ensured
(iv) Production centers are independent of each other. Hence, effective planning and loading can be made. Thus, total production cost will be reduced.
(v) It offers greater flexibility and allows change in product design, product mix and production volume.

d. Combination type layout
Now a days in pure state any one form of layouts discussed above is rarely found. Therefore, generally the layouts used in industries are the combination of the above-mentioned layouts. Every layout has got certain advantages and limitations. Therefore, industries would to like use any type of layout as such. Flexibility is a very important factory, so layout should be such which can be molded according to the requirements of industry, without much investment. If the good features of all types of layouts are connected, a compromise solution can be obtained which will be more economical and flexible.

**2.2) Time Study**

ILO defines time study as a work measurement technique for recording the times and rates of working for the elements of specified job carried out under specified conditions, and for analyzing the data so as to obtain the time necessary for carrying out the job at a defined level of performance. Time study is the technique of establishing an allowed time standard to perform a given task, based upon measurement of work content of the prescribed method, with due allowance for fatigue and personal and unavoidable delays.

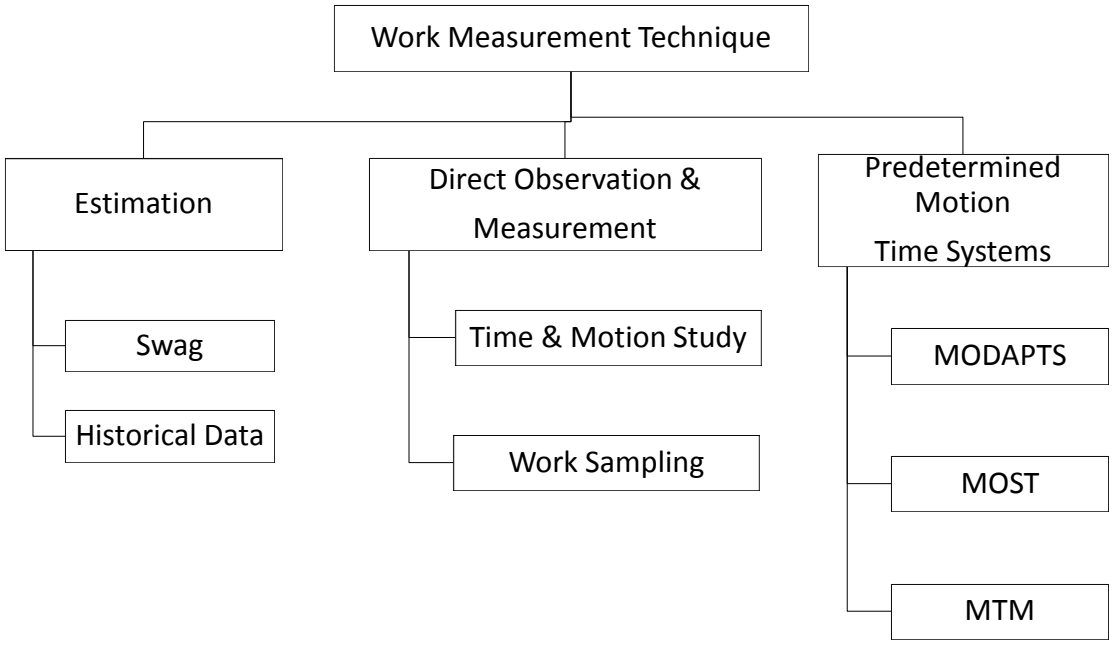


*Figure 1*

### 2.3) Simulation

Simulation is defined as method which imitates real systems processes. It means simulation is used to design a model and perform different actions on it in order to illustrate how this real system may work under different condition. Therefore, main reason behind using simulation is to understand and improve systems and processes. Simulation provides the user with a greater breadth and depth of information on which to base decisions. It is capable of handling the complexity of large systems, even a whole factory. In addition, the simulation approach supports sensitivity analysis by allowing rapid changes to the model logic and data.

The types of layouts are listed below:

**a.** Robotic Simulation:
A digital mock-up is built, which emulates the static and dynamic characteristics of a Robotic work-cell, which can be evaluated and optimized after conducting carefully planned what-if analyses. Simulation exercise provides a validation of concept and processes of assembly lines, system layout, validation of tooling, weld guns, other kinematic devices including the robot reach studies. Simulation is also used to establish process cycle times including robot motion times using specific Robot controller software.

**b.** Discrete Event Simulation:
Discrete Event Simulation is used to model complex manufacturing systems consisting of products and resources such as Machines, Robots, operators, Handling & Storage devices, which are linked physically and logically. It has extensive experience in various business domains to build geometric and logical models of complex production systems to analyze and optimize systems with varying product mixes, inter-arrival times, lot-sizes, MTBF, MTTR etc. using the following features of Discrete Event Simulation.

I. Throughput Analysis & What-if Analysis
II. Cycle Time Analysis
III. Buffer size requirements, Bottleneck Identification & de Bottlenecking
IV. Manpower Planning, Accessibility & Workspace Analysis
V. Alternatives & Optimization
VI. Facility Planning & Plant Utilization

**c.** Ergonomic Simulation:
Ergonomic Simulation offers its services for analysis of human factors involved in any production system. A digital human mannequin is used to confirm compliance to requisite standards and also to verify safety, comfort, reach and visibility related issues in the work environment. This type of simulation is a must for manual stations to ascertain fatigue and performance related problems before start of production.

**d.** System Dynamics Simulation
This is a very abstract form of simulation modeling. Unlike agent-based modeling and discrete event modeling, system dynamics does not include specific details about the system. So, for a manufacturing facility, this model will not factor in data about the machinery and labor.
Rather, businesses would use system dynamics models to simulate for a long-term, strategic-level view of the overall system. In other words, the priority is to get aggregate-level insights about the entire system in response to an action — e.g., a reduction in CAPEX, ending a product line, etc.

## 3. Process Flow Diagram

Electric Shift on Fly line consists of several workstations. Considered nine workstations as active stations required to run the assembly line. It is assumed that all required part level sub-assemblies are ready to process. The process flow diagram for the assembly line is as follows,

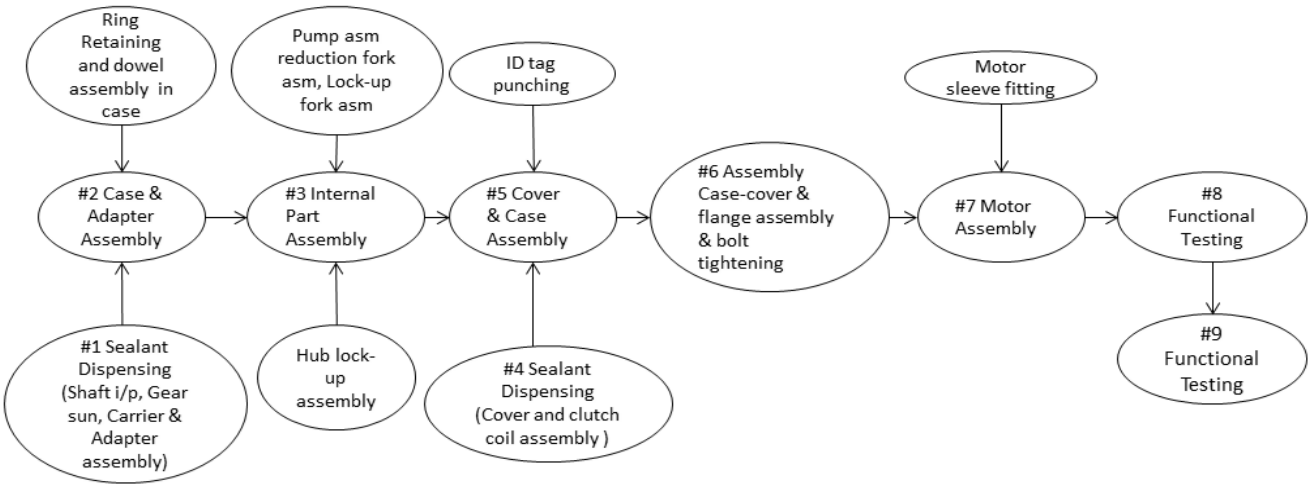


*Figure 2*

## 4. Methodology

**a.** System Identification: Electric Shift on Fly line of transfer case is considered as a system. The system consists of eight work stations.
**b.** Establish Objectives: This is the most important phase of any simulation project. The aim of any simulation project should be to make a better business decision.
**c.** Data Collection: Data has not been collated before. So, performed a small work study in order to collect data.
**d.** Statistical analysis: From the collected data, determined distribution for each work station which is required input for discrete-event simulation.
**e.** Structuring & building model: Structuring model typically takes the form of a sketch of the facility to be modeled. The plan should identify which WITNESS element is to be used to model each real-life process. It may also contain information regarding the input and output rules to be used on key elements. The main steps in building a model are creating elements (defining, displaying and detailing).
**f.** Running the model: After creating model, run the model and modify it by adding, changing or deleting elements.
**g.** Testing the model: It includes verification & validation of the model. The model will be verified by running the model for different input parameters and checking the outputs. Validation will be accomplished using hypothesis tests.
**h.** Experimentation: Apply what if analysis.
**i.** Results and conclusion: Witness creates a wide range of statistics for the elements being used in model. Use FLEXSIM reports such as idle time of work station, busy time of work station, number of units produced within allocated time, number of units scrapped, etc.

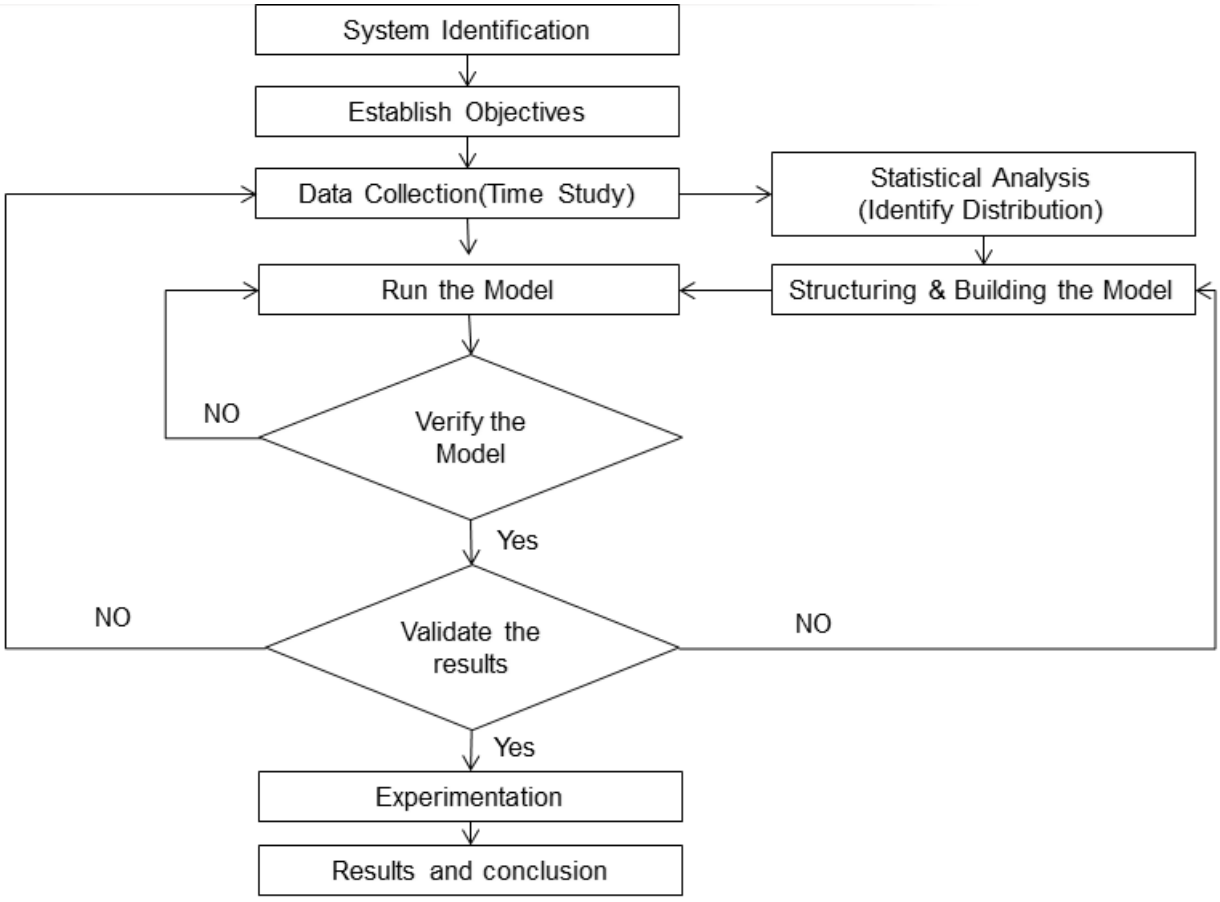


*Figure 3*

## 5. Simulation

In this project Simulation is done using FlexSim. Flexsim is a timeline simulator for windows operating system. We can program a layout by two methods in this software. One method uses actual layout picturing and programming each type of machine or station to do its appropriate operation. The other method includes program the flow of materials in a process flowchart. The second method is visually not so appealing and is difficult to execute. So, in the upcoming models, I have used the first method. For the sake of ease of viewing, all the operators have been hidden and only the machines are shown in the visuals. We can assume an operator at each station. As mentioned above, the RTV application station is ignored and the cycle times adjusted that way. This ensured ease of programming and did not show any significant deviation in the results.

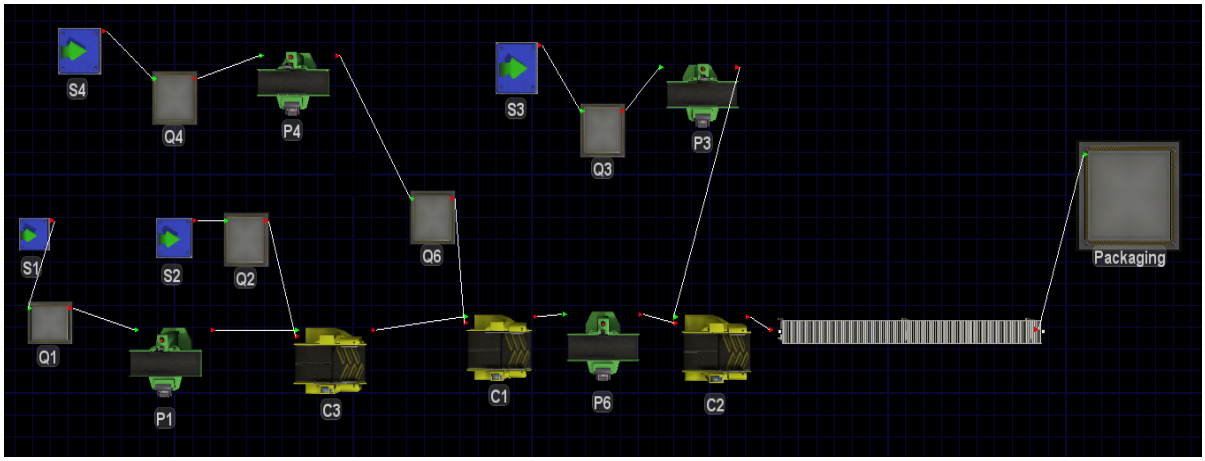


*Figure 4- ESOF Line Model Simulation*

| Sources | Processors | Combiners |
|---|---|---|
| S1- Adapter Assembly | P1- Adapter Dowel and Oil Seal | C1- Case Adapter Assembly |
| S2- Planetary Carrier Assembly | P3 - Cover bearing, oil seal, dowel | C2 - Case Cover Assembly |
| S3 – Cover Seal Assembly | P4 - Case ring gear, dowel, oil | C3 - Planetary Carrier, Sun Gear, Adapter Assembly |
| S4 – case | P6 – Internal Parts Assembly | |

*Table 1- Index*

## 6. Data and Calculation

### Cycle Time

Formula used for cycle time = machine time + handling time

| Station code | Cycle time (s) |
|---|---|
| P1 | 480 |
| P3 | 310 |
| P4 | 330 |
| P6 | 127 |
| C1 | 126 |
| C2 | 10 |
| C3 | 10 |
| Conveyer Station 1 | 185 |
| Conveyer Station 2 | 135 |
| Conveyer Station 3 | 314 |

*Table 2*

### 6.1) Current Layout

The current layout of the ESOF assembly line though in working phase has some drawbacks. The excess travel of the operator for a single sub-assembly takes more time due to the excess travel between the two workstations. This not only consumes extra time, but also increases operator fatigue, which ultimately hampers their efficiency to do the work.

This drawback was eliminated by proposing a new layout considering various factors such as distance travelled, time consumed, calculated time of proposed layout, operator fatigue, area consumed etc.

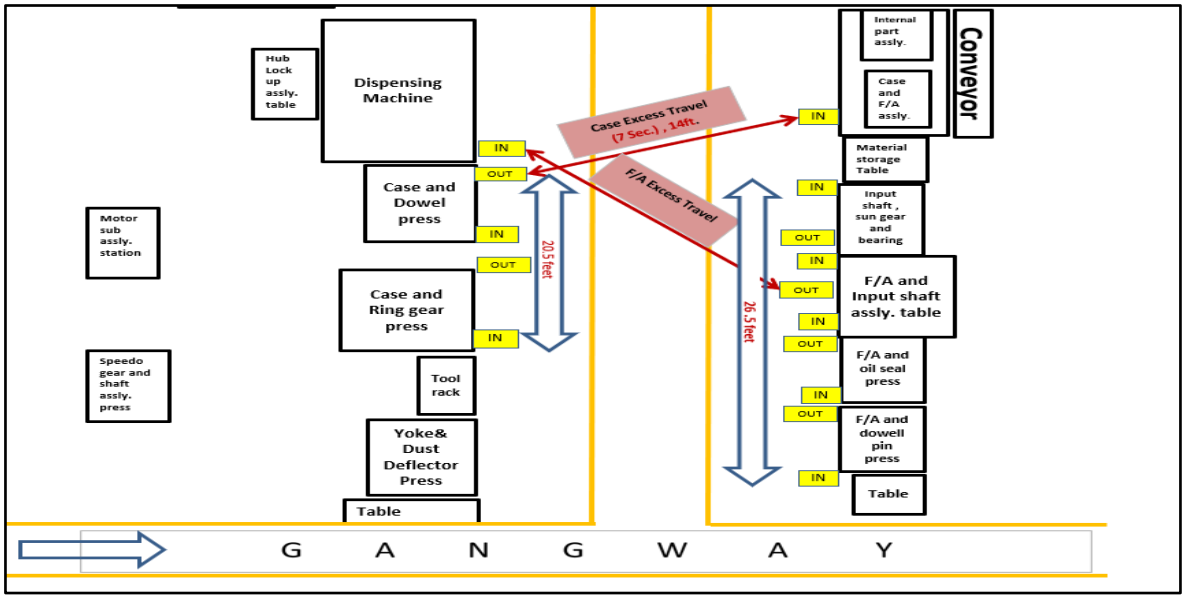


*Figure 5*

Total number of Transfer cases assemblies per day (Avg.) = 100

Therefore, for each day time taken = (Time in min/60) *100 hr

Time taken for a month = (Time taken for a day) *25

Time taken for a year = (Time taken for a month) *12

| | | | | Time in hr. | | |
|---|---|---|---|---|---|---|
| Station name | Distance In feet | Time in sec. | Time in min. | For 1 day | Station name | Distance In feet |
| Case sub assly. | 34.5 | 21 | 0.35 | 0.583333333 | Case sub assly. | 34.5 |
| Input & F/A sub assly. | 54.5 | 30 | 0.5 | 0.833333333 | Input & F/A sub assly. | 54.5 |
| Total | 89 | 51 | 0.85 | 1.416666667 | Total | 89 |

*Table 3*

**6.2) Proposed Layout**

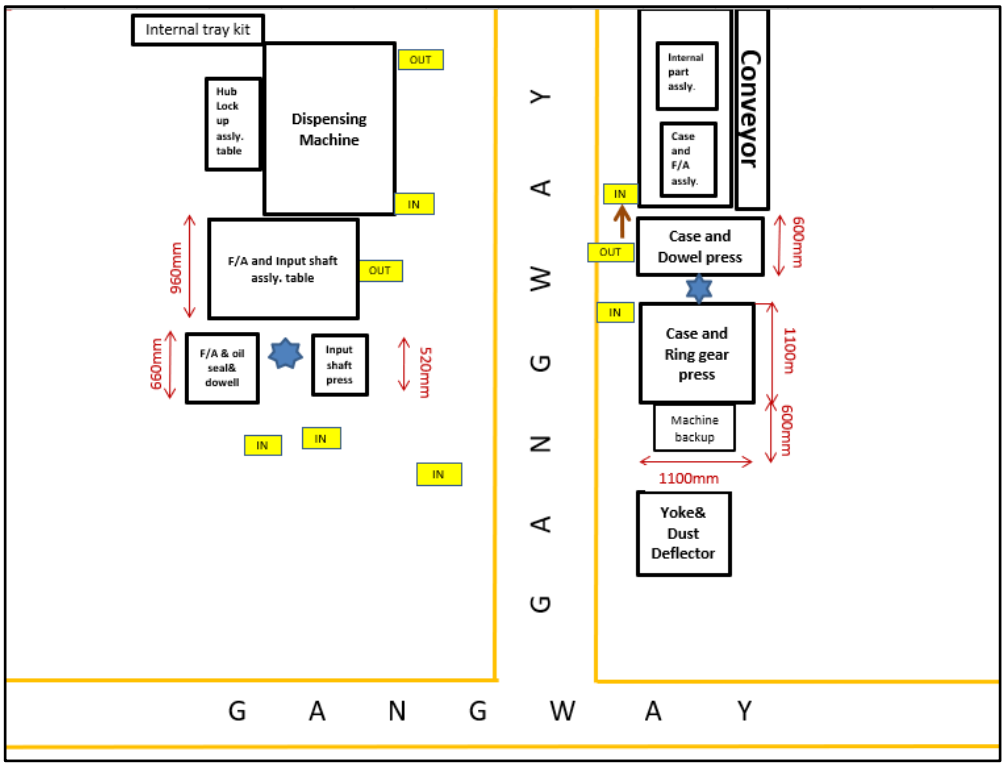


*Figure 6*

Distances and time saved calculations:

All time and distance are calculated by observations and data

| | Calculations for 1 T/C | | | | | |
|---|---|---|---|---|---|---|
| | Total Time Taken (sec.) | | Distance Travelled (feet.) | | Total time saved in sec) | Total distance saved (in feet) |
| Station | Before | New | Before | New | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Case Assembly | 21 | 4 | 50.5 | 6 | 17 | 44.5 |
| F/A and I/P Shaft assembly | 30 | 5 | 54.5 | 4 | 25 | 50.5 |
| Total | 51 | 9 | 105 | 10 | 42 | 95 |

*Table 4*

| Total time & distance saved per day | Calculations for 100 T/C | | | | | |
|---|---|---|---|---|---|---|
| | Total Time Taken (hr.) | | Distance Travelled (feet.) | | Total time saved (in hrs) | Total distance saved (in feet) |
| Station | Before | New | Before | New | | |
| Case Assembly | 0.58 | 0.11 | 5050 | 600 | 0.47 | 4450 |
| F/A and I/P Shaft assembly | 0.83 | 0.14 | 5450 | 400 | 0.69 | 5050 |
| Total | 1.42 | 0.25 | 10500 | 1000 | 1.17 | 9500 |

*Table 5*

| Total time & distance saved per month | Calculations for 2500 T/C | | | | | |
|---|---|---|---|---|---|---|
| | Total Time Taken (hr.) | | Distance Travelled (feet.) | | Total time saved (in hrs) | Total distance saved (in feet) |
| Station | Before | New | Before | New | | |
| Case Assembly | 14.58 | 2.78 | 126250 | 15000 | 11.81 | 111250 |
| F/A and I/P Shaft assembly | 20.83 | 3.47 | 136250 | 10000 | 17.36 | 126250 |
| Total | 35.42 | 6.25 | 262500 | 25000 | 29.17 | 237500 |

*Table 6*

Implementing this new assembly layout will save both the time and the distance travelled of the operator which will ultimately affect his efficiency and would be able to complete a greater number of jobs in the given stipulated time.

## 7. Result

Plant layout type- Combination type layout

Simulation Takt time- 5 min 45 sec

Observed Takt time- 6 min 5 sec (Observing 10 completions and taking an average)

Average Efficiencies for machines throughout one shift

| **Station code** | **Efficiency (%)** |
|---|---|
| P1 | 98 |
| P3 | 98 |
| P4 | 98 |
| P6 | 95 |
| C1 | 85 |
| C2 | 95 |
| C3 | 98 |
| Conveyer Station 1 | 95 |
| Conveyer Station 2 | 85 |
| Conveyer Station 3 | 100 |

*Table 7*

## 8. Conclusions

1. Important aspects of the manufacturing facility include Plant layouts, Workforce management, Maintenance of equipment, Process design and daily operational management.

2. Management is as important as engineering.

3. Decisions even before the production starts are crucial for smooth production.
4. Education and awareness lessons dedicated to the operators is important.
5. Efficiency of any facility is directly affected by all the factors mentioned in point 1.
6. Usage of Combination type plant layouts is better than pure layout types.
7. Motion and time study reduce and controls cost, improves working conditions. Motion study offers great potential for reducing human efforts in great extent.
8. Time study develops effective and efficient work methods, balance assembly lines, select proper equipment and layout manufacturing facilities.
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