Simulation study and analysis of plant layout in tin container industry

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Abstract. The productivity of any manufacturing facility depends on how well various processes involved in the plant are interconnected. Plant layout comprises of various departments and within these departments, there are different processes which are interdependent on each other. Proper design of plant layout combines all different workstations under single frame so as to enhance the productivity. But several small scale industries utilize the same old traditional layout which was framed during their establishment and therefore as they grow eventually over the years, due to change in market trends or to meet increasing customer demand redesigning of plant layout plays vital role. Analysis of existing plant layout helps in identifying loophole areas and explores measures to eliminate bottlenecks present. The main aim of this study is to find out most optimal way of arranging various workstations in the existing facility that will satisfy the present day demand from the customers which substantially increases the production rate. This study has been carried out at a tin container manufacturing industry named as LVT containers situated in Hubballi, Karnataka, INDIA. Analysis was conducted using the ARENA simulation software and the results obtained from simulation experiment were the basis for proposing potential changes in the existing plant layout.

Keywords: Productivity; Traditional layout; Bottlenecks; Production rate; Simulation experiment.

1. Introduction
LVT containers is a medium scale industry capable of producing more than 500 no’s tin containers every day. Production line consists of five main processes side seam welding, stretch forming, body flanging, top seaming and bottom seaming. According to the plant in charge, the plant utilizes the optimum machineries and adequate technology for producing tin containers. The industry over the years has earned vast customer base through its consistent product delivery and quality due to which there has been increase in demand for their product. Through the observation it was clear that the industry still had the traditional layout in which the utilization of space, machineries and man were not optimum. The industry had earlier employed some trial and error method to increase the production capacity but had difficulties in terms of implementation including their existing workflow got hampered and cost of implementation was not realized. Hence these reasons called for analysis of existing plant layout through the software tool which doesn’t affect work flow and whose results are reliable so that the industry can utilize results of such study for real time implementation. Iqbal M and Hashmi M S J explained simulation study on industrial management behaviour in food industries [4].

In order to explore the possible potential arrangement of workstations at the factory floor, a simulation study was conducted at a tin container production line.

Simulation is a powerful modelling and analysis technique used to evaluate and improve dynamic systems of all types [6]. The objective of the study was to maximize production rate through detailed analysis of existing plant layout to meet the increasing customer demand. Simulation study is carried out through several orientation visits to the plant and getting familiar with the system components.
Among available simulation software's such as Arena 10.0, Promodel, Process model etc, Arena 10.0 was used to run real time simulation and build the system model [9]. McLean C and Kibira D used Promodel software to analyze existing plant layout by integrating short processing time, work schedule and work areas [10]. With the simulation run results congestions in different stages on the production line were determined. Through simulation experiments several scenarios were developed to identify feasible solution to increase production rate. Introduction of change into existing system always has a cost attached to it. Therefore payback period of capital investment was also calculated.

2. Methodology
The objective of the study was accomplished by conducting a detail analysis of existing plant layout through simulation method. All the stages, their processes, inter-arrival times, resources are identified and reported. Then, a simulation model is built using modules present in simulation software and it has to be verified and validated so that it represents true behaviour of the existing system. Once a validated model is built, it is used to conduct the simulation experiment to look for feasible solution which maximizes the productivity of the plant.

Figure 1. Steps in simulation study

Simulation study demands detail information of each and every process of the plant layout considered. Based on these data related to product flow route, relation between each operation unit, processing times, breakdown times, inter-arrival times etc, a simulation model is built. This model should mimic the behaviour of real system considered. Finally the same model is utilized to analyze possible potential scenarios to improve the productivity. Simulation experiment results are reliable and can be implemented in real time execution.

3. Plant layout analysis
The manufacturing process of the tin container at the LVT containers, Hubballi has five main stages, namely side seam welding, stretch forming, body flanging, top seaming and bottom seaming. These stages have been adapted by LVT containers and hence the same processes and sequence has been used for the analysis. The production starts with welding of tin sheet across its edge to form one enclosed material. Next stage is concerned with providing the rectangular shape to the tin sheet which is called as stretch forming. Thereafter it is body flanging stage in which the rectangular containers edges are tapped to form the flanges at the top and bottom side. Finally top and bottom seaming stages are carried out to attach the plates at the respective ends. Top seaming and bottom seaming stages are shown under single block in fig 2.
3.1. Analysis of existing plant layout

During plant visit orientation, distances between each workstation and delay times were obtained from observation data handbook of LVT containers. Further same data was collected physically during actual operation of the various processes and also verified with handbook data for authentication.

Distance between each stage of the plant was noted down and major delays were observed at couple of stages. All the distances and delay times are listed in the table 1.

| Sl no | From               | To                   | Distance (Meters) | Delay time (Seconds) |
|-------|--------------------|----------------------|-------------------|----------------------|
| 1     | Slitting section   | Welding section      | 6.51              | 0                    |
| 2     | Welding section    | Forming section      | 32.13             | 10                   |
| 3     | Forming section    | Flanging section     | 9.78              | 0                    |
| 4     | Flanging section   | Seaming section      | 86                | 20                   |
| 5     | Seaming section    | Inspection section   | 8.08              | 0                    |
| 6     | Inspection section | Inventory section    | 13.89             | 10                   |
|       | Total              |                      | 156.39 meters     | 40 seconds           |

Also data on arrival rates, processing times of five stages, activity times and breakdown times were obtained from observation data handbook of LVT containers. Processing time of each process follow triangular distribution and adhesive gel has to be filled at body flanging machine for every two hours which takes time between 1 to 2 minutes. Detail data collected is shown in table 2.
Table 2. Data collected at various workstations.

| Sl no | Workstation          | Processing time (seconds) | Adhesive gel refill |
|-------|----------------------|---------------------------|---------------------|
|       |                      |                           | Frequency (minutes) | Refill time (minutes) |
|       |                      |                           | (exponential)       | (uniform)             |
| 1     | Slitting sheets      | Tri (4,6,8)               | -                   | -                    |
| 2     | Side seam welding    | Tri (11,12,15)            | -                   | -                    |
| 3     | Stretch forming      | Tri (5,7,9)               | -                   | -                    |
| 4     | Body flanging        | Tri (10,12,14)            | 120                 | 1,2                  |
| 5     | Top seaming          | Tri (6,8,10)              | -                   | -                    |
| 6     | Bottom seaming       | Tri (7,8,9)               | -                   | -                    |

3.2. Proposed plant layout

Arrangement of proper sequence of production in a plant is the key to productivity improvement. Proposed plant layout arranged the work areas according to the sequence of operations performed in production facility. Thereby long distance and their associated time delay were reduced substantially. Further this proposed plant was subjected to simulation study to evaluate the potential outcomes from it.

Figure 4. Proposed plant layout

Now the distances between the various workstations and also delay time associated with is recorded to know the difference between the existing plant layout distances and modified plant layout distances. Table 3 shows distances between workstations and delay times in proposed plant layout.

Table 3. Distance and delay times in proposed plant layout

| Sl No | From       | To          | Distance (Meters) | Delay Time (Seconds) |
|-------|------------|-------------|-------------------|----------------------|
| 1     | Slitting section | Welding section | 9.35             | 0                    |
| 2     | Welding section   | Forming section | 8.08             | 0                    |
| 3     | Forming section   | Flanging section | 9.18             | 0                    |
| 4     | Flanging section  | Seaming section | 32.13            | 05                   |
| 5     | Seaming section   | Inspection section | 7.88            | 0                    |
| 6     | Inspection section | Inventory section | 13.89           | 0                    |
|       | Total         |             | 80.51 meters      | 05 seconds           |

Modified plant layout shows that the material movement can be reduced from 156.39m to 80.51m i.e. 48.51% reduction and delay time from 40 sec to 5 seconds i.e. 87.5% reduction.
3.3. Calculation of takt time

- Shifts per day: 1
- Total working time per shift: 480 minutes
- Time breaks per shift: 2*5 minutes : 10 minutes
- Lunch time per shift: 16 minutes.
- Breakdown time per shift: 40 minutes
- Actual working time per shift = {total working time – (total breaks+ down time)} : 480 – (70+16) = 394 minutes
- Customer demand per day = 1000 containers/day
- Takt time = (Actual working time / customer demand per day) = 394 / 1000 = 0.394 minutes.

The takt time required to meet the customer demand is calculated and found to be 0.394 minutes. Average cycle time to produce a single tin container with current capacity is 1.5 minutes but in order to meet the demand we have found out takt time to be 0.394 minutes. Hence 1.1 minutes of cycle time has to be cut down. As proposed plant layout has reduced distances between each workstation, through simulation study the same pant layout can be examined whether it can produce required numbers of containers to meet customers need.

4. Simulation study

Simulation study has been carried out through Arena 10.0 analysis software. Arena software provides various modules through which one can build model of the system that he wants to study. Once the system is built, potential changes can be applied to existing system’s model to see the results. As all necessary data related to working of various workstations has been collected, hence a model which depicts same behaviour as the actual system is built as shown in fig 5.

![Simulation model of existing plant layout](image)

**Figure 5.** Simulation model of existing plant layout

4.1. Verification and validation

For verification, Simulation software Arena was used to prove that movement of entities is same as the flow of the parts in the existing tin production line. Simulation model is a duplicate version of real system whose behaviour should match to that of system as much as possible. Therefore validation of the arena model is done, which requires model to show number of tin containers produced same as number of tin containers produced by real system. Through simulation run, the number of tin containers produced per day was 554 no’s and according the plant records number of tin containers produced per day was 500 to 550 no’s which is acceptable.

4.2. Simulation runs and experiment

If As we have already proposed modified plant layout which reduces the material movement and delay time, now we can apply those changes in the existing simulation model to see what happens with productivity. Fig 6 shows system model with necessary changes according to modified plant delay time shown in table 3.
The result obtained from this model was that number of containers produced by the system was 1114 numbers. Hence it can be said that this proposed plant layout if implemented would meet customer demand under given cycle time.

4.3. Potential scenarios
As modified plant layout has created enough vacant spaces which can be utilized for potential capacity expansion. Also it was observed from simulation run results that average queue of entities passing through side seam welding and body flanging workstations was high compared to other stations.

Therefore space utilization and elimination of Queuing at both stations can be achieved by:

- Scenario 1: Through modified plant layout, now there is a provision for introducing another welding machine due to the space created.
- Scenario 2: Having additional machine for body flanging for the same function (as refilling of adhesive could be done alternatively).

These scenarios are incorporated in the modified simulation model which has been generated earlier. Another welding machine is added by introducing resource number 2 for welding process. Also same procedure is followed for flanging process. To know the results of potential scenarios on the modified plant layout, simulation model was built according to combined changes from scenarios. The model incorporating these changes is shown in fig 7.

The result obtained through simulation run of this model was that number of containers produced by system was 2369 numbers. As compared to result obtained from modified plant layout simulation model i.e. 1114 numbers, these proposed scenarios have increased productivity by almost two times and hence implementation of these scenarios needs to be considered by plant management.

5. Cost analysis
The proposed scenario calls for additional cost to be invested. Hence it is necessary to conduct cost analysis to check whether the change proposed to the system is economically viable or not. Table 4 shows days required to recover the capital invested for both scenarios 1 and 2.
Table 4. Cost analysis

| Scenario | Cost of scenario (Rs) | Cost of labour (Rs/day) | Container/day | Additional container/day | Net profit of scenario/day (Rs) | Days required to recover scenario cost |
|----------|-----------------------|-------------------------|---------------|-------------------------|--------------------------------|---------------------------------------|
| Current  | 1114                  | 0                       | 0             | 0                       |                                |                                       |
| Scenario 1 | 4,50,000             | 350                     | 1535          | 421                     | 31125                          | 14                                    |
| Scenario 2 | 2,08,000             | 1643                    | 529           | 39325                   |                                |                                       |
| Scenario 1 & 2 | 6,58,000           | 800                     | 2369          | 93325                   |                                | 7                                     |

6. Conclusions

The main purpose of the study to increase the production rate was achieved. The simulation results showed the proposed plant layout is able to produce the required units of tin containers within the given cycle time. Earlier longer distances and delay times between various workstations were decreased by the proposed plant layout. Also the possibility of further increasing the capacity of the plant was checked through establishment of potential scenarios. Simulation model was built to check their feasibility.

Results of implementation of these potential scenarios showed that proposed plant would be able to produce twice as much as the existing plant layout would produce. These scenarios introduced additional cost to the plant which has to be invested for their execution. Hence payback period of the capital investment required for implementing the new proposed scenario from the additional net profit was also calculated and is estimated to be 7 days.

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