International Journal of Engineering Applied Sciences and Technology, 2021
Vol. 6, Issue 4, ISSN No. 2455-2143, Pages 311-317
Published Online August 2021 in IJEAST (http://www.ijeast.com)

KAIZEN EXECUTION IN DIGITAL WAY

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***Abstract*- The demand for a product in the market is very complex and to suit the taste of the customer, the product needs to be customized. This customization increases the product variety in the manufacturing plants which results in, difficulty in manufacturing operations such as an increase in inventory level against limited storage space, extra use of man and machine, and subsequent increase in cost. The competition among the competitor is growing stiffer day by day and thus, continuous improvement and lean manufacturing is the need of the hour to sustain in the market. This paper aims at the implementation of lean manufacturing concepts with the help of digital tools such as process simulation, discrete event simulation, digital factory, and ergonomics analysis and to evaluate the benefits of it.**

Keywords: Lean, Digital, Kaizen, Kitting, Discrete event simulation, assembly.

I. INTRODUCTION

The word Kaizen is derived from two Japanese words “Kai” and “zen”. “Kai” means change and “zen” means for the better [9]. Thus, Kaizen means "change for the better" or "continuous improvement." It is a business philosophy regarding the processes that continuously improve operations and involve all employees. Digital Kaizen in this paper refers to the concept of using digital tools such as

Discrete Event Simulation, Process Simulation, Ergonomics Analysis and Digital Factory, in the process of Kaizen. Digital Kaizen gives more flexibility, cost-effective, time-efficient, and resource independent approach, which helps to overcome the barriers of Lean Manufacturing.

Thus, this paper aims to propose a project-based implementation approach to overcome these barriers. To achieve this feat one of the tool of the Lean Manufacturing, Digital Kaizen is used.

II. METHODOLOGY

The target of the Digital Kaizen was set to optimize the manufacturing operations to eliminate the waste. The two major wastes were identified, excess storage of inventory and over utilization of space. After the identification of the targets, a cross-functional kaizen team was established to achieve the objective. Kaizen team used the PDCA cycle for the control and continuous improvement of processes. PDCA stands for plan–do–check–act or plan–do–check–adjust. Here, the Plan denotes to establish processes to achieve desired results. Do stands to carry out the objectives from the Plan step. In the Check step, the data gathered from do phase is compared with the expected outcomes. "Do" and "Check" phases help to identify issues with the process. In the Act phase, actions are taken to eliminate the issues and to achieve the desired results. The detailed step by step process flow has been described in the flowchart, shown in Figure1.

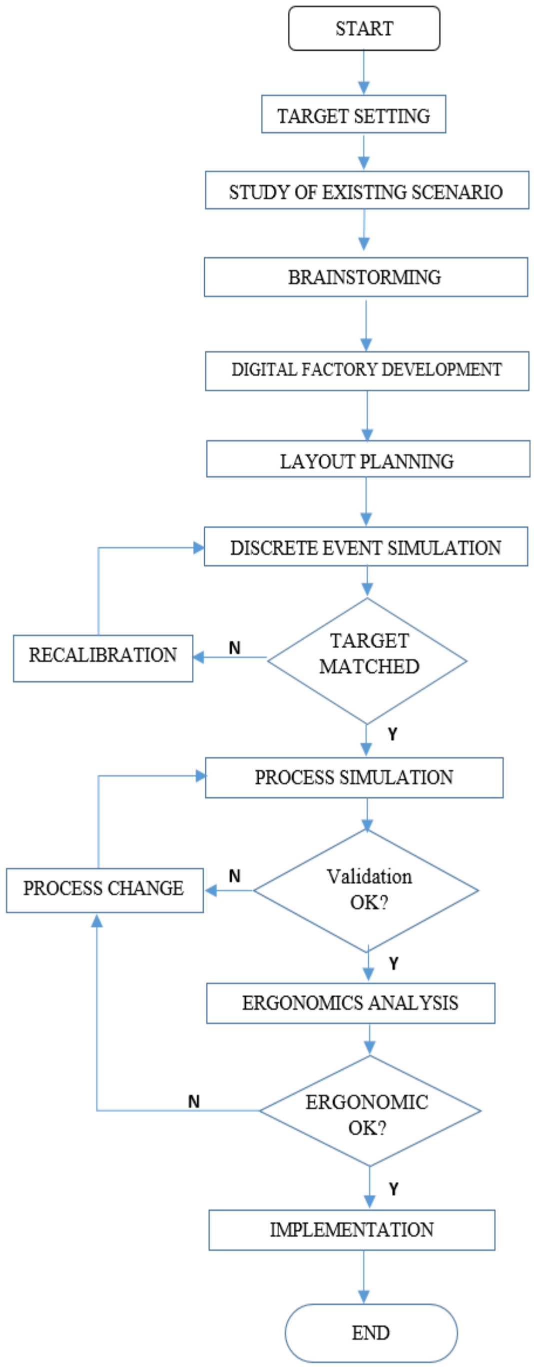

Figure 1- Digital kaizen approach

2.1 Existing scenario study and brainstorming

The chassis assembly produces thirty major varieties of vehicles. It consists of three different assembly lines, the frame assembly line, pre inversion line, and post inversion line. The digital kaizen is done phase-wise in these lines and it started with the frame assembly line. The frame assembly line consists of 12 stations. On average, each station consists of fitment of 6-8 components. Few of the components are specialized as per model while most of them are common to all models. The frame is assembled with preliminary components like brackets, nylon pipes, relay valves, air tanks, lift axle kit, etc. before transporting it to the pre inversion line. There is a total of 457 unique components that are assembled in the frame assembly line considering all the variants. Material is feed continuously to the lineside and irregular inventories are maintained near the lineside storage.

Firstly, the components data was analyzed and the components were categorized into A, B, and C class according to their shape, size, weight, and material handling equipment. 'A' category components were heavy and mostly required material handling equipment, 'C' category contains all the fasteners and small brackets, and rest all intermediate parts fall in the 'B' category. It was found that there were fifteen 'A' class components, two hundred and twenty-two 'B' class components, and two hundred twenty 'C' class components. This huge direct supply of material caused a chaos at the lineside inventory. Often due to confusion many wrong parts were fitted to the chassis. Moreover this huge material handling from warehouse to lineside store further involved a lot of resources. After a number of session of brainstorming it was decided to introduce the kitting concept in the assembly line instead of continuous supply in order to control the inventory and material flow. In kitting, materials are supplied in kits. All the 'B' class and C class parts were considered for kitting.

2.2 Development of digital factory of assembly line

In order to make changes in existing facility, one needs to better understand the existing facility and for that digital factory helps a lot. Digital Factory can be simply understood as a replica of a physical factory in the digital world. It allows to configure, model, simulate, assess, and evaluate items, procedures, and system of a manufacturing plant before the physical factory is constructed. **Figure 2** shows the cad model of the digital factory. All Simulation and validation activities are carried out in Digital Factory which is scaled 1:1 ratio of the original factory.

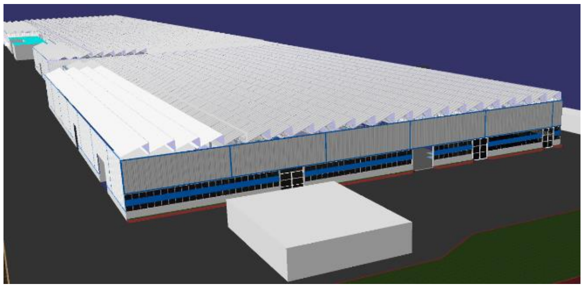

Figure 2 CAD model of the digital factory

Digital factory is developed with the help of 2D layout. The digital factory is first divided into different segments like the civil structure, assembly lines, machines, trolleys, hoists, tools, etc. Each segment consist of different number of components. All the required dimensions of the different components are gathered and CAD model is developed using CAD software. Once the CAD of all the components is ready, it is assembled as per the layout and a digital factory is formed.

2.3 Layout planning for kitting

As kitting concept is introduced in the plant, thus the material needs to be supplied in kits. In order to supply material in the kit, kits need to be prepared. Thus, an additional facility of kitting store is required where kits need to be prepared. The planning and validation for this kitting store are done digitally. First area finalization was done for kitting store keeping the constraints like material handling condition, material storage condition, space availability, and congestion on existing gangways, in mind. After the area finalization, layout proposals are developed in the Digital Factory itself. Initially, two proposals were developed. One was U shape store plan and the other was a parallel row kitting plan. Both these scenarios were validated with process simulation in which a kitting trolley was moved in the store and virtual filling trials were done. From the validation, the parallel row kitting area was considered for the operation as the U shape kitting store was consuming 60 percent more space compared to the parallel rows. Figure 3 shows the layout of the kitting store.

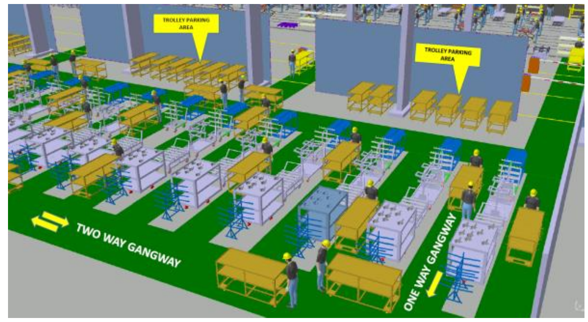

Figure 3 Kitting store layout

Benefits of Digital Layout Planning*:*

- Reduce rework by validating virtually
- Identify hurdles in processes
- Save huge time that requires for physical trials.

2.4 Material flow and space analysis

Once the store is finalised, the question arises related to supply of kits from kitting store to assembly line. The questions like number of kitting trolleys required for the material movement, number of manpower required for material movement, inventory level etc. These all question are answered with the help of Discrete Event Simulation.

The in-plant material flow optimization was done with the help of Discrete Event Simulation. In-plant material flow refers to the movement of the material inside the plant. A discrete-event simulation models the operation of a system as a (discrete) sequence of events in time. Each event occurs at a particular instant in time and marks a change of state in the system. It enables to model, simulate, explore and optimize logistics systems and their processes. In discrete event simulation, the first step is to build the model which replicates the existing material flow scenario. For example, mapping of material movement from manufacturing plant docks to their respective stores, movement of material from store to kitting store, movement of material from kitting store to kitting trolley, and their consumption in the assembly line. These models help us in the analysis of material flow, resource utilization, inventory level, and material movement distance. In these models, we can tweak the parameters like labor count, material handling equipment count, the path used for material flow, etc. to optimize our man, machine, and material used in the logistic flow.

In this case, a discrete event simulation was performed for three different scenarios, first by keeping 40 minutes of inventory at the kitting store, second by keeping the inventory of 60 minutes of inventory at the kitting store, and third by keeping 120 minutes of inventory at the kitting store.

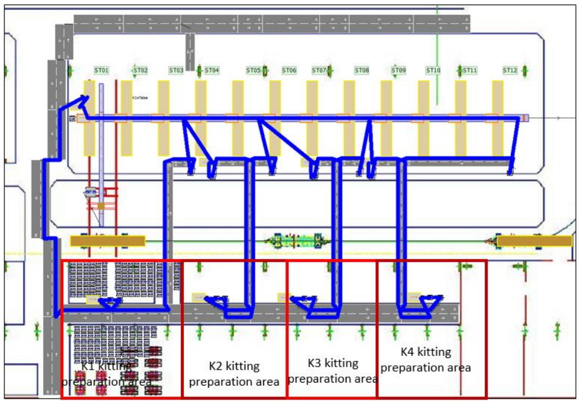

Figure 4 Material flow simulation

Here 40 minutes of inventory denotes the amount of material present in the line which can run the line for 40 minutes without any material shortage. After running the simulations, it was found that 1 hour of inventory gives the optimum results with the average utilization of labors as 58 percent, the average utilization of material handling equipment as 67 percent with optimum congestion at the gangways. The model with 40 minutes of inventory saves the storage space but showed high congestion at the gangway. The model with 2 hours of inventory consumed the most space and showed poor average utilization of manpower as 28 percent. Thus the inventory level at the kitting store was fixed to 60 minutes. Figure 4 shows the material flow panning in discrete event simulation.

Main outcomes of discrete event simulation:

- Identify excess inventory and most congested area
- Determined optimum number of trolleys and bins
- Helps to finalize optimum storage space

2.5 Kitting trolley design, ergonomic analysis and validation

From the results of in-plant material optimization, the frame assembly line which consists of 12 stations was further divided into three sections. Section 1 from station 1 to station 4, section 2 from

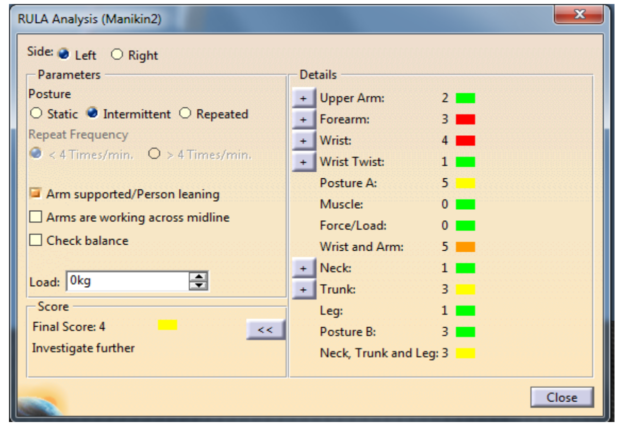

Figure 5 CAD model of kitting trolley

station 5 to station 8, and section 3 from station 9 to station 12. In a section, each frame was supplied with

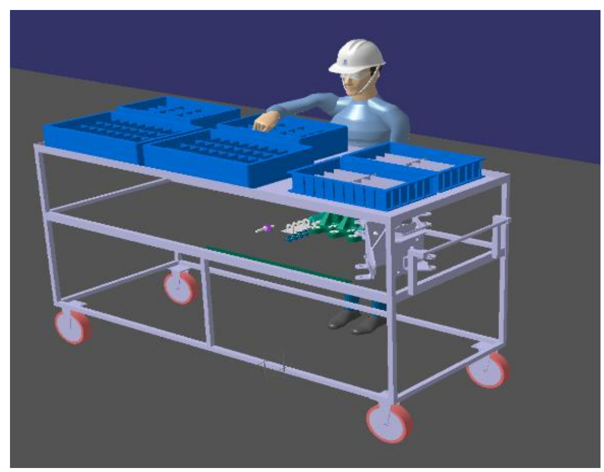

Figure 6 Concept design of kitting trolley RULA score.

a kitting trolley which contains all the parts required

for that particular frame. For example, once a frame is introduced at station 1, a kitting trolley is

attached to that frame which contains all the parts of that particular frame till station no 4 (Section 1). Once the kitting trolley reaches to the end of a section it gets empty. The empty trolley is pulled out and the new trolley is supplied for the next section and the process continues.

The different vehicle variant consists of different number of parts in each section and also different sections have different number of parts. If the kitting trolley is designed as per variant or the section than it would create a huge chaos. So, the major challenge was to design a common kitting trolley for

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different variant. Using CAD Software, the kitting trolley was designed. For validation purpose, the variant with most number of components was selected and its components were virtually placed in the kitting trolley. Using the Ergonomics Analysis and Visibility analysis the height of the shelves of the trolley was optimized for operator ranging from height of 5 feet and 4 inches to 6 feet. The designed trolley is shown in the Figure 5 for reference. Moreover, the reachability of components by the operator was also validated with the ergonomics RULA analysis as shown in Figure 6. In the analysis, the load value is taken as zero as we were concerned about the reachability not the weight of the parts. After a number of iterations on the design the final design was freezed and physical trial were done at frame assembly line.

2.6 Process simulation

With the addition of kitting trolley, many operation processes need to be validated again. For this, we approached the validation in the digital world itself using Digital Manufacturing Software. In the frame assembly line, once a framed is introduced to the line, a kitting trolley is attached to it. As we have twelve stations, each station would contain 1 frame and 1 kitting trolley, thus the space in which earlier only 12 frames were there, needs to be validated along with the 12 trolleys. The space validation was done and clearance of 1400 mm was found between the consecutive stations, which was good for operator movement. The assembly processes were also validated with the help of process and human simulation. In these simulations, the actual assembly processes are simulated in the virtual world where interference of parts, tool reachability, and ergonomics issues are validated.

III. RESULTS

After the implementation of the Digital Kaizen outcomes, evaluation was done with respect to reduction in inventory and saving in space. That have significant impact on reducing rework and cost. In next sections, inventory and space reduction illustrate briefly.

3.1 Invetory reduction

It is observed that the optimum inventory reaches in the plant when inventory at kitting store is fixed to 60 minutes. The inventory before digital kaizen and after digital kaizen are compare in the table and graph.

Table 1 - Inventory Reduction

S. No	Part Details	Before kaizen Lineside inventory (no. of cont.)	After kaizen Lineside inventory (no. of cont.)	Quantity reduced
1	Lift axle	20	12	8
2	Trunion	32	24	8
3	Arb	40	20	20
4	Battery box	16	8	8
5	V Rod	40	20	20
6	Fuel tank Bkt	90	60	30

There is significant reduction in inventory after digital kaizen. Total A class inventory was 238 before kaizen and it is reduced by 94 which is 144 after the kaizen, refer below graph.

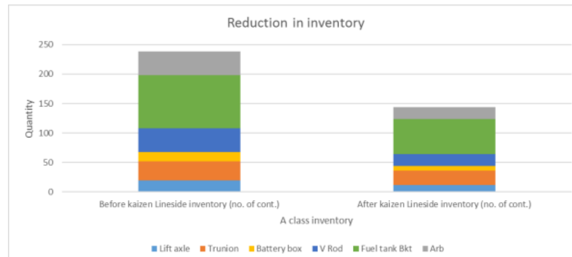

Figure 7 Inventory Utilization of A class components

3.2 Space reduction

Space reduction is analyzed from the 2D layout the before (excess inventory at lineside store) and after (60 minutes of inventory) material plotting in assembly line showed a significant area saving. Saved space has shown in the pictorial representation of area utilized before and after digital kaizen.

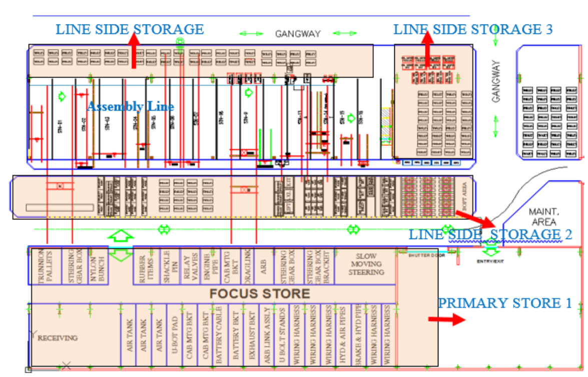

Figure 8 – Existing Layout before kaizen

After digital kaizen based on outcome to keep inventory for 60 minutes in store, huge area is saved at line side, new layout has shown in **Figure 9.**

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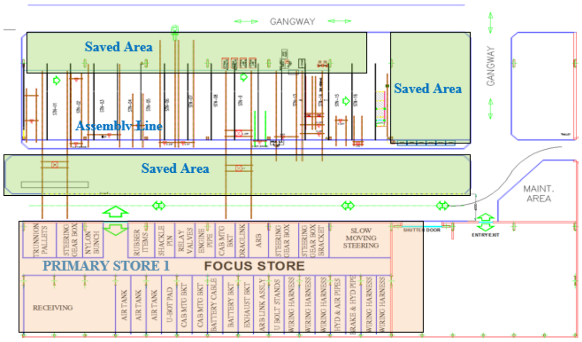

Figure 9 – New Layout after kaizen

Saved area in terms of square metre (sqm) after and before kaizen is mentioned in **Table2**. Approx. 521 sqm area is saved by implementing digital kaizen.

Table 2 – Area Calculation

Area Used	Primary Store 1 (Square Metre)	Line side Store 1 (Square Metre)	Line Side Store 2 (Square Metre)	Line side Store 3 (Square Metre)	Total Area (Square Metre)
Before Kaizen	1376.63	151.80	146.82	222.41	1897.66
After Kaizen	1376.63	0	0	0	1376.63
Space Saved					521.03

Approx. 27% area is saved that leads to improve in line side movement for the operation. Saved area has also been shown in below graph.

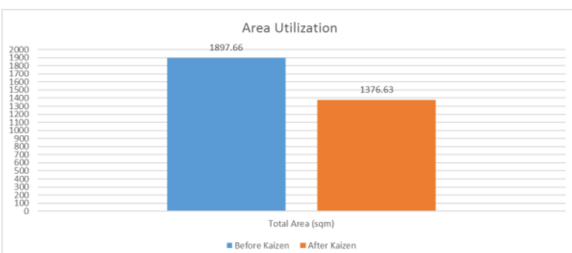

Figure 10 – Area Utilization Graph

IV. DISCUSSION

The digital advantage is calculated by comparing the digital and conventional kaizen approaches in terms of man-hours saved during the execution of the project.

Table 3 - Man-hour in Conventional Kaizen

Activity	Manpower involved	Time involved (Hours)	Trials	Total man-hours
Logistic Planning	12	120	1	1440
Trolley Design	10	32	3	960
Process Simulation and Space Validation	15	16	3	720
Total				3120

The **table 3** and **4** describes the detail calculation of man-hours involved in conventional approach and digital approach respectively. **Figure 11** shows a graph plot between the two.

Table 4 - Man-hour in Digital Kaizen Approach

Activity	Manpower involved	Time involved (Hours)	Trials	Total man-hours
Logistic Planning	6	48	1	288
Trolley Design	4	32	1	192
Process Simulation and Space Validation	3	24	1	72
Total				552

The greatest here advantage comes in form of elimination of multiple physical trials involved in conventional approach compared to the digital approach.

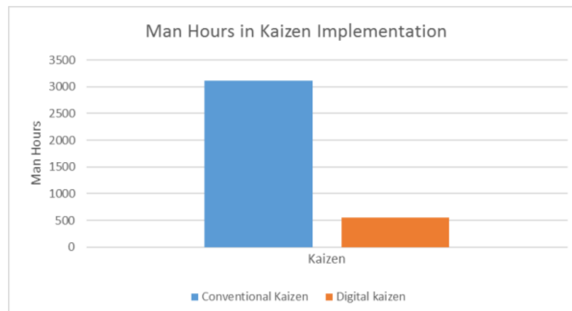

Figure 10 – Man-hour Involved

V. CONCLUSION

This paper is based on how Digital kaizen helped the Manufacturing unit to achieve lean manufacturing capabilities. The main advantage of the digital kaizen approach is that it gave a lot of flexibility in the process where modifications and re-planning can be done in no time and physical iteration was avoided. The results showed that the Digital kaizen brought the reduction in **man-hours by 82.30%**, area saving of **521.03 square meters** and part inventory is reduced by 94 parts for 'A' class components. These all waste reduction helps to take competitive advantages and achieve the objective of Lean Manufacturing and ultimately allows manufacturing units to reduce its operational cost.

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