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AN INTEGRATED DMAIC METHODOLOGY FOR DYNAMIC RESOURCE ALLOCATION IN WHEEL AXLE MANUFACTURING ENVIRONMENT

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ABSTRACT

The allocation resource in a dynamic manufacturing environment is a tedious work since the allocation is controlled by various constraints like space, resource availability, manpower, inventory motion etc. Many standard approaches are proposed by the Research and Development (R&D) division to sort out the resource allocation process, which are more specific to the particular system or organization. Even though, the outcome of the standard approach is effective but not higher than the performance of Quality Improvement Techniques (QIT). The incorporation of QIT in a dynamic system is hard because these QIT are meant for static systems i.e., the factors and their levels should be known to control it. This article aims to propose a new integrated DMAIC (IDMAIC) methodology to standardize the dynamic system and to enhance its performance. The basic quality tool is used to the study the factors and constraints of the system and further, the DMAIC integrated standard approach will be implemented to enhance the performance of the system. The Value Stream Mapping (VSM) technique is used to determine the efficiency of the proposed IDMAIC methodology. For the real-time study, this approach is implemented in a wheel axle manufacturing environment and the performance of the IDMAIC methodology is evaluated.

Key words: Lean Manufacturing, Quality Tool, Resource Allocation, DMAIC, Six Sigma.

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1. INTRODUCTION

The modern manufactures are renovating the industries into flexible and lean manufacturing environment to response the customer/client voice. In this scenario, the system becomes dynamic and controlled by various constraints like space, resource availability, manpower, inventory motion etc [1]. In this aspect, the Research and Development (R&D) division is concentrating to attain high efficiency in production rate, profit, and delivery (due date) without forgoing the lean concept [2]. The R&D is developing their methodology of execution specific to the particular organization since they are a lack in adopting universal quality tool with their standard approach. Many researchers made the attempt to incorporate the quality tool or Quality Improvement Techniques (QIT) with the standard approach to improving the performance of the system in achieving the throughputs [3, 4]. George Byrne et al. reported that lean Six Sigma initiatives led to product innovations, redesigned processes, and streamlined supplier chain and increase revenue growth by 80% [5]. Trevor Cadden and Stephen John Downes suggested a business model which makes every effort to create a more holistic view of supplier integration; extending the scope beyond the individual firm-centric factors [6]. Jiju Antony conducted an opinion survey and concluded that six sigma is uniformly applicable for large, medium and small companies [7]. In fact, the responses are more rapid in smaller companies compared to larger corporations.

Several researchers have implemented these tools and techniques in many industries and studied the barriers to improving the performance of lean manufacturing in various aspects. Pugazhenthi and Anthony Xavior [8] had implemented TPM concept through a proposed heuristic to reduce the idle time of machines in flowshop. As the outcome, the production rate had been increased twice at the standard rate. Issac et al. had addressed group scheduling problems in hybrid flowshop environment and stated that the optimum allocation of critical machines could lesser the lead time of production environment [9]. The literature clearly states that the incorporation of six sigma concepts could lead to the lean manufacturing environment. But the pass over of standard merits will result in implementation failure for a static resource system. This research work aims to incorporate the six sigma concept with adopting the standard approach and the newly proposed methodology is implemented in a manufacturing company to characterize its potential.

2. METHODOLOGY

An effective QIT for an existing system or manufacturing environment is six sigma based DMAIC concept [10]. The merging of the standard approach with DMAIC methodology could have the merits of both standard and six sigma approaches [11]. Therefore, a new Integrated DMAIC (IDMAIC) methodology has been proposed, the steps involved in it are stated below and graphically represented in Figure 1.

The IDMAIC methodology has five stages,

Stage 1: Define the system and identify the factors influencing the requirement or outcome. In other words, identify the project goal and its subgoals. In standard approaches, the Ishikawa diagram (Cause and Effect Diagram) is used to define the system target and requirements.

Stage 2: Measure is the key aspects of the system to estimate the significance of the factors, which influences the response of the system. In standard approaches, the motion of job and placements of pallets are measured using takt time methods.

Stage 3: Analyze the data and investigate the relationships of all the factors to find out the root cause of the defect. The general investigated parameters are storage, TAKT time and production rate.

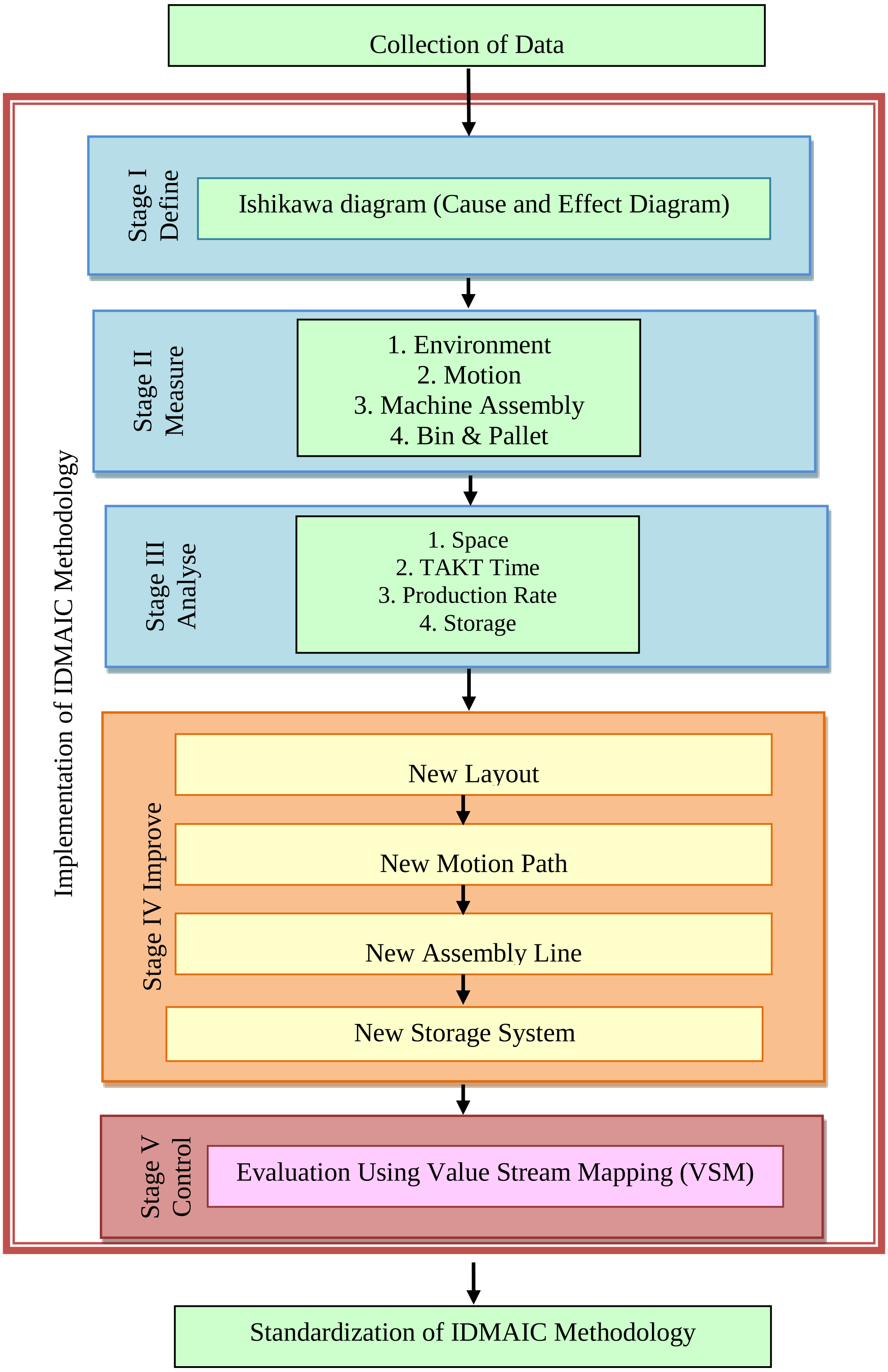

Figure 1 Schematic Representation of IDMAIC Methodology

Stage 4: Improve the process using standard techniques like the design of experiments, poka-yoke or trial and error etc. The standard approach is selected to improve the layout, motion path, and storage system.

Stage 5: Control the stages to ensure the deviations from the target. The control system is the merging of evaluation and modification to meet the target. This process is repeated until the desired quality level is obtained. The commonly used evaluation process for the TAKT time and motion study is Value Stream Mapping (VSM).

3. EVALUATION OF IDMAIC METHODOLOGY – CASE STUDY

3.1. Basic Study

For real-time evaluation of proposed IDMAIC Methodology, the job motion and storage line are selected from an axle assembly plant. The basic study is carried out to infer the available layout, design, approach and its performance. A set of survey inquiries is framed to conduct the basic study to define the system.

3.2. Implementation of IDMAIC Methodology

3.2.1. Define

A detailed study is conducted to collect the data about the factors influencing the system and its major responses. Based on the survey, the cause and effect diagram has been plotted for the assembly, layout and motion study as shown in Figure 2. The major influencing factors on resource utilization are inventory, machine operation, process control and environment.

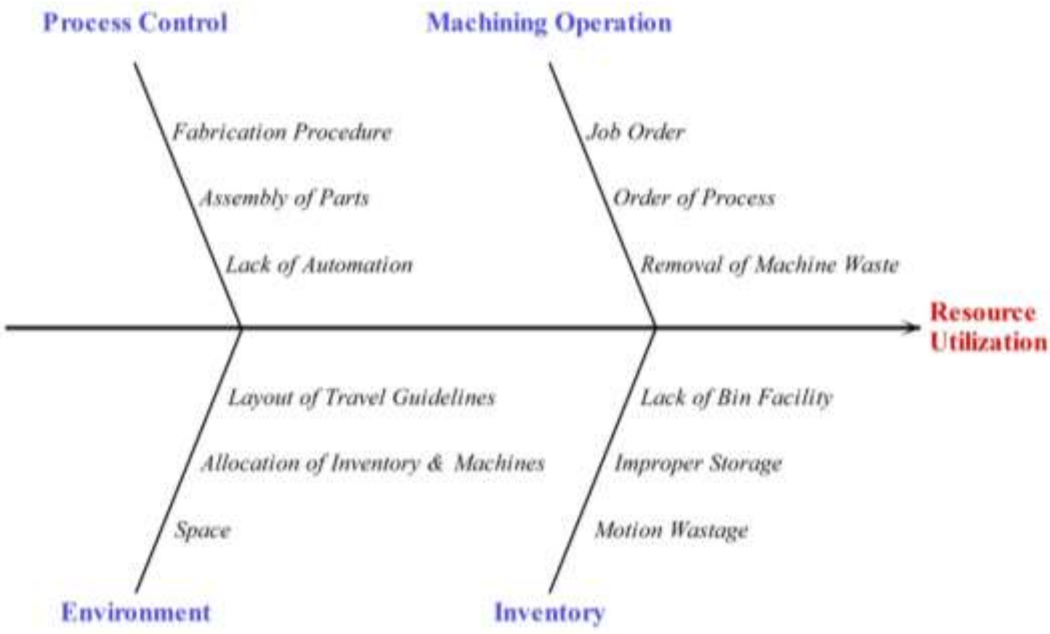

Figure 2 Cause and Effect Diagram

3.2.2. Measures

In stage measure, the source or available resources are measured to extract the benefits and demerits of the system/assembly environment. The following criteria are measured.

Environment: The area allotted for workspace.

Motion: The units of job or any resource travel in the workspace.

Machine Assembly: The layout of the machine arrangement to process the job in sequence.

Bin & Pallet: The object to transport or storage the job.

3.2.3. Analyse

Environment/Workspace

The total area covered for the study is 327.39 m^2, among that the used and unused areas are 102.25 m^2 and 225.14 m^2 respectively.

TAKT Time

In the case study organization, averagely 21 working days per month, there are two shifts per day with each have 9.5 hours. There is a break and scheduled downtime of half an hour per shift, hence the actual available hours per annum is 4536 working hours i.e. 272160 minutes.

TAKT Time = Net Available Time / Customer Demand

The net Available Time is the available time per period of time (for example, per shift) excluding breaks and scheduled downtime and the Customer Demand is Customer demand per period of time (for example, per shift). The customer demand and TAKT Time for the case study organization is furnished in Table 2.

Table 2 Customer Demand and TAKT Time for the Axle Assembly Plant

Model	Quantity	Product Variety	Customer Demand	TAKT Time (minutes)
777 Dumper	600	3	1800	151.2
2021 Loader	1080	2	2160	126.0
773 Dumper	300	3	900	302.4
1035 Dumper	252	3	756	360.0

Production Rate

Table 3 Value and Non – Value Time for Assembly Frame

S.No.	Name of Assembly	Value Addition Time (minutes)	Non – Value Addition Time (minutes)
1.	Radiator and Cowl Assembly	115	25
2.	Hydraulic Tank Assembly	75	10
3.	Fuel Tank Assembly	20	12
4.	Dual Relief Valve	6	1
5.	Steering Cylinder Assembly	10	10
6.	Tilt Cylinder Assembly	30	10
7.	Lift Cylinder Assembly	20	7
8.	Link Assembly Bucket	12	5
9.	Dump Lever Assembly	5	3
10.	Air Cylinder Bucket Leveler Assembly	25	12
11.	Front Frame Assembly	325	20
12.	Lift Arm Assembly	25	5

The production rate is indirectly termed as the value of working in each frame. Similarly, the fame could also have the non-value working time to maintain the performance of the particular frame. It is allocated for maintenance, service, idle time etc. it is necessary for every the frame to allocate minimum 15-30% of non-value time from the value/working time. The value and non – value addition time for assembly frame is tabulated in Table 3.

Storage

The storage unit is allocated to store the raw source for the axle assembly. The finished products and semi-finished products also stored in the storage unit for delivery. Around 175.04 m^2 of the unused area is allocated for a storage unit.

3.2.4. Improvement

Layout

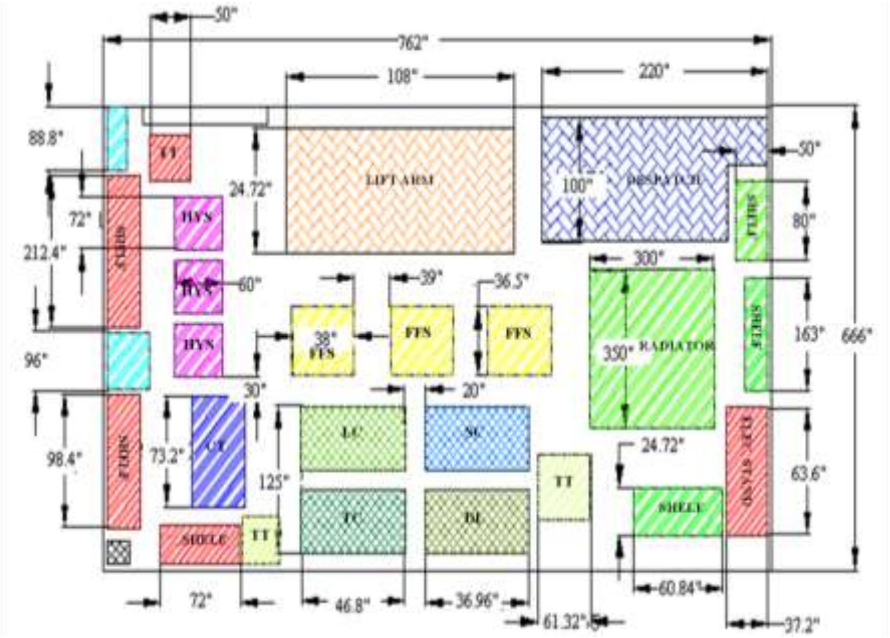

Figure 4(a) Existing Layout of the Case Study Organization

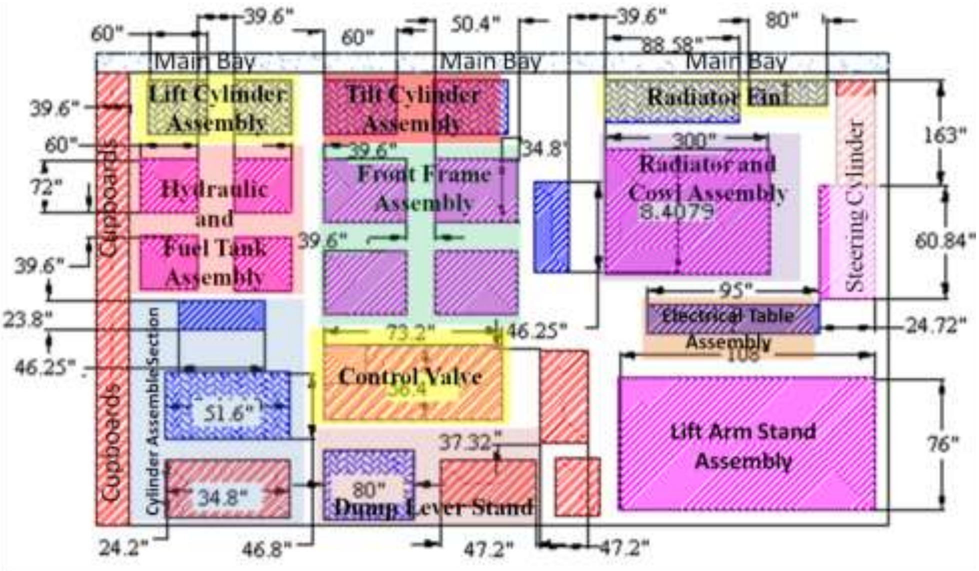

Figure 4(b) proposed Layout of the Case Study Organization

The existing layout of the case study organization is shown in Figure 4 (a) and its proposed layout is shown in Figure 4(b). The layout is changed to accommodate 6 Cabs instead 4 Cabs without the addition of space, while 3 batch works on 3 cabs material is moved for 3 cabs to completely eliminate the TAKT time.

Motion Path

The motion path in the existing layout and proposed layout of the case study organization are shown in Figure 5 (a) and (b) respectively. The three operators are fixed at three benches and the material is rearranged just behind it. The three sets of operators fixed for assembling three cabs at a time. This modification leads to TAKT time and waste walk of assemblers. The TAKT time is reduced to about 20 units by the proposed layout. In further, the material picker is arranged for kitting and kitting to start for 30 days of the action plan.

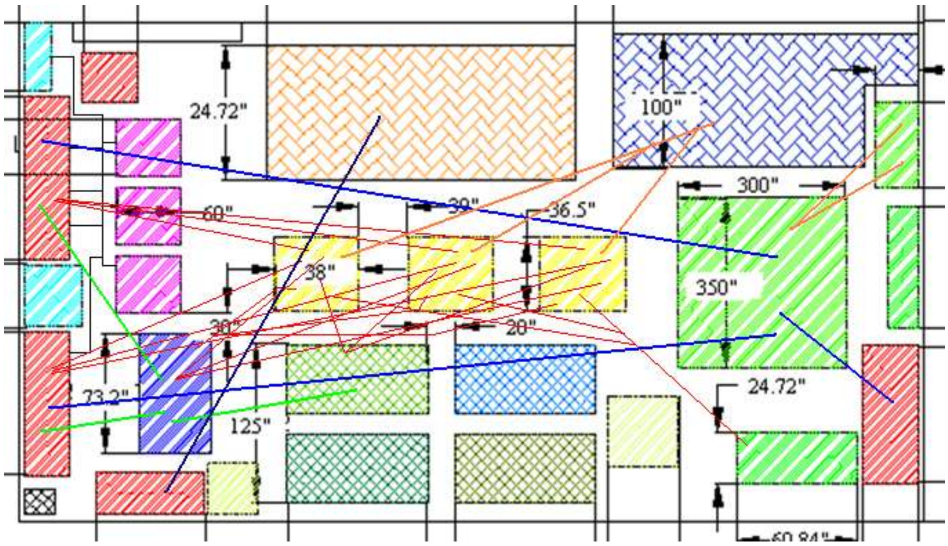

Figure 5(a) Motion Path for the Existing Layout of the Case Study Organization

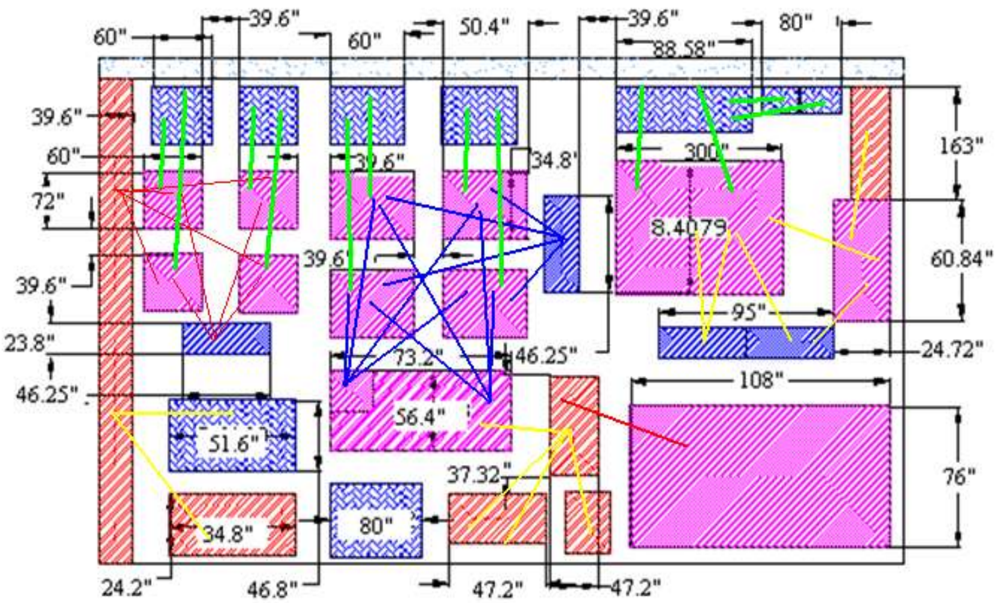

Figure 5(b) Motion Path for the Proposed Layout of the Case Study Organization

Assembly

The path line of the hydraulic assembly is changed to reduce the transportation and assembly time. The assembly paths of the existing model and the proposed model are shown in Figure 6 (a) and (b) respectively. The proposed modification leads to modification in pallet arrangement. Even though the expenses arrived, the overall outcome of the 30 days work plan could reduce around 12.7% of the net available time.

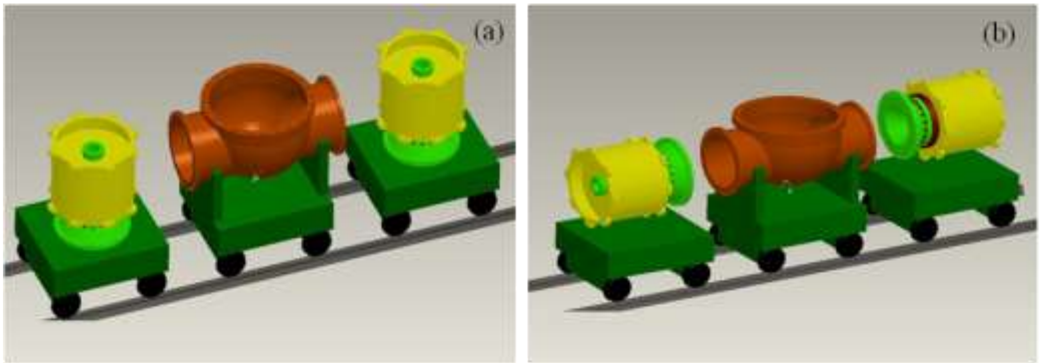

Figure 6 Assembly Paths for (a) Existing Model and (b) Proposed Model

Storage

The storage unit is allocated with excess space in the existing model (Figure 7 (a)). Therefore, to reduce the storage unit and to support the transportation of products and raw material, the pallets are redesigned and modified as shown in Figure 7 (b). In further, the front, side & steering panels, seat and headliner are stored 100 m away locations created to free the storage space. By the impact of pallet modification, the travel time/transportation time of the product is reduced half of the actual time.

Figure 7 Photography of (a) Existing Pallet Model and (b) Proposed Pallet Model

Figure 8 Photography of (a) Existing Bin Model and (b) Proposed Bin Model

Similarly, the bins to store the accessories and raw products are designed and modeled as shown in Figure 8. By the impact of bin modification, the handling and stock maintenance is improved and the quality of infrastructure is improved.

3.2.5. Control

The control is the stage to maintain the performance of the proposed or improved system. To estimate the performance of the proposed methodology, the Value Stream Mapping (VSM) is carried. For this analysis, a random shift is selected out of 42 shifts of a month. The shift time, worker performance, machine efficiency, and material availability are standardized. For the standardized system, the production rate is analyzed. As an outcome of the proposed methodology, the weekly demand is attained about1.5 times faster than the existing solution. It is measured in terms of the production rate of a shift, i.e. the target of a day is 4 units. The existing solution outcome is 4 units a day and the proposed methodology outcome is 6 units a day. Therefore, the target can be achieved in 4 days of a week i.e. 28 shifts out of 42 shifts is enough for attaining the total outcome.

4. RESULTS AND DISCUSSION

The performance of the proposed IDMAIC methodology is analyzed by comparing with the standard approach. The comparison is conducted in terms of people, cost and quality; and the results are tabulated in Table 4. From Table 4, it is inferred that the quality of the product by IDMAIC is increased twice of the product by the standard approach. Along with the improvement of quality, the value of manpower and cost are increased.

Table 4 Comparison of Standard Approach and Proposed IDMAIC

	Metric	Baseline	Target	Current Status		After 30 Days	
				Value	Improvement (%)	Value	Improvement (%)
People	Standard Approach	1.7	2.85	2.7	94.7%	2.8	98.2%
	IDMAIC	0	5	4	80.0%	6	120.0%
Quality	IDMAIC	0	5	3	60.0%	6.0	120.0%
Cost	IDMAIC (TAKT Time)	183.0	130.0	120	108.3%	100.0	130.0%

5. CONCLUSIONS

The IDMAIC methodology has been proposed successfully to integrate the standard organization approach with the DMAIC of six sigma tool. A case study has been carried out in an axle assembly environment to evaluate the performance of the IDMAIC methodology. A survey is taken to understand the cause and effect of the standard approach in the system. From that the major influencing factors, which influences resource utilization are identified along with the remedies. The implementation IDMAIC methodology along with the standard approach of the system has improved resource utilization and attained 1.5 times improved production compared to standard approach; even though the value of manpower and cost are increased to 3.5% and 21.7% respectively. As overall, the proposed IDMAIC methodology has better efficiency in turning the system to lean manufacturing environment. In further, this kind of approaches needs to be examined specific to the system.

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