Development of a Systematic Framework to Optimize the Production Process in Shop Floor Management

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Abstract In the production process, waste elimination on the shop floor is an essential task to increase production levels. Various approaches like kaizen, total quality management, six sigma, and lean six sigma are used for this purpose; however, lean management proves itself a prominent approach to achieve a high level of productivity. This information paves the way for the present study. In this article, the authors attempted to develop a framework for optimizing the production processes by identification of the wastes in shop floor management. The results of the study showed that the developed framework can reduce processing time, production time, and production costs as well as improve the quality level. The novelty of this work lies in the fact that the implementation of the developed framework has been lead to optimization and improvement in production on the shop floor. On the basis of acquired results, authors strongly believe that the present work will be highly beneficial for industry persons and researchers to improve shop floor management.

Keywords Production planning · Shop floor management · Waste elimination · Modeling · Process optimization

1 Introduction

Production systems that manufacture several products and work in highly competitive environments are focused to meet consistently high productivity levels within limited constraints [1–4]. Here, constraint means resource availability like time, machinery, cost, shop floor area, and worker. Such a competitive environment can be regulated by planning an appropriate production framework. Planning production

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framework is a critical issue in the manufacturing environment; in the worldwide industries, a very high amount is spent on production planning that requires improvement in strategy and technique [5–7]. An extensive research work has been done in previous decades on production framework development for shop floor management. However, emerging thinking that the developed production framework has not suitable for a dynamic environment where highly volatile production environments. The developed framework has been implemented for stable demand conditions.

The process improvement technique has been implemented for shop floor management extensively in previous research articles. The proposed framework has emerged as an alternative to improvement in shop floor management by using process improvement techniques. The process improvement techniques mainly include lean manufacturing, kaizen, total quality management, and six sigma [8–11]. These techniques have been implemented for productivity enhancement and resource optimization [12–14]. The modified framework of process improvement techniques maximizes productivity because it enables the identification and elimination of waste. Waste means non-productive activities of the production system.

Vinodh et al. [15] have explored shop floor improvement in a systematic manner by value stream mapping (VSM) and showed an important role of the framework in the enhancement of productivity in the manufacturing environment. Garre et al. [16] have identified problems in the production line of a pressure vessel manufacturing by implementing the lean concept. The result showed that productivity enhancement has been obtained by the elimination of non-productive activities such as excessive inventory time and transportation time. Kumar et al. [17] proposed an integrated framework for optimizing resources using VSM and fuzzy and implemented on the shop floor of a storage tanks manufacturer. The effectiveness, quality, and cost have been reduced as a result of the study by the implementation of the proposed framework. Tripathi et al. [18] proposed a framework for the elimination of non-productive activities using lean techniques. It was found in the study that the productivity of automobile industries may have improved by the implementation of the proposed framework. Yadav et al. [19] have proposed a lean six sigma (LSS) and fuzzy-based hybrid framework for quality improvement and reduction of non-productive activities. The developed framework robustness has been evaluated by obtained improvement in the manufacturing industry. Coppini et al. [20] implemented a simulation tool software using VSM in an industrial gearbox industry. It was revealed as a result that 56.7% productivity improvement, 60% reduction in lead time, 10% reduction in idle time for the supplier, and 30% reduction in idle time for foundry has been obtained by the modified framework. Salleh et al. [21] investigated total quality management and lean implementation in a forming industry using Delmia Quest Software. It was revealed as a result that the implementation of Delmia Quest Software with the proposed framework was able to obtain improvement in production. Andrade et al. [22] have implemented VSM and simulation in an assembly line of the clutch disk manufacturing industry. The result of the study revealed that the integrated approach of VSM and simulation was an efficient framework, and obtained 7% reductions in production time and also improved 10% in the use of work position. In the proposed framework in this research work, the process improvement technique has been used to improve production and optimize resource utilization.

2 Research Objective

The objective of the present research work is to investigate the effect of the process improvement technique using the proposed framework to enhance the production performance of the manufacturing unit. The following challenges and problems are considered in the present work.

1. Higher production time due to change over time (CO).
2. Higher production time due to cycle time (CT).
3. Higher production time due to non-value-added activities.
4. Higher production time due to unskilled worker.
5. Higher production time due to improper material handling.

3 Research Methodology

A methodology has been designed using production information for shop floor management by statistical analyses. The methodology is consisted of 7 steps and shown in Fig. 1.

Section 1 comprised information related to production is collected, while in Sect. 2, the production operations in the industry are shown on a map. Section 3, observed the non-productive activities in production. A mathematical model is developed in Sects. 4, 5 and applied to a mining machinery manufacturing unit, and the improvement in Sect. 6 was evaluated with the help of ANOVA, suggesting that if the model meets the criteria If applicable, then the floor management of the shop should be implemented otherwise Sect. 4 should be repeated again.

4 Research Gap

It is concluded from the literature review that most of the research was based on productivity improvement using the revised framework. In these researches, there was no study of production within resources and capital costs. It was very clear from the literature that lean manufacturing was a prominent process improvement technique and most preferred in a competitive environment, in comparison with other techniques like kaizen, total quality management, six sigma [23–25]. Lean manufacturing has a combinatorial effect on productivity improvement and it can work within limited resources [26–28]. This research work attempts to enhancement in productivity and optimization of resources within limited constraints by the lean manufacturing philosophy. Here, Constraints mean resources availability and budget.

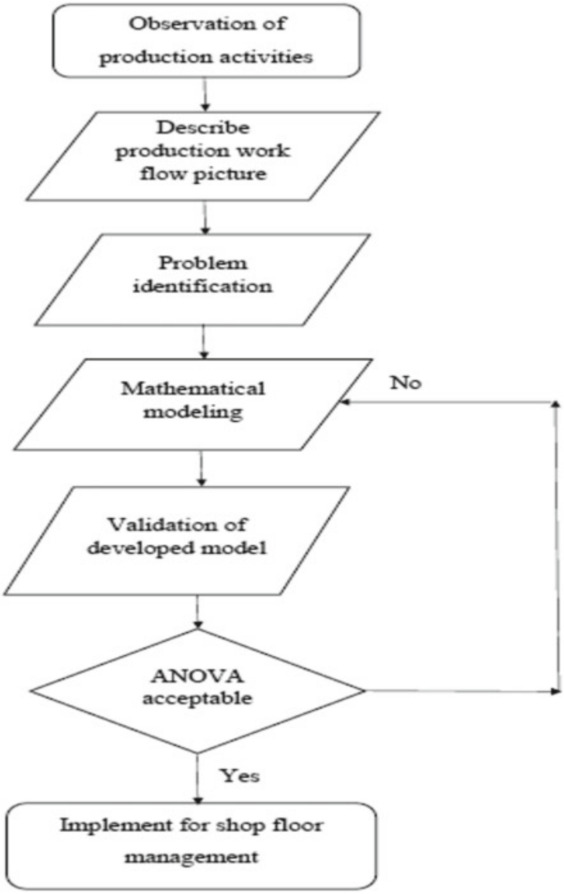

Fig. 1 Research methodology

5 Industry Description

The present research work has been performed in ABC Pvt. Ltd. manufacturing located at India. ABC Pvt. Ltd. is a leading manufacturer of earthmoving equipment (skid steer loader). Skid steer loader is a miracle in the earthmoving machinery due to its compactness and versatility. When this skid steer loader comes to the test of strength and surviving in the Indian conditions, it proves its reliability over any other earthmoving machinery. Figure 2 shows the observed production workflow on the shop floor.

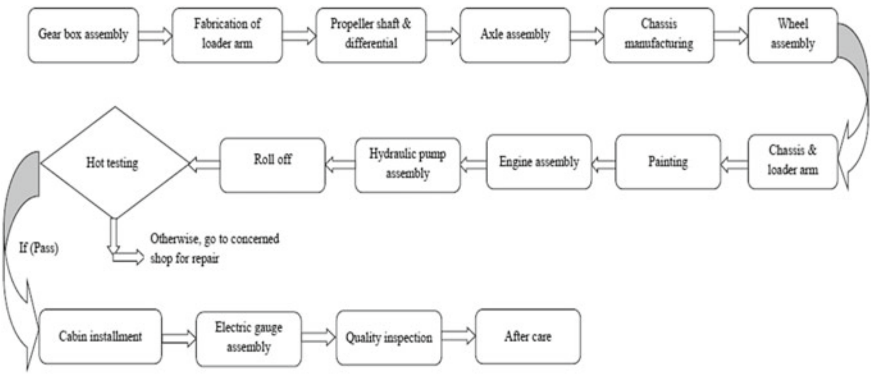

Fig. 2 Flow chart of production processes

6 Results and Discussion

It has been observed during the inspection of the shop floor that the present industry is facing problems regarding the higher production time. The problems have been identified in the changeover time, worker, cycle time, and unnecessary activities of different production processes. These problems significantly affect the budget and resources utilization of the industry. Therefore, it is required to get rid of these problems for shop floor management. Thereby in present research work, a framework has been developed using lean manufacturing to eliminate waste. Table 1 shows identified problems by the implementation of a lean manufacturing technique on the shop floor.

The developed mathematical model helps us to obtain quantities and variables of production needed for improvement in productivity. In this manner, production on the shop floor has been simulated using the Minitab software. This simulation will determine the productivity level with the optimization of resources. This mathematical model has been developed according to the following production data and shown in Table 2. Production data has been collected by shop floor observation and discussion with employees of the industry.

After analysis, an equation in terms of production has been developed. Equation (1) shows the developed second-order quadratic mathematical model.

$$\begin{aligned} PT = {} & +168.46729 + 2.47415\,CT - 0.12353 * CO \\ & - 46.32216 * NO - 62.78335 * NA + 0.067126 * CT * CO \\ & - 0.85213 * CT * NO - 0.13303 * CT * NA - 0.29786 * CO * NO \\ & - 0.45042 * CO * NA + 26.78279 * NO * NA \end{aligned} \tag{1}$$

An analysis of variance (ANOVA) has been performed to check the adequacy of the developed model. The results of ANOVA for *PT* are tabulated in Table 3.

Table 1 Identified problems on production shop floor

S.N	Process	Problem
1	Gearbox assembly	Higher change over time
2	Fabrication of loader arm	Lack of material handling equipment and worker
3	Propeller shaft and differential assembly	Lack of worker, location of operation
4	Axle assembly	Lack of planning
5	Chassis manufacturing	Higher change over time
6	Wheels assembly	Lack of shop floor area
7	Chassis and loader arm fabrication	Higher setup time, more workstation
8	Painting	Outsourcing
9	Engine assembly	More workstation, lack of worker
10	Hydraulic pump assembly	Lack of planning, lack of material handling equipment
11	Hydraulic motor assembly	Lack of planning, lack of material handling equipment
12	Roll-off	Unnecessary process
13	Hot testing	Lack of worker, lack in shop floor area
14	Cabin installment	Lack of planning
15	Electric gauges assembly	Lack of equipment
16	Quality inspection	Lack of planning, more workstation
17	Aftercare	Lack of planning, unnecessary process

99% confidence level is considered in performing ANOVA, which indicates that the P-value of developed models should be lower than 0.01 for adequate and reliable response model. From Table 3, it has been observed that the calculated P-value for the developed mathematical model is lower than 0.01. P-value helps to decide the rejection or failure or rejection of the null hypothesis. Therefore, it has been confirmed that the developed mathematical model has a higher degree of fitness to predict the values of the corresponding response. The calculated F-value of the response model has also been found within the acceptable range for the KW, KD, and KT as 25.47, 17.87, and 14.11 respectively.

7 Conclusions

In the present work, the authors developed a framework using lean manufacturing and validate by a case example of the earthmoving machinery manufacturing industry. This research work attempts to develop a mathematical relationship among various production parameters which include the effect of the worker, CT, CO, number of

Table 2 Production data analysis for mathematical modeling

S.N	Operation	Abbreviation of operation	Processing time (minute)	CT (minute)	CO	No. of operator (NO)	No. of activities (NA)
1	Gearbox assembly	*A*	125	90	30	2	5
2	Fabrication of loader arm	*B*	195	110	30	2	4
3	Propeller shaft & differential assembly	*C*	95	70	20	3	7
4	Axle assembly	*D*	65	35	20	3	6
5	Chassis manufacturing	*E*	210	160	40	4	5
6	Wheels assembly	*F*	85	60	35	4	3
7	Chassis and loader arm fabrication	*G*	215	175	40	5	6
8	Painting	*H*	2520	480	120	5	5
9	Engine assembly	*I*	145	90	35	3	6
10	Hydraulic pump assembly	*J*	45	30	15	2	4
11	Hydraulic motor assembly	*K*	55	35	40	2	4
12	Roll-off	*L*	45	25	45	3	2
13	Hot testing	*M*	3095	3000	55	5	7
14	Cabin installment	*N*	185	125	35	3	6
15	Electric gauges assembly	*O*	235	195	25	3	5
16	Quality inspection	*P*	125	95	20	3	4
17	Aftercare	*Q*	45	25	15	2	3

Table 3 ANOVA table of the processing time

Source	Sum of squares	Degree of freedom	Mean square	*F*-value	*P*-value
A-CT	52,861.47	1	52,861.4	159.4	0.0001
B-CO	19,473.73	1	19,473.7	58.74	0.0003
C-NO	4693.69	1	4693.69	14.16	0.0094
D-NA	389.79	1	389.79	1.18	0.3199
AB	16,215.52	1	16,215.5	48.91	0.0004
AC	5150.87	1	5150.87	15.54	0.0076
AD	387.55	1	387.55	1.17	0.3211
BC	18.41	1	18.41	0.056	0.8215
BD	344.52	1	344.52	1.04	0.3473
CD	367.05	1	2367.05	7.14	0.0369
R-Squared 99.98%			Adj R-Squared 99.96%		

steps, and process time. Based on real production information, these factors have been mathematically modeled.

The following conclusions are drawn from the present research work:

1. It has been observed that the proposed framework can improve the process performance and optimization of resources.
2. The proposed framework is enabled to reduce CT, CO, production activities, and costs.
3. It has also observed that the proposed framework remarkably reduced processing time and this reduction has been validated by mathematical modeling.
4. Processing time is improved by changing the production parameters and processing time has an effective influence on productivity, cost, and delivery time.
5. The authors of the present research work strongly believe that the present framework could be beneficial for industry persons in the enhancement of productivity level.

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