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Assessing the moderating role of the extent of implementation of lean methods in predicting productivity improvement

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Abstract

Purpose – The study aims to explore the argument of implementing the lean method to part or whole of an operation by examining the moderating impact of varying levels of the extent of implementation of four different lean methods, along with their functionalities, in predicting productivity improvement (PI).

Design/methodology/approach – As the focus of understanding the efficacy of lean principles is shifting from process to industry level, this study tried to generalize the approach by gathering data from 132 large Indian auto component manufacturers. This involves an assessing/monitoring approach rather than measurement.

Findings – Results highlighted the interdependence or individuality of the extent of implementation of lean methods and their functionalities. Findings revealed a significant moderating effect in improving productivity to a greater extent of 50%.

Research limitations/implications – Adopting an assessment approach to a measurement study provides a noteworthy contribution to bridging theory and practical consequences. The findings can be appropriately extrapolated to medium and small enterprises forming a critical connection in the entire automobile manufacturing ecosystem.

Practical implications – The study showed that even if a lean method is applied to a certain extent of operations the chances of PI are significant. This is important for decision makers as they confront problems of optimum resource allocation.

Social implications – PI, reduced cost and generalization of results would enable the auto component industry to become more competitive.

Originality/value – The examination of the moderation effect of a lean principle implementation extent, along with that of its functionalities to predict the improvement in productivity from its existing level, is a major outcome of this study.

Keywords Lean methods, Kanban, Single-minute of exchange die, Systematic layout planning, Standardized work, Productivity, Assessment

Paper type Research paper

Introduction

The benefits to productivity improvement (PI) with the adoption of lean methods, such as Kanban, Kaizen, single-minute of exchange die (SMED) and layout standardization have

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been well established and documented (Dresch, Veit, de Lima, Lacerda, & Collatto, 2019; Rajagopalan, 2020). The studies have emphasized the functionalities of these methods in removing/reducing different types of waste. Moreover, each method has multiple functions, such as Kanban prescribing reduced inventory and overproduction. Considering the multiplicity of functions, this study intends to highlight which functionality contributes to the greatest extent to PI. This influence over the productivity outcome was further enriched by examining the impact of varying levels of the extent of their implementation. Such examination entails understanding whether PI gets significantly augmented by applying changes to a part or all the operations. Due to the extensive number of steps, a process becomes immense so applying a lean method to the entire process may not be feasible considering cost and time constraints (Souza, Lacerda, Riehs Camargo, Dresch, & Piran, 2018). Thus, to examine the varying levels of implementation, for instance, 25%, 50%, 75% or more, of different lean methods, this study has assessed their moderating effect along with the direct effect of their functionalities. Fundamental to this assertion is that the higher the principle implementation level, the higher the benefits (Ahlstrom et al., 2021). This is significant in highlighting the interdependence or individuality of lean methods and their functionalities. Moreover, this effect was examined on the ability of lean methods to predict improvement in productivity from existing level. Therefore, examining the moderation effect of the extent of a lean principle implementation and its functionalities is a major outcome of this study.

Another highlight of this study is its approach to the *assessment* rather than the *measurement* of mentioned impacts. The reasons are twofold: firstly, past studies (Demeter & Matyusz, 2011; Psomas, 2021) have emphasized measuring the effect by deducing improvement in individual key performance indicators of lead-time, cycle time, material movement, etc. However, this was firm-specific and not at the industry level. At the firm level, the outcomes of such indicators vary from one organization to other. Secondly, organizations tend to implement a combination of lean methods each with a specific role in eliminating particular waste, rather than only a single method to accrue maximum benefits. In such cases, managerial perspectives recorded in the interval form, like, the implementation of Kanban, have reduced over-production by 25%, and SMED by 50%, thus becoming more viable than measuring variety of indicators for each firm. Thus, assessing the managerial perspective of the degree of implementation was applied to generalize the interactive effect between extent and functionalities and the integrative effect of the number of lean methods.

Theoretical background

Lean manufacturing

Lean manufacturing is a philosophy for structuring, operating, controlling, managing and continuously improving industrial production systems. Lean manufacturing aims to minimize waste in the process that does not add value but incurs a cost (Ledon, García, Vega, & Bernabe, 2018). It is termed lean because it uses fewer resources, such as labor, manufacturing space, inventory, time in designing new products and investment required for production compared to mass production (Bhamu & Sangwan, 2014). Implementing lean principles effectively reduces waste and strengthens the entire production process, especially when there are risks of supply disruptions (Hu & Kostamis, 2015). The fundamental aspect of a lean system is developing a continuous improvement in the environment within manufacturing organizations by eliminating inefficiencies, thereby improving employee motivation (Alptekinoglu & Ramachandran, 2019). This is important as benefits tend to show an upward trend at the beginning, which tapers off significantly without consistent involvement of the workforce (Netland & Ferdows, 2016).

However, implementing the lean system provides only marginal gains in productivity in small- and medium-sized firms due to a lack of willingness amid management towards the effectiveness of these methods. Workforce intervention in the form of constant improvement and monitoring rather than a one-time application is the bedrock of a lean system (Zhou, 2016). Unfortunately, such an approach was majorly lacking in small and medium enterprises (Brown, Schmitt, & Schonberger, 2015). However, in large-scale suppliers, such impediments were few providing impetus to effective implementation and making this study on the assessment of lean methods' feasibility.

Kanban

Suppliers apply a batch production system for their operations, as they are required to produce different versions of products for OEMs. This makes operations irregular and hinders keeping inventories low (Muller, Tolujew, & Kienzle, 2014). Providing multiple products requires flexible workstations with minimum waiting time and defective items. Kanban is seen to fulfil these objectives quite effectively as it does not allow production until there is customer demand (Olaitan, Yu, & Alfnes, 2017). Moreover, scheduling intermittent production by incorporating the Kanban system significantly reduces inventories and thus improves productivity (Bernegger & Webster, 2014). The Kanban system is designed to minimize inventory and deliver the raw material or semi-finished goods to the next machine only when asked. Thus, under this system, only the correct quantity of product is made available at the right time reducing the over-production waste (Garza-Reyes, Kumar, Chaikittisilp, & Tan, 2018). Simic et al. (2021), highlighted the importance of the Kanban system in improving the transportation of materials from one workstation to another with minimal work-in-process inventory when it is effectively combined with material flow management in the automotive industry (Yang, 2000).

Above discussed relevant literature highlighted significant functionalities of reducing over-production and inventory. However, testing the combined effect of both functionalities and their interaction with the extent of implementation of Kanban led to the formulation of the following hypothesis which was directional, as the interactive effect was inferred to have greater influence:

H1. The interactive effect of the extent of Kanban implementation and its functionalities on PI is greater than their individual effect.

Single-minute exchange of die

Suppliers providing a variety of parts or components to fulfil the demand of OEMs face the challenge of reducing set-up time between two production orders. However, as the machines remain dormant while being set up, it results in capacity losses, unnecessary inventory and delays in responding to customer needs (Gel, Fowler, & Khowala, 2020). Such a state is termed *wasteful activity* and adds no value to the final product in lean philosophy. The SMED method developed by Dillon & Shingo (1985) effectively reduced set-up times by identifying and eliminating wasteful activities during changeover (Singh, Singh, & Singh, 2018). The method provides flexibility to production processes making them responsive to the demand for various products. In addition, reducing set-up times helps in effectively planning batch sizes allowing suppliers to successfully implement product variety as a competitive strategy (Dave & Sohani, 2012).

Thus, the SMED method is instrumental in improving production metrics of set-up time, cycle time and especially work-in-process inventory. However, examining the influence of these functionalities along with varying degrees of implementation led to the testing of the following hypothesis:

H2. The interactive effect between the extent of implementation of SMED and its functionalities on PI is greater than their individual effect.

Layout standardization/systematic layout planning

In the competitive business environment of providing a range of products with short product life cycles, machines and processes need to be flexible, and the layout of a manufacturing facility should be adaptable and less rigid (Hosseini, Wong, Mirzapour, & Ahmadi, 2014). Agility inbuilt into layout design significantly reduces material handling cost and improves other productivity measures, such as transportation costs and lead time (Potadar & Kadam, 2019). New layouts have been effectively designed through various procedures, such as systematic layout planning (SLP), simulations (Derhami, Smith, & Gue, 2020) or the application of quantitative methods such as quadratic assignment programming (Vitayasak, Pongcharoen, & Hicks, 2017). However, the simplicity of the application and emphasis on giving proper importance to human experience in complex decision-making made SLP, originally developed by Muther & Wheeler (1994), an effective method in layout optimization resulting in productivity enhancement.

Thus, the prime functionalities on which the effectiveness of the SLP lean method is measured are the reduction of material movement time and set-up time between processes with the least disruption. However, any drastic changes in a layout are always a costly process and thus should be avoided. Testing the ideal situation of a low degree of implementation of SLP, a higher impact on productivity and the influence of its functionality led to the following hypothesis:

H3. A low degree of implementation of SLP, along with its functionalities, has a greater impact on PI than a high degree.

Standardized work

The unnecessary motion of both man and material is another form of waste demonstrated in lean principles, delaying the performance of value-adding activities and leading to the loss of productivity (Whitmore, 2008). Standardizing activities, as suggested by the lean philosophy in the automotive industry, decreases variations in job functioning (Thurer, Stevenson, Silva, Land, & Fredendall, 2012). Work and time study methods help standardize the activities, so they are performed in a structured manner (Zare, Croq, Hossein-Arabi, Brunet, & Roquelaure, 2016). This becomes essentially important in the case of jobs involving a series of tasks, as is the case of auto component manufacturers. Standardizing work activities by these suppliers was instrumental in reducing the waiting time, cycle time, over-processing and wasteful motions (Mor, Bhardwaj, Singh, & Sachdeva, 2018). More importantly, standardizing the work provided discipline to work culture, considered the core of a lean system to proliferate. Further benefits of documentation of the process, reductions in variability, easier training of new operators, reductions in injuries and strain and a baseline for improvement activities through standardization significantly affect PI (Johansson, Lezama, Malmsköld, Sjögren, & Ahlström, 2013). Thus, work standardization provides qualitative benefits in addition to quantitative measures.

Therefore, instead of measuring performance towards improving individual productivity metrics, the approach to assessing such improvement along with the extent of its implementation by observing the degree of overall PI led to the following hypothesis:

H4. The interactive effect of the extent of implementation of standardized work and its functionalities on PI is greater than individual functions.

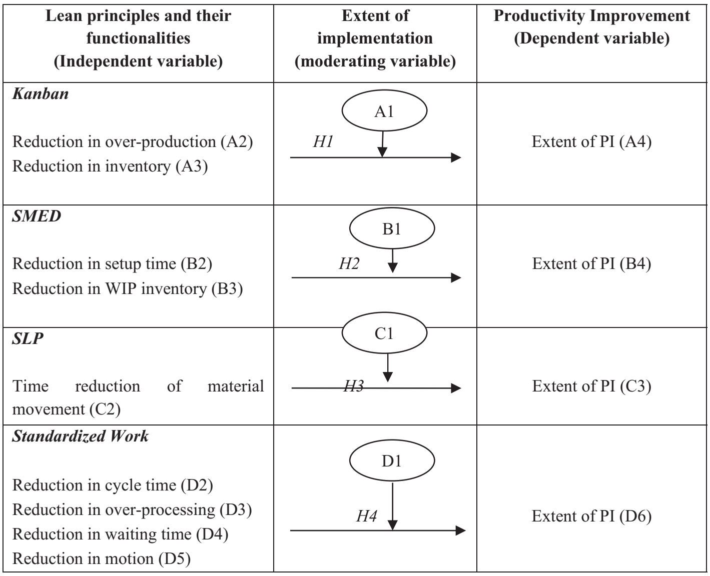
The hypothesis involving the relationship between the extent of implementation of selected lean methods, their functionalities and their influence on PI is shown in the following model (Figure 1).

Methodology

Pilot study for identification of major lean methods in the auto component industry

In the pilot survey, 30 large auto component manufacturers were asked three questions: firstly, participants were required to select the type of waste they confront in shop floors out of seven established waste types in the lean philosophy. Secondly, the respondents were required to select the most effective method to reduce waste from a list of various lean methods. Lastly, the extent of these waste reduction methods was measured by categorizing the response into five groups, as "to the extent of 0%, 1%–25%, 26%–50%, 51%–75% or >75%".

Results showed that 40% of the firms accepted that Kanban implementation helps reduce over-production and inventory to the extent of >75%, whereas greater than 50% considered it to be an extent of 51%–75%. Similarly, 50% of the firms accepted that SMED implementation helps reduce inventory and set-up time to the extent of >75% and 25% to the extent of 51%–75%. On the other hand, 45% of the organizations accepted that SLP helps in time reduction of material movement to the extent of >75%, whereas 40% to the



Source: Figure by authors

Figure 1. Conceptual model

extent of 51%–75%. Lastly, 50% of the organizations accepted that standardized work (SW) helps reduce over-processing waiting and motion to the extent of >75%, while 40% to the extent of 51%–75%.

Main study. The study aimed to examine the contribution of varying degrees of lean methods to PI of large auto component manufacturers in India. Therefore, the first step was to select such manufacturers. According to 2020 Auto Component Manufacturer Association report (https://www.acma.in/annual-report.php) 30% of firms (approximately 250) out of 832 auto component manufacturers in India are large enterprises. These are direct suppliers to OEMs and have either implemented or are in the process of implementing lean methods. Therefore, the entire population of these 250 suppliers was contacted to be part of this survey. However, only 132 (52.8%) agreed, making a sample size greater than 50%, which is considered fairly representative of the population (Field, 2013). Furthermore, this sample was reduced to cover only those firms that had already established lean methods. This also fulfils the condition of assumptions, such as enough human involvement and resource availability for applying lean methods.

For data collection, one manager from every firm was selected for the study who was responsible for implementing lean methods in these firms. The participants were administered a detailed structured questionnaire. The questionnaire had specific statements regarding each of the four lean methods. For Kanban, they were coded as A1 (moderator), A2 and A3 (independent) and A4 as a dependent variable; for SMED, B1 (moderator), B2 and B3 (independent) and B4 (dependent); for SLP, C1 (moderator), C2 (independent) and C3 (dependent); and for SW, D1 (moderator), D2, D3, D4, D5 (independent) and D6 (dependent). Details of statements are shown in Figure 1. Each statement was scored as grouped data, and five categories were created to understand the extent of application of a particular technique, namely, >75%, 51%–75%, 26%–50%, 1–25% and 0% which were coded as 4, 3, 2, 1 and 0, respectively.

Data collected through the structured questionnaire was categorical, with each statement being responded in any of the five categories. Multiple regression was considered the appropriate statistical technique to assess the relationship and contribution of each independent variable to PI. Regression also helps to predict PI when one of the predictors is enhanced. However, as the data were categorical both for independent and dependent variables, linear regression could not be applied in its basic form. Instead, logit regression was used for the purpose. Logit regression applies logarithmic statistics on data to perform the functions of regression. As, in this research both variables are categorical, each having five categories, *multinomial logit* was applied. It is essential to understand the baseline of the model. For example, a company might apply 0% of a particular waste reduction technique, meaning there would be no improvement in productivity as no intervention in the form of lean technique was applied. So 0% would mean productivity level at the existing level with no waste reduction technique in force.

Findings

Role of Kanban in productivity improvement

Multinomial regression on the role of Kanban as a lean manufacturing technique in improving overall productivity showed that A1, A2 and A3 contributed to explaining the occurrence of outcome A4 by 62.3% significantly ($-2LL = 20.745$; χ^2 $(4) = 34.576$; $p = 0.000$) proving the model to be significant. Three levels of productivity, namely 26%–50%, 51%–75% and >75%, were impacted by these variables.

PI by 26%–50% (A4 = 2): A1 and A3 were found to be the primary contributors in explaining Kanban's role in any PI to the level of 26%–50%. Results showed that if organizations increase the extent of implementation of Kanban (A1) from 26%–50% to 51%–75%, then the chances of productivity enhancement to 26%–50% could be 2.568% (Wald $\chi^2 = 7.521$ (1); $p = 0.004$), as indicated by high and positive exp (b). However, a similar prediction increases to 4.287% (Wald $\chi^2 = 6.458$ (1); $p = 0.003$) if Kanban's application in reducing inventory (A3) was increased from 1%–25% to 26%–50%. Interestingly, the enhancement in PI to this level does not involve any significant interaction between the extent of implementation (A1) and any Kanban functionality (A2 or A3), leading to the non-acceptance of *H1*.

PI by 51%–75% (A4 = 3): Kanban's role in explaining productivity to the level of 51%–75% was found to be explained by A1 and A3, simultaneously implying acceptance of *H1*. Results show that if firms apply Kanban to the extent of 1%–25% (i.e. A1 = 1) and to the extent of 26%–50% for the reduction of WIP inventory (i.e. A3 = 2) simultaneously, it can have significant (Wald $\chi^2 = 9.852$ (1); $p = 0.001$) effect on the chances of occurrence of the outcome. High and positive odds ratio indicated that if A1 and A3 were increased simultaneously by one unit, i.e. 26%–50% and 51%–75%, respectively, then the chances of PI to the level of 51%–75% could be 16.574%.

PI by >75% (A4 = 4): Lastly, PI to a very high level (>75%) as Kanban was found to be explained by the interaction effect of A1 and A3 significantly (Wald $\chi^2 = 8.427$ (1); $p = 0.027$) validating *H1*. Exp (b) value indicates that if the extent of Kanban implementation was increased from 26%–50% (i.e. A1 = 2) to the level of 51%–75% (i.e. A1 = 3) simultaneously with its role in reducing inventory to >75% (i.e. A3 = 4) from 51%–75% (i.e. A3 = 3) then there could be 17.524% chances of increase in the outcome.

Conclusion: In summary, results showed that out of A2 and A3 functionalities, only A3 interacted significantly with the moderating variable. Specifically, PI through Kanban occurs considerably only when it is applied to the extent of or more than 50% along with its function of inventory reduction, rather than using it for mitigating over-production.

Role of single-minute exchange of die in productivity improvement

Multinomial regression results showed that B1, B2 and B3 contributed to explaining the occurrence of the outcome B4 by 74.6% significantly (−2LL = 31.457; χ^2 (4) = 23.457; $p = 0.000$). All four levels of productivity were impacted by these variables.

PI by 1%–25% (B4 = 1): The results indicated that the first level of enhancement in PI does not require any simultaneous effect of the extent of SMED implementation and any of its functionalities implying the non-acceptance of *H2*. Detailed analysis of results indicated that if PI was at a level of 1%–25%, then its chance of improvement was predicted significantly (Wald $\chi^2 = 5.238$ (1); $p = 0.042$) by applying the functionality of reducing exceeding production to the extent of 1%–25% (i.e. B2 = 1). Furthermore, the odds ratio of 3.217 implied that if the application of B2 is increased from 1%–25% to 26%–50%, then the chances of an increase in productivity to 1%–25% (i.e. B4 = 1) from 0% (i.e. B4 = 0) is 3.874%.

PI by 26%–50% (B4 = 2): However, for a higher level of PI, results showed that the over-production (B2) functionality of SMED should be applied to the extent of 26%–50% then chances of PI increase gets augmented by 5.632%. Moreover, without such an enhancement in B2, and keeping it to the existing level chances of PI to 26%–50% were 9.713%, if the B3 functionality of SMED is applied to the extent of 51%–75%. The individual effect of the extent of implementation of SMED (i.e. B1) had no significant influence on PI. Moreover, no interaction effect was found, implying the non-acceptance of *H2*.

PI by 51%–75% (B4 = 3): Results showed that a further higher level of PI of 51%–75% could be achieved not by individual but by the significant simultaneous effect of B1 and B3

(Wald $\chi^2 = 9.584$ (1); $p = 0.001$), proving *H2*. Exp (b) of 7.852 implied 12.726% chance of increase in outcome if the extent of SMED application (B1) could be increased to 26%–50% (i.e. to B1 = 2 from B1 = 1) and if the role of SMED in inventory reduction is increased to the extent of 51%–75% (i.e. from B3 = 2 to B3 = 3).

*B4 = 4 (>75%):*Lastly and most importantly, all three predictors of B1, B2 and B3 have a significant (Wald $\chi^2 = 5.328$ (1); $p = 0.045$) simultaneous effect on the prediction of the outcome to the extent of >75%, implying acceptance of *H2*. If the SMED level of implementation is enhanced from 51%–75% to >75% (i.e. from B1 = 3 to B1 = 4), whereas application of B2 and B3 increases from 51%–75% to >75%, then chances of PI to increase to level of >75% were 18.587%.

Conclusion: Results showed that moderating and independent variables contribute significantly though independently, that is, without any interaction if productivity is to be improved to less than 50%. However, if both functions of SMED represented by B2 and B3 interact significantly with the moderator (B1), productivity is intended to improve higher than 50%.

Role of systematic layout planning in productivity improvement

The multinomial regression results showed that C1 and C2 contributed in explaining the occurrence of the outcome C3 by 42.71% significantly (−2LL = 39.975; χ^2 (2) = 34.521; p = 0.027). Two levels of productivity, namely 1%–25% and 26%–50%, were impacted by these variables indicating that further improvements in layout do not result in significant improvement in productivity.

PI by 1%–25% (C3 = 1): Prediction in the improvement of outcome C3 at a level of 1%–25% due to the application of SLP was found to be significantly explained by C1 (Wald χ^2 = 5.143 (1); $p = 0.023$) and C2 (Wald $\chi^2 = 7.562$ (1); $p = 0.004$), independently implying on the non-acceptance of *H3*. An increase in implementation of SLP (C1) from 26%–50% to 51%–75% could increase the chance of increase in outcome by 4.767% as indicated by positive and greater than one exp (b) = 1.574. Similarly, an increase in implementation of SLP for time reduction of material movement (C2) from 1%–25% to 26%–51% could improve the chance of an increase in outcome by 5.369% as indicated by exp (b) = 2.316.

PI by 26%–50% (C3 = 2): Similarly, an improvement in overall productivity to the level of 26%–50% was found to be significantly explained and predicted by C1 (Wald $\chi^2 = 9.175$ (1); $p = 0.021$) and C3 (Wald $\chi^2 = 6.235$ (1); $p = 0.042$), again independently implying the non-acceptance of *H3*. The chance of PI due to SLP was estimated to be 9.453% if an organization increases its practice of SLP (C1) from 51%–75% to >75%. However, if the application of SLP to reduce material movement (C2) was increased from 26%–50% to the extent of 51%–75%, then the chances of an increase in overall productivity were found to be 10.178%.

Conclusion: Interestingly, in the case of the SLP, moderating variable has no interactive effect at any level with any of the functionalities, although both impacted PI outcomes positively and independently.

Role of standardized work in productivity improvement

Results showed that all predictors contributed to explaining the occurrence of D6 outcome by 79.45% significantly (−2LL = 24.678; χ^2 (4) = 29.758; $p = 0.015$). Four productivity levels, namely 1%–25%, 26%–50%, 51%–75% and >75%, were impacted by these predictors, indicating that further improvements in SW result in significant PI at all levels.

PI by 1%–25% (D6 = 1): PI to the level of 1%–25% was found to be significantly predicted by D1 (Wald $\chi^2 = 7.125$ (1); $p = 0.041$) and D4 (Wald $\chi^2 = 6.475$ (1); $p = 0.032$) and the scope of PI at this level was greater. Thus, only a further increase in D1 (extent a firm implements SW) and D4 (extent SW helps the waiting time reduction) independently (implying the non-acceptance of *H4*) from 1%–25% to 26%–50% was found to positively increase the chance of improvement in overall productivity by 8.459% and 9.561%, respectively. Exp (b) values substantiate the positive impact due to interventions of predictors.

PI by 26%–50% (D6 = 2): This level of PI (D6) due to SW was found to be significantly predicted by D2 (Wald $\chi^2 = 9.532$ (1); $p = 0.001$) and D3 (Wald $\chi^2 = 5.694$ (1); $p = 0.003$) if both are implemented to the extent of 1%–25%. This level of PI also does not require simultaneous effect either of functionalities or with the extent of implementation, implying non-acceptance of *H4*. Moreover, an increase in their implementation by one unit, i.e. to the level of 26%–50%, would increase the chance of the occurrence of an outcome by 3.127% and 5.564%, respectively.

PI by 51%–75% (D6 = 3): A higher level of PI, that is, 51%–75% was significantly predicted simultaneously by D1 and D3 (Wald $\chi^2 = 9.107$ (1); $p = 0.001$). Positive odds ratio indicated that the chance of PI to the extent of 51%–75% (i.e. D6 = 3) was 13.742% if extent of D1 is increased to 51%–75% from 26%–50% (i.e. from D1 = 2 to D1 = 3) simultaneously with D3 from 51%–75% to >75% (i.e. from D3 = 3 to D3 = 4) implying acceptance of *H4*.

PI by >75% (D6 = 4): Lastly, PI to an extent of higher than 75% (D6) was found to be predicted significantly by the interaction of D1, D2 and D5 (Wald $\chi^2 = 10.143$ (1); $p = 0.003$) implying acceptance of *H4*. Results showed that if all these three functionalities are implemented simultaneously to the extent of >75% then chances of PI to level of >75% could enhance by 19.641%.

Conclusion: Results showed that at a low level of implementation (1%–25%) of the moderator, productivity improves significantly to the level of 50% without having an interaction effect with functionalities. However, to have higher levels of PI (>50%) the moderator interacts significantly with them.

Discussion

This study discussed the lean methods' contribution to the PI of large auto component manufacturers in India. The extant literature has focused on measuring effectiveness through improvement in individual key performance indicators, such as cycle time, process lead-time and work-in-process inventory, among others (Leonardo et al., 2017). This approach is deemed effective if done at the firm or process level. However, the focus is shifting from measuring the effectiveness of a particular lean method to the efficacy of the entire bouquet of methods, and also from firm to industry level. Firms, especially on a large scale intend to adopt an integrative rather than a piecemeal approach to implementing lean methods as the benefits accruing from it would be more significant (Narayanamurthy & Gurumurthy, 2016). Past studies lacked such attention. To fulfil both gaps, this study offered a transformation of the performance examination from measurement to assessment.

Furthermore, the assessment approach focuses on understanding, firstly, how varying levels of implementation of the functionality of a lean method work. For instance, if a manager perceives the functionality of reduction in over-production, akin to Kanban, is to the extent of 25%, then what are the chances of PI from the existing level? Similar assessments for varying levels of each lean method provided inferences about which functionality would influence PI the most.

Most importantly, based on the assertion that the higher the extent of implementation, the higher the chances of PI, this study investigated the impact of the extent of implementation of a lean method by formulating it as a moderating variable to compare its augmented effect with the direct effect of lean method functionalities on PI. This approach helped reveal at what level of implementation of a lean method it would interact with its functionalities to predict the chances of PI from its existing level. Thus, examining the interaction effect level of different lean methods and assessing prediction levels are major outcomes of this study making it novel.

Moreover, the primary reason for the shift from process to firm-level monitoring is the realization, especially at the supplier level, that the lean philosophy foundation is the integration of both quantitative and qualitative approaches. Without instilling a culture of continuous improvement and paying attention to detail as routine, other measurable criteria fail to deliver the full benefits of the lean system (Sakthi Nagaraj, Jeyapaul, Vimal, & Mathiyazhagan, 2019). The emphasis on quantitative aspects showed that PI by applying lean methods displays a stagnating effect after a certain implementation level. Moreover, further significant enhancement could only be achieved by stressing the human aspects of work involvement, problem-solving skills, etc. Thus, the assessment approach is justified, as it involves the analysis of the contribution of both human and quantitative aspects.

Examining this combination of different lean method assessments, the individual and interactive roles of their functionalities and the extent of implementation in predicting PI, and also their application in the large auto component industry that forms a vital link in the entire supply chain makes this study original.

This study's results firstly showed that the primary lean methods applied for the reduction of specific wastes in the auto component industry were Kanban, applied to reduce the waste of over-production; SMED, to reduce waste of inventory; SLP, to reduce the time involved in material movement and lastly, SW to reduce the waste due to over-processing, during waiting and motion. In addition, the managers' perspective on the extent of PI due to lean method functionalities application provided information about only those attributes of each lean method that significantly contributed to PI. Results also showed that if such an identified functionality is applied to a certain extent (between 1% to >75%) then productivity can be improved by known measures from the existing level. This is a major outcome of the study, i.e. emphasizing the impact of varying degrees of application of each lean method functionality in improving the existing productivity levels. It would enable a decision maker to focus their limited resources on the method with the maximum impact on PI.

These findings identified two patterns: firstly, if firms intended to improve productivity by lower levels like 0% to 1%–25% or to 26%–50%, then intervention only from one function of a lean method was sufficient. On the other hand, if intentions were to improve productivity to higher levels of 51%–75% or >75%, firms needed to apply a lean method at higher levels, involving a combination of functions. Notably, the study showed that all lean methods under study had a significant moderating role, except SLP. Moreover, in addition to the independent role of functionalities of these lean methods, results showed that PI gets significantly enhanced only when the extent of implementation of lean principle increases simultaneously with functionalities to a level higher than 50%. This is an important implication as its understanding asks for greater diligence and application of resources at the shop floor level to achieve significantly higher results.

Practical implications

The study's findings highlighted the application of specific attributes, but not all, of different lean methods to affect PI. Importantly, it showed that even if a lean method is applied to a certain extent of operations, the chances of PI are significant. This is important for decision makers, as they confront problems of optimum resource allocation. For instance, layout modification requiring huge labour and machine downtime is least preferred by management, even if it enhances productivity to a higher level. Targeted allocation in enhancing a specific attribute, such as reduction in unnecessary motion, would have a significant and higher impact. Results also showed that a higher percentage of changes in productivity occurs with the simultaneous intervention of more than one attribute, and to a higher degree. It would suffice to say that this could cause substantial expenditure. Thus, the study findings would allow management to adopt a feasible approach to applying lean methods.

Moreover, due to the demand for a wide variety of automobiles fuelled by increased competition, OEMs are shifting the onus of providing an increased variety of parts or components to suppliers (Yin, Stecke, & Li, 2018). By assessing the performance of lean methods in large suppliers, this study could be a stepping stone for other players in the supply chain. Lastly, metric-based performance evaluation misses the contribution of the human aspects, such as work involvement and teamwork. In contrast, the assessment approach taking into view overall rather than specific improvement provides a wholesome picture. The findings of this study could encourage managers to adopt such an approach.

Future research

The assessment methodology of specified lean manufacturing techniques has been developed in the present study especially for auto component manufacturing organizations. However, these methods suffer from certain limitations applicable to a particular environment. To ensure their efficacy, the researcher should make sure that the groundwork for their application has been established. For example, specific tools such as 5S enable a clean, sorted and sustainable shop floor; if established beforehand, proper employee awareness for effective human–machine interaction, among others, will provide significant positive results. Lean methods are applied in this study in a relatively stable system. However, most of the production systems combine both push–pull systems (Panwar, Jain, Rathore, Nepal, & Lyons, 2018).

Future studies can focus on the effectiveness of lean methods in such mixed systems and can compare efficacy with traditional push systems. This study adopted SLP as a layout modification tool to reduce wastes of WIP inventory and wasteful movement in spite of other numerous methods available only because most of firms in the industry under study were using it. Future research can examine the efficacy of other layout modification methods in PI. Lastly, the present research considers implementing specific lean approaches for India's large-scale automotive component manufacturing organizations. However, medium and small enterprises also connect critically to the entire automobile manufacturing ecosystem. Further studies can examine and compare the outcomes of lean methods among these players.

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