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Lean Manufacturing Structural Model for Improving Operational Performance of Diverse Industries

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ABSTRACT: The benefits of employing Lean Manufacturing (LM) on industrial organizational performance is still an ongoing debate. This paper aims to explore the impact of implementing LM techniques on operational performance across different industries in Saudi Arabia. A structural LM model that is consistent with the Toyota Production System (TPS) was presented. For data collection in established companies a structured survey was used. Of the 120 companies contacted, 67 useful responses imply a response rate of 55.8 % were obtained. The structural and operational models have been evaluated using the Social Sciences Statistics Program (SPSS) and SmartPLS 3. The results showed that by implementing the specified LM tools, the operational performance can be enhanced.

KEYWORDS: Lean Manufacturing, Toyota Production System, Structural Equation Model, TPS house, Operational performance.

I. INTRODUCTION

Recently, both international and national regulatory bodies have put pressure on the manufacturing corporations to be sustainable due to concerns about global warming and waste loss [1, 2]. Lean Manufacturing (LM) is a concept or philosophy employed to achieve sustainability, increase competitiveness and improve performance of the organizations [3]. The main specific targets of LM are to maximize value, eliminate waste, and improve productivity. Initially, LM was applied in the manufacturing companies, but later the service sectors such as education, healthcare, hotels and transportation have implemented it [4, 5, 6]. The philosophy of LM matches with the managerial level through a series of steps and practices one of which is the lean bundles. Many of the barriers to effective implementation of LM are people-related such as managers' lack of attention and workers' less motivation [7, 8]. Modern leading countries such as USA, Japan, Canada, UK, Germany, and South Korea have employed LM to improve the operational performance and increase the productivity of their operations and products. On the other hand, developing countries like India, Malaysia, Indonesia, Turkey, Brazil, Thailand, are trying to apply the LM concept for reducing production costs and keeping their products or services highly competitive [7]. However, manufacturing companies in other developing countries have been still struggling and requiring improvement in terms of operational performance and waste reduction [9, 10]. Figure 1 below shows the LM five fundamental principles: value creation, value stream recognition, continuous process flow, production pull and perfection [11, 12]. Value stream mapping (VSM) or process mapping is a very effective tool to figure out where the waste occurs in the process. VSM can simply map all the processes and activities performed to get a certain product or service. It covers all operations from the point of initiation crossing the manufacturing and delivery of the products to the point of purchasing by the consumer [13, 14]. Application of LM can be classified into six fields; planning and control, process and equipment, design, human resources, supplier, and customer satisfaction [15, 16].

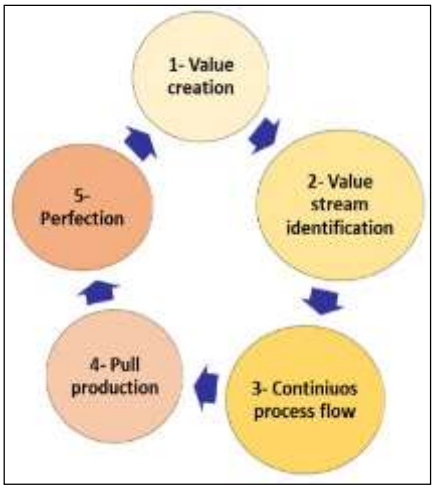

Figure 1. Fundamental principle of lean manufacturing

In 2016 Saudi Arabia presented its vision 2030 as a strategic framework for diversifying its economy, increasing productivity and improving competitiveness of the manufacturing and industrial organizations. However, few efforts have been done for applying LM in both public and private companies. Although many previous researches all over the world have discussed the impact of LM on enhancing operational performance, there is a lack of studies have been applied in Saudi Arabia's industries. Therefore, this paper, seeks to evaluate the influence of LM on operational performance and a structural model was proposed to evaluate and analyse selected organizations.

II. LITERATURE REVIEW

The principles of lean manufacturing have been found by Toyota Motor Company. The main tools that have been used by Toyota included Value Stream Mapping (VSM), Just-in-Time (JIT), and Continuous Improvement. Furthermore, the previous literature discussed the relationship between LM and financial performance as an effective factor of sustainability and waste management [17, 18, 19]. Initially, the term LM was used to compare the Toyota Production System (TPS) with mass production that has been implemented in the Western countries. After the World War II, Toyota had been faced with many problems in terms of labor strikes, and it was on the edge of bankruptcy. Meanwhile, the concept of TPS for eliminating waste in the machining shop had been developed by Taiichi Ohno [20]. The TPS house is now a well-referenced model in most industries around the world [21, 22, 23]. Later, lean activities have been recommended in different fields, including pharmaceutical, electronics, ceramics, aerospace, and the automotive industries [24, 25]. Many researchers [26, 27, 28, 7] focused on the beneficial results and enhancing operational performance that attained when implementing LM tools. For example, the effects of plant size, plant age, and unionization status were examined. In addition, four bundles of interrelated and internally consistent practices; Just-in-time (JIT), Total Quality Management (TQM), Total Preventive Maintenance (TPM), and Human Resource Management (HRM) have been developed [29]. The previous researches showed that lean techniques make a significant contribution to operating performance of the company and explain the variability in operating performance after consideration of the industrial effects and related factors [30]. Salem and Zimmer [31] have investigated the application of lean principles to the construction sector.

Unfortunately, it has not seen such encouraging results. However, the manufacturing sector has experienced productivity and quality improvements with a reduction in cost and lead times. Dal Pont et al [32] conducted a research on selected highperformance manufacturing companies from nine leading countries; the United States, Spain, Japan, Germany, Sweden, Korea, Italy, Austria and Finland. The effects of TQM, JIT, and HRM on operational performance have been investigated. The results showed that the three practices have significant effects on operational performance. The influences of TPM, TQM and JIT on the organizational performances in 64 Brazilian firms have been investigated by Marodin et al. [33]. The analysis showed no significant effect of TQM on measures of operational performance. However, the JIT had a major influence on the turnover of inventories while TPM had a positive impact on the lead time. Fullerton et al. [34] examined the correlation between financial performance and the extent of deployment of JIT technique. The study has been applied on manufacturing companies in the United States. The results indicated that the companies applying JIT realized more profit than those have not been applying it. Several studies showed how HRM practices affect the operational performance of the organization [35]. Nakamura et al. [36] assessed the influence of JIT practices on some key performance measures of various manufacturing industries in USA and Japan. The authors provided an empirical evidence that JIT can enhance six manufacturing plant performance measures: percent downtime, passed percentage, shipped percentage, cycle time, lead time, and inventory. Fullerton and McWaters [37] reported that the implementation of

continuous improvement, and waste reduction practices improves the organization competitiveness. Certainly, employment of JIT enhances performance through lower inventory levels, lower quality costs and a better response to customers. Lean Production Index (LPI) has been used by Kojima and Kaplinsky [38] to assess the performance of automobile companies in South Africa. The LPI has three elements that comprise of consistency, versatility, and continuous improvement. Mapfaira et al. [39] investigated the effect of LM on the performance of manufacturing firms in Botswana. Handling with variation and the lower level of skilled labors considered as the major drawbacks in implementation of LM successfully. Davy et al. [40] found that there is a significant relationship between implementation of JIT and quality of the end product. The literature study performed by Maware and Adetunji [41] indicated that three constructs: JIT, TQM and HRM have been used to establish qualitative models of measurements. It has been noticed that these constructs were correlated with TPS house bundles that are integrated with Flow, People, and Jidoka. Jidoka is a Lean manufacturing principle that means building quality into the process. It is known from the Toyota production system and was established by the Japanese industrial designers. The main objective of Jidoka is to ensure that quality is automatically integrated into the manufacturing or production process. Jidoka helps in detecting and immediately correcting deviations or errors in the production process. As long as a mistake happens Jidoka pauses the process. Many other researchers such as Giorgia Dal Pont et al. [42] , Rahman et al. [43] , Agus et al. [44], Al-Tahat and Jalham [45], , Hofer et al. [46], and Vinodh and Joy [47] , also studied the LM effect on operational performance of various industries. Shrafat and Ismail [48] concluded that in developing and underdeveloped countries very limited studies have been conducted on the applications of LM. Marodin et al [49] reported that developed countries are often faced with challenges to become Lean because of changes in market behaviour. Although selecting a common structural model for Lean is typically difficult, few companies in Saudi Arabia adopted the structural model (Toyota Production System; TPS) that developed by Dennis, and shown in Figure 2.

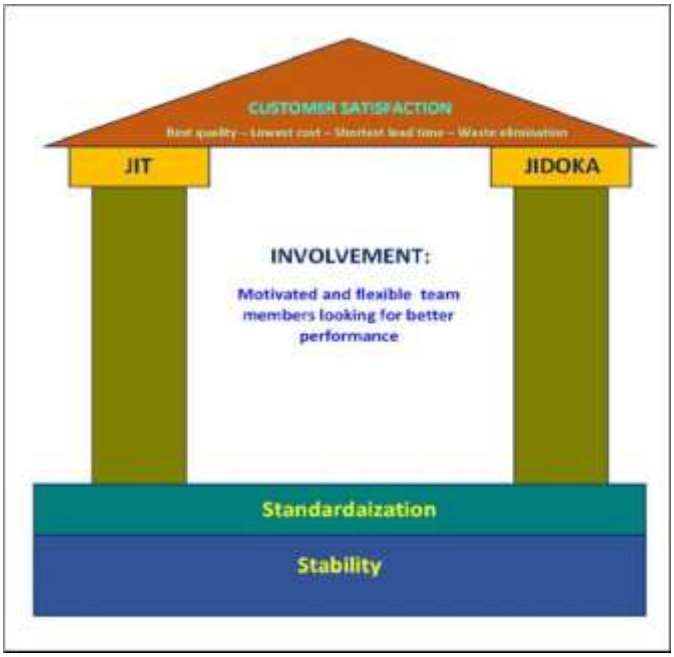

Figure 2. Model of Toyota Production System (TPS)

TPS represents the bases on which all lean practices and resources are built such as standardization and stability, people integration, Jidoka, JIT, and consumer satisfaction. The TPS house mainly aims to improve the stability of the manufacturing systems and the competitive advantage of the firm. Therefore, stability and standardization are the foundation of the house. Stability allows the construction of the pillars (JIT and Jidoka), while standardization permits predictable and stable results. JIT pillar allows the system to run with minimal inventory, and Jidoka causes the system to stop when any fault has been detected [50]. People integration is the heart or core of the house and the involved staff must be flexible and continually pursue change. When applying LM the house's roof gives the final goal of achieving the shortest lead time, lowest cost and best quality [51]. The previous lean models have concentrated on either lumping a variety of lean strategies together or incorporating them independently in the same composite constructions. When lumped together they are called as bundles, constructs, factors, latent structures and dimensions [45, 52]. The abundance of lean models has made it difficult to explore this area. Many authors created models from this massive pandemonium, but their structures were greatly different from each other. Therefore, simply adopting a model from the literature as the acceptable lean structural model is difficult, since authors have constructed various models. This work would look at the use of lean bundles in constructing a model of structural equation.

A. Structural Equation Modelling (SEM)

Structural Equation Modelling (SEM) is a technique that determines and approximates models of linear relationships [53]. The measurements and structural components are the two components for SEM models. The structural model displays the casual link between latent variables. The measurement model consists of the latent variable and their indicator variables. SEM enables researchers to use latent variables to model path analytics, and can validate relationships between measured variables and latent variables [54]. SEM enables researchers to use latent variables to model path analytics, and can validate relationships between measured variables and latent variables. Also, SEM provides a set of reliable and valid relationships that provide a comprehensive explanation of the real scenario. Therefore, it is well appropriate for both theory confirmation and the theory development. The model hypothesis can be assessed against empirical data to show how well it fits the data. The researcher begins by formulating a theoretical model to conduct the SEM analysis, followed by model specification, parameter definition and match evaluation. SEM is one of the most popular approaches used for data processing. The major advantage of SEM is its versatility, which enables researchers to identify relationships between dependent and independently variables [55, 56]. Furthermore, SEM makes correlation between theory assumptions and calculation experiments against empirical evidence. It has also been shown that SEM enables simple and independent estimation by a single study [57]. It is also possible to study a complex system which allows to explore casual relationships among latent variables. Specifically, this analysis searches for a recursive pattern.

B. Proposed LM Model

This section discusses the latent variables and the interactions between them are hypothesized. The TPS house comprises elements (constructs) such as stability and standardization, JIT, integration of people, and Jidoka. The study is generally about solving a recursive model. LM's success depends on employer engagement, empowerment, and team effort, all of which are HRM practices. People incorporation integrates a program designed to encourage workers to constantly enhance workplace processes in order to increase the company's productivity and performance. Employees are responsible for carrying out the work and implementing modifications caused by LM. They also control their own systems as they emerge in the method and solve problems. Fullerton et al. and Dal Pont et al. [32] showed that flexible staff working in teams makes a strong commitment to JIT and therefore JIT is affected by people's integration. Chandler and McEvoy and Yang [58] found that HRM has a strong and positive effect on TQM. The hypothesizes can be considered as follows:

H1: the dimension of people integration is related positively to JIT,

H2: people integration impacts Jidoka positively,

H3: people integration is strongly associated with stability and standardization.

Stability and standardization are designated as the condition of the system which is able to provide items consistently and uniformly with small variations, such as fluctuation of production, system malfunction, human failure and product varieties matching. Stability and standardization help in eliminating interrupted activities as orders are issued on time, equipment is run as scheduled and work standards are applied. The main objective of standardization is to establish standards in the methods and processes of work [59]. It is also easier to assess the source of the problem when the processes are standardized. When the processes are standardized, it's also easier to recognize and evaluate the source of the problem. The effectiveness of LM will decrease if stability is not implemented [60]. Stability and standardization also guarantee that processes are carried out in the correct manner to ensure quality products are produced each time. Hence, the proposed hypotheses are as following:

H4: Stability and standardization are correlated positively with JIT,

H5: Stability and standardization are correlated positively with Jidoka.

A study conducted by Flynn et al. [61] found that the JIT performance increased with the use of quality management practices. Kannan and Tan [62] have found a strong relationship between JIT and TQM practices. Other research studies have also investigated the effect of JIT and TQM on the performance of companies. Mann and Kehoe [63], Shah and Ward [64], Talib et al [65], Rahman et al. [43], Sadikoglu and Olcay [66] showed that when an organization invests in quality practices, higher financial returns and enhanced operational performance are achieved. Rahman et al [43] showed that JIT has a positive relationship to operating performance in small and medium-sized enterprises. So, the hypothesis is that:

H6: a positive relationship is existing between Jidoka and JIT,

H7: a positive relationship is existing between JIT and operational performance, H8: Jidoka positively impacts the operating performance.

Figure 3 shows the structural LM model that was developed to measure the effect of Lean tools on operational performance. Based on the literature survey, most of the studies emphasized on the relationship between specific practices and performance rather than considering the enhancement of the performance due to the implementation of lean procedures. Moreover, there is no measuring tool has been developed to appraise LM in Saudi Arabia.

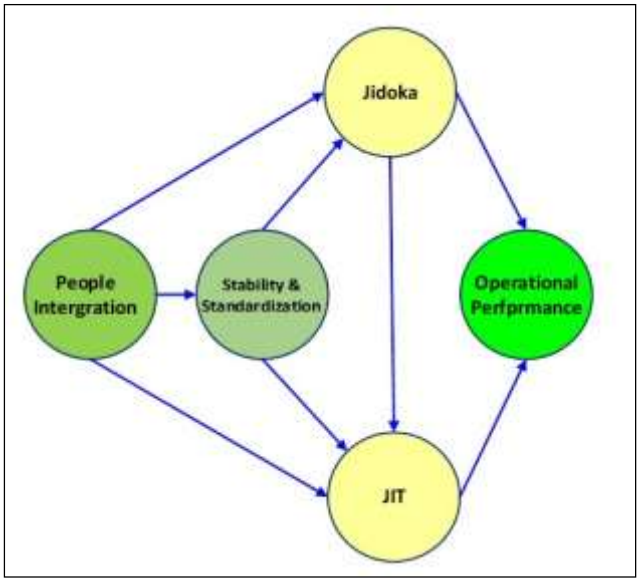

Figure 3. Structural model to lean measurement

III. RESEARCH METHODOLOGY

I. Measuring Tools

In order to measure the impact of LM constructs on the operational performance a questionnaire was developed for the model. The questionnaire was divided into three main parts: Section A contained company information. Section B concentrated with questions regarding the level of company adoption of LM constructs. Section C included questions relating to the company's operational performance. The questions with 7-point quantifiable measuring scale were applied by various authors such as Khanchanapong et al. [67], Dora et al. [68], Garza-Reyes et al. [69], and Wickremasinghe [70]. Shah R et al. [71] and Belekoukias et al. [72] evaluated the operational performance in terms of speed, flexibility and reliability items. For measuring operational performance, a 5-point scale was applied, with 1: representing a decline of more than 20 percent; 2: a decline of 1–20 percent; 3: It remained the same; 4: increased by 1–20% and 5: increased by over 20%. A pilot study was conducted to get ideas about the questionnaire from industry practitioners and academics. To ensure reliability and construct validity, some items had been discarded, modified, or added.

II. Data Collection

The current research targeted 120 firms to be evaluated (either public or private). These companies had fallen under the industrial and manufacturing companies of petrochemicals, steel, plastics, pharmaceutical, food, cement, electrical and electronics. Sixty questionnaires were hand-distributed while other companies have been contacted by emailing a Google form link. A total of 67 useful and comprehensive responses represented a response rate of almost 55.8%. The distribution of the responses obtained by the researchers is shown in Figure 4.

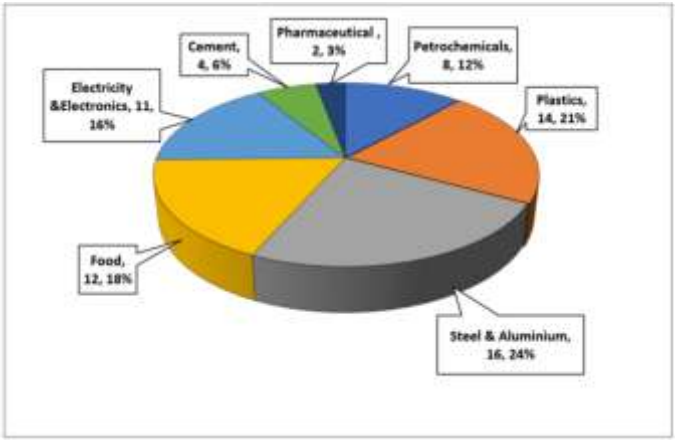

Figure 4. Distributions of the responses obtained from different industries

III. DATA ANALYSIS

The data analysis was carried out using the Statistical Package for Social Sciences (SPSS- v25) and the SmartPLS3. SPSS was used to analyse the exploratory factors, while the measurement and structural model were assessed using SmartPLS 3. Assessing the

model includes appraising the relationship between LM constructs and their measurement items, while evaluating the structural model determines the correlation between the constructs.

IV. FINDINGS & DISCUSSION

A. Appraising the Measurement Model

To ensure the validity of the collected data, the sample was tested for reliability and validity. The coefficients such as alpha coefficient (Cronbach's alpha), rho_A, average variance extracted (AVE) were used in analyzing and appraising the model. The reliability of each variable was more than 0.7, and the reliability of the overall sample was 0.85, demonstrating that the questionnaire had good internal consistency. The adoption of measuring items from previously published articles ensured the questionnaire was highly reliable. Initially a total of 49 items were chosen to measure the five LM constructs. Exploratory factor analysis has been used to reduce the number of items for constructs and to evaluate validity, thus assuring a parsimonious description for the five latent factors (JIT, Jidoka, people integration, stability, and standardization and operational performance). After the preliminary review nineteen items were eventually chosen for the constructs. The Bartlett's test was significant with a $p < 0.001$. The analysis showed that the five-factor structure with a model variance of 60.672 %. The results of Cronbach's alpha were within the range of 0.661 - 0.876 for each construct. This can be considered as an acceptable to high level according to Gotz et al. [73], and Bevilacqua et al. [74]. To ensure construct validity, the average variance extracted (AVE) should be >0.5 [75]. The obtained AVE values of the current study were > 0.6, meaning that the construct is valid. The all obtained statistical parameters Cronbach's alpha, rho_A, composite reliability, and AVE are displayed in Figure 5. The Fornell-Larcker criterion is a dominant approach for assessing discriminant validity for SEM. Therefore, Fornell-Larcker criteria was applied to ensure the validity of interrelation constructs. The results in Table 1 revealed that the whole measuring items supporting discriminating validity. Moori et al. [76] and Jose Benitez et al. [77] reported that when the AVE values are greater than the correlation between the factors, discriminating validity is ensured.

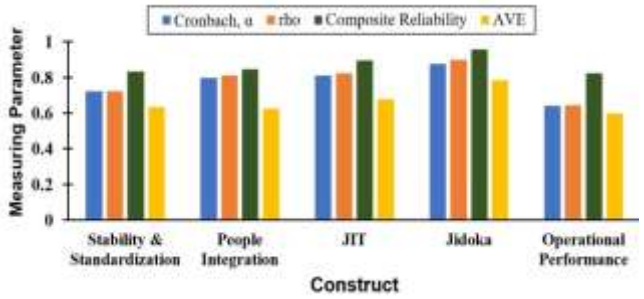

Figure 5. Construct validity and reliability

Table 1. Results of Fornell–Larcker Criterion

	JIT	Jidoka	Operational performance	People integration	Stability and standardization
JIT	0.767	---	---	---	---
Jidoka	0.672	0.845	---	---	---
Operational performance	0.389	0.371	0.762	---	---
People integration	0.511	0.565	0.272	0.782	---
Stability and standardization	0.564	0.612	0.331	0.501	0.800

B. Evaluating the Structural Model

The coefficient of determination R2 was determined as a statistical measure for assessing the developed structural model. In the analysis of human and social researches, if the R2 value is 0.26 it is considered significant [78]. The obtained R2 values of the current model ranged from 0.328 to 0.687 for the dependent variable. Therefore, the correlation is significant. The R2 values were 0.63, 0.67, 0.30, and 0.41 respectively for Jidoka, JIT, operational performance, and stability and standardization. This proved that People integration, JIT, and Jidoka had a good impact on performance of the operations. Structural Equation Modelling (SEM) is commonly used to appraise and analyse unobservable 'latent' constructs. SEM usually invokes a measurement model that describes latent variables by means of one or more observed variables, and a structural model that attributes relationships between latent variables [79]. The relationships between constructs of a structural equation model can be assessed with independent regression equations. SEM is justified in the social, education, and business sciences because of its ability to attribute

relationships between latent variables from observable variables [80]. Figure 6 shows a schematics diagram of the structural connection between people integration, stability & standardization, JIT, Jidoka and operational performance. It can be noticed that people integration has a stronger relationship with stability and standardization than with Jidoka and JIT according to the structural coefficients which were 0.660, 0.318, and 0.168, respectively. Stability and standardization have been strongly related to Jidoka than to JIT. The structural coefficients were 0.562 and 0.221, respectively. A high coefficient of 0.518 can be observed between Jidoka and JIT constructs. Thus, a close interaction is approved between those two constructs.

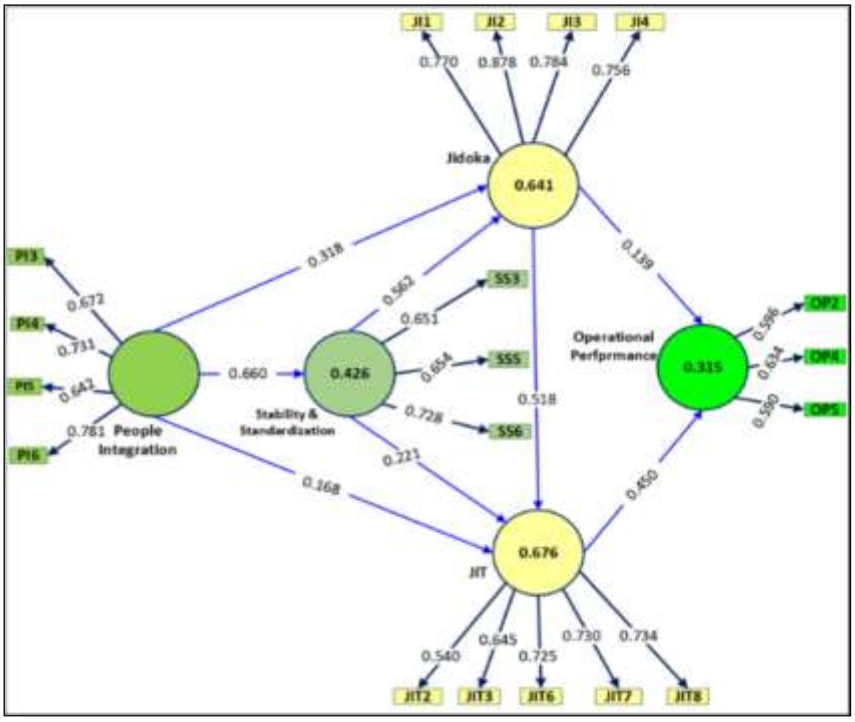

Figure 6. Schematics diagram of Structural Equation Modelling (SEM)

Overall results showed the most significant impact of people integration on operational performance (0.376), followed by JIT (0.361), stability and standardization (0.335), and Jidoka (0.224). The results accordingly confirm the findings of other authors (Dal Pont G, 2008; Furlan A, 2011; Belekoukias I, 2014; Wickramasinghe, 2017; Marodin GA, 2019). In Figure 7 through Figure 9, the standard deviation (SD), T-statistics, and the p values have been determined to be used for evaluating the hypothesis in terms of acceptance or rejection.

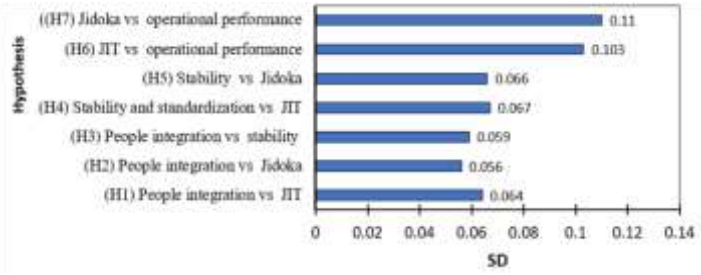

Figure 7. Standard deviation (SD) of all hyp othesis

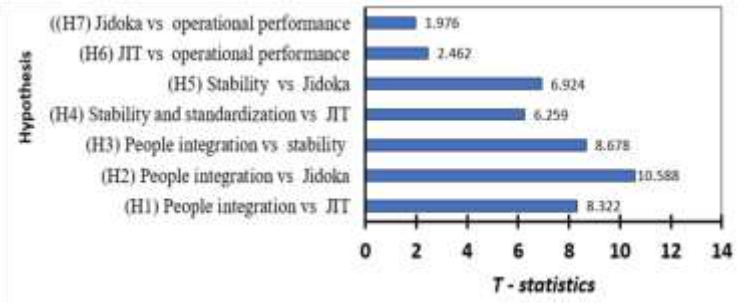

Figure 8. T-test of all hypothesis

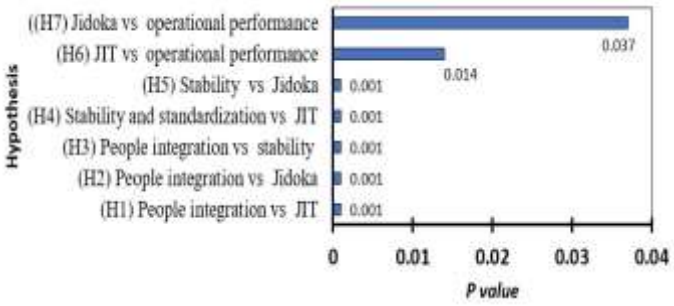

Figure 9. P value of all hypothesis

According to the obtained values shown in the graphs all the hypotheses have been supported. Therefore, the proposed model can be used to determine the effect of applying LM on the operation performance. Lean manufacturing (LM) is founded on the concept that any activity that fails to make value is waste or muda and should be either removed or reduced. Therefore, principally the goal of LM is to reduce or remove wastes. LM is more effective when manufacturers produce high volume and steady demand. The aim of the current study was to investigate the influence of implementing LM tools such as people integration, stability and standardization, JIT and Jidoka on business performance across companies across Saudi Arabia. The findings supported all the hypotheses that were established to show that operational performance may be enhanced by the LM techniques. Several studies around the world have shown that implementation of LM tools results in operational performance enhancements. Furthermore, the results of the current study are corresponding with many researchers such as Eswaramoorthi et al. [81], Nawanir et al. [82], Khanchanapong et al. [67], Osama M. Irfan [10], Abby Ghobadian et al. [8], and Sachin Kamble et al. [83] who have shown that the application of LM has provided positive results and competitive advantage for manufacturing organizations. The results showed the necessity to train the employees about the importance of Implementing LM since people are the backbone for successful implementation of any process or system. This proposes that managers should invest in training staff to be able to drive the LM implementation. People Integration had a good interaction with JIT and Jidoka suggesting that workers were working to increase the flow of materials and the quality of the manufactured products. Stability and standardization also had more significant effect on JIT than Jidoka. A reliable and consistent network improves manufacturing efficiency as the flow of materials through the production floor is less interrupted. Jidoka and JIT had positive operational performance relationships. That is because the operating performance is improved as high-quality materials and goods pass into the production system. The greatly influenced performance enhancement variables were speed, flexibility, and dependability. The operational performance path coefficients indicated that flexibility had the significant contributions to LM, followed by speed and reliability. The strongest point of LM implementation in Saudi Arabia is that employees have been motivated by the program making them dedicated and hard-working. This management approach has also helped numerous enterprises to keep improving their systems. It was noted that LM's weakness was that the project competes with other management programs initiated by organizations for resources. The opportunities were to make organizations more competitive because once they applied the stability and standardization practice, they were able to set and follow standards for their processes. The quality of the products, designs, flow and communication has improved. In some cases, implementing LM caused concern among workers over job losses through retrenchment, but the management convinced them that some would be reassigned to other areas.

V. CONCLUSIONS

Lean manufacturing techniques are highly positive in its findings, resulting in strong evidence that lean clearly has a beneficial contribution to improving environmental and operational performance of organization. The current study verified that applying LM tools results in enhancements in the variables of operational performance such as dependability, speed, and flexibility. The operation performance was influenced by the four elements of TPS house, where people integration was functioned as a prerequisite for other elements. Management of people is essential for ensuring that LM's supports (JIT and Jidoka) and foundations (stability and standardization) are attainable. Stability and standardization help to create an environment where LM can be applied [84]. When the variability in the Lean system is too high, it becomes difficult to get results when applying Lean. Therefore, the degree to which the various functional areas as well as system products are standardized contributes to the effective adoption of LM. JIT allows for the uninterrupted flow of items and materials through the network with a minimal inventory in operation. A key characteristic of a Lean system is the level and extent of uninterrupted material flow through a system. Jidoka helps in minimizing defects within the manufacturing system. This guarantees that quality is sustained at all phases of product design, production and manufacturing. That in effect improves the organization's operational performance.

The results also demonstrated that LM can also succeed in improving the operational performance of industrial organizations in Saudi Arabia. The main limitations of this research were that more corporations could have been used to reassess the model, and the model might also be evaluated in other developing countries.

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CONFLICTING OF INTEREST

The author declares that he has no conflict of interest.

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