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TECHNICAL ARTICLE

Development of framework for sustainable Lean implementation: an ISM approach

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Abstract The survival of any organization depends upon its competitive edge. Even though Lean is one of the most powerful quality improvement methodologies, nearly two-thirds of the Lean implementations results in failures and less than one-fifth of those implemented have sustained results. One of the most significant tasks of top management is to identify, understand and deploy the significant Lean practices like quality circle, Kanban, Just-in-time purchasing, etc. The term 'bundle' is used to make groups of inter-related and internally consistent Lean practices. Eight significant Lean practice bundles have been identified based on literature reviewed and opinion of the experts. The order of execution of Lean practice bundles is very important. Lean practitioners must be able to understand the interrelationship between these practice bundles. The objective of this paper is to develop framework for sustainable Lean implementation using interpretive structural modelling approach.

Keywords Toyota production system (TPS) · TPS practices · Lean · Just-in-time (JIT) · Practice bundles · Interpretive structural modelling (ISM)

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Introduction

In many ways, Lean is an updated version of just-in-time (JIT). For all practical purposes they share the same approach to change. Both are focused on the process adding value and eliminating waste in the process (Näslund 2008). Both methods also origin in the Toyota production system (TPS) (Näslund 2008; Petersen 2002; Vokurka and Davis 1996; Womack and Jones 1994). At the heart of the Toyota production system (TPS) is a production system that has become known as JIT. The TPS JIT theory (or Lean production theory as it is now called) relies on a pull-type production system, where only the parts that are needed are present (plus a minimal number of additional units for the approaching work in progress) (Matsubara and Pourmohammadi 2009).

The success of the Japanese in the employment of JIT production has received a great deal of attention in the past two decades (Ouyang et al. 2007). Severe competition, demand for cost-effective product, demand for qualitative on time-in full delivery at right place, marketing and economic issues, etc., forced many organizations to adopt JIT/Lean concepts in the last decades. Currently, in India about 150 companies in the automobile industry use Lean manufacturing, but it is yet to permeate other areas (Mehta et al. 2012). In India, companies like Maruti Udyog Limited (MUL), Eicher, Escorts, Telco, Tisco, TVS, etc., have adopted JIT-based systems and improved their product quality (Singh and Garg 2011).

According to Saboo et al. (2014), although there is evidence that some manufacturing companies in India have adopted Lean manufacturing practices and VSM as improvement approaches, several studies and authors argue that this application is either feeble or has not been fully successful. The traditional Lean paradigm results in nearly two-thirds of the implementations ending in failure while only 16.67 % of those implemented have sustained results—though for less than twelve months (Casey 2009). Indian industry is still struggling to implement Lean principles and philosophies (Singh et al. 2010). The failure in managing Lean implementation process is often consolidated to poor mindset and inadequate understanding of the Lean concept itself (Mostafa et al. 2013). Benton and Shin (1998) mentioned that the major implementation problems centre on cultural, human, and geographical factors. In fact, there is a list of reasons why the Toyota manufacturing system does not work in western firms. The reasons include cultural differences, geographical dispersion of suppliers, and different management styles, etc.

Successful Lean system demands an integrated structure of supporting practices. Support of TPS practices is integral part of sustainable Lean implementation. The TPS is not a toolbox, where a company can pick out the instruments that appear to be useful, but represents an approach that has to apply all TPS principles as a system in order to be effective (Thun et al. 2010; Liker 2004). Furthermore, it is important to note that success necessitates the integration of TPS practices and definitely not highly selective use of just one practice (Thun et al. 2010; Towill 2007). Hitherto, US manufacturers have been unable to replicate the success of JIT management practices used by their Japanese counterparts (New 2007; White et al. 2010). White et al. (2010) believe the sequences of implementations have been ineffective and are the reasons for these results.

There are more than hundred Lean practices available and being practiced by industries (Rose and Nordin 2011; Pavnaskar et al. 2003). In this research, the critical Lean practices commonly cited by many researchers are only considered. Lean practices include quality circle, total quality management (TQM), total productive maintenance (TPM), kanban, single-minute exchange of die (SMED), etc. These Lean practices act as enablers for successful implementation of Lean system. The Lean practice bundles not only affect the successful implementation of Lean but also influence one another. Thus, it is very essential to understand the mutual relationship among the Lean practice bundles. Some practice bundles lay foundation for the other Lean practice bundles. Some are dependent, some are independents and some have interrelationship. The practice bundles which have high driving power and dependency need more attention. The sequential approach of implementation of these practice bundles is essential.

The understanding of the hierarchy of Lean practice bundles would be helpful for the top management implementing the Lean concepts. To motivate the industry towards Lean implementation, significant Lean practice bundles required to be identified, analysed and discussed. This can be a guide for taking appropriate action for successful implementation of Lean system. The effective and sustainable implementation of Lean assumes tremendous significance in this context.

Lot of research has been carried out in the field of modelling Lean system. Some researchers did empirical studies and presented conceptual or theoretical models. Various modelling tools and techniques based on the mathematics, statistics, operation research (OR), computer simulation, structural equation modelling, AHP, Petri nets, etc., were used. More details on existing Lean models are described in Section 3. But as far as authors' literature review on Lean and JIT is concern nobody used interpretive structural modelling (ISM) for JIT or Lean systems. The prime purpose of this paper is to offer a framework for sustainable Lean implementation in manufacturing industry. The authors attempt to expand the body of knowledge by considering the following two criteria.

1. Developing the relationship between each of critical Lean practice bundles and
2. Developing a framework for sustainable Lean implementation

The research is based on secondary data, which includes compilation of research articles, web articles, survey reports, thesis and books, etc., on automotive industry. The main aspect of the paper is the development of roadmap for sustainable Lean implementation using ISM methodology. The salient features of the research are:

1. It represents the collective wisdom of Lean practitioners in the form of interpretive structural model.
2. It offers phase-wise road map for sustainable Lean implementation based on ISM.

This paper is further organized as follows. Research methodology is described in second section. Section three contains information about existing JIT/Lean models/frameworks. Lean practices are introduced briefly in Section four. Section five provides detail information of Lean practice bundles. Overview of ISM and Lean modelling using ISM is discussed in Section six. MICMAC analysis of developed ISM model is carried out in Section seven. The model is validated in Section eight. Section nine discussed the ISM model—a framework for Lean implementation. Finally, Section ten includes general conclusions with research findings, implications, limitations and suggestions for future research.

Research methodology

The main objectives of this paper are:

(a) To identify and prioritize the Lean practices bundles
(b) To discover and analyse the interaction among identified Lean practices bundles using ISM and

(c) To develop a framework for sustainable Lean implementation

In this research, study factors are the Lean practices bundles for successful Lean implementation. Authors have identified eight significant Lean practices bundles from literature review and opinion of the experts.

This work can be characterized as, first, theoretical concept, specifically for the review of literature on practices in Lean/JIT implementation and second, developing a model for deployment of Lean strategy. The approach of the research is exploratory in nature, which constitutes a secondary source. First the relevant literature is reviewed. The authors focused on literature from 1991 to 2013. Literature review includes Lean implementation in various companies across the globe. The literature survey was augmented by use of online computerized data base like Taylor and Francis Science Direct, Google Scholar, Springer Link, World Scientific, Bing, etc., using primary keywords such as JIT, Lean, Lean supply, JIT manufacturing and ISM, and secondary key words like practices, benchmarking, modelling, framework, etc.

The research is based on secondary data, which includes compilation of research articles, master theses, doctoral theses and survey reports and books after scanning the reference sections of the initially selected papers in the domain of Lean, JIT and ISM. The ultimate list of articles reviewed for this paper covers articles published in reputed referred scholarly journals on JIT and Lean.

Based on this search, articles that met the criteria of practices in Lean or JIT implementation and presented a model or framework were selected. A survey of literature was carried out on the basis of editorial scope and contents of the journals and a list of journals was compiled. Journals stating in their editorial scope issues such as Lean, JIT, TPS and ISM were selected. A comprehensive review of the table of content of the journals, abstracts, and wherever necessary review of the complete paper was carried out. Literature Review primarily focus on Lean implementation in manufacturing sector like automotive, machine tools, heavy industries, aerospace etc. and secondarily on other sectors like supply chain management, transportation, relationship management, service, etc.

The flow chart of research methodology used in this study is shown in Fig. 1.

Structural self-interaction matrix for Lean practice bundles was developed by the team members comprising of five Lean practitioners and experts. Structural self-interaction matrix later on used to develop an ISM model showing relationship between the studied variables. The interaction among the Lean practice bundles was analysed using ISM. MICMAC analysis was used to analyse the driving power and the dependence of the

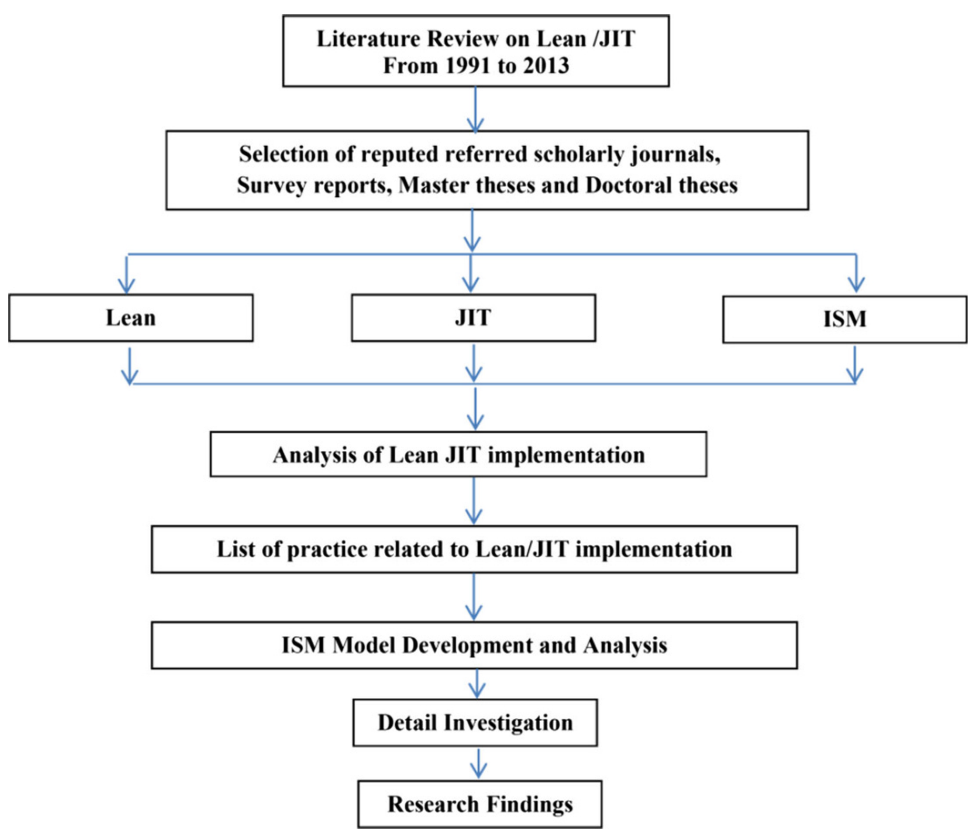


Fig. 1 Flow chart for research methodology

Lean practice bundles. It requires examination of direct and indirect relationships between the Lean practice bundles rather than considering these Lean practice bundles in separation. This analysis will help the managers to devise the strategy for rolling out the Lean in their organization.

Existing JIT/Lean models

Many researchers have carried out research work in the field of modelling Lean system using various modelling tools and techniques based on the mathematics, statistics, operation research (OR), computer simulation, structural equation modelling (SEM), analytic network process (ANP), analytic hierarchy process (AHP), petri nets, etc. Some researchers did empirical studies and presented conceptual or theoretical models. Some of the models are cited in this section.

Martínez-Jurado and Moyano-Fuentes (2012) developed a Lean production adoption model that includes the factors that were detected and their respective interrelationships. Iwase and Ohno (2011) discussed a single-item, multi-stage, serial JIT production system using two types of kanbans in which customer demands and production capacities are stochastic. The system is modelled as a discrete-time, M/G/1-type Markov chain with the unit of time being one withdrawal cycle. Ma et al. (2011) focused on the modelling and analysis of the cross-organizational workflow systems in the context of Lean supply chain (LSC) using Petri nets. Gopinath and Freiheit (2012) proposed a waste relationship model that can be used to derive the relationship between different wastes in a Pareto-optimal waste-dependent Lean system. Chung et al. (2013) developed a replenishment policy for a deteriorating inventory model with price-dependent and incentive-dependent sale. The total revenue for the deteriorating inventory model considers pricing, rebate and JIT delivery policy and future price increase from the supplier. Weng et al. (2012) proposed several dynamic routing strategies for JIT production in hybrid flow shops and using computer simulations to compare the performance of dispatching rules combined with the proposed routing strategies with dispatching rules and/or previous routing methods.

Emde and Boysen (2012) proposed a mathematical model in context JIT supply of mixed-model assembly lines. Khorshidian et al. (2011) developed a mathematical model using genetic algorithm for JIT single machine scheduling with pre-emption and machine idle time. Jie and Wen (2012) presented a conceptual model for Lean 6R military logistics information network based on JIT. Lyonnet and Toscano (2012) developed an analytical model for calculating the optimal quantity to be produced to provide decision elements for determining the best production strategy or for production planning, in particular, in the context of Lean application.

Vinodh and Joy (2012) used SEM to analyse Lean manufacturing practices in different industries and to identify the critical factors for its success implementation. Inman et al. (2011) used structural equation model incorporating agile manufacturing as the focal construct is theorized and tested. The model includes the primary components of JIT (JIT purchasing and JIT production) as antecedents and operational performance and firm performance as consequences to agile manufacturing. Aloini et al. (2011) proposed an integrated model, whose hypotheses were then tested via structural equation modelling on an international dataset from 452 manufacturing firms. Yan et al. (2011) developed an integrated single-supplier, single-buyer inventory model for a deteriorating item in a JIT environment.

Hodge et al. (2011) developed a conceptual model for implementing Lean tools and principles in a textile environment. A hierarchical approach to implementing Lean was proposed. Wahab et al. (2013) designed and developed a conceptual model for leanness measurement in the manufacturing industry. Roslin and Shahadat (2014) proposed a conceptual model on implementation of a lean manufacturing system for manufacturing industry in Malaysia, specifically for the automotive parts manufacturing industry.

Powell et al. (2013) proposed ERP-based lean implementation process. Jie et al. (2014), implementing the Lean Six Sigma framework in a Printing Company. Ramesh and Kodali (2012), proposed decision framework based on a novel formulation of the integrated Analytical Hierarchy Process (AHP) for maximizing Lean manufacturing performance. Mostafa et al. (2013) proposed a project-based framework with four implementation phases along with appropriate practices and decision tools to each phase. Pullan et al. (2011) proposed a concurrent engineering framework based on application of information technology and object oriented methodology for Lean manufacturing. Karim and Arif-Uz-Zaman (2013) proposed methodology for lean implementation built on the five lean principles. Anand and Kodali (2009) presented a comprehensive framework which consisted of 65 Lean practices. These practices were divided into concepts, principles, practices, competitive priorities, stakeholders and functions of an operations department. Saurin et al. (2011) introduced a framework for assessing the use of Lean production (LP) practices in manufacturing cells (MCs).

Although lean benefits are extensively recognized from Toyota's success stories, the current roadmaps and frameworks look incomprehensible from the view of practitioners (Mostafa et al. 2013). ISM base structural framework for Lean practice and its bundles do not exist in the literature. According to Mostafa et al. (2013), existing lean initiatives are not demonstrated in a structured nature. A crystal clear structural roadmap is necessary for sustainable Lean implementation since Lean implementation is a journey and not an adoption of isolated practices.

Lean/JIT practices

Lean manufacturing or Lean production is a production practice, which regards the use of resources for any work other than the creation of value for the end customer, as waste (Vienazindiene and Ciarniene 2013). According to Bozdogan (2010), Lean comes closest to providing a holistic view of company management systems by embodying a tightly knit set of mutually supportive precepts and practices driving its central value creating operations (Sunjka and Murphy 2014). Lean and its associated practices are generally considered best practices in the operations management field (Longoni et al. 2013).

Since lean manufacturing is a multi-dimensional construct, the results demonstrate that approximately 80 % of the respondents have implemented many dimensions of Lean—focus on customer needs, pull system, setup time reduction, total productive maintenance, supplier performance, statistical process control, and cross-departmental problem solving (Ghosh 2013). JIT is focused at continual improvement through all kinds of waste elimination at every level of operations. JIT should be considered as holistic set of sequential management practices implemented throughout the organization. According to Thun et al. (2010), JIT is achieved through the implementation of numerous, well-known practices such as Kanban, short setup times and multi-skilled workers.

The Lean practices are interrelated to each other. Application of individual practice as a separate tool for improvement may defeat the purpose of Lean philosophy. There is a great risk of Lean failure if Lean practices are applied in isolation or in improper sequence. There are certain obstacles in the implementation of Lean manufacturing practices. But they can be overcome by successful planning (Mehta et al. 2012).

Lean practice bundles

Many researchers grouped these practices in different bundles. The term ''bundle'' is used to capture categories of inter-related and internally consistent Lean practices. Shah and Ward (2003) identified 22 Lean practices and classified these practices into four "bundles" of Lean production: just-in-time (JIT), total quality management (TQM), total preventive maintenance (TPM) and human resource management (HRM). White et al. (2010) grouped ten JIT practices in four bundles namely conformance quality practice bundle, delivery reliability practice bundle, volume flexibility practice bundle and low cost practice bundle.

Following Lean practices bundles are used in this paper based on the literature reviewed and opinion of experts/ Lean practitioners:

5.1 Waste elimination practice bundle
5.2 Conformance quality practice bundle
5.3 Delivery reliability practice bundle
5.4 Volume flexibility practice bundle
5.5 Low cost practice bundle
5.6 Human resource management practice bundle
5.7 Health and safety practice bundle and
5.8 Creativity & innovation practice bundle

The core content of a Lean strategy includes practices for HRM, cost minimization, quality enhancement, fast and reliable delivery response, volume flexibility, waste elimination, health and safety, creativity and innovation, etc.

Wastage elimination practices

Non-value-added activities (Non-VA) are activities, which are not required for transforming the materials into the product that the customer wants. Anything, which is non-value-added may be defined as a waste (Al-Khafaji and Al-Rufaifi 2012). Wastes are any procedures, materials, equipment, tools or activities that do not add value and can be eliminated or simplified (Al-Tahat and Eteir 2010). The activity in which no desirable change takes place in shape, size, dimension, taste, colour, place or any other desirable characteristic from customers' point of view is called as non-value-added activity. According to Pullan et al. (2011), Lean is a production practice, which regards the use of resources for any work other than the creation of value for the end customer as waste.

Lean pursue for elimination of all kind of waste from manufacturing system so as to make it more efficient and effective. Generally, wastes are invisible and add to the product cost. Obviously, customers are not willing to pay for waste. So, it is very important to identify the sources of waste and eliminate them. According to Rose et al. (2010), the organization no matter the sizes, large or small is crucial to eliminate waste, in order to increase the profit or return on investment (ROI). The identification of opportunities for seven types waste is exposed through value stream mapping.

Conformance quality practice bundle

Survival of any organization depends upon the production and selling of quality and cost-effective products and services. Quality means delighting the customer by meeting their stated and implied needs. The organizations which have strong quality foundation and culture only will be able to survive in stiff global competition. Total quality management (TQM) philosophy is focused on achieving customers' satisfaction through continual improvement deploying participative management programs throughout the organization. Total quality control emphasizes on improving internal quality aspect of business. Vendor development focuses on improving external quality aspect of business. These practices stress on quality enhancement in all activities and functions in the organization and in the entire supply network. Thus, we can conclude that the Conformance quality practice bundle includes TQM, TQC, SQC, six sigma and supplier management/vendor development.

Delivery reliability practice bundle

The organization must be in position to supply the customers demand as per specifications along with the term and conditions of mutual agreement. According to Ahmad et al. (2003), pull-type links with suppliers and customers enable a plant to be agile and responsive and, therefore, enhance delivery reliability. The improved flow of material and information throughout the supply chain leads to delivery reliability of the organization. The organization's ability to reliably deliver products to the customer may enhance by implementation of focused factory, group technology and uniform workload.

Volume flexibility practice bundle

According to Husseini et al. (2006), volume flexibility is defined as ''the ability to change the volume of output of a manufacturing process in accordance to customer orders''. Flexibility is the ability of a manufacturing system to cope with changes in the nature, mix, volume or timing of its activities (Garg et al. 2001). If the production changes to meet a peak demand, it must use a flexible process that can meet peak demands and still work efficiently during slacker times (Gupta 2011). Prahlad and Hamel (1990) demonstrate that manufacturer has to provide, what the customer demands, i.e., lower priced products with fast delivery speeds. To respond to these needs of product customisation and shorter lead times, companies are prompting to reduce their production batch sizes (Singh and Khanduja 2010). A flexible work force and flexible machines both are equally vital to achieve JIT manufacturing. Thus, JIT offers the flexibility to the organization and keeps the manufacturing system in synchronization with its ever changing environmental conditions. Ability of the organization to meet customers' demands quickly leads to the flexibility of manufacturing system. The volume flexibility practice bundle consists of setup time reduction, multifunction employees and small lot size/single piece flow.

Low cost practice bundle

The profit or loss incurred is equal to the difference between market price and product cost. Manufacturer does not have any control on the market price of product. The market forces dictate the price of the product. Profit can be increased by reducing cost price of product (Singh and Khanduja 2010). Nowadays, customers have wide choice of products. In today's cut-throat competition customers demand low-cost high-quality products. Manufacturers should be able to produce and sell the cost-effective product. High quality with low cost will give a company cutting edge over its competitors. A company with solid foundation of quality, minimal waste, innovative products and processes and quick response to customers demand or flexibility will be able to trim the product costs. JIT practices minimize the use of costly buffers (e.g., work-in-process) and eliminate waste in all stages of production. Thus, unit cost of production is expected to decrease (Ahmad et al. 2003). The best practices for cost reduction are inventory reduction, kanban and JIT purchasing.

Human resource management practices bundle

HR practices can be conceptualized as the glue that holds the other Lean production practices together (Longoni et al. 2013; de Treville and Antonakis 2006; Cua et al. 2001). JIT environments can be characterized as dynamic systems requiring awareness and management of change processes. There is evidence to suggest that the combination and emphasis of the overall human resource strategy employed in the JIT environment are potentially more important than the individual elements (Power and Sohal 2000). According to McNamara (2014), Lean manufacturing has failed to consider human aspects in the past, resulting in undesirable working conditions that can negatively affect commitment, and goes on to identify the role human behaviour plays in the performance of operating systems.

This paper focused specific attention on HRM practices having impact on cost, quality, delivery and flexibility. The practices in HRM bundle include Quality Circle, communication of goals, effective employee development programs, creating a culture of Lean improvement, rewards and recognition and effective labour management relations.

Health and safety practices bundle

According to Longoni et al. (2013), when Lean is done right it need not be mean, rather Lean should continue to be considered a best practice, not just for its potential to improve operational outcomes but also because of its potential to improve the health and safety of the workers who run the system. But what is important to be noticed by practitioners is that the adoption of Lean without the human component is not only mean, it is bad for operational outcomes as well (Longoni et al. 2013). The practices in health and safety bundle consist of five S, Six S, Poka Yoke (error proofing), Visual Management, Standardised work, Ergonomic Work station or cell design and total productive maintenance (TPM).

Creativity and innovation practices bundle

The Lean practitioners need to be creative and innovative in developing newer techniques to make manufacturing more qualitative, cost effective, flexible and safe to respond to customers' requirements. Leung and Lee (2004) identify 'operation Leanness' and 'new-value creativeness' as the two principal competencies of manufacturing firms (Wan and Chen 2008). According to de Haan et al. (2012), a Lean system continually challenges workers to creatively use their talents, skills, and experience to signal anything that may be identified as waste and to remove impediments to a job well done, thereby improving process control and output quality. It was found that the openness, creativeness, and the challenging mentality were found positively influencing the kaizen transfer (Yokozawa et al. 2010). Results from studies carried out by de Haan et al. (2012) indicated that challenging and enabling workers to creatively use their talents and skills in daily work will most likely lead to positive results. Creativity and innovation practices bundle includes Kaizen (Continuous Improvement), applications of advance technologies.

Interpretive structural modelling (ISM)

Introduction to ISM

Original theoretical development of ISM is credited to J.W. Warfield. Sage and Smith (1977); Sage (1977); Farris and Sage (1975) have contributed to the development and application of the ISM methodology for a variety of purposes—especially, those concerned with decision analysis and worth assessment in large-scale systems. Interpretive Structural Modelling (ISM) is a tool which permits identification of structure within a system. The system may be large or small in terms of numbers of elements; and it is the larger, complex systems which benefit the most from ISM (Farris and Sage 1975). ISM readily incorporates elements measured on ordinal scales of measurement and thus provides a modelling approach which permits qualitative factors to be retained as an integral part of the model. In this, it differs significantly from many traditional modelling approaches which can only cope with quantifiable variables (Janes 1988).

ISM is a systematic application of some elementary graph theory in such a way that theoretical, conceptual and computational advantage are exploited to explain the complex pattern of conceptual relations among the variables (Shahabadkar et al. 2012; Charan et al. 2008). ISM uses words, digraphs and discrete mathematics to reveal the intrinsic structure of system/complex issues/problem under consideration. Interpretive structural modelling (ISM) can be used for identifying and summarizing relationships among specific variables, which define a problem or an issue (Sage 1977; Warfield 1974). It provides us a means by which order can be imposed on the complexity of such variables (Jharkharia and Shankar 2005; Mandal and Deshmukh 1994).

The ISM process transforms unclear, poorly articulated mental models of systems into visible, well-defined models useful for many purposes (Mishra et al. 2012; Ahuja et al. 2009). ISM transform absolutely instinctual process of model building into a more methodical and structural approach. Team members acquire much greater insight of the system by both individually and collectively. It also enhances the communication within heterogeneous groups during the process of model building.

ISM has been used by researchers for understanding direct and indirect relationships among various variables in different industries. ISM approach has been increasingly used by various researchers to represent the interrelationships among various elements related to the issue (Attri 2013).

There are certain prerequisite conditions need to satisfy to apply ISM technique successfully. The critical points in the application of ISM techniques are discuss as follows.

1. ISM is an interpretive learning process needs involvement of the stakeholders/concern change agents/team members working collectively to solve the problem.
2. The identification of system variables and the interrelationship between variables is of prime importance to achieve the exact structural model.
3. Team members must have experience and the in-depth knowledge of the issue/system under consideration.

- The enrich sources of the wisdom are personal knowledge, active practical experiences and exposures to failed as well as successful attempts of Lean implementation in the organizations for an individual member as a part of implementation team. The lessons learned from successful and failed Lean implementation in the organization must be documented and shared through

Table 1 Brief comparison between AHP, ANP and ISM

Analytical hierarchy process (AHP)	Analytic network process (ANP)	Interpretive structural modelling (ISM)
Discipline of hierarchy has to be strictly followed	Deals with loose networks	Involves a set of interconnected criteria
Assumes functional independence of an upper part of hierarchy from its lower one	Takes into account the interdependencies and non-linearity	Establishes the "leads to" relationships among the criteria
Fails in complex real life problems	Useful in real life non-linear problems	Captures the complexities of real life problems
Moderate ability for capturing dynamic complexity	Lower ability for capturing complexity	Higher ability for capturing dynamic complexity

Source: Thakkar et al. (2008)

proper knowledge management (KM) system. Organizational knowledge management is absolutely necessary so that the organization is independent of any person—transfer to another department or not working in the particular organization during execution of improvement programs.

- The Lean consultants are the rich source of profound knowledge as they work on various projects across the industries and hence have diversified exposure and experience in the areas of their specialization. This profound knowledge must be tapped for developing a roadmap for sustainable Lean implementation. ISM used the collective wisdom of the team members which includes Lean practitioners and consultants to convert mental model into a structural model by considering the interrelationship of variables involved in the process or system.

The justification for selection of ISM technique to analyse the interaction among identified Lean practices bundles and modelling is discussed here. Interpretive structural modelling (ISM), analytic network process (ANP) and analytic hierarchy process (AHP) are three contemporary modelling techniques applied frequently in the literature. Thakkar et al. (2008) compared these three techniques and extracts from that comparison is shown in the Table 1. Table 1 presents the exceptional virtues of ISM over other modelling techniques.

Applications of ISM

ISM is a well-known technique, which can be applied in various fields. ISM has been applied by a number of researchers to develop a better understanding of the systems under consideration (Mudgal et al. 2010). Use of Interpretative Structural Modelling (ISM) is inspired by the versatility displayed by this method, as reported by researchers, across a wide spectrum of economic and competitive complexities affecting businesses (Sagheer et al. 2009). Table 2 provides the details of the applications of ISM in various system/Field.

Procedure for model development using ISM

Complex issue/problem can be defined by many interconnected elements or variables (factors) related to it in terms of a system. The ISM process begins with certain system-related data, ideas, skills, and/or knowledge possessed by the team members. Identification of vital and significant variables and establishment of interrelationship between variables is very important for accurate model development using ISM. The ISM ends with the structural model exposing the interrelation between various elements, their dependency/independency and the level of each element.

Certain stepwise procedure is to be adopted to develop a model or frame work using ISM. Ravi and Shankar (2005) described the various steps involved in the ISM methodology as follows:

Step 1: Variables affecting the system under consideration are listed, which can be objectives, actions, and individuals, etc.

Step 2: From the variables identified in step 1, a contextual relationship is established among variables with respect to which pairs of variables would be examined.

Step 3: A structural self-interaction matrix (SSIM) is developed for variables, which indicates pair-wise relationships among variables of the system under consideration.

Step 4: A reachability matrix is developed from the SSIM and the matrix is checked for transitivity. The transitivity of the contextual relation is a basic assumption made in ISM. It states that if a variable A is related to B and B is related to C, then A is necessarily related to C.

Step 5: The reachability matrix obtained in Step 4 is partitioned into different levels.

Step 6: Based on the relationships given above in the reachability matrix, a directed graph is drawn and the transitive links are removed.

Step 7: The resultant digraph is converted into an ISM, by replacing variable nodes with statements.

Step 8: The ISM model developed in Step 7 is reviewed to check for conceptual inconsistency and necessary modifications are made.

Interpretive structural model (ISM) development

In this paper, Fig. 2 presents an adaption of Singh et al. (2003) general ISM methodology. The interrelationships

Table 2 Applications of ISM in various systems/fields

Sr. no.	Reference	System/field	Variables	ISM deployed
1	Kumar et al. (2013a)	Lean system	Variables related to man, machine, material etc	For modelling 18 variables of Lean Manufacturing system implementation. Note: However these variables are not classified and treated as an individual factor
2	Eswarlal et al. (2011)	Renewable energy	Enablers	Modelling the implementation of the enablers of renewable energy for sustainable development
3	Wang et al. (2008)	Energy sector	Barriers	To investigate the interactions among the major barriers to energy saving in China
4	Satapathy and Mishra (2013)	Electricity utility sector	Design requirements	To find interrelationship between design requirements for service quality of electricity utility sector
5	Singh and Kant (2008)	Knowledge management	Barriers	To develop the relationships among the identified knowledge management barriers
6	Yrd and Omur (2010)	Innovation process	Barriers	For modelling and establishing the relationship among the barriers encountered in innovation process in Turkey's condition
7	Khurana et al. (2010)	Indian manufacturing industry	Enablers	For modelling of information sharing enablers for building trust in Indian manufacturing industry
8	Ahuja et al. (2009)	Building project management	Benefits	To assess importance of perceived benefits of collaborative Information Communication Technology (ICT) adoption for building project management
9	Alawamleh and Popplewell (2011)	Virtual organization	Risk sources	Modelling of risk sources in a virtual organization
10	Diabat et al. (2012)	Food supply chain	Risks	Analyses the various risks involved in a food supply chain
11	Pfohl et al. (2011)	Supply chain	Risks	To identify and understand interdependencies among supply chain risks on different levels (e.g. 3PL, first-tier supplier, focal company etc.)
12	Faisal et al. (2007)	Supply chain	Enablers	To analyse the enablers for Supply chain agility
13	Kumar et al. (2013b)	Supply chain	Effective customer involvement	To model of variables for effective customer involvement in green concept implementation in supply chain management
14	Diabat and Govindan (2011)	Green supply chain	Drivers	Modelling the drivers affecting the implementation of green supply chain management
15	Luthra et al. (2011)	Green supply chain	Barriers	To developed a structural model of the barriers to implement green supply chain management (GSCM) in Indian automobile industry
16	Mudgal et al. (2010)	Green supply chain	Barriers	To model and analyse key barriers of green supply chain practices
17	Kannan et al. (2008)	Green supply chain	Supplier selection criteria	Analysed the interaction of criteria that is used to select the green suppliers who address the environmental performance using interpretive structural modelling (ISM) and analytic hierarchy process (AHP)
18	Sharma and Gupta (1995)	Waste management	Actions required	To develop a hierarchy of actions required to achieve the future objective of waste management in India
19	Kannan et al. (2009)	Reverse logistics	Selection criteria	To develop model for the selection of reverse logistics provider
20	Ravi and Shankar (2005)	Reverse logistics	Barriers	To analyse the barriers of the reverse logistics in automobile industries

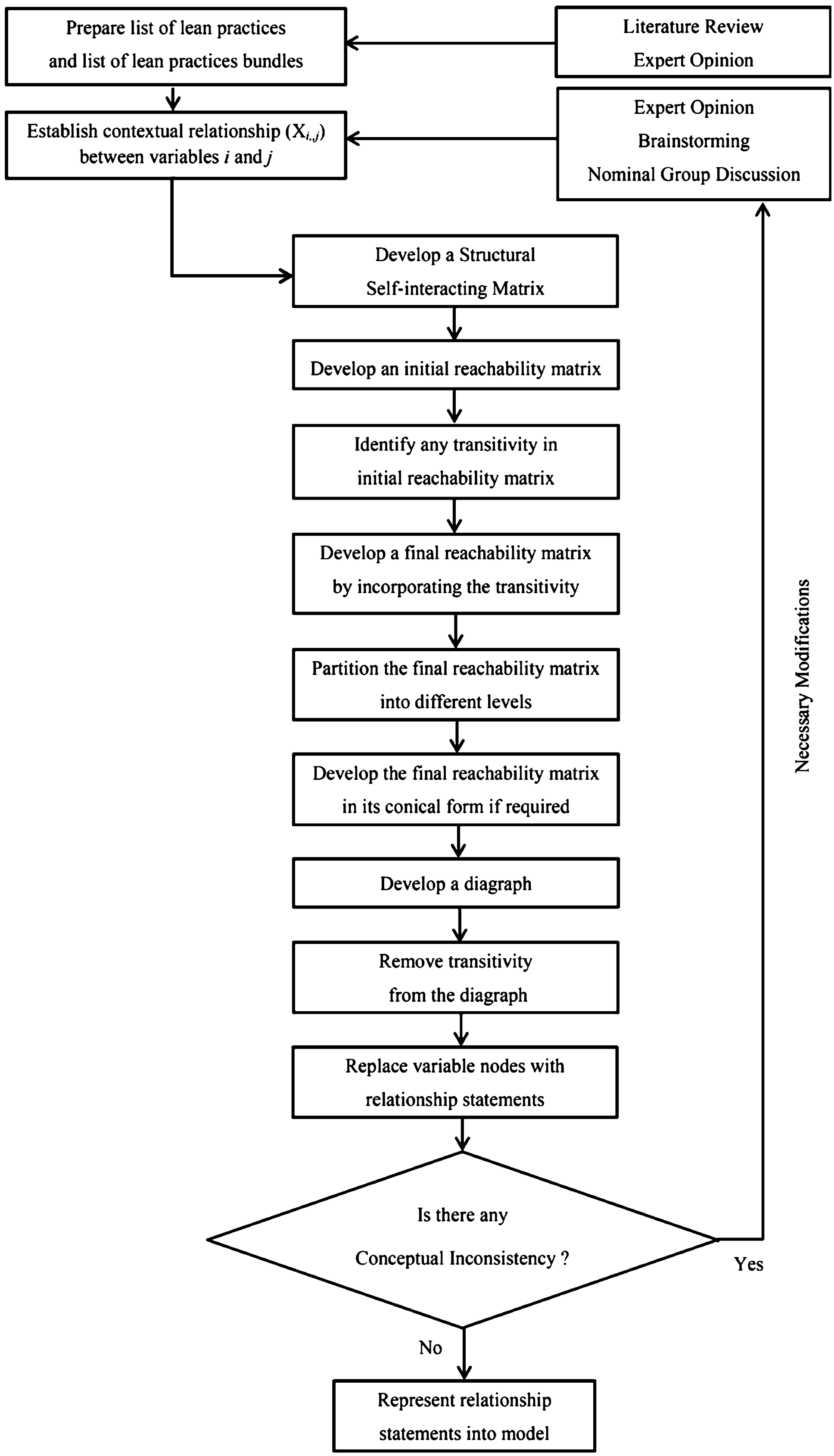


Fig. 2 Flow chart for preparing ISM

among different Lean practice bundles for successful Lean implementation have been achieved through these steps, which are illustrated in Fig. 2.

Structural self-interaction matrix (SSIM)

Eight Lean practice bundles were identified through literature review and experts opinion. The next step is to analyse the interrelationship between these Lean practice bundles using ISM. ISM methodology suggests the use of the expert opinions based on various management techniques such as brainstorming and nominal group discussion technique in developing the contextual relationship among the Lean practice bundles. These experts from the industry and academia were well conversant with Lean practices.

'Leads to' or 'influences' type of contextual relationship is chosen for analysing the Lean practice bundles. This means that a particular Lean practice bundle influences another practice bundle. On the basis of this, contextual relationship between the identified Lean practice bundles is developed.

Following four symbols were used to denote the direction of relationship between the Lean practice bundles (i and j):

V Lean practice bundle i influences Lean practice bundle j
A Lean practice bundle i influenced by Lean practice bundle j
X Lean practice bundles i and j influence each other
O Lean practice i and j do not influence each other since they are unrelated

Consultation and discussions with the five Lean practitioners and experts, helped in identifying the relationships between the identified Lean practice bundles. On the basis of contextual relationship between Lean practice bundles, the SSIM has been developed. To obtain consensus, the SSIM was further discussed by the same group of experts. On the basis of their responses, SSIM has been finalized and it is presented in Table 3.

Development of the initial and final reachability matrix

The next step is to develop the initial and final reachability matrix from the SSIM.

(a) Initial reachability matrix

Obtain the initial reachability matrix from the SSIM format by transforming the information of each cell of SSIM into binary digits (i.e., 1 s or 0 s). This transformation has been done by substituting V, A, X, O by 1 and 0 as per the following rules. Rules for transformation are given in Table 4.

Table 3 Structural self-interaction matrix (SSIM) for lean practice bundles

SN	JIT practice bundle	8	7	6	5	4	3	2	1
1	Waste elimination	A	A	A	V	V	V	V	
2	Conformance quality	A	O	A	V	O	V		
3	Delivery reliability	A	A	O	V	A			
4	Volume flexibility	O	O	A	V				
5	Low cost	A	A	A					
6	Human resource management	V	V						
7	Health and safety	A							
8	Creativity and innovation								

Following these rules, initial reachability matrix is prepared as shown in Table 5.

(b) Final reachability matrix

To get Final reachability matrix, the concept of transitivity is introduced, and some of the cells of the initial reachability matrix are filled in by inference. If a variable 'i' is related to 'j' and 'j' is related to 'k', then transitivity implies that variable 'i' is necessarily related to 'k'. The final reachability matrix is developed after incorporating the transitivity concept in Table 5 and is presented in Table 6, wherein entries marked † show the transitivity.

Level partitioning the final reachability matrix

After creating the final reachability matrix, obtain the structural model (digraph). Warfield (1974) has presented a series of partitions, which are induced by the reachability matrix on the set and subset of different variables. From these partitions one can identify many properties of the structural model (Farris and Sage 1975).

The reachability set and antecedent set for each Lean practice bundles are established from the final reachability matrix. The reachability set for a particular Lean practice bundle consists of the practice bundle itself and the other practice bundles, which it influences. Whereas the antecedent set consists of the Lean practice bundle itself and the other practice bundles which may influence it. Subsequently, the intersection of the reachability and antecedent

Table 4 Rules for transformation

If the (i, j) entry in the SSIM is	Entry in the initial reachability matrix	
	(i, j)	(j, i)
V	1	0
A	0	1
X	1	1
O	0	0

Table 5 Initial reachability matrix for lean practice bundles

SN	Lean practice bundle	8	7	6	5	4	3	2	1
1	Waste elimination	0	0	0	1	1	1	1	1
2	Conformance quality	0	0	0	1	0	1	1	0
3	Delivery reliability	0	0	0	1	0	1	0	0
4	Volume flexibility	0	0	0	1	1	1	0	0
5	Low cost	0	0	0	1	0	0	0	0
6	Human resource management	1	1	1	1	1	0	1	1
7	Health and safety	0	1	0	1	0	1	0	1
8	Creativity and innovation	1	1	0	1	0	1	1	1

Table 6 Final reachability matrix for lean practice bundles

	JIT practice bundle	8	7	6	5	4	3	2	1	Driver power
1	Waste elimination	0	0	0	1	1	1	1	1	5
2	Conformance quality	0	0	0	1	0	1	1	0	3
3	Delivery reliability	0	0	0	1	0	1	0	0	2
4	Volume flexibility	0	0	0	1	1	1	0	0	3
5	Low cost	0	0	0	1	0	0	0	0	1
6	Human resource management	1	1	1	1	1	†*1*	1	1	8
7	Health and safety	0	1	0	1	0	1	†*1*	1	5
8	Creativity and innovation	1	1	0	1	†*1*	1	1	1	7
	Dependence	2	3	1	8	4	7	5	4	

Table 7 Level partition—iteration 1

Lean practice bundle no.	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 5	1, 6, 7, 8	1	
2	2, 3, 5	1, 2, 6, 7, 8	2	
3	3, 5	1, 2, 3, 4, 6, 7, 8	3	
4	3, 4, 5	1, 4, 6, 8	4	
5	*5*	*1, 2, 3, 4, 5, 6, 7, 8*	5	*I*
6	1, 2, 3, 4, 5, 6, 7, 8	6	6	
7	1, 2, 3, 5, 7	6,7, 8	7	
8	1, 2, 3, 4, 5, 7, 8	6, 8	8	

Table 8 Level partition—iteration 2

Lean practice bundle no.	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4	1, 6, 7, 8	1	
2	2, 3	1, 2, 6, 7, 8	2	
3	*3*	*1, 2, 3, 4, 6, 7, 8*	*3*	*II*
4	3, 4	1, 4, 6, 8	4	
6	1, 2, 3, 4, 6, 7, 8	6	6	
7	1, 2, 3, 7	6, 7, 8	7	
8	1, 2, 3, 4, 7, 8	6, 8	8	

Table 9 Level partition—iteration 3

Lean practice bundle no.	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 4	1, 6, 7, 8	1	
2	*2*	*I, 2, 6, 7, 8*	*2*	*III*
4	*4*	*1, 4, 6, 8*	*4*	*III*
6	1, 2, 4, 6, 7, 8	6	6	
1	1, 2, 7	6, 7, 8	7	
8	1, 2, 4, 7, 8	6, 8	8	

sets is derived for all the Lean practice bundles and levels of different Lean practice bundles are determined. The Lean practice bundles for which the reachability sets and the intersection sets are identical, assigned the top level in the ISM hierarchy. The top-level Lean practice bundles are those that will not lead the other Lean practice bundles above their own level in the hierarchy. Once the top-level Lean practice bundle is identified, it is discarded from further hierarchical analysis (i.e., that Lean practice bundle from all the different sets) and other top-level Lean practice bundles of the remaining sub-group are found. This iteration is repeated till the levels of each practice bundle are found out (Tables 7, 8, 9, 10, 11, 12, 13). Level identification process of these Lean practice bundles is completed in seven iterations.

Final list of Level partitions is given in Table 14. The identified levels aid in building the digraph and the final model of ISM. Top-level Lean practice bundles are positioned at the top of digraph and so on.

Development of conical matrix

Conical matrix is developed by clubbing together Lean practice bundles at the levels achieved, across rows and columns of the final reachability matrix. Table 15 shows the final reachability matrix in the conical form. Most zero (0) variables are in the upper diagonal half of the matrix and most unitary (1) variables are in the lower half. The driving power of a Lean practice bundles is determined by summing up the number of 1 s in the rows and its dependence power by summing up the number of 1 s in the columns. Thereafter, ranks are determined by giving highest ranks to the Lean practice bundles that have the maximum number of 1 s in the rows and columns indicating driving power and dependence power, respectively.

Table 10 Level partition—iteration 4

Lean practice bundle no.	Reachability set	Antecedent set	Intersection set	Level
1	*1*	*1, 6, 7, 8*	*1*	*IV*
6	1, 6, 7, 8	6	6	
1	1, 7	6, 7, 8	7	
8	1, 7, 8	6, 8	8	

Table 11 Level partition—iteration 5

Lean practice bundle no.	Reachability set	Antecedent set	Intersection set	Level
6	6, 7, 8	6	6	
7	*7*	*6, 7, 8*	*7*	*V*
8	7, 8	6, 8	8	

Table 12 Level partition—iteration 6

Lean practice bundle no.	Reachability set	Antecedent set	Intersection set	Level
6	6, 8	6	6	
8	*8*	*6, 8*	*8*	*VI*

Table 13 Level partition—iteration 7

Lean practice	Reachability set	Antecedent set	Intersection set	Level
6	*6*	*6*	*6*	*VII*

Table 14 Final list of level partitions

Level	Lean practice bundle no.	Lean practice bundle
I	5	Low cost
II	3	Delivery reliability
III	2	Conformance quality
III	4	Volume flexibility
IV	1	Waste elimination
V	7	Health and safety
VI	8	Creativity and innovation
VII	6	Human resource management

Development of digraph

An initial digraph including transitivity links is obtained on the basis of conical matrix. It is generated by nodes and lines of edges. If there is a relationship between the Lean practice bundles '*i*' and '*j*', this is shown by an arrow that points from '*i*' to '*j*'. After discarding the indirect links (i.e., remove transitivity), a final digraph is developed (Fig. 3). The top-level Lean practice bundle is positioned at the top of the digraph and second-level Lean practice bundle is placed at second position and so on, until the bottom level is placed at the lowest position in the digraph.

Table 15 Conical form final reachability matrix for lean practice bundles

	Lean practice bundle	5	3	2	1	4	7	8	6	Driver power
5	Low cost	1	0	0	0	0	0	0	0	1
3	Delivery reliability	1	1	0	0	0	0	0	0	2
2	Conformance quality	1	1	1	0	0	0	0	0	3
4	Volume flexibility	1	1	0	0	1	0	0	0	3
1	Waste elimination	1	1	1	1	1	0	0	0	5
7	Health and safety	1	1	†*1*	1	0	1	0	0	5
8	Creativity and innovation	1	1	1	1	†*1*	1	1	0	7
6	Human resource management	1	†*1*	1	1	1	1	1	1	8
	Dependence	8	7	5	4	4	3	2	1	

Building the ISM-based model

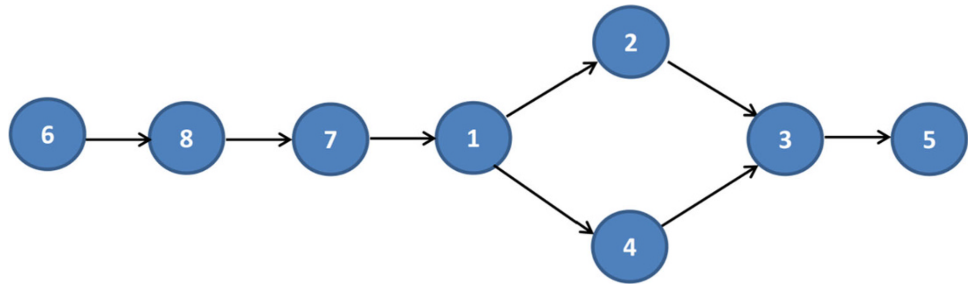
In the next step, the digraph is converted into an ISM model by replacing nodes of the Lean practice bundles with statements as shown in Fig. 4. From the model developed with the identified Lean practice bundles in this research, it is clear that the most important Lean practice bundle that enables successful implementation of Lean is HRM (Lean practice bundle 6), which comes as the base of ISM hierarchy whereas low cost practice bundles which are dependent on other Lean practice bundles has been appeared on top of the hierarchy.

MICMAC analysis

Matrice d'Impacts croises-multipication appliqué an classment (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC. The MICMAC principle is based on multiplication properties of matrices (Mudgal et al. 2010; Sharma et al. 1995). The objective of the MICMAC analysis is to analyse the driving power and the dependence of the variables (Faisal et al. 2006; Mandal and Deshmukh 1994).

The dependence and the driving power of each of these Lean practice bundles are shown in Table 4 or Table 13. In this table, an entry of '1' along the rows and columns indicates the driving power and the dependence,

Fig. 3 Diagraph for lean practice bundles



respectively. Subsequently, the driving-dependence power diagram is constructed as shown in Fig. 5. As an illustration, it is observed from Table 3 that Lean practice bundles no. 8 (Creativity and innovation) is having a driver power of 7 and a dependence of 2. Therefore, in this figure, it is positioned at a place corresponding to a driver power of 7 and a dependency of 2 in the driving-dependence power diagram.

In this analysis, the Lean practice bundles described earlier are classified into four clusters (Fig. 5).

1. Autonomous Lean practice bundles,
2. Dependent Lean practice bundles,
3. Linkage Lean practice bundles and
4. Independent Lean practice bundles.

Independent Lean practice bundles cluster consists of human resource management, creativity and innovation, health and safety and waste elimination. These Lean practice bundles are the key drivers for Lean implementation. Management has to pay maximum attention to these bundles to get quick and sustainable results. Volume flexibility practices bundle falls in autonomous cluster which has weak driving power and weak dependence (refer to Fig. 5: driving power and dependence diagram). This bundle is relatively disconnected from the whole system and has very few links, which may be strong. The management has to pay attention to all the identified risk sources in 'volume flexibility' practice bundle. Table 16 provides more details about clusters and its characteristics.

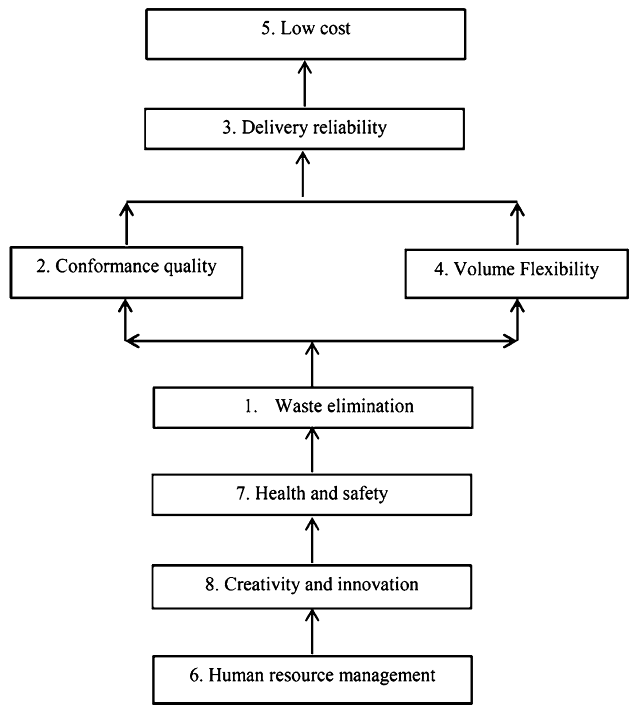


Fig. 4 ISM-based model for lean practice bundles

Validation of ISM model

It is essential to test and validate the model developed for its appropriateness. Model can be validated through different tools and techniques. Model validation may be carried out qualitatively by comparing the already established and widely accepted theory, concepts or rules. Alternatively, the developed model can be validated through comparing with the results obtained by different modelling techniques like analytical hierarchy process (AHP). It may be carried out qualitatively through collection of data with structure questionnaire, personal interviews and sample surveys. Also, ISM model may be validated quantitatively using structural equation modelling.

In the present case, the ISM model developed is tested and validated using first qualitative approach as mentioned above. That means the model validation is done qualitatively by comparing the already established and widely accepted theory, concepts or rules. The ISM model obtained in this work is validated with the help of five Lean principles suggested by Womack and Jones (1997).

Lean practices and the five Lean principles

Following The Machine that Changed the World, Womack and Jones (1997) developed comprehensive Lean philosophy, based on five principles; hat could be applied to the entire enterprise not just to manufacturing. Brief definitions of these principles are as follows.

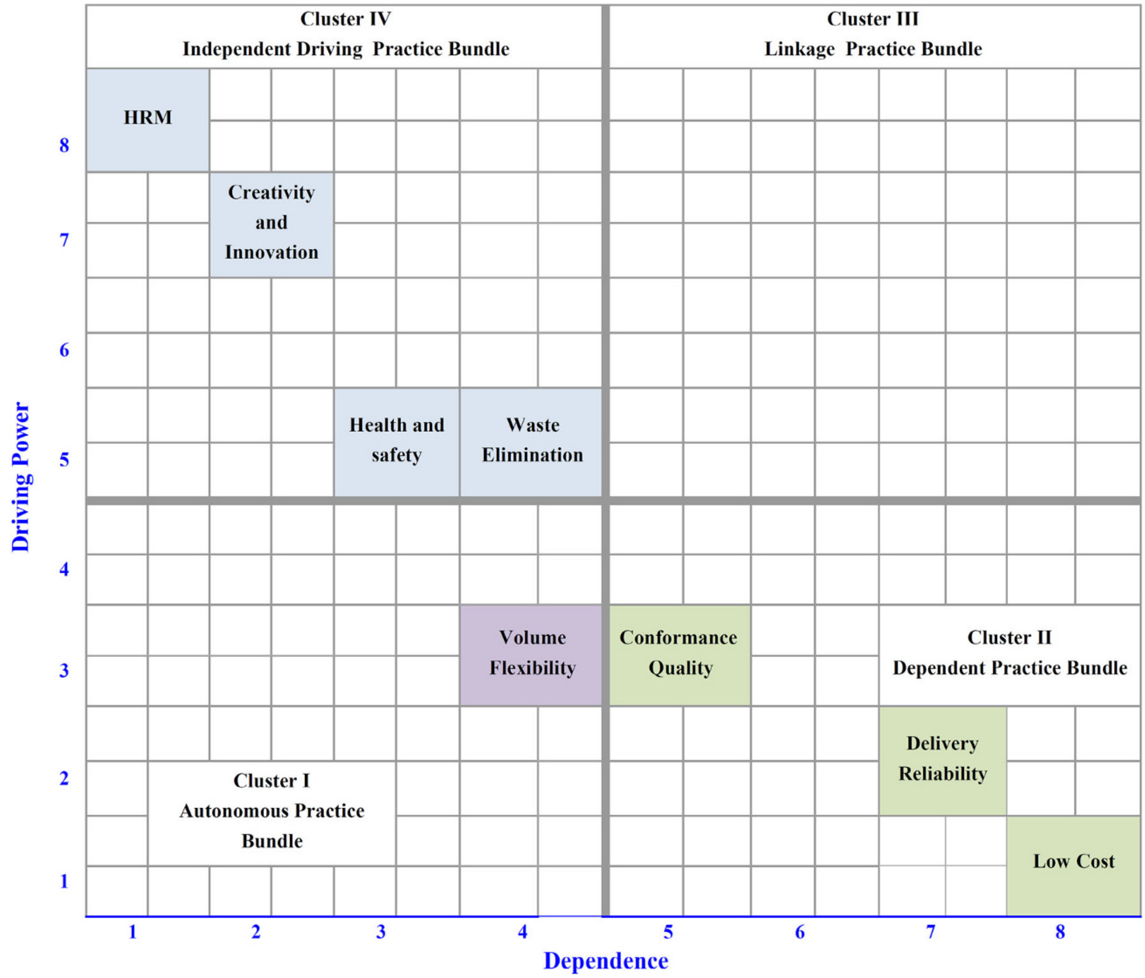


Fig. 5 Driving power and dependence diagram

Specification of customer value

Specify value from the perspective of the ultimate customer as well as the internal and external stakeholders in terms of specific products, information, and services with specific capabilities or applications offered at a specific price or cost and time (Haque and James-moore 2004).

Identification of value stream

A value stream is defined as all the value-added and non-value-added actions required in order to provide a specific product, service, or combination of products and services, to a customer, including those in the overall supply chain as well as those in internal operations (Huang and Liu 2005; Sullivan et al. 2002; Rother and Shook 1999; Womack and Jones 1996). Identify the entire value stream for each product or product family and eliminate waste (Haque and James-moore 2004).

Improvement of production flow

Make the remaining value creating steps flow (Haque and James-moore 2004). The method of aligning the processes to facilitate the critical path (Parry and Turner 2006).

Use of pull mechanism

Let the customer pull the process. Design and provide what the customer wants only when the customer wants it (Haque and James-moore 2004)

Pursuit of perfection

Strive for perfection by continually removing successive layers of waste as they are uncovered (Haque and James-moore 2004). Develop and amend the processes continuously in pursuit of perfection (Parry and Turner 2006).

Table 16 Clusters and its characteristics

Cluster no.	Clusters	Characteristics	Driving power	Dependence	Lean practice bundles
I	Autonomous lean practice bundles	These lean practice bundles are relatively disconnected from the system, with which they have only few links, which may not be strong	Weak	Weak	•Volume flexibility
II	Dependent lean practice bundles	These lean practice bundles are the automatic followers of other bundles	Weak	Strong	•Low cost •Delivery reliability •Conformance quality
III	Linkage Lean practice bundles	These Lean practice bundles are unstable, in the sense that any action on these practice bundles will have an effect on others and also a feedback on themselves	Strong (key variable)	Strong	–
IV	Independent Lean practice bundles	These Lean practice bundles are the key drivers for implementation. Management has to pay maximum attention to these bundles to get quick results	Strong (key variable)	Weak	•Human resource management •Creativity & innovation •Health and safety •Waste elimination

Desirable outcomes are expected after implementation of every Lean practice. Womack and Jones' Lean Principles offer the guidelines for successful implementation of Lean. The relationship of Lean practices with Womack and Jones' Lean Principles is given in Table 17 and Table 18.

Table 17 and Table 18 indicate the contribution of each practice bundles against five Lean principles supported by the literature reviewed. The framework for Lean Implementation is shown in Fig. 6 indicating the Lean practice bundles and implementation period on x axis versus five principles of Lean on y axis. Implementation period depends upon the rigour, winningness, available resources, etc., of the organization wanted to implement Lean systems. Naturally, implementation period may vary from organization to organization. The sequential order of Lean implementation is having agreement with the worldwide accepted five principles suggested by Womack and Jones (1997); it is evident from Table 17 and Table 18 as well as from Fig. 6.

HRM practice bundles create value and value stream (principle no. 1 and 2). Creativity and innovation practice bundles contribute towards creation of value, value stream and flow as well ((principle no. 1, and 3). Remaining practice bundles create flow of material and information (principle no. 3). The last bundle, i.e., low cost contributes to create pull in the system (principle no. 4). The fifth principle 'Perfection' is applicable at all stages of Lean implementation. It follows the Plan–Do–Check–Act (PDCA) cycle for improvement and ultimately perfection. Hence, we can conclude that the model is tested and validated qualitatively.

Discussion

The JIT strategy was developed by Taiichi Ohno at Toyota Motor. JIT is an integrated, problem-solving management approach aimed at improving quality and facilitating timeliness in supply, production and distribution (Lai and Cheng 2009; Davy et al. 1992). The JIT is based on ''zero concept'', which aims to achieve zero defects, zero queues, zero breakdown, zero inventories and so on (Manavizadeh et al. 2013).

Lean practitioners must have the understanding of the major Lean domains and issues to implement it successfully. The major domains of Lean system may be categorized as human centric, organization centric, systems centric and technology centric. The issues of Lean system in each domain are as follows:

1. Human centric:

Change management is one of the challenging issues in Lean implementation. It includes employees, suppliers, customers and human-related virtues (attitude and behaviour) like leadership, teamwork, cooperation, habits, etc. Knowledge management is another significant area to be focused on extracting, compiling, preserving and sharing the knowledge acquired through experience.

2. Organization centric:

It includes top management, culture, finance, resources, etc.

Table 17 Relationship of Lean practices with Womack and Jones' Lean Principles

Sr. No.	Lean/JIT Practice	Value	Value Stream	Flow	Pull	Perfe-ction	Source
1	**Wastage Elimination Practices Bundle**						
1.1	Value Stream Mapping (VSM)	◘	♣	£			◘ *Marvel and Standridge, 2009; Bhasin and Burcher, 2006; Motwani, 2003;* ♣ *Braglia et al., 2006*
1.2	7 Wastes and Waste elimination	◘	≠	£			◘ *Gopinath & Freiheit, 2012; Hodge et al. 2011; Roth, 2011; Marvel and Standridge 2009;Motwani,2003; Sánchez and Pérez,2001; Womack and Jones, 1996; Karlsson and Åhlström,1996* ≠ *Sezen et al., 2012*
2	**Conformance quality practice Bundle**						
2.1	Total Quality Management (TQM)	◘					*Wali and Boujelbene, 2010*
2.2	Total Quality Control (TQC)	◘		£			*White et al., 2010*
2.3	Statistical Quality Control (SQC)			£			£ *Suggested by experts*
2.4	Six Sigma			£		£	£ *Suggested by experts*
2.5	Supplier Management or Vendor Development	◘	◘	£			*Marvel and Standridge, 2009; Shah and Ward, 2007;Bhasin and Burcher, 2006; Motwani, 2003; Sánchez and Pérez, 2001*
	Supplier base reduction	◘	◘	£			*Marvel and Standridge, 2009; Bhasin and Burcher, 2006; Karlsson and Åhlström,1996*
3	**Delivery reliability practice Bundle**						
3.1	Focused Factory (FF)			◘			*White et al., 2010*
3.2	Group Technology (GT)		♥	◘			♥ *White et al., 2010; Rother and Shook, 1999* ◘ *White et al., 2010*
	Cellular Manufacturing(CM)			§ ◘	◘		§ *Bortolotti & Romano, 2012; Nahm et al. 2003* ◘ *Marvel and Standridge 2009; Bhasin and Burcher, 2006; Motwani, 2003; Monden, 1993*
3.3	Uniform Workload (UW)			◘			*White et al. 2010*
	Level Production			◘			*Marvel and Standridge 2009; Detty and Yingling, 2000; Monden, 1993*
4	**Volume flexibility practice bundle**						
4.1	Reduced Setup times (SU) [SMED]			£		◘	£ *Suggested by experts* ◘ *Marvel and Standridge 2009; Shah and Ward, 2007;Bhasin and Burcher, 2006*
4.2	Multifunction Employees (MFE)			◘		◘	*Marvel and Standridge 2009; Motwani, 2003; Sánchez and Pérez, 2001; Karlsson and Åhlström, 1996*
4.3	Small Lot Size			◘			*Sezen et al. 2012; Taj 2008; Rubio and Corominas, 2008; Gonzalez-Benito 2005; Christiansen et al. 2003; Sanchez and Perez 2001; Oliver et al. 1994, 1996*
	Single piece flow			◘			*Marvel and Standridge 2009; Shah and Ward, 2007; Motwani, 2003*

Table 18 Relationship of Lean practices with Womack and Jones' Lean Principles

Sr. No.	Lean/JIT Practice	Value	Value Stream	Flow	Pull	Perfe-ction	Source
5	**Low cost practice Bundle**						
5.1	Inventory Reduction			◘			◘ *Sezen et al., 2012 ; Taj 2008; Gonzalez-Benito, 2005; Christiansen et al., 2003; Sanchez and Perez, 2001; Oliver et al., 1994, 1996*
5.2	Kanban (KAN) [JIT Pull System]			¥	◘		¥ *Bortolotti & Romano, 2012; White et al., 2010 Braglia et al., 2006* ◘ *Deflorin & Scherrer-Rathje 2012; Gupta, 2012;Cottyn et al., 2011; Lu et al., 2011; White et al., 2010; Marvel and Standridge, 2009; Yang et al., 2007; Liker and Meier, 2006; Bhasin and Burcher 2006; Sánchez and Pérez, 2001; Detty and Yingling, 2000; Karlsson and Åhlström, 1996; Monden,1993*
5.3	Just-in-Time Purchasing (JITP)				◘		*White et al., 2010*
6	**Human Resource Practices Bundle**						
6.1	Quality Circles (QC)	◘	♠	£			◘ *White et al ,2010* ♠ *Karlsson and Åhlström,1996*
6.2	Communication of goals	£		£			£ *Suggested by experts*
6.3	Effective employee development programs	£		£		£	£ *Suggested by experts*
6.4	Creating a culture of lean improvement	£		£		£	£ *Suggested by experts*
6.5	Rewards and recognition			£			£ *Suggested by experts*
6.6	Effective labor management relations	£		£			£ *Suggested by experts*
7	**Health and Safety Practices Bundle**						
7.1	Five S (Work place Organization) and			€		◘	€ *Jiménez et al., 2012* ◘ *Marvel and Standridge, 2009; Bhasin and Burcher, 2006;Detty and Yingling, 2000; Monden,1993*
7.2	'6 S'			◘			*Anvari et al., 2011*
				£			£ *Suggested by experts*
	Error Proofing (Poka Yoke)			£		◘	£ *Suggested by experts*
7.3	Visual control or Management			◘	◙		◘ *Ablanedo-Rosas et al., 2010; Parry & Turner, 2006; Liker, 2004* ◙ *Deflorin & Scherrer-Rathje, 2012; Liker and Meier, 2006*
7.4	Standardised work			◘			*Deflorin & Scherrer-Rathje 2012;Marvel and Standridge 2009; Liker and Meier, 2006; Detty and Yingling, 2000; Monden,1993*
7.5	Ergonomic Work station or Cell Design			£			£ *Suggested by experts*
7.6	Total Productive Maintenance (TPM)			◘			*White et al. 2010;*
8	**Creative & Innovative Practices Bundle**						
8.1	Kaizen		£			◘	*Al-Tahat and Eteir, 2010*
	Continuous Improvement		£			◘	*White et al. 2010; Bhasin and Burcher, 2006; Shah and Ward, 2007; Motwani, 2003; Sánchez and Pérez, 2001; Detty and Yingling, 2000; Karlsson and Åhlström, 1996; Monden, 1993*
8.2	Applications of advance technologies			£		£	£ *Suggested by experts*

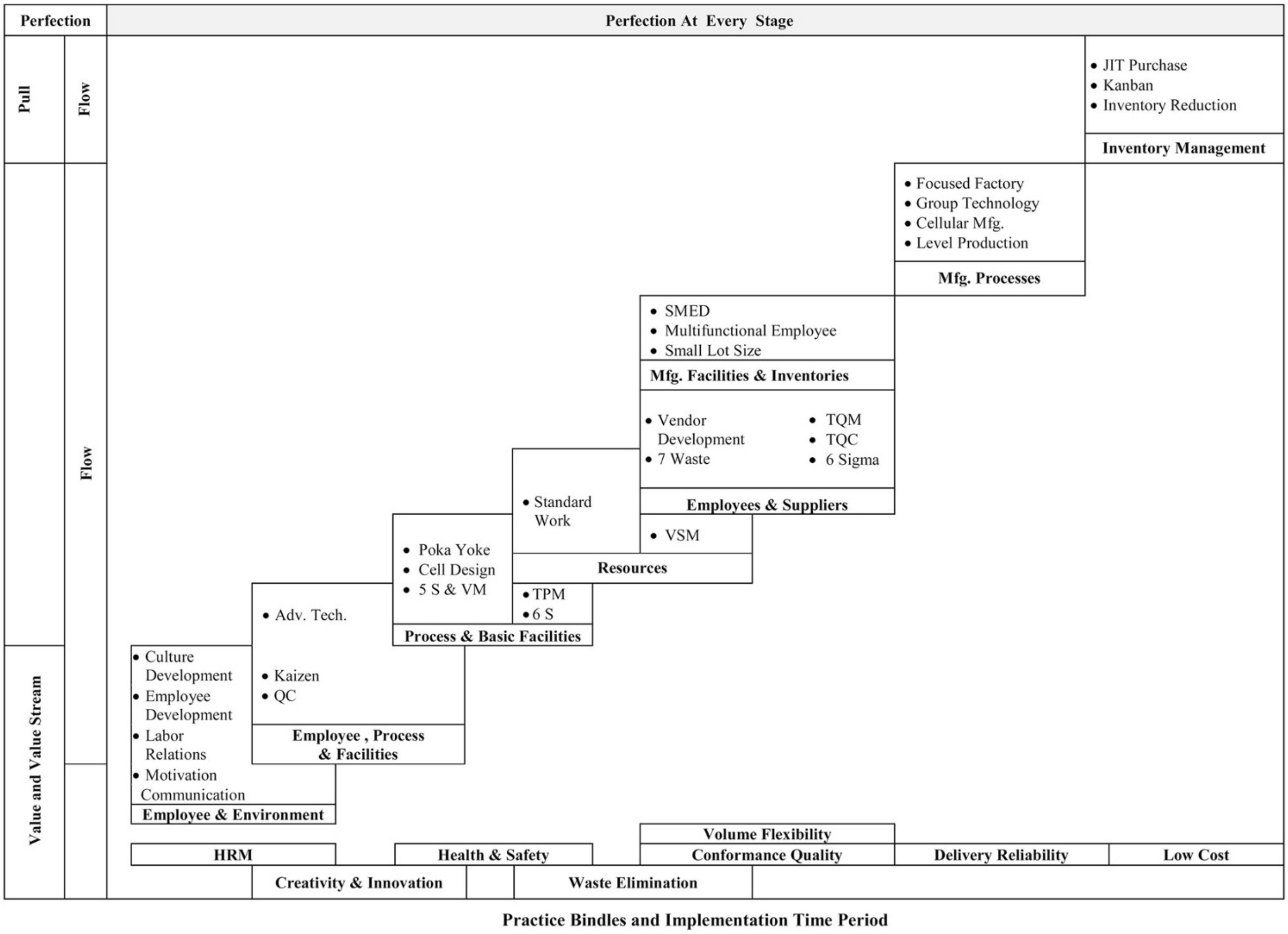


Fig. 6 Framework for lean implementation

3. Systems centric:

It includes forecasting, infrastructure facilities, logistic support, etc.

4. Technology centric:

It includes process management, communication technology and information support, etc.

Sustainable competitive gains cannot be achieved overnight. According to Liker (2004), the understanding of people and human motivation, the ability to cultivate leadership, teams, and culture are important success factors for Lean.

ISM model: a framework for Lean implementation

ISM-based model for Lean practice bundles (Fig. 4) suggests the priority order (in phase-wise manner) of Lean practice bundle implementation is as follows:

1. Human resource management practice bundle.

The practices in HRM bundle include quality circle, communication of goals, effective employee development programs, creating a culture of Lean improvement, rewards and recognition and effective labour management relations.

2. Creativity and innovation practice bundle.

Creativity and innovation practices bundle includes Kaizen (Continuous Improvement), applications of advance technologies.

3. Health and safety practice bundle.

The practices in Health and Safety bundle consists of five S, Six S, Poka Yoke (error proofing), Visual Management, Standardised work, Ergonomic Work station or Cell Design and total productive maintenance (TPM).

4. Waste elimination practice bundle

The identification of opportunities for seven types waste is exposed through value stream mapping.

5. (a) Conformance quality practice bundle

The conformance quality practice bundle includes TQM, TQC, SQC, Six Sigma and Supplier Management/vendor Development.

(b) Volume flexibility practice bundle

The volume flexibility practice bundle consists of setup time reduction, multifunction employees and Small Lot Size/Single piece flow

6. Delivery reliability practice bundle

The organization's ability to reliably deliver products to the customer may enhance by implementation of focused factory, group technology and uniform workload

7. Low cost practice bundle

The best practices for cost reduction are inventory reduction, kanban and JIT purchasing.

Framework for Lean implementation in phase-wise manner is depicted in Fig. 6 which is actually developed from ISM model. Figure 6 provides a plan for roll out of sustainable Lean implementation in the organization in a phase-wise manner. This acts as a roadmap for implementation of Lean system in the organization. It shows the sequential approach for sustainable Lean implementation. In this sequence, the order of particular practice bundle is very important. If Lean implementation is not directed in the appropriate sequence then there is high risk of Lean system failure.

Phase 1: human resource management

Toyota's underlying assumption is that carefully selected and developed people over long periods of time will continuously improve processes and ultimately lead to competitive advantage and mutual prosperity. These philosophical underpinnings lead to very different views of how to manage and develop people and different views of the role of the human resources department in the firm (Liker and Hoseus 2010). Lean production should be considered as a human system. The Lean process requires the development of a number of interrelated policies covering all aspects of HR policy and practice. Such policies aim to facilitate employee involvement, flexibility, and empowerment and are claimed to be radically different from traditional HR practices (Preece and Jones 2010). The whole process is said to become more people-centred and people-driven because only employees can identify ways of improving existing processes and products (Preece and Jones 2010; Forrester 1995).

Human resource management (HRM) practice should be focused on respect for people around to develop the culture like Toyota for continual improvement, creativity as well as innovation. The culture builds upon the ways employees think and behave. It is based on the mutual trust and benefits. HR policies and practices should be transparent. The two way communication should be direct and crystal clear. Training need of employees should be identified. Every employee should be trained to create learning organization. The efforts of employees for growth of company should be recognized and publically appreciated with some rewards. The relationship between top management and employees should be cordial and effective. Ultimately, a platform of 'Quality Circle' for continual improvement (even though incremental) should be established to empower the workers to solve the routine problems surfaced on shop floors using their talent and experience. Thus, journey towards Lean enterprise commences with proper human resource management. Human resource management (HRM) is the foundation for Lean enterprises. Human resource management (HRM) practices add value and helps in identifying value stream of the business.

Phase 2: creativity and innovation

Creativity can be viewed as the ability to invent or develop something new of value (Childs and Tsai 2010; Childs 2006). 'Creativity provides a workable approach to an unsolved problem or a previously unrecognized opportunity' (Childs and Tsai 2010; Bogen and Bogen 2003). Innovation is not a trial and error method. Innovation is the end results of 'out of the box' creative thinking. Creativity generates many new and original ideas and things through observations, brainstorming, daydreaming, etc. These ideas are screened by evaluation based on certain criteria like benefits, techno-economical feasibility, etc. Only feasible and usable ideas are converted into reality.

According to Smith (2005), the goal of innovation is to create business value by developing ideas from mind to market or idea to cash. Customer is ready to pay for creative and innovative products or services only when it adds 'value' in the eyes of customer. Thus, creating "new things" is neither necessary nor sufficient for business innovation. It makes no difference how innovative a company thinks it is. What matters is whether customers will pay. Successful innovation requires the careful consideration of all aspects of a business (de Farias and Akabane 2011).

The innovativeness of any organization depends upon the values, work environment, leadership qualities, the creative contributions of its employees and the policies or existing systems to taps the creativity of its talented employees. There are many creative methods available which can be used to enhance and provoke our generative activity but professionals tend to restrict their attention to very few methods (Childs and Tsai 2010). Methods that can be used to enhance creativity and stimulate imagination include synectics, lateral thinking, morphological analysis, analogy, TRIZ, mind mapping, 6-3-5 chart, etc. (Johari et al. 2011). Innovation can be brought in systematically with organization's willpower as well as systematic and structured training. Creativity of employees can be enriched by learning and using creativity techniques in routine work.

The above discussion stress on significance of some of the human resources practices like building an organization culture for improvement, team of creative employees, systematic and structured training and a platform to solve the problem (Quality Circle, Kaizen) to foster the creativity and innovative attitude of employees for long-term sustainability in the market by offering value-added products and services to the modern aggressive customers.

Creativity and innovation practices bundle includes slightly advance version of quality circle, i.e., Kaizen (continuous improvement). Kaizen can offer only incremental improvements. For more radical improvements organization has to use other creative methodologies like TRIZ, latest technology for manufacturing, support of information & communication technology, etc. More creative and innovative products can be manufactured by applications of advance technologies, internet, software and computer programs which requires heavy investment. At this point, the organization can decide whether to go for incremental improvements or radical improvements depending upon the Lean implementation maturity and financial health of the organization. Organization also has to determine whether it has the in-house capability and talent or to recruit capable employees in this phase. Alternatively, the organization may take help of external consultants to develop pool of in-house talent and to develop products and services.

Hence, once the foundation (the human resources practices) is ready then organization can launch the second phase of Lean journey simultaneously along with the first phase. This development is clearly shown in Fig. 6 (Framework for Lean implementation) as partial overlapping of HR practices along with creative and innovation practices on time scale. Creative and innovation practices are also add values, help in identifying value stream of the business and ensure proper flow of information and material.

Phase 3: health and safety practice bundle

Customers and organization cannot compromise on health and safety issues. Some health and safety issues are externally (outside the company premises) related to the customers and some related to the internal employees. Customers expect that the products or services should not land them in dangerous position or situations. In this paper, the focus is on the internal health and safety issues related to employees during manufacturing. The practices in health and safety bundle consists of five S, Six S, Poka Yoke (error proofing), visual management, standardised work, ergonomic work station or cell design and total productive maintenance (TPM). These practices create the safe working environment and work place organization on the shop floor where safety is very important. It ensures streamlined flow of information and material with minimum strain on workers. Clearly, it is evident that the creative and innovation capability is the prerequisite for implementing health and safety practices. For example, ergonomic work station or cell design has to consider the movements of body elements and strain on it while performing certain task. Similarly, designing the Poka Yoke devises, Visual Management, five S, Six S and Standardised work needs application of creative and innovative minds. Once the organization acquires the capability in creativity and innovation then it can work on the third phase of Lean journey simultaneously along with the second phase. This development is clearly shown in Fig. 6 (Framework for Lean implementation) as partial overlapping of creative and innovation practices along with health and safety practices on time scale.

Phase 4: waste elimination practice bundle

Lean manufacturing aims to identify and eliminate waste to improve the performance of the business. Generally, seven types of wastes exist like over production, over-processing, inventory, motion, defects, waiting and transportation in any system. Underutilization of human talent is also considered as a waste by some Lean practitioner.

The identification of opportunities for seven types waste is exposed through value stream mapping. A value stream represents all the steps in a process that transform raw materials into a finished good and will include flows of information and materials throughout the process (Marvel and Standridge 2009; Tapping et al. 2002). The process flow defined by the future state VSM leads to a detailed production system design that incorporates Lean techniques such as kanban controls on inventory and a cellular organization for production (Marvel and Standridge 2009). Elimination of waste is achieved through streamlining the production process with proper equipment layout, and reducing setup time to adhere to the daily schedule made possible by a pull system (Ahmad et al. 2003).

Phase 3 (health and safety) practices like Poka Yoke, Visual Management, five S, Six S and Standardised work also help us in eliminating the non-value-added activities. This ensures undisturbed flow of material in the system. This development is clearly visible in Fig. 6 (Framework for Lean implementation) as partial overlapping of health and safety practices along with waste elimination practices on time scale.

Phase 5 (a): conformance quality practice bundle

The survival of any organization depends on the degree of customer support. Highly satisfied customer stick to the brand he/she likes. But in today's cut-throat competition customer is having wide choice for comparable quality products. So, the quality parameters are not only the design or customers' specification but also the right cost, in right quantity, on time-in full delivery at right time and at right place. To enhance the quality in internal manufacturing facilities many new methodologies from TQM to Six Sigma have been adopted by industries from time to time. Even statistical quality control techniques are being used by small companies as well. The raw material should be of good quality to produce good quality product. Here, suppliers come into picture. So, organization must have vendor development plans as Lean advocates few reliable supplier bases.

Phase 4 Waste elimination practices like Value Stream Mapping (VSM), standard work, etc., automatically leads to quality improvement and cost reduction. This ensures undisturbed flow of material in the system. Hence simultaneously company can start phase 5 (a) conformance quality practices along with phase 4 of waste elimination. This situation is clearly visible in Fig. 6 (Framework for Lean implementation) as partial overlapping of waste elimination practices along with conformance quality practices on time scale.

Phase 5 (b): volume flexibility practice bundle

The ability of manufacturing system to adjust the volume of production (supply) as per the customers demand is termed as volume flexibility. Manufacturer should be in position to meet the demand of variety of products at peak level at rapid rate with competitive price and also remain efficient during slack period. Hence, small batch size (ideally single piece flow) is preferable. Flexible assembly line is desirable in this case. Thus, JIT offers the flexibility to the organization and keeps the manufacturing system in synchronization with its ever changing environmental conditions. A flexible work force and flexible machines both are equally vital to achieve JIT manufacturing. The operators should be multi-skilled and machine/equipment must be set up as quickly as possible to cope up with small lot size of variety of products. Since, volume flexibility practices can help in achieving reliable delivery, we can start implementation of this bundle simultaneously with conformance quality practices.

Phase 6: delivery reliability practice bundle

Customer should get the demanded products as per his/her terms which include the competitive cost of product, supply schedule and quality specification, etc., the manufacturing system must be flexible and agile for quick response to customers' demands. The improved flow of material and information throughout the supply chain leads to delivery reliability of the organization. Hence, delivery reliability practice bundle should be implemented only after the plant acquires flexibility and conformance to quality practice bundles. The organization's ability to reliably deliver products to the customer may enhance by implementation of focused factory, group technology and uniform workload.

Phase 7: low cost practice bundle

The best practices for cost reduction are inventory reduction, kanban and JIT purchasing. JIT emphasizes on minimum inventories in the manufacturing system. Once the order is triggered by downstream customer, kanban control system sends the signal to upstream supplier JIT for inventories or raw materials. This is the point of JIT purchase. Since the inventories are drastically reduced the production cost becomes very low. It also mitigates the risk of obsolete inventory, blocking of capital in inventories, etc. Eventually cost reduction is the ultimate benefit Lean. It is the end result of relentless pursuit of Lean implementation throughout the supply chain.

Moreover, in this phase organization has to establish JIT purchase system with external suppliers. Kanban control mechanism has to be design and established on shop floor to implement JIT purchase. Kanban system is a complex system and requires lot of expertise and resource facilities. Naturally, low cost practices are to be adopted at the end of Lean implementation journey. The same is evident from Fig. 5 (Driving power and dependence Diagram). It shows that low cost practice bundle has highest dependence and lowest driving power and hence it appears at the top of ISM model.

Conclusions

Research findings and implications

The major implementation issues are related to the human, cultural, facilities and resources factors. According to Yasin et al. (1997), for successful JIT implementation, an organization must accept JIT as an organizational philosophy, change or modify its operating procedures, production system, and organizational culture. Firms have to develop mutually beneficial relationship with suppliers and customers. Organizations have to achieve and maintain accurate demand forecast. According to Fullerton et al. (2003), firms that implement and maintain JIT manufacturing systems will reap sustainable rewards as measured by improved financial performance.

This paper makes two broad conceptual contributions. First, it explores Lean practice bundles for successful implementation of Lean and second, it provides brief description of eight Lean practice bundles that will be helpful for further studies. Although, ample literature is available on Lean involving various issues related to it. The relationship between Lean practices has not been modelled for manufacturing organizations. The present model will help managers and Lean practitioners to understand the relationship in detail. This research assumes importance in this context. Another contribution is the transfer of compiled information from researcher to their peers to assist in designing the structurally robust Lean implementation strategies.

In this research, Lean practices of manufacturing organizations are modelled in terms of their driving power and dependence. Strong driving power (with weak dependence) practices should be dealt with strategic moves as they influence other factors. Thus, focus towards the cost reduction without compromising on quality can be accomplished by continuously improving the driving practices. The objectives of present research include identification and ranking the Lean practices and their influence on cost reduction. It involves a number of key practices, therefore, a model showing interaction would offer a great help to managers and Lean practitioners. Contextual relationship can be developed between the Lean practices using brainstorming while an overall structure can be extracted for the system under consideration using ISM. The overall effort put in the present research has ensued in identification of significant Lean practice bundles for sustainable implementation in manufacturing organizations and in development of relationships to gain managerial insights into the priority of these practices.

The Lean practice bundles not only affect the effective implementation but also influence one another and have to execute in proper sequence in agreement to five principles suggested by Womack and Jones. This can be a guide for taking appropriate action to roll out the successful Lean deployment. The success of global manufacturing strategies such as Lean will not be entirely based on application of appropriate tools and techniques alone but also on the interactions between top management and employees. Top management may play significant role in how the Lean strategy is understood, implemented, and deployed effectively throughout the organization.

Limitations and suggestions for future research

In terms of limitations associated with the present study is primarily focused on Lean in manufacturing sector. The Lean implementation issues in other sectors may slightly differ from manufacturing sector. The issues may vary based on country, geographic location within the country and work culture of the organization. The ISM model is highly dependent on the experience and judgements of the expert team. The validation of model developed using ISM can be done more robustly and quantitatively using structural equation modelling or through sample surveys.

Once the Lean practice bundles are identified, a number of research propositions may be proposed that would be appropriate for further study and research concerning the modelling the Lean practice bundles using various modelling techniques like AHP, ANP, etc. Implementation strategy can be developed for successful and sustainable implementation of Lean using tools like Quality Function Deployment (QFD), Failure Mode and Effect Analysis (FMEA), Balance Score Card and Hoshin Kanri policy deployment, etc. Research work in this area may act as a roadmap for successful Lean implementation. It would be a light house to Lean practitioners and researchers.

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