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A framework for lean manufacturing implementation

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The lean implementation initiatives can be categorised as roadmap, conceptual/implementation framework, descriptive and assessment checklist initiatives. A literature review on the lean initiatives has examined 28 initiatives. A set of rules is proposed to evaluate these initiatives with respect to nine factors impacting lean implementation. The evaluation has proved that the implementation frameworks have highest association with lean factors. However, existing lean initiatives are not demonstrated in a structured nature. The failure in managing lean implementation process is often consolidated to poor mind-set and inadequate understanding of the lean concept itself. In this paper, an attempt has been made to propose a framework to overcome some of the limitations. The proposed framework is constructed as a project-based framework with detailed four implementation phases. Appropriate practices and decision tools are proposed and assigned to each phase. However, the proposed framework is at conceptual stage. It requires further implementation to be validated.

Keywords: lean manufacturing; lean implementation initiatives; success factors of lean implementation; implementation framework; initiative evaluation rules

1. Introduction

Lean manufacturing is an integrated sociotechnical system, which comprises a package of management practices that can be applied to eliminate the waste and reduce the variability of suppliers, customers and internal resources and processes (Anvari, Zulkifli, Yusuff, Ismail, & Hojjati, 2011; Shah, Chandrasekaran, & Linderman, 2008). Lean concept has been widely accepted in the service and manufacturing industries. Numerous literatures have reviewed the lean benefits and applications. The term lean was first coined by Krafcik (1988). Subsequently, Womack, Jones, and Roos (1991) used the term lean production to describe the Toyota production system (TPS).

Womack and Jones (2003) stated that lean principles can be applied in any industry. Different types of organisations have implemented lean manufacturing. Nevertheless, Marvel and Standridge (2009) argued that few organisations attain significant improvements by applying lean. As the improvements remain localised, those organisations are unable to sustain the continuous improvements. Baker (2002) reported that the success percentage of UK organisations on lean implementation is less than 10%. It is believed that the main reason of unattainability of lean benefits is the incomplete understanding of the lean concept and the purpose of the lean practices. Some companies misapply the

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lean practices. The main reasons of the misapplications are as: 'use of wrong tool to solve a problem', 'use of single tool to solve all of the problems' and 'use the same set of tools on each problem' (Pavnaskar, Gershenson, & Jambekar, 2003, p. 3077). Incorrect application of lean concept leads to waste of the organisational resources and reduction in employees' confidence in practising lean (Marvel & Standridge, 2009). It is suggested that scope and content of lean manufacturing should be holistically verified prior to any lean implementation (Crute, Ward, Brown, & Graves, 2003).

Some managers and employees presumed that the factor behind Toyota success was about the cultural roots, but not lean practices. Despite criticism raised by other organisational management, Toyota as a successful leading organisation in lean application has demonstrated high performance with its production system established in all multinational manufacturing sites (Wafa & Yasin, 1998). Although lean benefits are extensively recognised from Toyota's success stories, the current roadmaps and frameworks look incomprehensible from the view of practitioners. Complications of lean implementation are believed to be driven by executive, cultural, managerial, implementation and technical barriers (Flinchbaugh, 1998). Therefore, the aim of this paper was to propose a comprehensive project-based implementation framework for lean transition in a practical manner. The proposed framework was built as a project-based implementation approach of detailed four phases. The paper anticipates enhancing the lean transformation process through the implementation framework proposed. To achieve the aim of this paper, the following four objectives were developed:

(1) To investigate lean implementation initiatives.
(2) To highlight the success factors for lean implementation.
(3) To evaluate different lean initiatives with respect to the success factors.
(4) To develop a framework for lean implementation containing the success factors.

The structure of this paper is organised into seven sections. After the introduction, the second section summarises the research methodology. The third section reviews the existing lean implementation initiatives. The fourth section attempts to quantify success factors of lean implementation. The fifth section presents a set of rules to assess the lean initiatives. The sixth section introduces a comprehensive structured framework for lean implementation. The last section discusses implication of the framework proposed and concludes the research objectives along with recommendations for further research.

2. Methodology

This paper aims to provide a more meaningful and effective path for lean transition within an organisation. To achieve the aim of this paper, four objectives were developed as illustrated in the previous section. Lean implementation initiatives were cross-examined through reviewing the literature. The main success factors for lean implementation were highlighted. Reviewing all lean initiatives was not feasible, however as far as possible the most widely published and relevant initiatives were reviewed in this paper. According to Cooper (1988), it is suggested that the literature review can be elaborated based on the purposive selection approach in which only related articles pivotal to the research topic were chosen to be reviewed. It means that the selected literature review specifically focused on the presentation of lean initiatives and process description.

Green, Johnson, and Adams (2006) stated that the most efficient way for searching the literature is the electronic databases. There are many different databases available

for searching. Therefore, it is important to search the appropriate databases that serve the objectives and the topic of the paper. There are publications that conducted a literature review to propose a roadmap and conceptual framework for lean implementation (Anand & Kodali, 2010; Anvari et al., 2011). In this research, the literature review and selection of the appropriate sources on lean implementation initiatives were conducted in two stages. The first stage aimed to search for relevant databases and select the relevant publications. The inclusive databases were Emerald, Elsevier, Springer, Science-direct, IOS Press, EBSCO Host Academic Search Premier, Inderscience, World Scientific, Academic Journals, Journal of Industrial Engineering and Management, American Society for Engineering Management and book publications. The filtering process of the selected databases utilised combinations of keywords to search for the article titles. The key words used for the search included 'lean manufacturing implementation', 'lean transformation', 'transition to lean', 'lean framework', 'lean roadmap' or 'applying lean'. Seventy publications which contained information relevant to lean manufacturing implementation were obtained at this stage.

The second stage involved scrutinising the abstracts and keywords of the selected articles. It revealed that lean implementation concepts varied in the scope of study. For example, Smeds (1994) focused on managing change towards lean enterprise; Jina, Bhattacharya, and Walton (1997) focused on applying lean principles; Crabill et al. (2000) emphasised on transition-to-lean roadmap; Womack and Jones (2003) used time frame for lean leap; Anand and Kodali (2010) developed a lean conceptual framework; Anvari, Norzima, Rosnay, Hojjati, and Ismail (2010) suggested a lean roadmap; and Powell, Alfnes, Strandhagen, and Dreyer (2013) introduced an ERP-based lean implementation process. Some of the works came from various areas of knowledge and disciplines such as simulation and training for lean implementation, impacts of lean implementation on the competitive advantage, management accounting systems impacts on lean implementations and lean principles in IT services. As a result, 28 articles with different types of initiatives were eventually selected. The initiatives were found in the forms of sequential description, diagrams and assessment checklist. An in-depth study into each initiative was conducted to highlight the critical factors of lean implementation. Proposing a set of rules to evaluate the lean initiatives with respect to the main success factors was included. The expected final outcome of the paper was to propose a lean implementation framework in a project-based structure.

3. Review of lean implementation initiatives

There have been various lean implementation initiatives proposed in previous research studies. The initiatives could be grouped into five categories: conceptual frameworks, implementation frameworks, roadmaps, descriptive and assessment checklist. The classification of these categories results from the name and characteristics of each initiative given in the literature. Some research studies may depict their implementation process as descriptive style. For example, Jina et al. (1997) suggested a descriptive diagram in applying lean principles to suit the high variety low volume situation. The diagram has three interrelated components: *product design geared to logistics and manufacture*, *organising manufacturing along lean manufacturing principles* and *integrative supplier relationships*. Womack and Jones (2003) described a time framework for a lean leap. It includes four phases: *get start*, *create a new organisation*, *install business systems* and *complete the transformation*. Shah and Ward (2003) defined the success of lean

implementation as it depends on three organisational factors: plant age, plant size and unionisation.

Other scholars have identified some guidelines for the implementation process. Karlsson and Åhlström (1996) developed an operational model which can be used to assess changes required to introduce lean manufacturing. Abdulmalek, Rajgopal, and Needy (2006) provided a general set of guidelines about the applicability of some lean practices in the process industry. Davies and Greenough (2010) developed a lean practice template. They claimed that it is comprehensive enough to represent possible lean activities within a company and particularly in the maintenance function. Some studies have used roadmaps for the lean transformation. Nightingale and Mize (2002) developed a transition to lean roadmap to assist organisations in their efforts to transform into lean enterprises. Feld (2001) proposed a streamlined roadmap for lean manufacturing through four phases: lean assessment, current state gap, future state gap and implementation. Marvel and Standridge (2009) enhanced Feld's roadmap by suggesting five phase roadmap including future state validation. Anvari et al. (2011) developed a dynamic roadmap determining the tools needed to be implemented in a firm based on its current state and type of industry.

In many scholarly works, the use of a diagrammed framework for representing the implementation process has been made available. Smeds (1994) proposed a generic framework for the management of changes towards lean enterprise. This framework consists of five phases such as analysis and model of the present state, identification of problems and opportunities, experimentation and selection of future state, implementing the change and stabilising the new mode of operations. Monden (1998) introduced a conceptual framework that describes how costs, quantity and humanity are improved by TPS. Åhlström (1998) noted that lean manufacturing consists of eight principles: elimination of waste, zero defects, pull scheduling, multifunctional teams, delayering, team leaders, vertical information systems and continuous improvement. He developed a framework for sequencing the lean production principles in the implementation process. Rivera and Frank Chen (2007) developed a logical and easy to understand framework for lean implementation. They grouped, into four waves, the lean practices that have more visible impact on the investment. Motwani (2003) developed a theoretical framework based on business process change. Anand and Kodali (2010) established a conceptual framework to demonstrate 65 lean elements, the internal stakeholders and decision levels. Mostafa (2011) constructed an implementation framework for lean manufacturing in 15 stages. Two newly introduced frameworks came from Karim and Arif-Uz-Zaman (2013) and Powell et al. (2013). Karim and Arif-Uz-Zaman (2013) developed a methodology for lean implementation based on the five lean principles. Powell et al. (2013) combined the methodologies for lean manufacturing and Enterprise Resource Planning (ERP) and proposed ERP-based lean implementation process. The study suggested that ERP implementation could be considered as an enabler for the lean implementation in an enterprise. Only one study by Sánchez and Pérez (2001) introduces lean production assessment checklist in six groups providing 36 indicators to assess the manufacturing changes according to the lean production principles.

The most successful lean initiatives are those which have been introduced as roadmaps and frameworks. Some of them represent conceptual guidelines for providing information on the lean structure both in practices and principles. Others provide outlines for the lean implementation process. However, low utilisation of lean initiatives and slow success rate of lean transformation process have been reported (Anand & Kodali, 2010;

Nordin, Deros, Wahab, & Rahman, 2012). It is assumed that such initiatives are not considerably comprehensive to the practitioners (Mohanty, Yadav, & Jain, 2007). This leads to a wrong mind-set on lean transformation. A successful initiative should comprise of, in its first stage, a tutorial segment such as lessons learned documentation and review, and a personnel communication segment. The communication segment only appears at end such as in Smeds (1994). Moreover, an expert team should be involved, beside the internal team to ensure an effective plan of lean implementation (Womack & Jones, 2003). In most organisations, the lean implementation team is new to the lean concept. The internal team members must have a considerable time to fully understand the concept.

To promote universality and familiarisation of the lean concept, simplified and comprehensive implementation frameworks become necessary. The robustness is also provided if a framework is built in a practical structured form. In other words, the lean transformation process should be distributed as a complete project, where it is being carefully planned, executed, monitored, controlled, evaluated and documented for lessons learned.

4. Success factors for lean implementation

A lean concept is a set of principles to remove all forms of waste within an organisation. Womack and Jones (2003) stated the five general principles of lean as: defining the value from customer perspective, mapping the value stream process to achieve the predefined value, creating the flow along the value chain, establishing pull system and pursuing perfection. Lean manufacturing system is a set of tools/techniques to identify and remove the waste (Anvari et al., 2010). Lean tools represent the lean principles in an implementation form. The aim of each lean implementation initiative provides guidelines or discusses the steps required for lean transition. Each initiative consists of some elements/components that an organisation needs to follow to achieve the lean transformation process (see Table 1). Some organisations face challenges to apply lean using some of lean initiatives (Anvari et al., 2010). These challenges could be related to the lean initiatives or an organisational practice of lean initiatives. Challenges of lean initiatives include category and elements of each initiative. Organisational challenges include all obstacles in the path of the lean implementation process such as executive, culture, management and technical issues (Taleghani, 2010). To successfully overcome these challenges, some critical factors must be pertained to the implementation process (Anvari et al., 2010).

To identifying the factors impacting lean implementation, this paper has conducted three dimensions of identification. In this first dimension, the paper conducted an in-depth study of 28 initiatives to highlight the critical components of lean implementation. The second dimension was to explore the previous studies emphasising some success factors of lean implementation including the studies of Achanga, Shehab, Roy, and Nelder (2006), Scherrer-Rathje, Boyle, and Deflorin (2009) and Anvari et al. (2010). This paper aims to propose a framework for lean implementation as a project-based implementation approach. Therefore, the last dimension is the integration of lean success factors into a project-based framework. From reviewing the previous literature, the current study identifies nine relevant factors to achieve lean transition. A brief description of these factors is presented as follows.

Table 1. Literature review summary of lean implementation initiatives and factors used in this study.

	Lean implementation initiative	Category	No. of elements	Factors impacting lean manufacturing implementation								
				*F*1	*F*2	*F*3	*F*4	*F*5	*F*6	*F*7	*F*8	*F*9
1	Plan for introducing the Toyota production system (Shingo, 1989)	Implementation framework	15					*	*			
2	The Generic Framework for the management of change towards lean enterprise (Smeds, 1994)	Implementation framework	6	*	*	*	*		*		*	
3	Conceptualisation of lean production (Karlsson & Åhlström, 1996)	Roadmap	4	*		*						
4	The components necessary for applying lean manufacturing principles (Jina et al., 1997)	Descriptive	3	*								
5	How costs, quantity, quality, and humanity are improved by TPS (Monden, 1998)	Conceptual framework	10					*				
6	Sequences in the Implementation of Lean Production (Åhlström, 1998)	Roadmap	8	*		*		*				
7	Transition- To- Lean in production operations roadmap (Crabill et al., 2000)	Roadmap	8				*	*	*		*	*
8	Lean manufacturing road map (Feld, 2001)	Roadmap	5		*		*	*		*	*	
9	A lean production model (Sánchez & Pérez, 2001)	Assessment checklist	5		*						*	
10	Enterprise level roadmap (Nightingale & Mize, 2002)	Roadmap	7	*			*		*		*	*
11	Time frame for the lean leap (Womack & Jones, 2003)	Descriptive	4	*					*			
12	Lean Implementation and contextual variables (Shah & Ward, 2003)	Descriptive	3									
13	Theoretical framework for lean manufacturing implementation (Motwani, 2003)	Conceptual Framework	7	*		*	*	*	*			
14	Lean transformation (Bicheno, 2004)	Implementation framework	12		*	*	*	*	*		*	*
15	Disciplined approach to lean manufacturing (Hobbs, 2004)	Disciplined approach (descriptive)	8			*		*				*
16	General guidelines for applying lean tools in the process industry (Abdulmalek et al., 2006)	Guidelines (descriptive)	3							*		
17	Waves of lean implementation (Rivera & Frank Chen, 2007)	Roadmap	4						*			

18	Simulation enhanced approach to lean manufacturing (Marvel & Standridge, 2009)	Streamlined approach (descriptive)	5		*						*	
19	Lean implementation roadmap for a high/low volume high/low repetitiveness (Wan & Chen, 2009)	Roadmap	8					*	*			
20	Proposed framework for implementation of lean manufacturing system (Anand & Kodali, 2010)	Conceptual framework	9					*	*			
21	A proposed dynamic model to leanness (Anvari et al., 2011)	Roadmap	5		*		*	*	*		*	
22	Lean implementation framework (Buus, 2011)	Implementation framework	17		*	*	*	*	*			*
23	Lean manufacturing implementation framework (Cheng Wong & Yew Wong, 2011)	Implementation framework	12		*		*	*				
24	Framework for lean manufacturing Implementation (Mostafa, 2011)	Implementation framework	15	*	*		*	*	*		*	
25	Stepwise implementation of lean production systems (Dombrowski, Mielke, & Schulze, 2012)	Implementation framework	9			*	*				*	
26	Organisational change framework in lean manufacturing implementation (Nordin et al., 2012)	Implementation framework	8			*	*	*	*			
27	Framework for an ERP-based lean implementation process (Powell et al., 2013)	Implementation framework	24	*	*		*	*	*			
28	Proposed lean implementation methodology (Karim & Arif-Uz-Zaman, 2013)	Implementation framework	17		*		*	*	*		*	
Number of resources				9	12	8	15	17	16	1	12	4

(1) *Expert team building* (F_1) – the use of experienced team to provide advice and manage the implementation process. The lean expert team is a key node in the process (Dombrowski, Mielke, & Engel, 2012). Teaming lean experts ensure deep expertise. Hiring lean experts facilitates and promotes the change towards lean. Furthermore, the expert team provides the required training and consultancy to the practitioners. The recruitment of lean experts may be initiated either from an internal cross-functional team or external consultant team (Bamber & Dale, 2000; Womack & Jones, 2003).

(2) *Situational analysis* (F_2) – an assessment of the current situations of an organisation. Internal assessment scans all organisational attributes such as personnel, facilities, location, products and services, in order to identify the organisation's strengths and weaknesses to apply lean. The external assessment scans the political, economic, social, technological and competitive environment to identifying opportunities and threats (Lozano & Vallés, 2007) to lean practices. The situational analysis helps to define the gap between the expected outcomes and the current situations.

(3) *Lean communication planning* (F_3) – the communication management processes with stakeholders at all levels. Puvanasvaran, Megat, Sai Hong, and Mohd Razali (2009) stated that communication is an important aspect for a successful lean implementation. Appropriate communication among the employees facilitates the lean implementation process. Miscommunication may lead to misunderstanding and misapplication of lean concept and tools. Moreover, it generates an ambiguity in employee's roles and responsibilities (Worley & Doolen, 2006). The study of Scherrer-Rathje et al. (2009) revealed that communicating the lean pilot project success increased the support from the shop floor and managers to expand the lean practice.

(4) *Training process* (F_4) – training programmes for the employees and managers on lean knowledge. The resistance to lean transformation among managers is usually caused by the lack of skills and lean knowledge (Barker, 1998). Likewise, employees' resistance to lean improvements is likely due to inadequate training and commitment (Crute et al., 2003). To overcome these problems, the organisations should emphasise effective lean-related education and training programmes as well as establish training assessment to measure the training impacts (Boyer, 1996; Pollitt, 2006).

(5) *Lean tools* (F_5) – a handmaiden of the implementation process. These tools need to be integrated into the practice in order to deliver a streamlined and high-quality process of transformation (Shah & Ward, 2003). It is suggested by Pavnaskar et al. (2003) that insufficiency of understanding lean tools and their utilisation results in misapplications and ineffectiveness. Moreover, the appropriate selection of lean tools contributes to better waste elimination decisions. It is reminded that not all lean tools can solve the same problem, and not all problems can be solved by a single tool.

(6) *Value Stream Mapping (VSM) or Process Mapping* (F_6) – highlighting several kinds of problems in the processes (Rother & Shook, 1999). Lean principles require manufacturers to investigate their processes and identify the value-added and non-value-added activities (wastes). Process mapping supports lean transformation by identifying opportunities for waste elimination (Cottyn, Landeghem,

Stockman, & Derammelaere, 2011). VSM is employed to identify the areas that need to be improved and to decide the wastes to be eliminated (Pavnaskar et al., 2003).

(7) *Lessons Learned Review* (F_7) – reviewing the past records of lean implementations. The review should be conducted prior to initiation of the standardised lean practices. According to Feld (2001), capturing lessons learned from a previous implementation stage is significant for a subsequent stage. Lessons can be obtained from inside or outside an organisation. Lessons-learned documentation keeps data, information and knowledge for future review.

(8) *Lean Assessment* (F_8) – evaluating the lean practice in different areas to provide a baseline for the organisation. It contains a set of metrics used for tracking the level of lean implementation efforts. Doolen and Hacker (2005) suggested that lean assessment should include tactical and strategic modules. According to Feld (2001), lean assessment provides an overall index of lean performance score of an organisation. Understanding the lean index can contribute to successful lean implementation as it provides authentic results for lean performance and directs decision-makers to corrective actions (Behrouzi & Wong, 2011). It is important to perform an assessment by an experienced team. The lean implementation team might have the necessary experience, but external consultant might be required to provide an additional beneficial perspective in the planning stage.

(9) *Lean Monitoring and Controlling or Lean Sustaining* (F_9) – tracking, reviewing and regulating the lean implementation performance and progress. If lean implementation is treated as a project, lean monitoring and controlling should be employed along the lean planning. It is to ensure that the implementation on lean follows the plan. The process recommends preventive actions for any unanticipated situations. Moreover, it allows any influencing factors in lean implementation to be identified (PMI, 2008). Monitoring and controlling include measuring of the actual lean accomplishment and comparing with the lean transformation plan. It can be learned from the study of Kumar and Phrommathed (2006) that absence of monitoring and controlling on lean implementation results in failures of the lean transformation. Establishing monitoring and controlling mechanisms ensures the sustainability of lean performance over long term. In some organisations, employees may attempt to return to their pre-lean methods (Scherrer-Rathje et al., 2009).

5. Evaluation methodology for lean initiatives

The literature review revealed that each lean initiative consists of built-in elements/components. In addition, some critical success factors for lean implementation have been identified. These factors were taken part in lean implementation steps of the 28 initiatives studied. Therefore, this paper hypothesised that the success of any lean initiative is contributed by two components as shown in Figure 1. The first component is related to the lean initiatives as it presents the association between the initiatives' elements and success factors of lean implementation (x_{ij}). This first component also includes the application time (t_i) and application cost (c_i) of the factors, number of lean factors (n) and initiative category (m_k). A second component is related to the organisational practicing of the lean initiatives. The component consists of the weight of factor importance (w_i), probability of factor success (p_i), weight of understanding each factor (u_i) and sustaining (τ_i) the employment of each factor to an organisation.

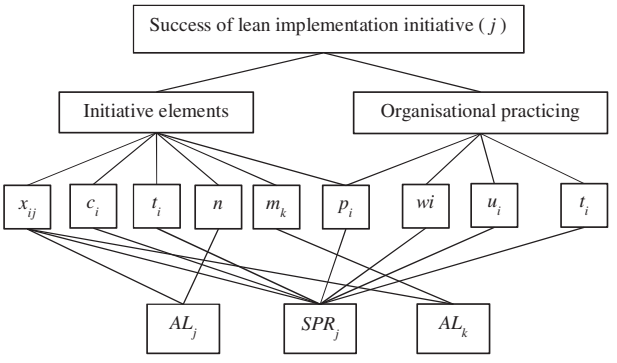

Figure 1. Success of lean implementation initiative (*j*).

Understanding each lean initiative is necessary for identifying any shortcomings in lean implementation applied. Selection of an initiative should be based on an efficient set of lean factors and effective evaluation rules. Here, a set of rules is proposed to evaluate the lean initiatives and their categories as follows.

$$\mathrm{SPR}_j = \sum_{i=1}^{n} \frac{x_{ij} w_i u_i p_i \tau_i}{t_i c_i} \quad \forall j \tag{1}$$

$$\mathrm{AL}_j = \sum_{i=1}^{n} \frac{x_{ij}}{n} \quad \forall j \tag{2}$$

$$\mathrm{AL}_k = \sum_{k=1}^{mk} \sum_{i=1}^{n} \frac{x_{ij}}{n m_k} \quad \forall k \tag{3}$$

where

SPR_j	success priority rate of initiative j,
AL_j	association level of initiative j,
AL_k	association level of category k,
i	success factor for lean implementation,
j	lean implementation initiative,
k	lean initiative category,
x_{ij}	1, if initiative j associates factor i; 0, otherwise,
w_i	weight for the importance of factor i to the organisation,
u_i	weight for understanding factor i,
ρ_i	probability of success of factor i,
τ_i	sustainability of factor i measured in time units,
t_i	application time of factor i,
c_i	application cost of factor i,
n	number of lean factors,
m_k	number of initiatives in category k.

The computation of the proposed measure of success priority rate (SPR_j) requires real field applications. Therefore, in this paper, an evaluation analysis is carried out for the 28 initiatives limited to the measure of association level (AL_k) of five lean initiative categories with respect to the proposed nine factors (as represented in Equation (4)).

$$\mathrm{AL}_k = \sum_{k=1}^{5} \sum_{i=1}^{9} \frac{x_i}{nm_k} \ \forall k, j, \quad k = 1, 2, 3, 4, 5 \text{ and } \quad j = 1, 2, 3, \ldots 28 \tag{4}$$

Table 2 represents comparisons between the presented lean initiatives according to category, size (number of elements in an initiative) and association with respect to the nine factors. It can be concluded after the examination that the initiative proposed by Bicheno (2004) was the best initiative containing seven out of nine factors.

Table 3 presents comparison of the five categories of lean initiatives with respect to the number of initiatives in each category (m_k), association level of each category (AL_k) which calculated using Equation (4), and association of each category with the nine factors. The implementation framework category can be seen as the best associated to the nine lean factors.

Figure 2 below presents lean factors association with lean initiative categories and with the 28 initiatives examined. The figure shows that although reported with the highest percentage among other factors, lean tools are moderately included (60.7%) in the total initiatives presented. On the other hand, lessons-learned documentation and review have almost been excluded from all initiatives studied. They are found available only in the roadmaps. It is discovered that the implementation frameworks offer the highest percentage in the training process (32.1%), while none of the studied implementation frameworks contains lessons-learned documentation and review. The highest percentage among the factors reported for roadmaps is for lean tools (21.4%). Nevertheless, the figure shows that low level of lessons-learned documentation and review has been implemented (3.6%). Among the descriptive initiatives, expert team building is found with more percentage than other factors under the same initiative category. It is presented that all of the descriptive initiatives studied completely lack lessons-learned documentation and review. A certain percentage of lean tools is found in the conceptual frameworks (10.7%). However, the factors omitted from this category are situational analysis, lessons-learned documentation and review, lean assessment, and lean monitoring and controlling (sustaining). In the last category of lean initiatives, the assessment checklist, the same percentage situational analysis and lean assessment can be seen (3.6%). On the other hand, other factors are reported absent.

6. Proposed framework for lean implementation

The evaluation above revealed some shortcomings among the lean initiatives. Although the implementation frameworks contained most of the lean factors, lessons-learned documentation and review were rarely included. Lean monitoring and controlling, and expert team building seemed frequently absent from the frameworks. It was found that some frameworks have suggested team building to be a part of lean transformation practice. This idea is in line with the idea of Womack and Jones (2003) that an expert team should be introduced in the lean implementation plan. In most organisations, lean implementation team is new to the lean concept. The team members may take a considerable time to fully understand the concept. Effectiveness of the implementation may need to rely on additional help from lean experts. Little attention has been given to the sequences of implementation of the initiatives elements. Åhlström (1998) attempted to emphasise on the natural sequences of the manufacturing tools and techniques according to it relationships and the availability of resources. Similarly, Bhasin and Burcher (2006) pointed out the lack of adequate project sequencing as one of the main problems in lean implementation.

Table 2. Individual comparison of lean initiatives.

Initiative	Category	Size	Lean factors									Sum
			F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	
Shingo (1989)	Implementation framework	15	0	0	0	0	1	1	0	0	0	**2**
Smeds (1994)	Implementation framework	6	1	1	1	1	0	1	0	1	0	**6**
Bicheno (2004)	Implementation framework	12	0	1	1	1	1	1	0	1	1	**7**
Buus (2011)	Implementation framework	17	0	1	1	1	1	1	0	0	1	**6**
C. Y. Wong and Y. K. Wong (2011)	Implementation framework	12	0	1	0	1	1	0	0	0	0	**3**
Mostafa (2011)	Implementation framework	15	1	1	0	1	1	1	0	1	0	**6**
Dombrowski et al. (2012)	Implementation framework	9	0	0	1	1	0	0	0	1	0	**3**
Nordin et al. (2012)	Implementation framework	8	0	0	1	1	1	1	0	0	0	**4**
Karim and Arif-Uz-Zaman (2013)	Implementation framework	17	1	1	0	1	1	1	0	0	0	**5**
Powell et al. (2013)	Implementation framework	24	0	1	0	1	1	1	0	1	0	**5**
Karlsson and Åhlström (1996)	Roadmap	4	1	0	1	0	0	0	0	0	0	**2**
Åhlström (1998)	Roadmap	8	1	0	1	0	1	0	0	0	0	**3**
Crabill et al. (2000)	Roadmap	8	0	0	0	1	1	1	0	1	1	**5**
Feld (2001)	Roadmap	5	0	1	0	1	1	0	1	1	0	**5**
Nightingale and Mize (2002)	Roadmap	7	1	0	0	1		1	0	1	1	**5**
Rivera and Frank Chen (2007)	Roadmap	4	0	0	0	0	1	0	0	0	0	**1**
Wan and Chen (2009)	Roadmap	8	0	0	0	0	1	1	0	0	0	**2**
Anvari et al. (2011)	Roadmap	5	0	1	0	1	1	1	0	1	0	**5**
Jina et al. (1997)	Descriptive	3	1	0	0	0	0	0	0	0	0	**1**
Womack and Jones (2003)	Descriptive	4	1	0	0	0	0	1	0	0	0	**2**
Shah and Ward (2003)	Descriptive	3	0	0	0	0	0	0	0	0	0	**0**
Hobbs (2004)	Descriptive	8	0	1	0	1	0	0	0	1	0	**3**
Abdulmalek et al. (2006)	Descriptive	3	0	0	0	0	0	1	0	0	0	**1**
Marvel and Standridge (2009)	Descriptive	5	0	1	0	0	0	0	0	1	0	**2**
Monden (1998)	Conceptual framework	10	0	0	0	0	1	0	0	0	0	**1**
Motwani (2003)	Conceptual framework	7	1	0	1	1	1	1	0	0	0	**5**
Anand and Kodali (2010)	Conceptual framework	9	0	0	0	0	1	1	0	0	0	**2**
Sánchez and Pérez (2001)	Assessment checklist	5	0	1	0	0	0	0	0	1	0	**2**
			9	**12**	**8**	**15**	**17**	**16**	**1**	**12**	**4**	**94**

Notes: 1: a factor is associated; 0: a factor is not associated; Size: number of elements in an initiative.

Table 3. Categorical comparison of lean initiatives of Table 1.

Category	m_k	AL_k	Lean factors									Sum
			F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	
Implementation framework	10	0.4	3	7	5	9	8	8	0	5	2	**47**
Roadmap	8	0.39	3	2	2	4	6	4	1	4	2	**28**
Descriptive	6	0.16	2	2	0	1	0	2	0	2	0	**9**
Conceptual framework	3	0.29	1	0	1	1	3	2	0	0	0	**8**
Assessment checklist	1	0.22	0	1	0	0	0	0	0	1	0	**2**
	28	–	**9**	**12**	**8**	**15**	**17**	**16**	**1**	**12**	**4**	**94**

In this paper, construction of a new framework is recommended under the implementation initiatives category. This is to overcome some of the limitations of the existing frameworks under the implementation framework category. This paper proposes a 22-element implementation framework constructed within four phases as shown in Figures 3 and 4. The phases include conceptual, implementation design, implementation and evaluation, and complete lean transformation phase. Monitoring and controlling process is integrated to all phases to ensure that the expected results towards lean transformation are completely delivered. The proposed framework takes in consideration a tutorial stage to guide the lean practitioners. Accordingly, the framework comes structured, more apprehensible and comprehensive. The four phases are explained in the following section.

6.1. Conceptualisation phase

This is the kick-off phase, which selects, widens scope and trains the personnel involved in the lean implementation. The principal data, information, and knowledge of lean are transferred to the team. Benefits of lean to the organisation should be also explored to make each member aware of why the lean implementation project is important. Therefore, enhancement of mind-set and understanding of lean concept can be expected. Continuous and historical lessons learned on lean, and association of lean practices with waste types must be highly focused.

6.2. Implementation design phase

This is the warming up phase, which designs the lean plan and prepares the lean team to the practice. This phase identifies the organisational lean current state and requirements through various analyses. The recommended tools for this phase mainly emphasise on decision-making process to deliver successful lean implementation. The analytic hierarchy process developed by Saaty (1980) can be used for measuring the degree of association between the waste types and lean practices. Predesigned questionnaire is developed for gauging the existing lean performance. Work sampling is a statistical-based method which can be used for evaluating the physical work. It determines the relative amount of time spent on various tasks through site observation. To validate the collected lean data, the findings of work sampling should be triangulated with the questionnaire assessment results. A well-designed questionnaire is fundamentally developed on iterative process and validity of the results. A cause and effect diagram can be used to understand the main causes of each waste type. These causes

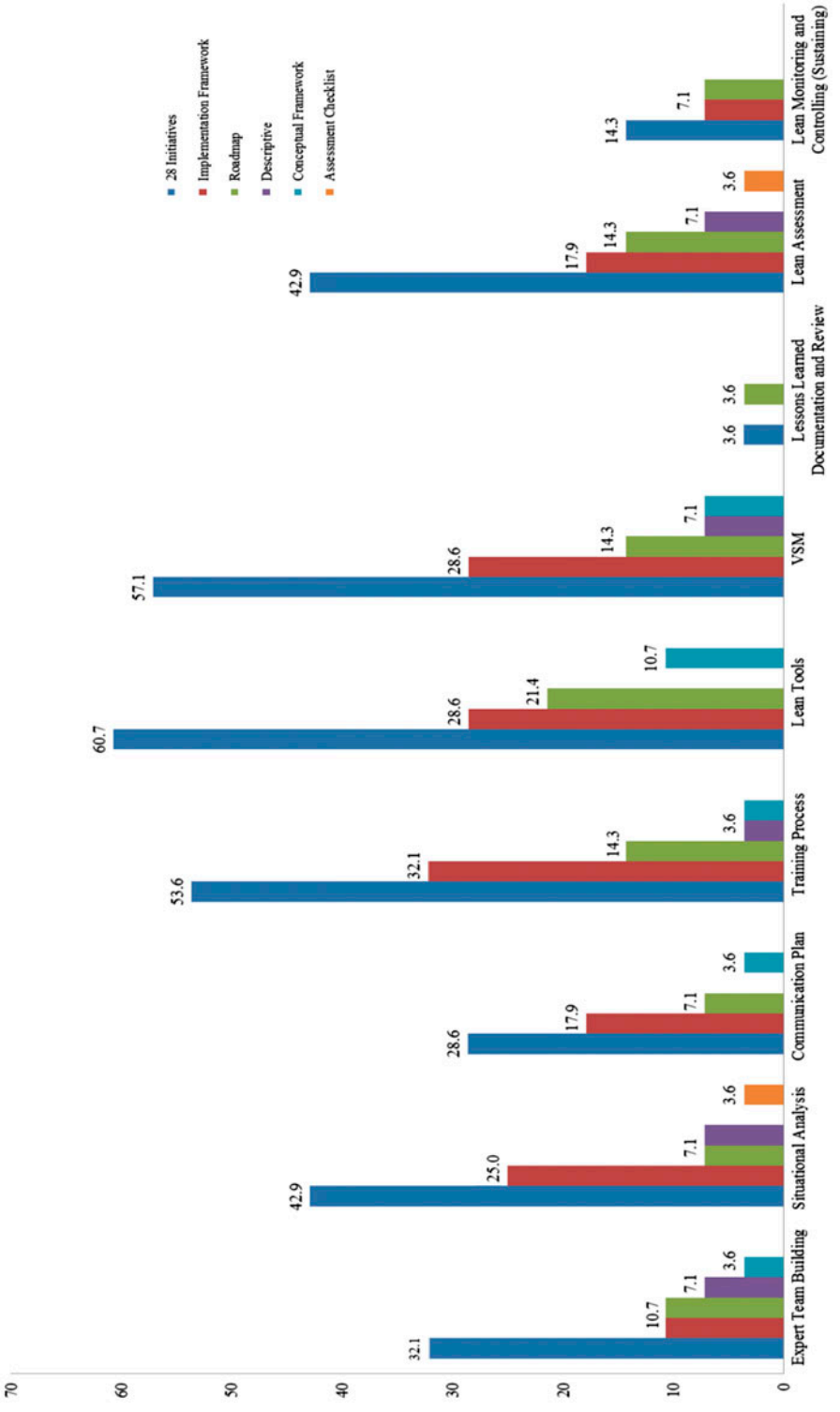

Figure 2. Lean factors association with initiative categories.

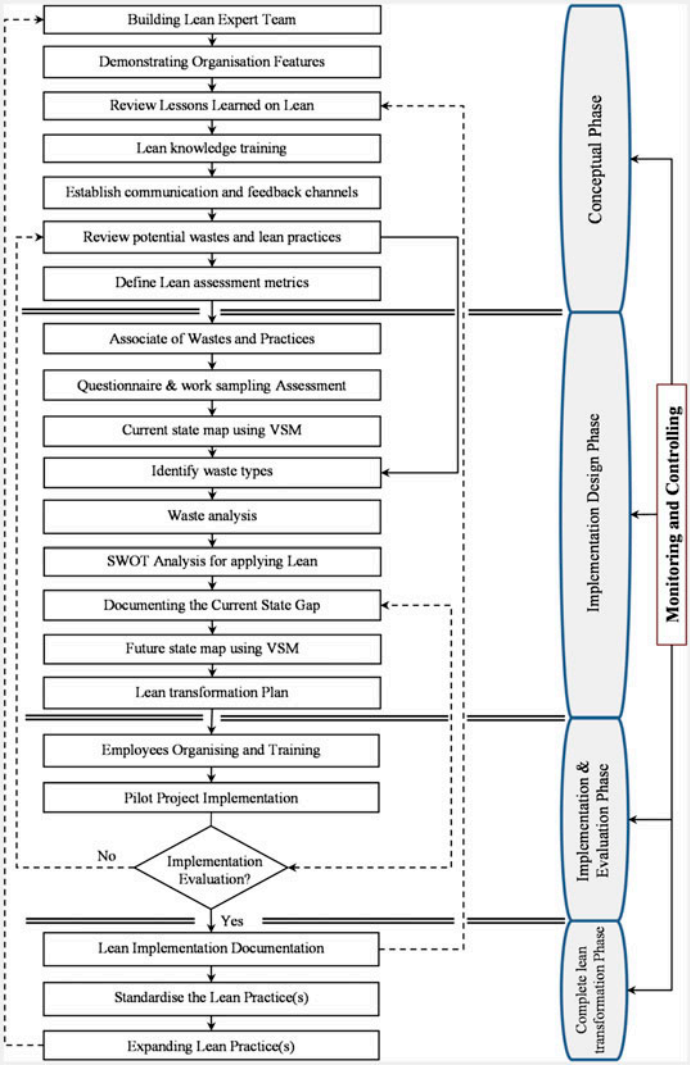

Figure 3. The proposed framework for lean manufacturing implementation.

are generally grouped as manpower, machine, material, method and measurement. The quality function deployment is another powerful tool for deeply demonstrating the linkage between waste types and lean practices.

6.3. Implementation and evaluation phase

This is the execution phase, which delivers and evaluates the lean plan. The implementation process starts with most troubled subunit of the organisation (Womack & Jones, 2003). A lean pilot project is suggested to be carried out to create a prototype or a trial implementation. The aim of the pilot project is to ensure that any expansion of lean implementation is based on the accuracy, effectiveness and efficiency. An implementation evaluation is a process in reassessing the empirical implementation strategies. The

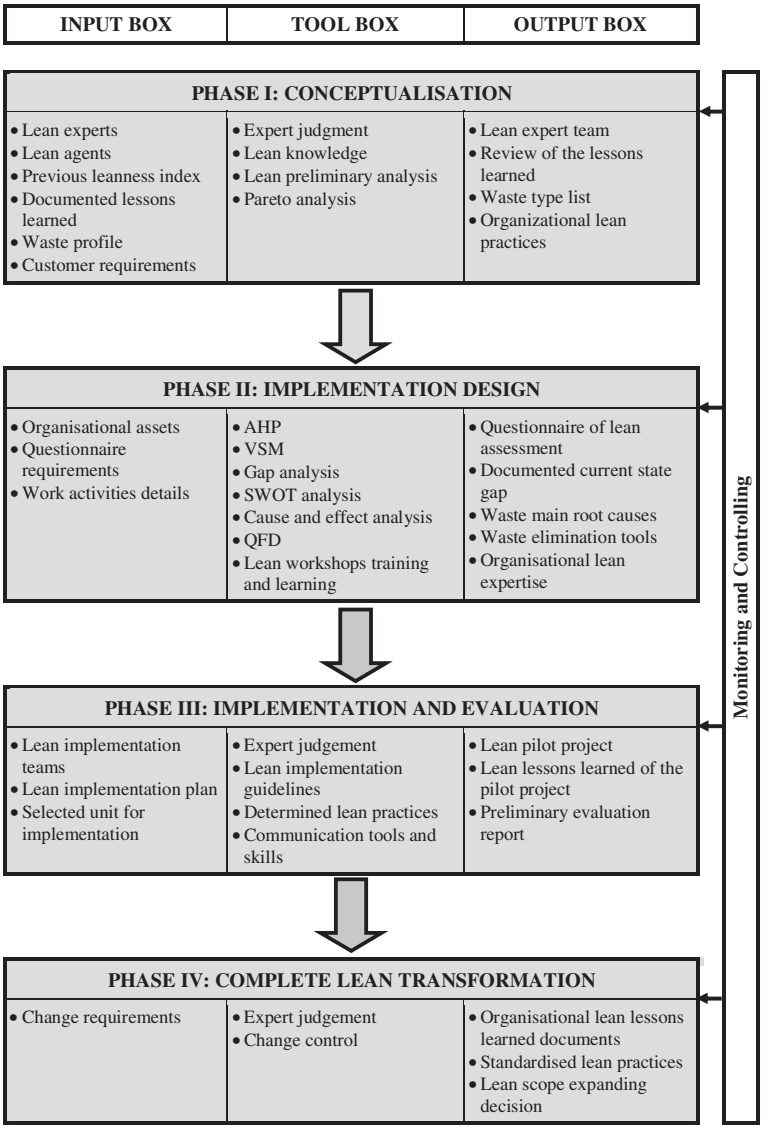

Figure 4. Tooling the proposed framework.

evaluation can be done using the pre- and post-questionnaire assessment. The evaluation is designed to be an iterative process to validate and standardise the implementation results.

6.4. Complete lean transformation phase

This is the final phase documenting the new lessons learned and scope changes resulted during execution, establishment of new lean standards and planning of continuous improvement. To accomplish lean transformation, the organisation must ensure that all necessary changes to the established requirements are implemented. This process aims

to optimise the results of lean practice prior to the process of standardisation or future utilisation of the practice. Expanding the scope of lean implementation is an indicator of continuous improvement whereas stakeholder's involvement at all levels must be included. Moreover, the standardised lean practice must be ratified by the key stakeholders.

6.5. Logic and features of the proposed framework

The notion of developing the lean implementation framework as a project-based implementation has been reflected from the work of Bhasin and Burcher (2006). The aim of this paper is to achieve practicality of lean implementation for effective lean outputs or outcomes of an organisation. It can be comprehended that the project process framework can contribute to the accomplishment of the objective addressed. Project processes aim at satisfactorily delivering outputs of a phase and passing them as inputs to the next phase (PMI, 2013). The processes permit lean implementation to be established in sequences from the conceptual phase to the phase of completion of lean transformation. Organising lean implementation into appropriate sequences is supported by Åhlström (1998). An additional benefit of sequencing using an integration of the monitoring and controlling process is to ensure that the results of each element within the four phases are delivered according to the organisational expectations. The ending of each phase consists of a milestone which operates as a gate for go or no-go decision toward the next phase. No-go decision reinforces the elements inside the phase to be repeated until they are completed at a satisfactory level.

The proposed implementation framework aims to overcome the limitations of the existing frameworks. The three highlighted features in the proposed framework are as follows:

- Building the lean expert team to enhance success in lean implementation.
- Lessons-learned review and documentation of lean implementation for continuous improvement.
- Lean implementation monitoring and controlling for sustaining lean outcomes.

7. Discussion and conclusions

Human element is an inherent integral component of the lean manufacturing system. Poor mind-set and misunderstanding of lean concept strongly restricts the lean implementation process and reduces the expected benefits for the organisation. This notion led to an investigation on 28 lean implementation initiatives. This study discovered five categories of lean implementation initiatives. Efforts like roadmaps and frameworks were found to have attempted to address the human factor. However, the most successful initiatives were those introduced as implementation frameworks, as proved in this paper. Generally, a robust lean initiative is that being well-structured, tooled and comprehensive enough to be apprehensive and understandable to the practitioners. In addition, it should focus on both human and technical factors in parallel manner all times. That in turn enables getting lean benefits within short time and ensures continuous improvement. It was evident that nine common success factors have been addressed across the literature. However, none of the initiatives studied contains all of the nine success factors. The lessons-learned review and documentation factor are highly

omitted. The expert team building, and lean monitoring and controlling factors are rarely included.

This paper has presented two contributions. First contribution is an evaluation methodology that is applied on the lean initiatives studied. Second contribution is a project-based framework structured to fit lean implementation. A set of rules for evaluation has been established to understand the association between the initiatives and their success factors. Moreover, this study has established a conceptual association between the success of lean initiative, initiative elements and organisational practice through the three constructed formulae. To overcome the limitations of the existing frameworks, the paper has proposed a lean implementation framework which covers all success factors found in the previous studies. The proposed framework has integrated project-based processes and been divided into four phases. The first phase mainly involves human factor while the remaining three phases are mainly technical. As an updated base of lean data, information and knowledge become an essential part of the process, it must be considered in the first phase of the proposed framework. This phase energises the continuous learning on lean, specifically for the implementation team and improves the process control. Attained leanness level should be measured, as set at end of the third phase, to verify the results before setting new standard, which ensure the continuous improvement.

The proposed work still evokes extension and field application. For future research, the authors recommend a validation of the proposed framework and exploitation of all possible tools guided in the tooling of the project processes. An advanced learning method should be added to make the lean implementation serve the vision, mission, objectives, goals and targets of the organisation.

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