International Journal of Mechanical and Industrial Technology ISSN 2348-7593 (Online)
Vol. 2, Issue 2, pp: (16-24), Month: October 2014 - March 2015, Available at: www.researchpublish.com

Application for Lean Enablers to Support Product Design and Development

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Abstract: **The present paper proposes the use of Poka-Yoke (Mistake proofing technique) and Knowledge based engineering, two lean enablers for product design and development. Few lean enablers can be used for lean product design and development. We have made rules for design and development of threading taps using these two lean enablers which can help develop web based application along with Microsoft SQL Server for lean product design and development.**

Keywords: **Lean Product Design and Development, Knowledge Based Engineering, Poka-Yoke, Lean Knowledge Life Cycle and Unified Modeling Language (UML).**

I. INTRODUCTION

In today's competitive global market, companies strive to employ best product development strategies by providing good products having, greater value and low cost. Lean thinking not only increases the value but also reduces the wastes. Many world's leading companies especially those in Europe are motivated to apply lean thinking in their product design and development. This research aims at providing the details of two lean enablers which can be used for proposing an application for lean product design and development.

II. RELATED WORK

Generally, a product is defined as a good, service, place, organization or an idea being produced or created. In author's research products are objects which are manufactured for the end user which is a customer. The main aim of product development is to provide the product at lower production costs, good quality and quick access to market which provides customer satisfaction [6], [10]. Product development is the number of activities starting with the awareness of a market prospect and finishing in the production, sale, and provision of a product [7], [20]. In this process, information is produced and documented so that it can be utilized successfully to produce a new product [5], [12].

Lean is one of the important and most applicable philosophies; it is not static at all and the definition is expanding with the passage of time. Initially lean was adopted to reduce waste and get more output with minimum resources. Now it is a concept for creating value along with the waste reduction [3]. Lean manufacturing was the first arena of lean thinking and was developed for the shop floor to reduce the waste and increase value [23]. It is very effective for shop floor manpower. After getting fruitful results from lean thinking at shop floor level, efforts were made for developing lean tools and models for enterprise, and it resulted into lean enterprises. Unfortunately lean enterprise has not been adopted by many industries except aerospace industry [1]. Lean product development is an organized approach for developing products and their related production processes in a knowledge-based continuous improvement environment, which focuses on the creation of value, and results in the reduction of waste [11], [14]. This is achieved by increasing a stream of activities so that decisions are made based on obtained knowledge [22]. In-order to survive and grow faster than their competitors, the lean product development team emphasizes on creating a knowledge-based continuous improvement environment [17], [21]. The main objectives of knowledge-based engineering are: automating the design tasks; supporting multidisciplinary

conceptual design; solving the specific problems; and, massive savings in time [9], [8], [19]. Knowledge life cycle is described as "a process that produces knowledge with a conceptual framework that provides a cognitive map of the processes" [2], [16], [18]. It includes a number of stages to develop a knowledge-based engineering application.

Mistake-proofing (Poka-Yoke) is the term which is mainly applied in lean manufacturing to eliminate error. The aim of mistake-proofing is to avoid the passing of defective product. Few researchers defined mistake-proofing as a device or practice that aims to prevent the error causing the defects. So they characterized mistake-proofing as a concept to correct the problem as close to the source as possible [15], [13]. Mistake-proofing has number of advantages: reduces the redesign, rework and repair requirements; removes the necessity for inspections; minimizes the defect rates; reduces the workstation inventory; and, minimizes lengthy documentation [4]. Lean product design and development is relatively a new field. In past, much work has been done on lean manufacturing and lean enterprises. Lean knowledge life cycle has been developed [16] by using knowledge based engineering but practical work is missing in it. In this field, research work has been done in three main stages of lean knowledge life cycle which are knowledge identification, previous product and domain knowledge capture, knowledge representation and knowledge sharing. Knowledge identification is difficult and requires much effort. In the same way knowledge sharing is not possible without knowledge capturing.

III. RESEARCH METHODOLOGY

The research methodology is composed of four phases as presented in Fig.1. It consists of literature review and study of data provided by industry, development of rules for design and development of threading taps and proposal for application by using poka-yoke and knowledge based engineering. After that validation of proposed application is done by experts of different fields.

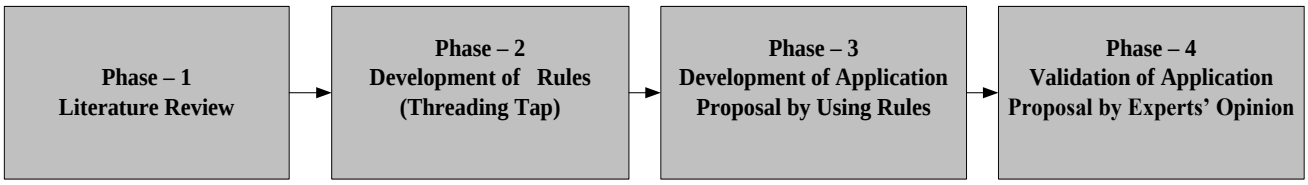

Fig. 1: Research Methodology

The first phase is obtaining a contextual understanding of lean product design and development. An extensive literature review on the issue of product development process, lean thinking, lean manufacturing, lean product design and development, poka-yoke and knowledge base engineering was performed. Along with this, sufficient data was obtained from industry to study the current methods and techniques for product design and development. In this stage, major target was the identification of lean enablers for product design and development.

Second phase involved developing rules for product design and development by using poka-yoke and knowledge based engineering. The third phase was related to the development of proposal for application by using developed rules. In last stage, validation of developed rules and proposed application was done by means of qualitative assessment. The objectives of the validation were to avoid unfairness and reliability issues. A case study regarding design and development of a threading tap was taken into account. In second stage, five interviews were conducted with experts of different fields. Proposed application was demonstrated to the experts and their feedback was captured using a detailed structured questionnaire. The aims of the interviews were to assess the validity and generalizability regarding proposed application. An iterative process was followed whereby modification to the proposed application was made based on the feedback received.

IV. LEAN ENABLERS FOR PRODUCT DESIGN AND DEVELOPMENT

Since the aim of this research is to enable the advantages of lean thinking, and to strengthen the designer's decision taking and mistakes elimination capability, suitable tools and techniques (enablers) were, therefore, identified through a literature review and industrial field study. After a detailed literature review and an interaction with industrial experts, two lean enablers were selected suitable to support lean product design and development. These enablers include poka-yoke (mistake-proofing) and knowledge-based engineering. Moreover, these enablers will help to avoid mistakes during product design for example in parameters identification, material specification, machine specification etc. Similarly in

manufacturing they will help in material selection according to proper specification and manufacturing processes. The description of each enabler along with example of rules development for threading taps is explained in next section.

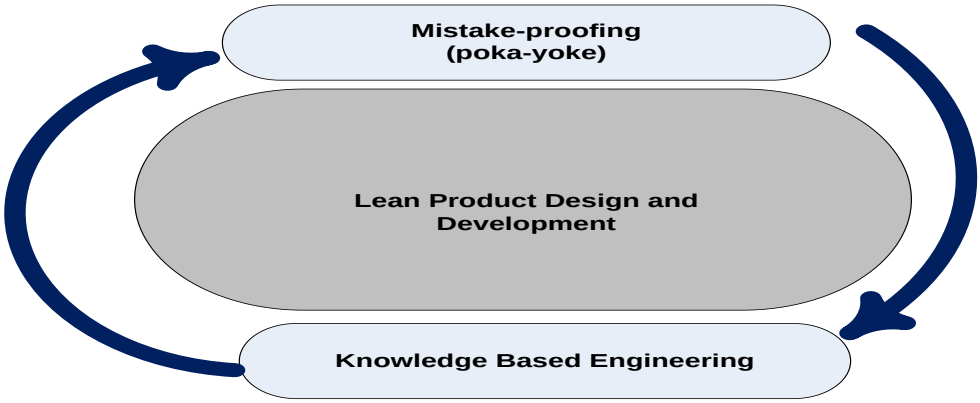

Fig. 2: Lean enablers for product design and development

A. Poka-Yoke (Mistake Proofing Technique)

This technique is also known as mistake proofing technique. In process of product design and development mistakes can occur at different stages where poka-yoke can be applied to eliminate different types of errors. A case study of threading tap was taken into account and three types of errors for design and development of threading tap were overcomed by using poka-yoke. UML diagram for design and development of a threading tap by using poka-yoke has been presented in Fig.4. Rules were developed for different types of mistake eliminations.

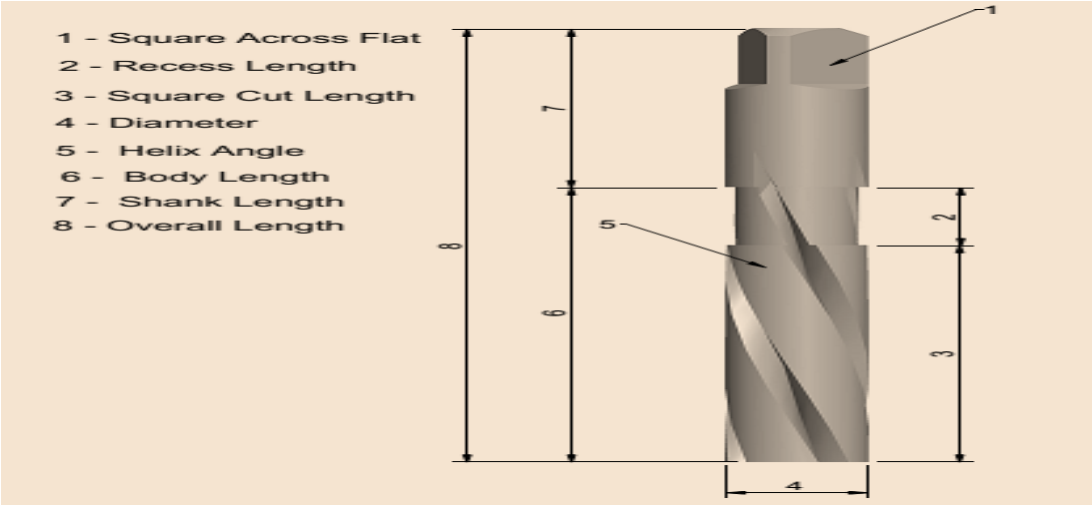

Fig. 3: Important Dimensions in Threading Reamer

a) Mistake Elimination in Product Design Parameters Selection

Designers can make mistakes during the design of product. No doubt these mistakes get reduced as the experience of the designer increases. The probability of mistakes is even higher in case of a complex or innovative design. In order to minimize these mistakes, parameters identification rules were developed and can be used by SMEs. These rules assess the CAD design to evaluate if the design has been developed within limits. Product design parameters and identification rules for threading tap are shown in UML diagram in Fig.4.

(b) Mistake Elimination in Process Parameters Selection

Another mistake that commonly occurs in product development is the selection of the right process parameters at the manufacturing stage, i.e. if the designer develops a design within recommended limits and standards, there are still chances that the manufacturer or process planner will misinterpret critical dimensions and apply incorrect process parameters. For example, in manufacturing of threading taps from high speed steel, Pre-Heating process is performed before heat treatment process. UML diagram for developed rules for this process is shown in Fig.4.

(c) Mistake Elimination in Manufacturing

In order to proceed for design and development of lean product, it is necessary to make the right assumptions. Incorrect assumptions can take us to incorrect estimation of total cost and different process parameters and ultimately a reduction in market profit and a loss in customer confidence. Therefore rules can be developed to identify material's manufacturability.

- Material's manufacturability in the manufacturing facility

  Rules have been developed to check the manufacturability of material as shown in UML diagram Fig.4.

- Machines' availability in the manufacturing facility

  Rules have been developed to check the availability of machines as shown in UML diagram Fig.4.

- Machines' capability to manufacture the component

  Rules have been developed to check the manufacturability of the material as shown in UML diagram Fig.4.

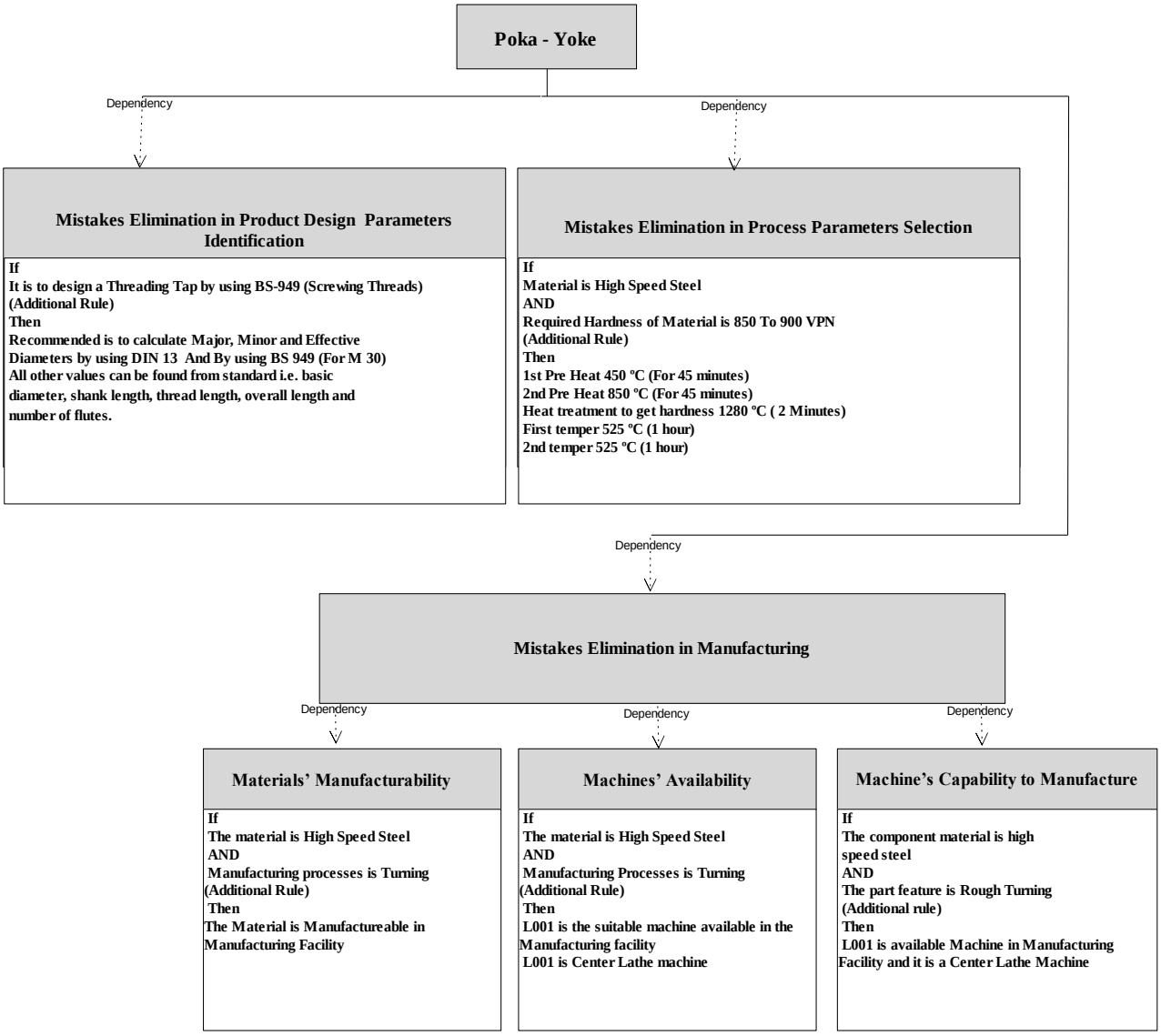

Fig. 4: UML Diagram of Poka-Yoke (Mistake Proofing Technique)

B. Knowledge Based Engineering

In this research, lean knowledge life cycle proposed by [16] has been employed to identify, capture and share knowledge in lean product design and development. This Lean Knowledge Life Cycle (LKLC) consists of seven steps. In this research only four steps were utilized. The detail of each knowledge life cycle stage along with its usability is given as:

(a) Knowledge Identification

The first stage of the knowledge life cycle is knowledge identification. In principal, it is an initial planning stage where the knowledge required for a specific problem is identified. In order to identify the knowledge for this research, a number of interviews with the product development teams and manufacturing units were conducted to identify the required knowledge. In addition, a detailed literature review was carried out. Since the research is related to lean product design and development therefore all the necessary data were identified which include the machines information, materials' capability, product design methods, etc.

(b) Previous Product and Domain Knowledge Capture

In this stage, the knowledge highlighted in the knowledge identification stage is captured. In the case of manufacturing of threading taps it was identified that the company was using manufacturing standards to design the product. Any fault coming in their design was informed and they were not keeping it in their record. Therefore rules were captured and processed further to apply in proposed application.

(c) Knowledge Representation

Once the knowledge is identified and captured, it is required to be presented in a form which can easily be transformed into a knowledge-based engineering application. In this research, the knowledge captured in stage two is presented in the form of rules. The captured knowledge is validated through industrial representatives to eliminate mistakes in these rules before they can be used in lean product design and development application. UML diagram of knowledge base engineering by using these four steps of lean knowledge life cycle developed by [16] is shown in Fig.5.

(d) Knowledge Sharing

The aim of this stage is to share the knowledge with all stakeholders so that they may access the knowledge in order to view or modify it when changes occur in product. In this research the captured knowledge was taken in the expressed form and provided to the SMEs so that they can keep it in record. In future, work by using these two lean enablers web based application along with Microsoft SQL Server database for lean product design and development can be developed.

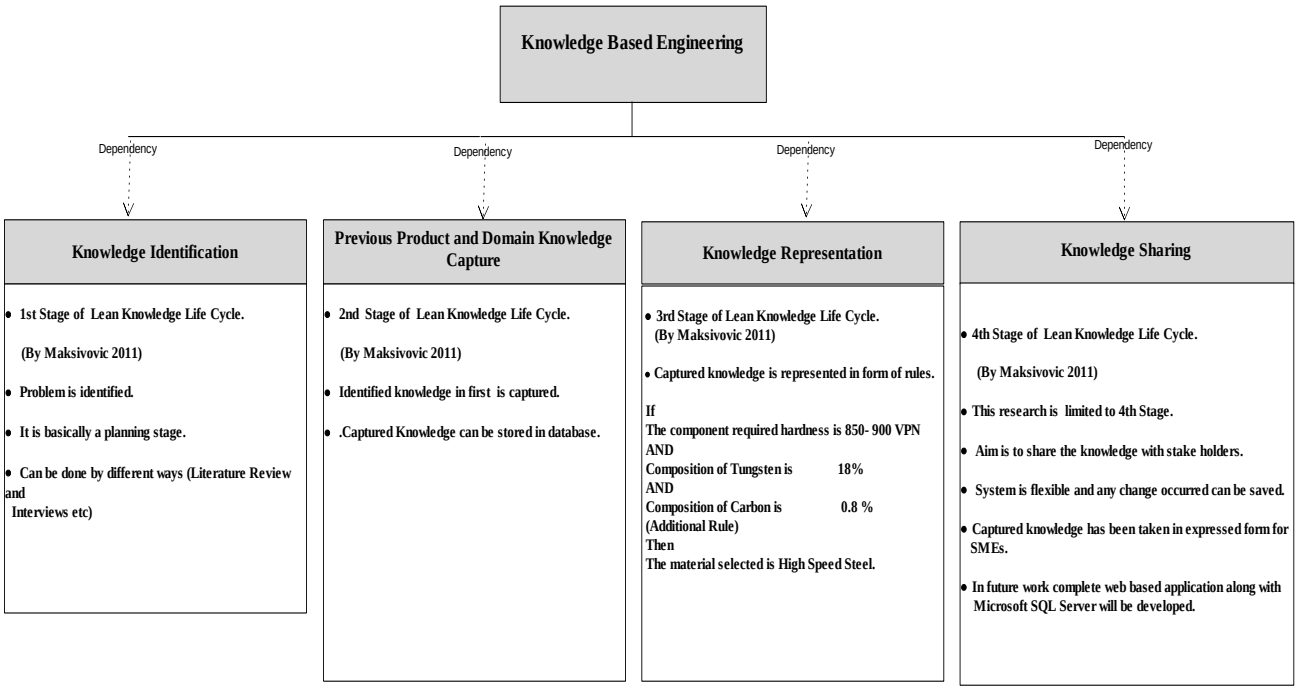

Fig. 5: UML Diagram of Knowledge Based Engineering

V. VALIDATION OF PROPOSED APPLICATION

The purpose of this section is to describe the validation of proposed application through a case study from a small manufacturing industry as well as qualitative validation with experts from different fields. The intention of validation through case study and experts is to ensure the quality and strength of the research.

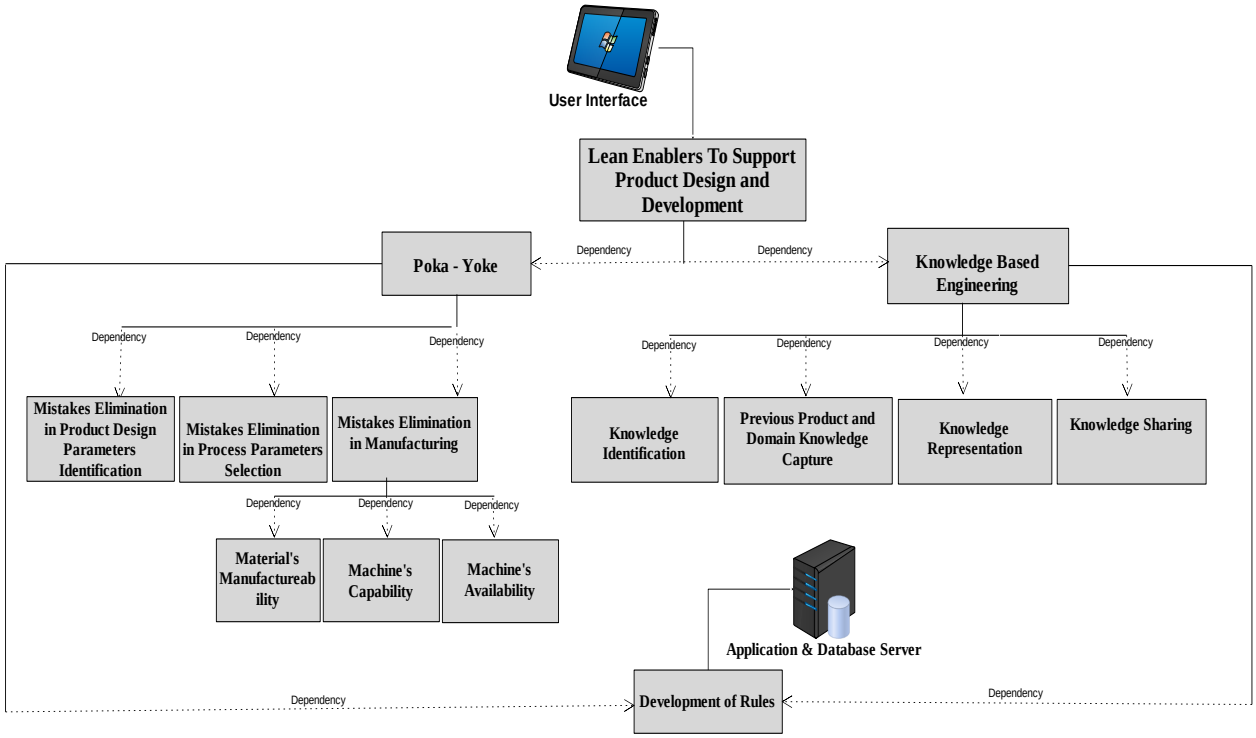

Fig .6: UML Diagram for Proposed Application for Lean Product Design and development by using Lean Enablers

(a) Validation through Expert's Opinion

The validation of proposed application as per developed rules was through experts in the related field. The validation was executed by experts in five different fields. i.e. designing, product development, Information Technology, manufacturing and Lean expert. The reason behind this method was to analyze the experts' views about the differences they feel after collecting the data and using it to transform into rules. A total number of five face to face interviews were performed in the validation of developed proposed application. Details of the experts involved in the validation study are provided in Table 1.

Table I: Details of Experts involved in Validation

Expert#	Organization	Role	Experience (Years)	Experience Area
01	Industry	Design Engineer	20	Product Design and Development
02	Industry	Product Development	15	Product Development Engineer
03	Information Technology	IT Expert	10	Application and Database Engineer
04	Industry	Manufacturer	12	Shop floor Engineer
05	Industry	Lean Expert	10	Academic

(b) Detailed Methodology for Experts Validation

The validation methodology for developed rules and proposed application by experts is explained below.

First of all, a brief presentation of about 10 minutes was made and presented to the experts. The purpose of this presentation was to explain the aim, objectives and structure of the proposed application. Similarly face to face interviews were carried out in the validation process. After that the experts were asked to fill in the validation questionnaire. In the questionnaire, the following issues were discussed:

a. Is the proposed application truly generalizable to other products also?

b. What are the potential benefits and limitations of the technique used to propose application?

c. Are the developed rules flexible and easy to use?

d. Has the application been developed for two lean product design and development enablers as per their true principles?

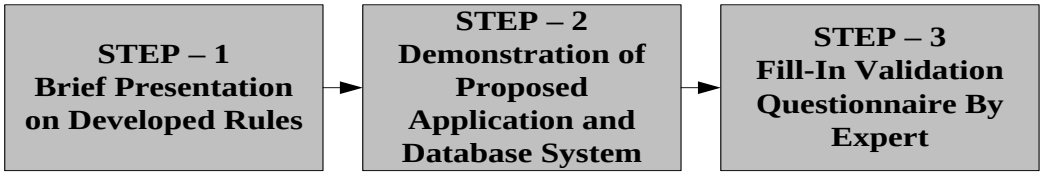

Fig. 6: Methodology for Validation by Experts

(c) Benefits of Using Developed Rules in Proposed Application

Benefits for Development Team

According to experts' opinion, use of these rules will speed up the selection process during the design stage to select alternative options. They also explained that small and medium enterprises (SMEs) have the capability to manufacture a large range of products because of the availability of a number of machines. The developed rules in proposed application can provide a good solution for those companies. In additions, the mistakes prevention reduces the wastes at the early design stage.

Benefits of Poka-Yoke considerations

Experts highlighted that machine availability and identification is fine at the initial design stage. Similarly the machines' capability is a consideration at the early stage and helps to eliminate the mistakes that occur in the later stages. Developed rules in proposed application generate mistake-proof results and help to improve the design. Engineers are prevented from choosing incompatible manufacturing processes and materials.

Benefits of the Knowledge-Based Engineering consideration

Experts stated that material manufacturability, machines' availability and capability identification rules will help to develop reliable results in the proposed application.

Strongest Features

Experts suggested that the proposed application will be easily used for product design and development as developed rules will create the actual results. We can see that all of this data is available in any manufacturing unit. What we need to do is to manage everything in a systematic manner and generate the results.

(d) Limitations of Using Developed Rules in Proposed Application

Limitations with respect to Application in the Organization

Experts identified that the companies manage their data in their own legacy system therefore the technique of proposing application by using poka-yoke and knowledge based engineering should be capable of integrating with that system. An expert stated that each organization requires the subjective data as per their manufacturing technology and therefore it is necessary to add more manufacturing processes when developing rules for their system.

Weakest Features in Developed rules

Experts informed that some additional data input during the design stage should be included so that detailed design parameters can be generated before drawing is made.

VI. CONCLUSION

This research has presented a review of techniques, tools and methodologies of lean manufacturing implementation and its impact assessment. The literature review identified a number of research gaps. Significantly, the review emphasized the need for further work in the area of lean product design and development. The proposed application will be working on developed rules which are created by using two lean enablers i.e. poka-yoke and knowledge based engineering. These are experimental rules which are capable of setting conditions for advice on implementing lean product design and

development. This research highlights that these rules can be used to develop a user-friendly application for lean product design and development .A proposal for such an application has been presented in a UML diagram in Fig.6. In future, complete web based application along with Microsoft SQL Server for lean product design and development will be made by using these two lean enablers. The current research focused on two lean product design and development enablers which are knowledge-based engineering, and mistake-proofing (poka-yoke). In future, more lean product design and development enablers may be identified to improve the lean product design and development process.

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