A FRAMEWORK FOR IMPLEMENTING LEAN MANUFACTURING SYSTEM IN SMALL AND MEDIUM ENTERPRISES

by

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ABSTRACT

In this paper, a conceptual framework to apply many techniques for implementing lean in the high-variety low-volume (HVLV) environment is presented. Lean production has increasingly being implemented as a potential solution for many organizations. Anyway, the lean formula is applicable directly only to the make-to-stock business, but the make-to-order (MTO) product environment has to adapt lean manufacturing principle. This paper has a two-phrase quantitative framework to transform small and medium enterprises (SMEs) to be lean. Phrase 1 has three interrelated components: (1) re-engineering an organization by using the power of computer simulation combined with business process. (2) Value stream mapping (VSM) is used to create a map of both value and waste in a given process. This tool has also a main drawback for job shop facility because many value streams are composed of hundreds of industrial parts and products. (3) Integrative supplier relationship is one of the most critical factors to maintain an advantage in the increasing levels of competition. Phrase 2 performs a just in time production schedule by using ant colony optimization technique combines with a simulation tool. The objective of this paper is to develop a suitable lean manufacturing system for SMEs. This modeling framework is also used to study the performance of the system for improving effectiveness. This paper addresses how to combine lean concept with simulation optimization, the step of this framework to obtain the optimization solution.

KEYWORDS
Small and Medium Enterprises (SMEs), Lean Manufacturing, Job Shop Environment

INTRODUCTION

Lean is based on learning from Toyota who increased market share by improving their processes, most notably on the shop floor, but also in design and development (Parry et al., 2010). Lean production has increasingly been implemented as a potential solution for many organizations. (Shah & Ward, 2007) defined lean production as an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability. The performance of lean production practices improve productivity through reduced lead times, material and staff costs, increased quality etc.

However, the lean formula is applicable directly only to the make-to-stock business, but the make-to-order (MTO) product environment as job shop has to adapt lean manufacturing principle (Chitturi et al., 2007). The key problem facing the high variety, low volume (HVLV) organization is that it has manufacturing system turbulence than the typical lean manufacturing. One of turbulence causal factors can be identified as schedule (Jina et al., 1997). Job shop production is characteristic of many SMEs within the MTO sector. Also, job shop scheduling can be applied to the manufacture processing and effect really the production time, the cost of production and on-time delivery for a plant.

Although lean manufacturing is becoming a popular technique for productivity improvement, SMEs are still not certain of tangible and intangible benefits they may achieve. To promote the use of lean manufacturing within the SMEs is the challenge. This paper proposes a conceptual framework to develop a suitable lean manufacturing system for SMEs. The rest of this paper is organized as follows. In section 2 illustrates the fundamental of this research and reviews related literatures. In section 3, the methodology of the proposed approach is described. Finally, conclusions and further research directions are provided in section 4.
LITERATURE REVIEW

This section presents a review of literature relevant to this research. This includes many issues in relation to main cores of the study which are briefly described as follows.

**Lean manufacturing System**

Many companies around the world have transformed lean concept from traditional approach as mass production system. The general concept of behind lean manufacturing is to reduce waste and the lead time. Waste is any human activity which absorbs resources but creates no value. Therefore, time is one of these wastes. A benefit of reduced lead time is that it improves customer feedback and allows for the producer to immediately address quality issues and concerns. A decreased lead time reduces the time it takes a company to satisfy the customers’ changing needs and wants.

An empirical study of 27 excellent lean manufacturers, where are all Italian, was investigated by (Panizzolo, 1998). The interviews were carried out with the aim of understanding the extent to which the various improvement programs or best practices were applied in the companies. (Taj, 2008) also investigated the adaptation of lean production and assessed its current state of practice in selected plants from 65 participants in China.

In order to accomplish the goals of lean manufacturing many tools have developed. One of the key lean tools is that of “Value Stream Mapping (VSM)”. This tool when used to create a map of both value and waste in a given process. Anyway, VSM has also a main drawback for job shop facility because many value streams are composed of hundreds of industrial parts and products. Thus, this complication cannot be addressed with the standard method (Braglia et al., 2006). From this reason, the traditional VSM method was found inadequate for mapping such a flow network.

**Business process**

The increasing popularity of business process orientation has yielded a rapidly growing number of methodologies, and modeling techniques and tools to support it. To select the right technique and the right tool is very important to develop the business modeling. The modeler must know and identify the purpose of the model to be constructed (Phalp, 1998).

Presently, the power of computer software plays a vital role for business process management. (van der Aalst et al., 2003) defined business process management as supporting business processes using methods, techniques, and software to design, enact, control, and analyze operational processes involving humans, organizations, applications, documents and other sources of information. Business process re-engineering combine with simulation technique was presented by (Berry et al., 1995) for concerning electronics products. They also claimed that business process re-engineering advocates the drive to minimizing total costs while maximizing customer service levels.

**Multi criteria decision making (MCDM)**

Decision-making with high stakes and stochastic future implications involves multiple actors. The reality of a group making these high-stakes decisions generates a requirement for creating communication links between the members of the decision-making group with a common understanding of the syntax and semantics of the underlying issues.

The problem can be abstracted as how to derive weights, rankings or importance for a set of activities according to their impact on the situation and the objective of decisions to be made. This is the process of multiple-criteria decision-making (MCDM). The field of MCDM is divided into multi-objective decision-making (MODM) and multi-attribute decision-making (MADM) Most of the MADM methods require that each attribute is given a weight or relative importance with respect to their impact on the decision problem being solved.

The intense global competition forces manufacturers, who seek to respond their customers with high quality products in the right time at the right place (Abdel-Malek et al., 2005). Hence the selection of strategic partners that will furnish them with the necessary products, components, and materials in a timely and effective manner to help maintain a competitive advantage is challenge (Sarkis & Talluri, 2002). From the subjective considerations are relevant to partner evaluation and selection decision. MCDM is a popular technique to deal with imprecision in supplier choice.
**Simulation**

Simulation modeling is a common paradigm for analyzing complex systems. This paradigm creates a simplified representation of a system under study. The paradigm then proceeds to experiment with the system, guided by a prescribed set of goals, such as improved system design, cost–benefit analysis, sensitivity to design parameters, and so on. Experimentation consists of generating system histories and observing system behavior overtime, as well as its statistics (Altiok & Melamed, 2007).

Simulation has enjoyed a great deal of popularity in the manufacturing, production, logistics, service, and financial industries. (Ruohonen & Jokitalo, 2008) applied simulation to improve the operation in the metal industry, such as the quality of service and productivity of the operation. (Greasley, 2008) estimated the size of storage areas required for a proposed overseas textile manufacturing facility. Hence, simulation is one of the most useful tools which can integrate with other techniques such as business process, operation research etc.

**Job shop scheduling problem**

The job shop scheduling problem is considered to be a good representation of the general domain and has earned a reputation for being notoriously hard to solve. It is probably the most studied and well developed model in deterministic scheduling theory, serving as a comparative test-bed for different solution techniques, old and new and as it is also strongly motivated by practical requirements it is clearly worth understanding (Jain & Meeran, 1998).

(van Laarhoven et al., 1992) investigated the potential of simulated annealing algorithm for the problem of finding the minimum makespan in a job shop. Their algorithm was better than two approximation approaches, but it consumed large running time.

**Ant colony optimization (ACO)**

The first combinatorial optimization problem which was solved by ACO is the travelling salesman problem (TSP). (Dorigo & Gambardella, 1997) explained the concept of an artificial ant colony to solve this problem. The key to the application of ACO is to identify an appropriate representation for the problem (to be represented as a graph searched by many artificial ants) and an appropriate heuristic that defines the distance between any two nodes of the graph. Then the probabilistic interaction among the artificial ants mediated by the pheromone trail deposited on the graph edges.

In ACO algorithms artificial ants are stochastic constructive procedures that build solutions by moving on the construction graph $G_C = (C, L)$, where the set $L$ fully connects the components $C$. The problem constraints $Q(t)$ are built into the ants' constructive heuristic. In most applications, ants construct feasible solutions. However, sometimes it may be necessary or beneficial to also let them construct infeasible solutions. Component $c_i \in C$ and connections $l_{ij} \in L$ can have associated a pheromone trail $\tau$ ( $\tau_i$ if associated with components, $\tau_{ij}$ if associated with connections), and a heuristic value $\eta$ ($\eta_i$ and $\eta_{ij}$, respectively). The pheromone trail encodes a long-term memory about the entire ant search process, and is updated by the ants themselves. Differently, the heuristic value, often called heuristic information, represents a priori information about the problem instance or run-time information provided by a source different from the ants.

**Simulation optimization**

When the mathematical model of a system is studied using simulation, it is called a simulation model. The process of finding the best input variable values from among all possibilities without explicitly evaluating each possibility is simulation optimization (Carson & Maria, 1997). (Eskandari et al., 2005) presented an enhanced genetic algorithm approach for dealing with multiobjective simulation optimization problems. This approach integrated stochastic nondomination-based multiobjective optimization technique with a simulation model and genetic algorithms. (Mejtky, 2008) presented an improved sweep metaheuristic for discrete event simulation optimization. The basic idea is to run a limited number of partial solutions in parallel and to search for solutions by searching the partial solutions.
METHODOLOGY

The above pockets of anecdotes and theories are indicative but inadequate in integrating the concept of lean for applying in SMEs as job shop environments. The research study aims to extend the understanding of the roles of lean concept for SMEs. An overview of the proposed system is shown in Figure 1 which comprises of 2 phrases, which are described below.

Phrase 1: A LET (Lean Enterprise Transformation) project

The Let project embraces of business process management, value stream management (VSM) and supplier selection. From the best of our knowledge, we found that information technology (IT) is an essential tool for severe competing in business world. But, this tool is also too expensive for SMEs, Especially for Thai SMEs, to investment. Hence, we developed the Let project as a fundamental to be lean for SMEs. In this phrase, some essentials of business process with simulation, a new approach VSM, method to select suitable suppliers are briefly described as follows.

Business process simulations

This research decides to use the most popular processing-model, IDEF0. IDEF0 models consist of a hierarchy of related diagrams. Each diagram is based on a diagonal row of boxes connected by a network of arrows. The boxes represent activities which are described by an active verb phrase contained within the box. Arrows represent the relationship between activities in terms of the information or objects used, required by activities (Colquhoun et al., 1993). This arrow structure is shown in Figure 2. Each diagram is referred to by its 'node number' that defines where it lies in the hierarchy of a model as illustrates in Figure 3.
Value stream management for SMEs

The phrase applies 8 steps to value stream management which was proposed by Tapping. Value stream management is a process for planning and linking lean initiatives through systematic data capture and analysis (Tapping et al., 2002). Anyway, for step 4 and 6, in job shop environment can not use the standard value stream map because the job shop produce a variety of products, does not necessarily produce the same product again, and the lead times to produce the products are short, possibly with in a day. Therefore, to stream line the value flow new value stream map has to be drawn for each new order (Alves et al., 2005). As mention above, this research applies a proposed approach is called a new value stream mapping approach for complex production systems. This was done by integrating the standard VSM approach with a set of additional tools derived from the manufacturing engineering area (Braglia et al., 2006). In particular, the framework is structured to explore the various branches of the whole value stream only if necessary and following an optimized order.

Selection supplier by fuzzy AHP: a stochastic approach

The procedure to select supplier by using MCDM technique is divided into the following parts:

Part 1: Fuzzy Analytic Hierarchy Process

AHP is a multiple criteria decision-making tool, which was founded by Saaty. This is an eigen value approach to make subjective comparisons for each pair of attributes or alternatives using a ratio scale. In order to overcome the shortcomings, the fuzzy logic principle was introduced into the AHP for MCDM (Cheng & Mon, 1994). This makes it possible to adopt the AHP in an environment where the input information or the relations between criteria and alternatives are uncertain or imprecise.


In the AHP, the uncertainty is propagated through a hierarchy resulting in the uncertain values for the global AHP weights of decision alternatives. It was clear that, this uncertainty associated with subjective judgmental errors may affect the rank order of decision alternatives and consequently reduce the decision maker’s confidence in the obtained results of the AHP (Eskandari & Rabelo, 2007). (Wanitwattanakosol et al., 2009) bridged the gap of fuzzy AHP and stochastic approach to find a best alternative of freight logistics hub. (Wanitwattanakosol et al., 2010) also improved this approach by using data mining to select merely significant criteria in order to reduce cost from collection data process.
ACO and simulation optimization for the job shop scheduling problem

The job shop scheduling problem is still a NP-hard and difficult to solve in practice. This research proposes a metaheuristic approach, namely an ant colony optimization (ACO) approach, to tackle this problem. Hence, for the one hand, this research applies ACO for ideal system. For the other hand, realization of the system is implemented by simulation optimization which comprises of ACO and simulation technique. The results from ideal and realization situation are compared. In ideal system is assumed that the procedure of business is flow and stable. But, in realization system, stochastic event always happen in the system. LET project is used to transform realization to be closeness ideal system.

CONCLUSION

The dramatic performance improvements available by following lean concept such as low waste principles are well established in high volume, relatively low variety situations. But the make-to-order (MTO) product environment as job shop has to adapt lean manufacturing principle. Most companies must carefully judge which lean practices they can use immediately and which need to be adapted to meet their special circumstances. The authors consider that the framework presented in this paper provides a structure for adaptation to be lean for SMEs. In future, the further research in each step of a framework by incorporated it with some data to see the real effect should be done.

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