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A conceptual framework of risk management in decision making method for scheduling and line balance monitoring of manufacturing system

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Abstract: Manufacturing systems helps in planning, controlling and monitoring throughout the manufacturing processes. Failure to perform reliable systems may cause problems through its lifecycle. Specifically, risk management is particularly pertinent for manufacturing projects, thus distinctive methods and education have been developed for such risk management. Fewer attempts are done in dealing with lean production risks during constructing of project. On the other hand, lack of methodology in recognizing and minimizing lean production risks during developing manufacturing systems resulted in nothing, except wasting a lot of money and energy, firing personnel, getting loans or bankruptcy. Consequently, for a more desirable management of risks associated with mass production of a manufacturing system, it seems necessary to develop an expanded image and a perspective of future horizon during constructing a manufacturing system. In this paper, a review from the previous works were conducted on risk management particularly risks in decision making method for scheduling and line balance monitoring in manufacturing system. A suggestion of conceptual model is discussed and presented. The identification of the effective production factors is also discussed. This review indicated that the appropriate selection of systems will help in the success of the manufacturing project.

Key words: Risk management; Manufacturing; Methodology

1. Introduction

Around the world, manufacturers are searching for new ways to address the growing demands of global manufacturing. They want the latest tools and technologies to boost performance in each aspect; operations, suppliers, partners, etc. They also search for solutions to help them produce more for less, lower their total cost of ownership (TCO) and improve their return on investment (ROI). Manufacturing systems need to plan and control the manufacturing process in details from the ordering and receiving raw material until delivery and after sale services to customers. Each company whether it is a manufacturing company or providing services may encounter with a lot different problems through its lifecycle if it was not designed well to face and confront with such problems. More than $250 billion is spent annually in the United States for facility designing, scheduling and re-scheduling (Tompkins et al., 2003). Therefore, it is vital to recognize harmful factors and design a flexible manufacturing system to cope with such harms during its life cycle.

There are various kinds of risks to be considered in studying risks of projects in project management studies. Risks are usually expressed in terms of finance, safety, logistics and social and environmental impacts. The risk types according to their nature and examples such as hazard risk, financial risk, operational risk and strategic risk.

Risk management has been defined as " the act or practice of controlling risk", that includes risk planning, assessing risk areas, developing risk-handling options, monitoring risks to determine how risks have changed, and documenting the overall risk management program. In managing risk, project managers must consider risk in their planning and scheduling practices. Risk management and scheduling are closely tight, where considerations of one requires a reassessment of the other, e.g., in creating strategy and plans to handle program risk, how the approach affects the program schedule must be considered. Hence, a plan that balances risk, cost, schedules and performance need to be developed (MacDaniel and Bahnmaier, 2001).

Furthermore, due to lack of methodology in recognizing and minimizing lean production risks during constructing manufacturing systems, nothing is obtained except wasting a lot of money and energy, firing employees, getting loans or bankruptcy. Risk management is therefore particularly pertinent for manufacturing projects, thus special methods and special education have been developed for such risk management. It is obvious, from the past literature search, less attempt are done in dealing with lean production risks during constructing of project. Also, there is a need

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to find new ways to use concepts of line balance monitoring during the constructing of a manufacturing system to minimize future harms.

Consequently, for a more desirable management of risks associated with mass production of a manufacturing system, it seems necessary to develop an expanded image and a perspective of future horizon during constructing a manufacturing system. Nowadays, the process of Risk Management is followed systematically as national necessity in many countries. Therefore, in this paper, by suggesting a comprehensive conceptual model, it will be tried to identify the effective production factors that may cause system failures. The process will consist of identify, plan and control risk during constructing of a manufacturing system and also to identify effective criteria and sub-criteria in each of the identified agents to be able to evaluate, analyze and select the most appropriate method.

2. Literature review

Designing appropriate manufacturing systems is an important part of manufacturing. Lean manufacturing is the basic techniques for improving the production rate with the minimum available resources. It is an efficiency based system on optimizing flow to minimize the wastage and using advance methods to improve manufacturing system by modified or change pre-existing ideas (Chahal, 2012). In a lean system, flexibility is necessary to achieve a high level of competitiveness. Since lean methodology is based on the principle that supply must adjust to demand, it is required that all the elements that compose the system are provided with a high flexibility, so that tasks can be changed quickly and without unnecessary loss of time (Boscà, 2012). On the other hand, Flexible Manufacturing System are based on the concept of flexibility which can be defined as the capacity of a system to adjust itself in response to changing requirements without significant expense in terms of time, effort, cost, or performance (Toni and Tonchia, 1998). Flexible manufacturing systems were introduced in response to a new demand for more variety and for greater responsiveness to changes in products, production technology, and markets.

The traditional project management has proved to be successful for simple and certain projects, where the problems that arise from the interactions between activities can be resolved without difficulty. However, for complex and uncertain projects, lean project management seems more appropriate where the management of the workflow and the value perspective focused on customer's specifications can allow managers to deal with uncertainty. Thus, to decide which method should be applied, it results necessary to evaluate the uncertainty and risks of each project before their beginning. In order to do that, risk project management seems as the perfect way to evaluate risks and complexity in projects (Bosca, 2012).

Since the 1960s, several methodologies have been developed and used for decision-making, performance, and risk assessment. In the context of decision-making, the methodologies are roughly divided into two categories: graph theory combined with matrix approaches, and multiple criteria methods. The multiple criteria methods are further classified into mathematical optimization and multiple criteria decision-making (MCDM). Researchers have applied mathematical optimization models to diverse manufacturing problems (Rao, 2011). The optimization method was used by Durand (1993) to assess analytically the performance of product portfolios in a company and its impact on individual product cost using the concept of "shared activity". Nevertheless, optimization models are often employed to find optimal solutions; they are therefore generative methods. For evaluation purpose, multi-criteria decision-making (MCDM) are more commonly used approaches (Greco 2004). Majority of researchers have developed models, methods and their visualized tools systematically or semi-systematically to identify risks in the project by integrating their models or methods using only one technique which identifies risks from one perspective (Basri et al., 2015). There are some techniques to achieve risk analysis of projects, 1) the qualitative technique such as Analytic Hierarchy Process (AHP) and risk matrix, and 2) the quantitative technique such as Fuzzy Logic, Tree, Monte Carlo Simulation, Failure Mode and Effect Analysis (FMEA), Event Tree Analysis (ETA), Fault Tree Analysis (FTA). To calculate probability and severity and getting an accurate result, quantitative analysis should be used in getting an effective risk assessment.

2.1. Scheduling and line of balance monitoring

The schedule, in project management practice, is a powerful planning, control, and communications tool that, when properly executed, supports time and cost estimates, opens communications among personnel involved in program activities, and establishes a commitment to program activities. Additionally, scheduling is integral to a program's acquisition strategy and to risk management, financial, and technical management plans, and an important element of the other management functions: organizing, staffing, controlling, and leading. On the other hand, poor scheduling can adversely impact a program in a number of areas. Haphazard schedules make it difficult, at best, to determine a realistic completion date and to efficiently allocate resources to the entire program. This creates financial problems-escalation of costs, increased support costs, delayed return on investment, funding cuts, or program termination.

Schedules can be presented in a variety of ways. According to the different treatment of uncertainty, scheduling methods were divided into two groups: reactive scheduling and preventive scheduling.

Reactive scheduling, dynamic scheduling, rescheduling, and online scheduling deal with the problem of modifying the original scheduling policy or generating scheduling policy on time when uncertainty occurs. Preventive scheduling or predictive scheduling generates robust scheduling policy before the uncertainty occurs (Ierapetritou and Li, 2009). On the other hand, (MacDaniel and Bahnmaier, 2001) classified four types of schedules that are commonly used; 1) the Gantt or bar chart, 2) the milestone schedule/chart, 3) the network schedule, and 4) the production schedule.

A network schedule is a graphical display of a project, including a representation of these relationships. The Program Evaluation and Review Technique, or PERT, is developed to enable managers to visualize the entire program, see interrelationships and dependencies, and recognize when and where delays are acceptable. Another network scheduling system which based on the concept of critical path was developed and named as Critical Path Method (CPM), was designed to focus on performance time and total program cost. Thus, PERT and CPM scheduling techniques have many similarities. A third network scheduling technique is the Precedence Diagram Method (PDM), functions to permit a more accurate depiction of relationships among various activities than is possible using the other two techniques. In general, network scheduling techniques permit the graphic portrayal of project activities and relationships among the activities, thus provides the basis for determining the project's critical path, predicting shortages, and identifying possible reallocation of resources to solve problems. Through the use of readily available software, network schedules are fairly easy to update and rework, thus providing managers with current program/project status information and control over activities and schedules.

Production scheduling involves the planning, execution, and control of repetitive activities, such as the manufacture of a large number of identical items. Efficient production requires the proper balance of materials, facilities, and personnel skills. It also requires a means to monitor the production process. The Line of Balance (LOB) technique is normally used for this purpose. It is also commonly used in identifying problem areas in the process that could adversely affect the delivery schedule, e.g. those activities that require attention and possibly corrective action, and can also be used for reporting the status of the manufacturing process and delivery schedule to higher management. In addition, it is a monitoring technique that gives prior warning of problems within a continuous production process. Nowadays, LOB application has been further expanded, making it suitable for a whole spectrum of activities ranging from research and development through job-shop and process flow operations. Line of Balance focuses on balancing the time taken for individual activities by either re-distribution of resource or by reducing process waste (MacDaniel and Bahnmaier, 2001).

Uncertainty appears in all different levels of the industry from the detailed process description to multisite manufacturing. Hence, the successful utilization of process models relies heavily on the ability to handle system variability. In the planning phase, scheduling contributes to the development of detailed functional plans and budgets and to identification and allocation of required resources throughout program activities. In addition to being an output of the process like Master Program Schedule (MPS), Integrated Master Plans (IMP) and Integrated Master Schedules (IMS), Functional Plans, Work Breakdown Structure (WBS), etc., it also contributes to the development of the other outputs. The early involvement of experts in scheduling techniques can contribute to the effective translation of strategic concepts and ideas into detailed logic diagrams, depicting the program activities and relationships among activities.

There are different scheduling concepts and techniques and how they can be applied and analyzed to manage effectively. A number of tools and techniques are useful in developing the logic diagrams that reflect the desired activity sequencing. Estimating activity duration is one of the most difficult aspects of schedule development and should be performed by people who are most familiar with the activity. Two key inputs to the estimation process are the resources required and assigned for the activity and the capabilities of the resources assigned. Historical information from other programs and from commercial databases can also be helpful in developing accurate estimates.

A number of techniques and tools are useful in developing schedules, many of which are contained in various scheduling software applications. Most contain the capability to perform various types of mathematical analyses to calculate theoretical start and finish dates for each activity based on the overall sequencing of the program activities. Two of the more commonly known analysis techniques are critical path method (CPM) and the Program Evaluation and Review Technique (PERT). Other commonly used scheduling development techniques focus on schedule development in light of resource (time, people, funds, material) constraints. Schedule compression and resource leveling provide the means to manage the effect of these constraints through the compression of activity duration and the leveling of resources throughout activities.

Uncertainty exists in every schedule. It is impossible to predict the length of time necessary to complete an activity, meet a milestone, or deliver a system, with a complete confidence. Little information exists in the early phases of a program, and planners must rely on personal experience and the estimates of experts. As a program progresses through the acquisition cycle, more information becomes available. Schedules developed in the latter phases of a program are based on more information and analyses, but they still lack complete certainty. Uncertainty introduces the element of risk in the planning process. Schedule risk is the likelihood of failing to meet schedule plans and the effect of that failure. When creating a schedule, one must assess the risk associated with the schedule. One technique for assessing this schedule risk involves estimate contributions for each activity's duration and aggregating these distributions using a Monte Carlo simulation or other analytical tools. The resulting program-level schedule is then analyzed to determine the actual schedule risk and to identify the schedule risk drivers. This technique uses a range of times that it will take to complete each activity. This approach results in a more realistic estimate of schedule risk because it accounts for much of the uncertainty inherent in the use of single-point estimates. This technique can be used in any acquisition phase beginning with the completion of the first statement of work. The schedule probability distribution function for each key activity should be developed as soon as the activity is included in the master schedule. Risk is inherent in all programs, and scheduling is one element of risk. Uncertainty introduced in estimating the duration of each activity causes most schedule risk. Probabilistic techniques are proven to be very useful in assessing the likelihood of failing to meet schedule plans and the impact of that failure.

2.2. Risk

Risk has different meanings to different people; that is, the concept of risk varies according to viewpoint, attitudes and experience. Engineers, designers and contractors view risk from the technological perspective; lenders and developers tend to view it from the economic and financial side; health professionals, environmentalists, chemical engineers take a safety and environmental perspective Kaya et al. (2012). Risk can occurs anytime and everywhere. Risk is a multi-facet concept (PMBok, 2008). A risk factor can be defined as a situation that may give rise to one or more project risks, and the risk factor itself doesn't cause a product, schedule, or resource target loss/damage. Risks play a significant part in decision making and may affect the performance of a project as they may cause cost overruns, delays on schedule and even poor quality if not dealt sensibly (Wiguna and Scot, 2005). Each project has a different level and combination of risks and will adopt different strategies to minimize them because the characteristics of projects are unique and dynamic.

3. Conceptual framework

In order to develop the proposed conceptual framework for scheduling and line balance monitoring of manufacturing system for risk management, and based on the review papers from the previous researchers, the proposed and preliminary methodology suggested to be used in this study is as depicted in Fig. 1.

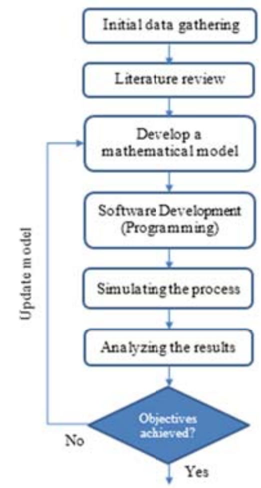


Fig. 1: The research methodology flow chart

The basis of research methodology consists of 3 major's phases:

Phase 1: Lean production modeling: As mentioned in the literature review, many of the researches used mathematical modeling for simulating the system. Therefore, mathematical modeling can be used as a trustful way for this research.

Phase 2: Project Management concepts: For using project management concepts the eight main areas of A Guide to the Project Management Body of Knowledge (PMBok, 2013) will be used as a complete reference for techniques in project management.

Phase 3: Risk management: One of the eight main areas of A Guide to the Project Management Body of Knowledge (PMBok, 2013), and is included in most training programs for project managers. Within the current view of project management as a life cycle process, project risk management (PRM) is also seen as a process that accompanies the project from its definition through its planning, execution and control phases up to its completion and closure.

In consistent to the prior research, and to define the important factors in determining the answer to the objectives of the research, a research framework is proposed (Fig. 2). It shows the core framework which consists of 3 major activities; risk identifying, risk analyzing and risk prioritizing. While conducting those three items, feedback from user or stakeholders is then necessary. In addition, external risk factors and the selection criterion also must be considered. Risk identification techniques, risk analysis, risk prioritization and risk factors/criteria are presented and discussed in the next section.

3.1. Risk factors/criteria

Risk can be categorized in different ways, depends on the nature of risk such as physical, design, financial, contractual/legal, construction, political, management, etc. (Wiguna and Scott, 2005; Ghosh and Jintanapakanont, 2004; Tah et al., 1993) classified project risks into external and internal risks.

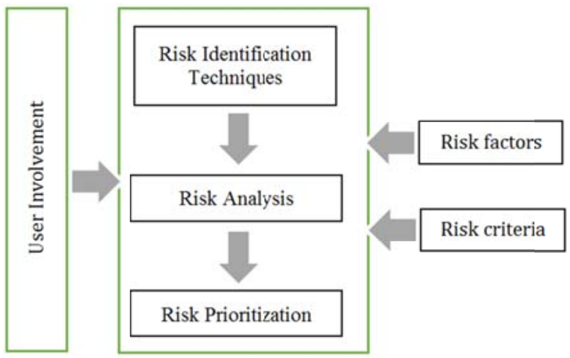


Fig. 2: Research conceptual framework

External risks are those that are prevalent in the external environment of projects, such as those due to inflation, currency technology change, natural disasters, politics, etc., and they are relatively non-controllable and so there is the need to continually scan and forecast these risks and in the context of a company's strategy. On the other hand, internal risks cover uncertainties due to labour, plant, material and subcontractor, resources and the site conditions, and they are relatively more controllable and vary between projects. In addition, (Renuka et al., 2014) classified risk into two types; non-engineering risk and engineering risk. Engineering risk is predictable factors. Meanwhile, non-engineering risk is non-predictable factors. The predictable factors should be managed at the earlier stage of the project and whereas the non-predictable factors involved uncertainties, which also should be estimated to ensure the successes of the projects.

3.2. Risk identification

A considerable number of studies have been conducted for identification of factors causing project delays and cost overruns. Intensive literature reviews, questionnaires/checklists and surveys with practitioners and experts usually were carried out as the methodologies. Other researchers used case studies, Delphi, risk register evaluation, fuzzy logic in project simulation, to identify practices and/or techniques used in risk management. Other identifying techniques reported in the past literatures are project documentation data (Sharif and Rozan, 2010), interviewing/brainstorming, reporting, decomposition, assumption analysis, and critical path analysis, and utilization of risk taxonomies, and plan data (Westfall, 2001). The questionnaire technique contains directed and specific questions in contrast to interviewing or brainstorming technique, which is the list of open-ended questions proposed to help brainstorm project users to identify any risks that may occur in the project. In the questionnaire surveys, the Likert scale and ranking in order on a single issue were the most common assessment approaches used. Formal risk management guidance documents, including APM (1997) and PMI (2000) propose the risk probability and impact approach to assess the degree of project risk. (Raz and Michael, 2001) reported this approach as the most frequently used for assessing project risk, with most of the practitioners surveyed generally used their subjective judgements or experiences to estimate the probability of risk occurrence and their impact, in a range from very low to very high. Various researchers have adapted the questionnaire risk identification technique which can measure risk manually and analytically. In addition, (Basri et al., 2015) suggested that combining different identification techniques will provide more robustness compared to adapting only one technique for the risk identification process. Also, as identification of project risks is regarded a dynamic process, it cannot be executed by either an individual such as a project manager or a specific department. Thus, combining all project users including project managers, project teams, and stakeholders in the process of risk identification is vital in deciphering the project risks.

In the early project phases, it is more important to identify all the potential types and sources of risk than to actually identify individual risk events. The appropriate risk identification method depends on the application area (i.e. nature of activities and the hazard groups), the nature of the project, the project phase, resources available, regulatory requirements and client requirements as to objectives, desired outcome and the required level of detail. Examples of tools and techniques that may further assist the identification of risks are; Examples of possible risk sources, Checklist of possible business risks and fraud risks, Typical risks in stages of the procurement process, Scenario planning as a risk assessment tool, Process mapping, etc. (Berg, 2010). The identification of the sources of the risk is the most critical stage in the risk assessment process because the sources are needed to be managed for pro-active risk management. A systematic method for identifying technical risks is the elaboration of a risk register where different types of risks and damage classes are documented.

3.3. Risk analysis

After the risks are identified, the following step is the analysis of the risks. Risk analysis can be a lengthy process, usually resulting in a formal report known as a risk assessment. A good risk management stresses a risk analysis process that is scientifically sound and supported by quantitative techniques (Hubbard, 2008). Moreover, the aim of risk analysis is to provide an insight into the risk profile of a project and to use these insights to drive the risk response process (PMI, 2008). Hence, understanding the characteristic of the risks is inevitable in obtaining a scientifically sound analysis. The characteristics or parameters that are used for analyzing the risks commonly are Probability of event and Risk Impact, Risk Uniformity, Risk Time Frame, Risk Correlation and Risk History (Basri et al., 2015).

The risk factors identified could be grouped into major risk categories (Gary and Larson, 2008). For the identification of what are perceived to be the most significant risk factors in each major risk category, a preliminary questionnaire could be designed that questioned participants to rank the risks in order of their importance. The intention is to produce a more manageable list of critical risk factors using a weighting approach. The participants who responded ranked each of the risk factors in each major risk category and this then will allow the top risk factors in each major risk category to be determined. In this event, some risk factors will be identified in each major category. While assessing the project risk at the initial stage of the project, practitioners may not have sufficient data at that time. So it is essential to develop a simple regression model for each project specific task.

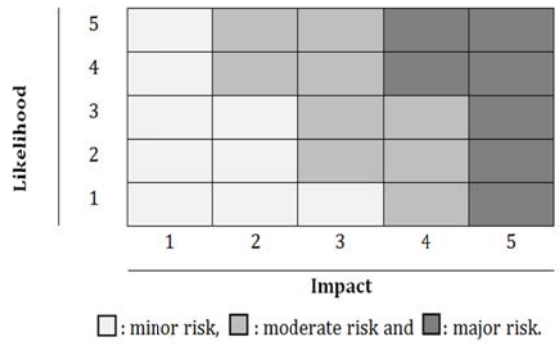
In this paper, risk impact types will be specified into five levels to evaluate the probability of occurrence of project risks i.e., "Not at all", "Not Much", "May Be", "Yes Certainly" and "Yes Very Much". In addition, for more precisely assessment, the numerical weight also will be used for the assessment (1, 2, 3, 4, and 5). In this study, based on the aforementioned risk characteristics, the example of a summary of the possibility of each characteristic are outlined in Table 1.

Table1: The possibility of each characteristic (Gary and Larson, 2008)

Relative or Numerical Scale					
Project Objective	1 Very Low	2 Low	3 Moderate	4 High	5 Very High
Cost	Insignificant cost increase	< 10% cost increase	10–20% cost increase	20–40% cost increase	> 40% cost increase
Time	Insignificant time increase	< 5% time increase	5–10% time increase	10–20% time increase	> 20% time increase
Scope	Scope decrease barely noticeable	Minor areas of scope affected	Major areas of scope affected	Scope reduction unacceptable to sponsor	Project end item is effectively useless
Quality	Quality degradation barely noticeable	Only very demanding applications are affected	Quality reduction requires sponsor approval	Quality reduction unacceptable to sponsor	Project end item is effectively useless

The major objectives of each risk impact are derived from the risk assessment method as shown in Table 2. Based on these impact levels, the risk characteristics or parameters that are mentioned before will be analyzed in this research as to their applicability for Scheduling and Line Balance Monitoring of Manufacturing System.

Table2: The risk impact matrix (Gary and Larson, 2008)



3.4. Risk prioritization

Risk prioritization helps to identify the risk that matters to major stakeholders and to support decision-making in risk responses for the effective risk management. It also identifies uncertainties where further investigation would be relevant to understand the extent of the uncertainty. Risk prioritization techniques varies, some are high level techniques designed to deal with risks identified primarily from a top-down perspective (often of greatest value in the earliest phases of a project), and some are simplest techniques that are appropriate given the data available. Three groups of techniques are available;

1) Techniques that focus exclusively on the risk attributes of probability and impacts – by comparing attributes combination on a risk-by-risk basis, the techniques are designed to prioritize risks within the context of a list of risk or a risk register,

2) Techniques that adopt a risk-by-risk prioritization approach- use various methods to broaden the perspective of risk prioritization with a fuller range of risk attributes,

3) Techniques that can prioritize risks quantitatively within a model that represents the combined effects of risks to levels up to and including the analysis of overall project risk (Hopkinson et al, 2008).

For example, Project risks can be characterized as follows: Technical Risk, Scope Risk, Schedule Risk, Cost Risk, Human Resources Risk, Regulatory Risk, Safety and Security Risk, and Political Risk. Project risk is usually captured in a risk register that summarizes both risks and opportunities for the project. The risk register is updated throughout the project as new risks are identified and other risks are closed out. It captures basic risks information needed to prioritize project risk, and also useful for assigning individual project team members who will be responsible for developing discrete risk response plans, monitoring them, and reporting on the risk status. Risks must be managed throughout the project life cycle. Many projects get bogged down by delays and poorly planned design, and engineering processes. Henceforth, attempts are made to accelerate the procurement and production phases which are not always possible. Moreover, any effort to accelerate the schedule beyond its optimal activity durations will result in additional labour, equipment, material and supplier costs.

4. Summary and conclusion

In this paper, a review from the previous works were conducted on risk management particularly risks in decision making method for scheduling and line balance monitoring in manufacturing system. A suggestion of conceptual model for risk management is discussed. The core framework consists of 3 major activities; risk identifying, risk analyzing and risk prioritizing is suggested and while conducting those three items, feedback from user or stakeholders is then necessary. In addition, external risk factors and the selection criterion also must be considered. Risk identification techniques, risk analysis and risk prioritization are also presented. Furthermore, the identification of the effective production factors is also discussed. Hence, this review indicated that the appropriate selection of systems will help in the success of the manufacturing project.

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