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Revealing engineering management contribution (EMC) to outputs of manufacturing SMEs: a literature review

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ABSTRACT

Background: This paper aims to present the contribution of engineering management to the outputs of Small and Medium Size Manufacturing Enterprises (SMEs). However, this study has built an empirical model with the elements of engineering management and outputs of manufacturing SMEs having huge implications in manufacturing sector. **Objectives:** The novelty of this paper will be that the contributions of engineering management to outputs of manufacturing SMEs have not been done so far and therefore, this study is a fundamental research. **Results:** This study has reviewed 82 journal papers in the relevant field which reveals that the contributions of engineering management to outputs is significant ($p < 0.05$). It also reveals that labour and capital are the major contributing elements of inputs to manufacturing process while engineering management appears a driving force. **Conclusion:** Findings of this study would be useful for productions and operations managers for improving productivity and performance of manufacturing SMEs.

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INTRODUCTION

Background of Study:

This study presents a review on small and medium manufacturing enterprise SMEs. It has identified the contributions of engineering management factors to the outputs of Small and Medium Size Manufacturing Enterprises (SMEs). It targets to evaluate inputs related to elements of engineering management. Further, the conceptual framework of this study is based on production and engineering management concept of manufacturing that is influenced by productions and engineering management literatures. The ultimate goal of this study is to contribute to measure the elements of engineering management to improve productivity and performance of manufacturing SMEs (Kotnour and Farr, 2005). However, previous studies have not emphasised the evaluation of SMEs in the perspective of engineering management to outputs of Small and Medium Size Manufacturing Enterprises (SMEs). Thus, a gap exists in this sector. Therefore, this review study is designed to meet this gap and to address the SMEs' factors issue which previously could not get the right attention. This paper is based on five main sections: (1) Concept of Engineering Management in Manufacturing SMEs (2) (3) findings of literature review (4) Scenario Analysis of Findings and (5) Conclusion.

Concept of Engineering Management in Manufacturing SMEs:

Engineering management is considered as a source for contemporary engineering organizations to gain improved production process in Small and Medium sized Manufacturing Enterprises (SMEs) (Shaw, 2002; Coates, 2004). Approaches to engineering management focus either on the efficient use of engineering resources or on the effective response to business environment changes such as the project approach (Zhang *et al.*, 2006; Lannes, 2001). It is important to improve the efficiency of Small and Medium sized Manufacturing Enterprises (SMEs) in order to meet the need for coordinated research and development by field of engineering management (Lock, 1993). Small and Medium Sized Manufacturing Enterprises (SMEs) need competence to organize and manage work processes in efficient ways to improve efficiency and effective outputs.

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Concept of Manufacturing SMEs:

Small and Medium Sized Manufacturing Enterprises (SMEs) play a significant role in achieving the targets of economies. It plays an important role in the acquisition of artistic and technical skills, export, investigation of new external markets to enhance gross domestic product (GDP). SMEs contribute 90% in the vast majority of economies worldwide and create jobs opportunities 40-80% in addition to contributing the most to GDPs of many countries. The majority of SMEs add up to the overriding form of business organisation, accounting for more than 95% to 99% of enterprises depending on the country (OECD, 2000). In the OECD member countries, SMEs are dependable to create net careers between 60-70% of establishments (OECD, 2002). These Small and Medium sized Manufacturing Enterprises (SMEs) need low capital investment per unit to outputs. They can be located in far-flung areas, use local natural resources and typical skills and meet local needs of limited market for consumer goods and services. SMEs also contribute in increasing and diversifying income using efficient use of capital. In literature, different taxonomies are available to order the wide variety of discrete part manufacture processes (Cubico and Favretto, 2008).

Concept of Production and Outputs:

Production transforms inputs of processes to finish product outputs. It is the process by which products and services are produced. Production includes step by step creation of one form of materials into another. It involves conversion to inputs that include: know-how, material, labour, equipment, capital methods, energy, and management to output products and costs by complex processes of transformation (Monden, 2011). In this way of operating resources and production facilities, it is also possible to include methods and regulations for process routines in the components of a production (Friedli, 2006). To sum up, Production is characterized through manufacturing of products that are produced and stocked in warehouses for sales (Corsten, 2007; Wulfsberg *et al.*, 2010).

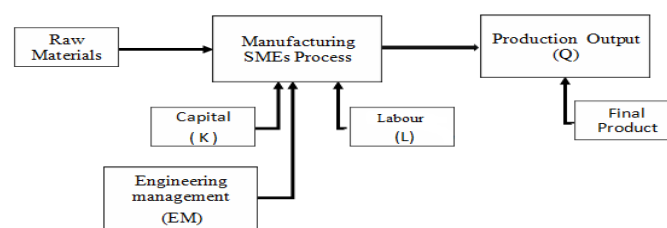
Method of Study:

The method of this study is based on methodical literature review that relates to engineering management contribution to production outputs in manufacturing SMEs. The 30 percent of articles published before 2005 and other 70 percent from 2005 to 2014 were reviewed. Eighty articles including from journals and books are reviewed. The researchers narrowed down the search to the articles, published in peer reviewed journals or conferences. In addition, no delineation is imposed on the outlets' field in order to enable potential research findings from different fields. The search processing based on Google Scholar and library is applied to provide a comprehensive and systematic methodology. The investigation option adopted was limited only to articles' titles and related keywords that include: manufacturing SMEs, engineering management, production, sustainability and their combinations.

Findings of Literature Review:

Manufacturing SMEs usually deal with small size production facility with labour, machinery and management. The raw materials being used are very specific to the objectives and nature of final products. However, the input output model of manufacturing SMEs is presented in the conceptual model below.

Conceptual Input-Output Model:



The model shown above can be represented by the following equation:

$$Q = A \cdot K^\alpha \cdot L^\beta \cdot EM^\lambda + \epsilon \quad (1)$$

The linear log form of the model is:

$$\text{Log } Q = \text{Log } A + \alpha \text{Log } K + \beta \text{Log } L + \lambda \text{Log } EM + \text{Log } \epsilon \quad (2)$$

Where, Q is output measured in terms of product value K is capital of SMEs involve in production process, L is labour needed for production, A is transformation factor from inputs to outputs, EM is engineering management needs to manage production. And α , β and λ are the elasticity of output from capital, labour and engineering management to be known as contribution. The estimated error is 'e'.

Contribution of Labour to Manufacturing SMEs:

Literature shows that labour made a significant contribution to production process. It is because major percentage of manufacturing SMEs is manually operated (Charoenrat *et al.*, 2013). In this connection, Mahmood (2008) investigated that the most common measure of contribution of labour to outputs is productivity. Output per labour is also being used to measure the contribution of labour. However, Mahmood (2008) again asserted that the contribution of labour to SMEs output is about 56 percent. Similarly, Kiani and Ahmed (2013) found that one percent increase of the capital for manufacturing process could contribute to increase labour productivity by 0.51 percent. Charoenrat *et al.*, (2013) used Cobb-Douglas production function in Thai manufacturing SMEs to estimate contribution of labour to production and found that it is highly significant at 1 percent level. Hsu and Chen (2000) evaluated labour productivity by comparing between large firms and SMEs in Taiwan; they also found that labour contribution to productivity with respect to capital per labour in large firms was about 88.21 percent, and it was 30.10 percent in SMEs. Pham and Hara (2011) measured labour productivity in industry sector; it had been increasing at rate about 0.05 percent per year from 1990 to 2007. Foresti *et al.* (2005) used a simulation labour productivity and they found about 21 percent in Italian small size of firms. Njoroge (2013) found that in small manufacturing enterprise the productivity of labour was improved from 6.54 in the year 2008-2009 to 8.25 in the years 2011- 2012. The labour productivity in Malaysian manufacturing sector to evaluate the domestic labour found 1.93 percent (Noor *et al.*, 2011). Subrahmanya (2010) found in Bangalore that positive correlation between labour productivity and capital contributed to production output during years 2001-2002 by 0.28 percent and increase by 0.60 percent in 2005-2006.

Contribution of Capital to Manufacturing SMEs:

Capital is one of the most pressing evaluation needs to output of manufacturing SMEs operators since finance is not being provided. Manufacturing SMEs are often using small capital inputs due to size, production, and lack of access to capital and inputs. It is especially interesting that the use of raw materials and machines can contribute to output (Wolf, 2001; Admassie and Matambalya, 2002). According to Taymaz (2005) productivity increases in small firms by contributing raw materials to output by 0.5 percent every year whereas its contribution reaches almost one percent to input of SMEs. Saleh and Ndubisi, (2006) found that rubber and plastic production outputs are increased by 13.1 percent. Similarly, Huang (2003) indicated that capital productivity is higher in urban than rural SMEs for over half of the major industries. Findings in his study of petroleum, fuel and recycling industry, shows that capital productivity is highly affected by the low capital inputs and results are relatively insignificant. St-Pierre and Raymond (2004) benchmarked the capital productivity in SMEs by using advanced manufacturing systems (AMS) to improve productivity. They found labour productivity increased 14 percent more than capital productivity which remains 3 percent. Due to raw materials and efficient utilisation of machinery and equipment through better maintenance and preventive methods is contribution to capital productivity. These elements worked for the capital productivity growth of manufacturing SMEs in order to deliver products that meet global market standards and provided customer satisfaction.

Contribution of Engineering Management to Manufacturing SMEs:

Engineering management (EM) contributes to managing and operating process of the manufacturing SMEs, raising the efficiency and effective production of output. Shaw (2002) proposed the activities of engineering management in order to support organization that include effective planning, monitoring, and measuring performance for improving production process. Further, Engineering management contributes to integrate management levels with technical expertise to coordinate efforts in different technical fields that include product design, development, and manufacturing (Bobcock, 2002; Morse, 2002). Moreover, the contribution of engineering management to production output based on functions that deal with the technological problem-solving tools, administrative work, policy and decision-making and managerial economics in order to oversee complex enterprises from conception to completion (Shaw, 2002). The contributions of elements are listed below:

Research and Development:

Research and development activities are the source of contribution of production output in manufacturing SMEs. R&D activities support the efforts to innovate or improve the existing production output in manufacturing SMEs (Ezell, and Atkinson, 2011). It also permits organisation to analyse several alternatives for internal R&D activities including the use of technological consultants, and recruitment of people (Santamaría, and Barge-Gil, 2009; Baumol, 2002; Jones, 2002; Ortega-Argilés, 2009). Tassej (2009) indicated that R&D has contributed by increasing 38 percent in output and 8.6 percent significant change in R&D intensity. However, R&D capability is positively correlated with manufacturing SMEs' performance in order to improve the manufacturing SMEs process by increasing productivity (Islam and Shazali, 2011; Sher and Yang, 2005).

Labour Skills:

Labour skills are the most important factors for contribution and productivity for better performance in production output in manufacturing SMEs (Mahmood, 2008). It is also positively correlated with improvements production to output, and technical efficiency. For example, Huang (2003) found in Thailand's SMEs that skilled labour as one of the significant factors contributing to production output. Skilled labour also in Tanzanian SMEs was positively related to technical efficiency (Admassie and Matambalya, 2002). Zahid and Mokhtar (2007) and Saleh and Ndubisi (2008) also found skilled labour as a positive effect on the technical efficiency and one of the internal factor was contribution output for challenges in Malaysian manufacturing SMEs. Charoenrat (2013) found skilled labour as one of the most specific factor that significantly affects the technical inefficiency of production output in SMEs.

Technology Level of Machinery and Process:

The technology level of machinery contributes to production output in manufacturing SMEs. Manufacturing is precision with more assured handling or control, more reliable, and efficient measurement production output (Qin *et al.*, 2010). If the level technology of machinery in manufacturing SMEs is low, the production outputs are inefficient which leads to conflicting quality product, low productivity level, and lack of competitiveness. This is shown in high materials wastage, high reworks rates, and inability to meet deadlines (Aldaba, 2010).

Machinery Maintenance:

Maintenance activities are essential in modern manufacturing practices to reduce the machinery breakdown (Lofsten, 1999). Through the optimizing maintenance parameters including labour skills, spare parts, and inventory machine performance can improve the efficiency of production output (Simões *et al.*, 2011). Therefore, in manufacturing SMEs, to make sure for required performance, maintenance managers need a good track of performance on maintenance process. The managers of maintenance are being called in, to lead to straight, and integrate the maintenance efforts to meet organizational goals of plans efficiently and effectively (Al-Najjar, 2007; Muchiri *et al.*, 2011).

Inventory Control:

Inventory involves more than 60% of the industry capital. Inventory optimization is important to ensure that production facility has optimum amount of stock, carrying cost, material purchases, storage, and stock. Out cost can be expensive and have impact on production output (Rajeev, 2013; Ferenčíková, 2014). In addition, manufacturing SMEs also face frequent raw material shortages in order to pay more due to variation in raw material price, inability to obtain credit terms, inadequate inventory management, and control of stock in raw materials (Kraipornsak, 2002; Rajeev, 2010).

Quality Control Activities:

Quality control activities are effective in bringing about cost reduction and improved quality. Methods and systems are used as parts of self-inspection tools and techniques (Dale, 2003). In manufacturing and engineering, quality control or quality engineering is a set of measures taken to ensure that defective products may not be created, in order to meet performance requirements quality that include statistical process control (SPC) is as an important step to production output. SPC can be used as a quality control tool and it can contribute to increase the total volume of production output (Sultana, and Azeem, 2009). According to Grewal and Gill (2007) manufacturing SMEs in the US, about 70 to 80 percent for the strategy, requires application of quality (Vijay, 2013).

Cost for Engineering Management:

Cost engineering management helps firms in decision making, cost, and budgeting with respect to product development. It is a method used for forecasting, and estimating the cost of a manufacturing activity or production output (Matipa *et al.*, 2008; Haapala, 2013; Matipa, 2008).

Engineering Information System:

An Engineering Information System (EIS) is a collection of facilities and services that provide support for the design, testing, and manufacture, maintenance of engineering artefacts, for the managerial and administrative concerns that accompany these tasks. Engineers and their managers engaged in hardware, software, mechanical, and architectural design (Wiederhold *et al.*, 1989). Furthermore, manger must be familiar with the obtainable process measurement as well as ways of presenting information. It will be gathered in an organized way so that labourers involved in the process could understand it. Organization needs to ensure that it

is receiving the necessary online information for making the right decision and developing production output (Lee, 2003; Chen and Liang, 2000).

Utilities Management:

Utilities used in manufacturing are often shared between the production fields of a position and formulations of an optimization of utilities used (Lindholm *et al.*, 2013). It is required to manage and determine the optimal source of utilities to each area at the site of the production process. The engineer manager has a role to play in optimizing the use of utilities for achieving production target (Kemppainen and Shonnard, 2005). The relationship of utilities and engineering management is to evaluate how much of the utilities such as IT, energy, water, are available at each time instant. This could be represented in percent of how much that is available and contribution to production output at normal operation of the site (Lindholm and Giselsson, 2013).

Process and Product Design:

Process and product design is a fundamental part of the wider concept of engineering that brings a set of skills, knowledge, and understanding to the origination and production. Moreover, product design is small change in production output or assembly that typically results in lower cost and higher quality. It is a product strategy that adds competitive advantage in the global market. Process and product design is well recognized as a part of engineering management activities, as increasing requirements of management methods are being incorporated into process and product design (Baxter *et al.*, 2008; Braha and Maimon, 1997; Petroski, 1996).

Process Planning, Implementation and Monitoring:

Process Planning is one of the most important activities to improve production output. The collaboration between engineering and management implementation requires the processes planning in manufacturing product (Ming *et al.*, 2008; Denkena *et al.*, 2007). Process planning in manufacturing firms makes clear steps of directions about how the product is to be fabricated in a manufacturing feature. In the advanced manufacturing, it will monitor how the process will be designed and laid out in research for the new product (Qin *et al.*, 2006).

Industrial pollution control department:

Pollution control and management is selected through the combined action of nature and evolution activities determined by the scientific communities, stakeholders, and manufacturers for the best alternatives whose application ought to guarantee pollution management and impact reduction (Woolman and Veshagh, 2006). In UK, manufacturing SMEs engaged in industrial activities together that contributes approximately 60% of commercial waste and 80% of pollution incidents (NetRegs, 2005). There are different options for reducing the impact of pollutants; however, the multidisciplinary engineering efforts for environmental pollution management have proved to be the most effective and sustainable (Haggar, 2010).

Health, Safety and Risk Management:

In manufacturing, firms must control, measure, and evaluate its safety and health performance in order to maintain its sustainable growth. Performance could be measured in reference to agreed standard, such as OSHA standard for sound level 45-60 db as comfortable sound level, 15 mg fume per cum of air in factory, oxygen 17-23gm/cum of air in factor (OSHA, 2005; El Haggar, 2010). In engineering, work requires the assessment and management of risk. Hazards need to be identified and consequences and probabilities analyzed. Management decisions must be made as to whether the risk is acceptable in which case the activity would continue with appropriate risk reduction and monitoring measures or whether the risk is unacceptable and the activity must not be undertaken (Amyotte and Eng, 2006; Ross and Athanassoulis, 2010; Rosen and Meston, 2011).

Bill of materials:

Manufacturing bill of materials (MBOM) is critical to the successful management of manufacturing resources. Through a deep and accurate MBOM, the new product introduction process is smoother, and the ramp to full production output is more controlled. By knowledge about all components and steps in the process manufacturing, the operations team could make appropriate trade-offs throughout the life of a product (Hall *et al.*, 2006; Orlicky *et al.*, 2003; Raharno and Martawirya, 2012).

Performance Evaluation:

Performance evaluation can be represented via single dimensional units such as work time, meters, nanoseconds, money, number of reports, the number of errors, and length of time to design hardware, and production output. Accordingly period of time gives to evaluation process an engineering change request (Starkel, 2000; Heckl and Moormann, 2010).

Scenario Analysis of Findings:

This paper has reviewed 80 journal papers published on different potential inputs and outputs of manufacturing SMEs including engineering management. Major areas considered in the framework for this study are labour, capital, and engineering management that contribute to output of manufacturing SMEs. The references matching to each particular area and major findings have been summarized in Table 1.

Attributes of engineering management on Manufacturing SMEs	Reference
Engineering Management in Manufacturing SMEs	Babcock and Morse (2002); Kotnour and Farr (2005); Shaw (2002); Coates (2004); Zhang <i>et al.</i> , (2006) Lannes (2001); Lock (1993).
Concept of Manufacturing SMEs	OECD (2002); OECD (2000); Cubico and Favretto (2008).
Concept of Production and Outputs	Monden (2011); Friedli (2006); Corsten (2007); Wulfsberg <i>et al.</i> , (2010).
Contribution of Labour to Manufacturing SMEs	Charoenrat <i>et al.</i> , (2013); Mahmood (2008); Kiani and Ahmed (2013); Hsu and Chen (2000); Pham and Hara (2011); Manning (2010); Foresti <i>et al.</i> , (2005); Njoroge (2013); Noor <i>et al.</i> , (2011); Subrahmanya (2010).
Contribution of Capital to manufacturing SMEs	Wolf (2001); Admassie and Matambalya (2002); Taymaz (2005); Saleh and Ndubisi (2006); Huang (2003); St-Pierre and Raymond (2004).
Contribution of Engineering Management to Manufacturing SMEs	Shaw (2002); Bobcock and Morse (2002).
Elements of engineering management	Reference
Research and development (R&D)	Ezell and Atkinson (2011); Santamaría and Barge-Gil (2009); Baumol (2002); Jones (2002); Ortega-Argilés (2009); Tassej (2009); Sher and Yang (2005); Islam and Shazali (2011).
Labour skills	Mahmood (2008); Huang (2003); Admassie and Matambalya (2002); Zahid and Mokhtar (2007); Saleh and Ndubisi (2008); Charoenrat <i>et al.</i> (2013).
Technology level of machinery and process	Qin <i>et al.</i> , (2010); Aldaba (2010).
Machinery maintenance	Lofsten (1999); Cooke (2003); Simões <i>et al.</i> , (2011); Al-Najjar (2007); Muchiri <i>et al.</i> , (2011).
Inventory Control	Rajeev (2013); Ferencikova (2014); Kraipornsak (2002); Rajeev (2010).
Quality Control Activities	Dale (2013); Sultana and Azeem (2009); Grewal and Gill (2007); Vijay (2013).
Cost for Engineering Management	Haapala (2013); Matipa <i>et al.</i> , (2008); Matipa (2008).
Engineering Information System	Wiederhold <i>et al.</i> , (1989); Markowski <i>et al.</i> , (2008); Chen and Liang (2000).
Utilities Management	Lindholm <i>et al.</i> , (2013); Kemppainen and Shonnard (2005); Lindholm and Giselsson (2013).
Process and Product Design	Baxter <i>et al.</i> , (2008); Braha and Maimon (1997); Petroski (1996).
Process Planning, Implementation and Monitoring	Ming <i>et al.</i> , (2008); Denkena <i>et al.</i> , (2007); Qinel <i>et al.</i> , (2006).
Industrial pollution control department	Woolman and Veshagh (2006); NetRegs (2005); Haggar (2010).
Health, Safety and Risk Management	OSHA (2005); Haggar (2010); Amyotte and Eng (2006); Ross and Athanassoulis (2010); Rosen and Meston (2011).
Bill of materials	Hall <i>et al.</i> , (2006); Orlicky <i>et al.</i> , (2003); Raharno and Martawirya (2012).
Performance Evaluation	Starkel (2000); Heckl and Moormann (2010).

Most of the above mentioned works are very specific and the following gaps are identified:

1. There has been a lack of empirical research on productivity evaluation related to engineering management.
2. Moreover, these studies have not tried to analyze and optimize the inputs-outputs with regards to production output and engineering management.
3. Most of the performance measurement model of SMEs does not have predictive power for future production performance with respect to engineering management.

In that regards, gaps are observed between existing performance measurement models and engineering management practices.

Conclusion:

This paper has provided a comprehensive literature review covering the topics of productivity evaluation in manufacturing SMEs. The area of engineering management in manufacturing SMEs is relatively new. In this regards, there are little practical solutions and experiences in this area, apart from approaches and tools used by large companies, which may not be flexible or applicable to the engineering sub-sector of SMEs. This finding of this study reveals the factors that have an impact on the production output of manufacturing SMEs products development are still ambiguous; hence, in-depth study in this area is suggested. This is because effective engineering management helps manufacturing SMEs to overcome the barriers of growth. To sum up, the researchers have provided observations and future research suggestions that would enrich newer knowledge in this domain.

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