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Understanding the key performance parameters of green lean performance in manufacturing industries

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ABSTRACT

The estimation and monitoring of key performance parameters of Green Lean in the manufacturing sector have recently attracted considerable attention. Performance measurement is an essential practice for measuring manufacturing industries' competitiveness. In this era of global competitiveness and customer expectations, manufacturing firms face various challenges. To solve these challenges, researchers in the academic and manufacturing world have observed a keen interest in green lean manufacturing practices. The concept of lean manufacturing was developed to maximize the use of resources and minimize waste at all manufacturing activities. On the other hand, Green concept in manufacturing sector relates to the environmental and social concerns. The manufacturing firms strive to find and improve output performance by using key performance parameters to find the possibilities in Green-lean concepts in the manufacturing sector. The purpose of this study is to identify and examine the various key performance parameters (KPPs) of Green-Lean practices in manufacturing industries. Future research will focus on ranking these KPPs of green lean manufacturing using appropriate Multi-Criteria Decision Analysis (MCDA) technique.

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1. Introduction

Several industries have accepted lean and green concepts to boost their overall performance and retain their competitive position in the market [1]. Green production systems which focus on minimizing the environmental impact of manufacturing processes and products are becoming increasingly important for our sustainable future. Green production systems are slow to gain attention as manufacturers concentrate on adopting Lean manufacturing systems, which are widely considered to be the world's most competitive manufacturing systems. In recent times, experts and the U.S. Environmental Protection Agency (EPA) have sought to 'make a link' between Lean and Green production systems, anticipating that Lean's rapid growth may help pave the way for the deployment of Green production systems [2]. The idea of "Lean" which originated out of the Toyota Production System after WWII uses various techniques, such as Just-in-time (JIT), 5S, continuous improvements, shortened lead times and inventories, improved

methods and waste disposal to increase customer satisfaction, quality, performance, flexibility and overall cost effectiveness [3]. On the other hand "green management" is a philosophy that focuses on balancing the environmental and social dimensions of organizations [4].

Manufacturing industries seek to monitor and strengthen manufacturing performance by using key performance parameters (KPPs). KPPs reflect the performance level that a system achieves by observable attributes, like the amount of material, energy or time spent in a process. KPPs are very crucial to understanding and enhancing manufacturing efficiency, from both the Green-lean manufacturing perspective of waste disposal and the business viewpoint of achieving strategic objectives [5]. Manufacturing industries' survival is strongly linked to long-term competitiveness; in other words, industries should make sure that manufacturing systems are perceived by excellent performance in terms of reliability, sustainability, flexibility and productivity [6].

This study aims to review the incorporation of Green-Lean concepts into manufacturing efficiency through the integration of manufacturing performance indicators. Manufacturing performance is the key to growth of many manufacturing firms. Better performance of manufacturing operations contributes to profitability

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ity. So, manufacturing industries must periodically review their performance in order to remain competitive. It is therefore important to identify and ensure better performance in global competition for manufacturing firms [7]. One difficulty in choosing metrics for green-lean performance is that it is not an intuitive process. In comparison to operational performance indicators, such as unit cost or product price, green indicators are not directly related to the function of the manufacturing component produced [8]. The purpose of the manufacturing performance indicators is to reflect the current position of manufacturing, monitor efficiency and performance, encourage the improvement plan and assess the efficiency of manufacturing decisions.

2. Method

The aim of this paper is to identify the key performance Parameters of manufacturing. A literature review was carried out to identify manufacturing performance parameters generally used for estimating manufacturing performance in the framework of green lean practices. The following key research databases are part of this review: Emerald, Scencedirect, IEEE, Springer and Proquest. The search for the database created hundreds of articles. Each research article has been reviewed to ensure that its contents are important for our research drives. The review and choice of research articles was based on the criterion that are only the major contributors on the key performance indicators relating to green lean principles in manufacturing industries.

3. Literature review

A literature review was performed to identify key performance parameters used to measure manufacturing performance of using Green Lean principles. Some of the identified key performance parameters to measure the effect of Green Lean is presented in Table 1.

Most of the words in the titles of cited research papers are represented in Fig. 1 in the form of word cloud. Next section of this document is for the discussion of the various KPP's in evaluating the impact of Green lean practices in manufacturing operations.

Table 1 Key performance parameters with literature support.

Literature Support	Key Performance Parameters of Green lean													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Amrina and Yusof [7]	✓	✓	✓	✓	✓			✓	✓	✓		✓		✓
Inman and Green [11]		✓		✓			✓	✓					✓	
Abreu, Alves [12]	✓	✓					✓	✓	✓					
Azevedo, Carvalho [13]	✓						✓	✓						
Aguado, Alvarez [14]	✓	✓												
Ante, Facchini [6]	✓	✓				✓								
Dieste, Panizzolo [15]							✓	✓		✓		✓	✓	✓
Sajan, Shalij [16]	✓						✓	✓	✓	✓				
Longoni and Cagliano [17]	✓	✓	✓				✓	✓	✓	✓				
Piercy and Rich [18]	✓	✓	✓				✓	✓	✓	✓		✓	✓	✓
Henaio, Sarache [19]	✓	✓	✓	✓	✓	✓		✓	✓	✓				
Helleno, de Moraes [20]							✓	✓	✓	✓				
Carvalho, Duarte [21]							✓	✓	✓	✓				
Sawhney, Teparakul [22]							✓	✓	✓	✓				✓
Verrier, Rose [23]							✓	✓	✓	✓				
Hajmohammad, Vachon [24]					✓		✓	✓	✓	✓			✓	
Carvalho, Azevedo [25]	✓	✓	✓	✓			✓	✓	✓	✓				
Aminuddin, Nawawi [26]							✓	✓	✓	✓				✓

Note-1- Operating Cost, 8- Air emission2- Product Quality, 9- Energy Consumption3- Customer Satisfaction 10- Safety of employees4-Delivery Time, 11- Image in Public5-Downtime, 12- Ingesting of solid wastes6- OEE, 13- Consumption of toxic materials7-Wastage 14- Job satisfaction



Fig. 1. Word clouds of the words in literature review.

3.1. Key performance parameter (KPP)

The absence of metrics to measure the effects of Green lean is one of the many challenges that prevent organizations from adopting green lean practices [9]. Preparedness of the measurement system is important for the effective adoption of the Green Lean, as KPPs can improve just by fixing the measurement system [10]. The main key performance parameters of green lean practices in manufacturing sector often undertaken the threefold principle of sustainability comprising of environment, economic and social factors. The literature generates several KPPs for green lean performance of the manufacturing industries. From the literature, mainly quality, cost, time and flexibility indicators are included economic performance of the industries. Different emissions like air emissions, emitting of polluted water and land resources, resource utilisation and hazardous wastage are environment parameters [7].

The key performance parameters may be classified into three categories namely environment parameters, economic parameters and social parameters. This categorisation is attempted to present in Fig. 2 [7] and discussed on the following sections:

3.2. Environmental performance parameters

The primary aim of the environmental performance parameter is to determine whether manufacturing operations will progress in a socially and environmentally responsible direction. Pusporini,

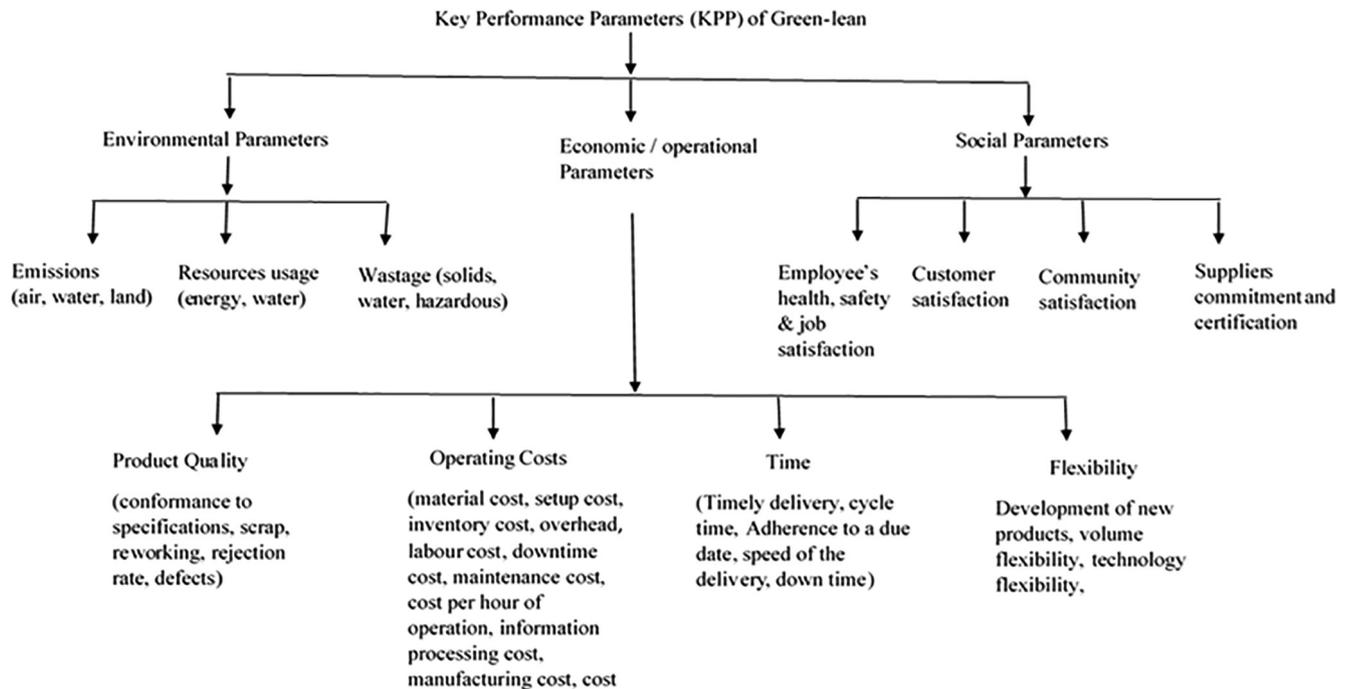


Fig. 2. Classification of KPP's of Green Lean.

Abhary [27] has found that based on WBCSD (World Business Council for Sustainable Development), there are seven metrics that have to be well-thought-out by manufacturer due to creating eco-efficiency for developing environmentally friendly products or processes. These authors further stated that these seven parameters are: decrease the material intensity of its goods and services, lessen the energy intensity of its goods and services, minimise the dispersion of any toxic materials, enhance the recyclability of its material, maximum using renewable resources, extend the durability of its products and increase the service intensity of its goods and services.

Rao, la O'Castillo [28] have also presented some metrics for calculating the manufacturing company's environmental performance. These include efficient raw material usage, packaging output percentage, returnable packaging, hazardous material proportion, share of recyclable raw materials, energy cost relationship, measure of energy use, water wastage, total waste production ratio, recycled waste share and hazardous waste ratio. Over recent times, with growing demand to reduce CO₂ emissions, increasing focus has been paid to CO₂ emission performance [29].

Waste is something that doesn't even contribute positively to the item, such as inventories, equipment installations, plant maintenance, transfer of parts and waste. So, the parameters will represent certain kinds of waste [30]. Increased pressure on the availability of freshwater, regulatory enforcement costs such as disposal of wastewater and consistency of water supply risks are putting water usage management to the manufacturing sector agenda [31]. If, after using Green Lean activities, the water consumption in manufacturing operations would be reduced, the performance will be shown accordingly.

3.3. Operational and economic parameters

Operational performance may be defined as the changes happening in the operational metrics after the implementation of Green-lean practices in the manufacturing organizations [32]. Operational performance is the extent to which quality, speed, consistency, versatility and cost of manufacturing and delivery of products and services are achieved at any point in time [33]. Those

parameters which are used for evaluating the effectiveness of internal system processes are referred to as operational performance parameters [34]. As concerned with economic performance, it is usually the most important factor for industries wishing to adopt Green lean practices, in particular for firms in developing countries [35]. Lead time, cycle time and inventory, productivity, cost of waste treatment and energy cost are economic indicators/parameters discussed by Thanki and Thakkar [36]. Again, product quality, different types of costs (such as inventory costs, labour cost, downtime cost, maintenance cost, cost per hour of operation, information processing costs, manufacturing costs) are operational performance indicators. In the subheads of product quality further parameters like rejection rate, number of defects, reworking on the manufactured products and the quantity of scarp are other operational and economic parameters to measure the impact of green lean implementation in manufacturing industries. Delivery time, cycle time and adherence to the due date of the orders of the products to be manufactured are other key operational parameters. The key performance parameters in this classification have been discussed as follows. Product quality is a distinguishing key performance parameter since it evaluates the standard of the product [37]. This parameter further affects customer satisfaction negatively. So, this KPP has been considered by various authors to measure the performance of Green Lean practices in manufacturing industries [38]. Some studies claimed that the delivery time would be reduced with a strong Green Lean framework [39]. Flexibility parameter indicates that manufacturing operations have the flexibility to cope to the various scenarios which may emerge as a result of changes in normal manufacturing processes. The changes caused to the various measures due to the greening and leaning process shall be considered [37].

3.4. Social parameters

Social parameters may be used to calculate a company's social identity based on assessment by consumers or employees or stakeholders [40]. The development of industrial social performance parameters presents researchers and practitioners with a major challenge [41]. So, it is very important to identify the social perfor-

mance parameters of industries which are interested to applying Green Lean practices in its operations. Human rights, employees satisfaction, community relations and customer satisfaction are the factors which are used by Chen and Delmas [41]. Employees health and safety, suppliers certification and their commitment toward industries are other social performance parameters [7].

If workplace safety and health of employees is neglected in manufacturing processes and the working environment, it is likely to cause death, disability or disease [42]. Implementation of Green Lean improves safety and health of the employees and customer satisfaction [43], so measurement of these parameters will measure the Green Lean performance. Customer satisfaction is the result of social responsibility of manufacturer, which is a main outcome of the Green Lean [44]. Supplier's commitment is the level to which suppliers are committed to greening and leaning [45].

4. Conclusions

Manufacturers are increasingly starting to understand the value of going Green Lean in a period of environmental responsibility. Environmental issues have risen widely and encourage manufacturing to reduce its effects on the environment by improving and refining production methods and optimizing their production processes. Although the research on Green lean issue has been widely growing for recent years, only few studies have been conducted to refine the key performance parameters of green lean aspects in manufacturing industries. The aim of this document is to identify the key performance parameters (KPP's) from existing literature for measuring the effect of green-lean practices on the performance manufacturing industries. Several key performance parameters have been identified from the existing literature. These KPPs will help manufacturers and policy makers to assess the impact of Green-lean practices. Future study may be carried out to refine these key performance measures and prioritize them by using Multi Criteria Decision Analysis Techniques such as Analytical Hierarchy Process (AHP) and structural equation modelling (SEM).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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