Outcome Based Approach to Lean and Green Manufacturing Processing

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Manufacturing industry has been contributing to global economy since the first industrial revolution. Since then, factories are built to supply manufactured goods (e.g. vehicle, toy, gloves and etc) around the globe. With the increase in manufactured goods demand, manufacturing industry has contributed to global warming directly. This increased in concern of global warming and resources depletion, the sustainability of manufacturing industry will be jeopardized. Lean and green approach is being introduced to manufacturing industry to assist the industry player to be more competitive without compromising the environment. The distinctive benefits and advantages of lean manufacturing can be observed through Toyota production system. Green manufacturing approach is adopted to reduce environmental pollution. Synergy of lean and green manufacturing will increase production value while limiting environment damage. The aim of this paper is to propose a framework to evaluate lean and green practise in the manufacturing industry. Outcome based model is used to evaluate the relationship between the expected outcome of lean and green and the five components (e.g. manpower, machine, money, material and environment). The relationship between of expected outcome from all components are shown in hierarchy network. The outcome hierarchy network will be further used to develop lean and green checklist. The checklist is used as data collection tool for data analysis purposes. Checklist also helps the industry player to have a better understanding and implementation of lean and green approach.

1. Introduction

Globalisation has unlocked the potential of cross boarder trading among countries. Manufactured industry has become the main economic contributor in South East Asia (SEA) countries. Workman (2018) discovered that China's Top 10 export items which consist about 67 % of the overall value of the global export are manufactured goods in 2017. The value of trading has also indicated an increment of 8.3 % from 2016 to 2017. The strong export signal indicates the importance of manufacturing industry in SEA economy, especially in developing countries.

Manufacturing industry players are facing challenges from political influence, economic stability, technology innovation, regulator restructuring and environmental pressure (Issa and Chang, 2010). Many players are struggling from uncontrollable factors and competition. Cost of resource and energy has been increasing proportionally with global demand. Lam et al. (2017) predicted that the world energy consumption will grow by 48 % until 2040. The effectiveness in resource and energy utilisation will reflect on the price competitiveness of the particular industry. Many manufacturing industry players are venturing into different technology to improve operation performance such as energy efficiency equipment, higher performance production equipment, renewable energy and others.

Environmental issues such as global warming and climate change have come along with the development of manufacturing industry. Many manufacturing industries have started operation for the past several decades but yet to adopt new technologies for operation and environmental improvement. Environmental issues have triggered public awareness which provoke the need for industry players to take environmental protection into operation consideration has been mandatory.

Global big manufacturing company has been venturing into lean manufacturing to stay competitive in the market. Lean manufacturing is defined as continuous elimination of waste (non-value added) from the manufacturing line. Manufacturing companies which are successful with lean manufacturing are Toyota and Ford. These big companies are able to create more values from their production by reducing production waste. Sezen and Çankaya (2013) discovered manufacturing industry started to adopt green approach in the early 1990s. Application of lean and green (L&G) approach in manufacturing industry is able to provide positive outcome to problems related to global economic and environment. Nonetheless, one of the main challenges of implementing L&G approach in manufacturing industry are the lack of proper guidance from industry expert.

Maynard (2013) mentioned that Toyota Production System (TPS) is one of the pioneer in lean manufacturing (LM). Mourtzis et al. (2016) mentioned that LM approach work by five main principles with defining value, identifying value stream, create smooth value flow, implement pull based production and strive for excellence. LM main focus is to eliminate any waste from the operation. The major wastes are categorized as over-production, waiting, transport, over-process, inventory, motion and defect (Liker, 2004).

Mittal and Sangwan (2014) found that green manufacturing (GM) helps the company to achieve better economy without damaging the environment. GM takes into consideration of lifecycle analysis (LCA) of product that will improves the environmental performance of the factory. According to Ma et al. (2012), the lifecycle analysis (LCA) of the product is relatively important at the initial design stage. LCA is a good tool to assist the manufacturer to identify potential environmental impact. The output from LCA can be feed in for Design for Environment (DfE) where green aspect can be incorporated into process design. For existing operation, energy consumption and carbon footprint emission are the main contributor to GM. Green energy and higher efficiency technology can be incorporated into the existing manufacturing premises to improve overall carbon footprint of the plant. Green technology such as co-generation, biogas, fuel-cell, photovoltaic can contribute positively to GM (Leong et al., 2018).

With the attributes from both LM and GM, synergy between lean and green (L&G) manufacturing enables the industry to achieve better performance without compromising the environment. Sawhney et al. (2007) discovered that manufacturing facilities that implement LM are able to reduce environmental pollution more effectively. LM reflects positive effect on environmental performance but do not specific deal with environmental problems. GM approach in manufacturing industry indicates positive effect on operation functions. Implementation of ISO 14001 standard which emphasis on environmental management system resulted in positive outcome in various area in the organization (Jabbour et al., 2013). L&G approach do not only complement both lean approach and green approach, it also exhibits synergy of L&G in operation performance. L&G approach has very strong commitment in waste elimination. Besides that, Leong et al. (2018) have also mentioned that L&G approach act as a strategy and solution for developing county to achieve sustainable manufacturing.

Due to lack of L&G expert in the industry, mathematic model of L&G framework to assist the manufacturing players to adopt L&G will be developed. Pampanelli et al. (2014) found that there are lack of L&G approach that merge their fundamental principles together. The development of L&G framework with expected outcome will ease implementation and understanding of L&G approach by the industry player. This will contribute to better understanding and implementation of L&G approach to achieve continuous improvement in the existing operation to improvement L&G attribute performance.

2. Methodology for development of lean and green framework

Figure 1 shows the proposed lean and green (L&G) approach sequence flow. L&G check list plays an important role to develop the evaluation framework for analysis. L&G check list will be developed based on five major component which are material, manpower, machine, money and environment. Figure 2 indicates L&G checklist structure. Data collected from L&G checklist will be feed into the evaluation framework. The evaluation framework will be used as a tool to evaluate the status of L&G in a manufacturing premise. The construction of L&G checklist is based on outcome-based model. Each component shown in Figure 2 will be broken down with expected outcome. The evaluation framework will perform evaluation based on the feedback from checklist. The outcome from evaluation model is expected to suggest area for potential optimization and debottlenecking.
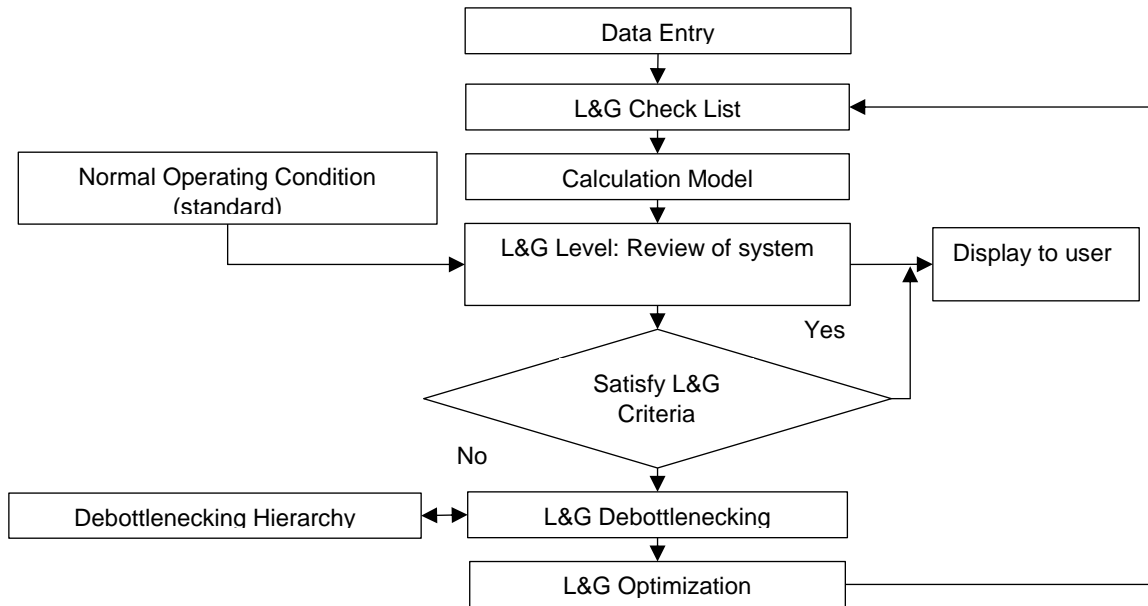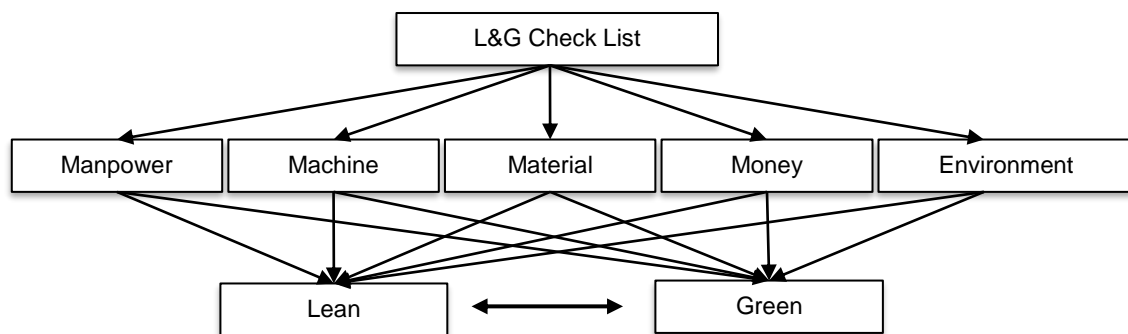
Figure 1: Structured Lean and Green framework

Figure 2: Lean and Green Check List

2.1 Outcome-based approach lean and green checklist

L&G focuses on value creation through waste elimination. Based on Figure 2, a breakdown of expected outcome for each component will contributes to L&G checklist. Table 1 to 5 indicate the expected outcome from L&G, manpower, machine, material, money and environment.

Table 1: Expected outcome of lean and green approach

No.	Description
A	Achieving operation energy consumption reduction as compare to initial baseline
B	Achieving carbon footprint reduction as compare to initial baseline
C	Achieving water consumption reduction as compare to initial baseline
D	Increasing in employee empowerment to improve productivity efficiency
E	Achieving production waste reduction as compare to initial baseline
F	Achieving reduction in unscheduled maintenance time as compare to initial baseline
G	Improving uninterrupted material flow to reduce unproductive schedule
H	Achieving improvement on employee capability and performance based on key performance index (KPI)
I	Achieving higher consistency on product quality control and management

2.2 Manpower

Talent being the most valuable asset to all industry contribute majorly to operation performance and efficiency. Employee competency and skillset are the main factors that will contribute to continuous improvement. The industry realized that retaining and training up new talent are critical to sustainable growth. The availability of capable and highly skilled workforce plays an important role in ensuring the growth of an organization (Leong et al., 2018). A balance between the organization and employee expectation. Continuous training and knowledge transfer will boost employee confident and empower them to strive for innovation. Table 2 list down the significant outcome from manpower perspective that will contribute to L&G approach.

Table 2: Expected outcome for Manpower (MP)

No.	Description
MP1	Increased in number of competence employee
MP2	Increase in employment of employee
MP3	Increase in key performance index (KPI) achievable rate among employee
MP4	Increased in medical awareness to improve health, safety and environment of employee
MP5	Maintaining a balance of workforce with different age.

2.3 Machine

Manufacturing industry has been contributing to the country economy since the first industry revolution. There are a lot of players in the market who still adopt the older technology. The advancement of manufacturing technology has been constantly improving to enable higher and effective productivity. The adoption of new innovative technology to existing operation setting will further enhance productivity and improve cost effectiveness. The need for machinery upgrade and preventive maintenance are essential to improve operation cost. Table 3 outline the important factor that can be contributed from machinery towards L&G approach.

Table 3: Expected outcome for Machine (MC)

No.	Description
MC1	Achieving higher production efficiency as compare to initial baseline
MC2	Achieving higher non-value-added by-product reduction rate
MC3	Achieving higher reduction rate on downtime for operation maintenance / product switching
MC4	Achieving higher energy consumption reduction rate in operation
MC5	Improving production quality and capacity

2.4 Material

Besides relying on machinery to improve operation performance, production materials also contributes significantly in improving productivity. Raw material and product are essential the most important element in manufacturing industry. Material that is being used in production is directly reflect on the performance of the production facility. Table 4 indicates the expected outcome from material section that can contribute to L&G approach. To improve sustainability of the operation, wastage of material should be at its minimum.

Table 4: Expected outcome for Material (MT)

Factors	Description
MT1	Achieving reduction in consumption rate of raw material
MT2	Improving production rate of main product
MT3	Achieving higher material inventory and handling reduction rate
MT4	Improving on product quality management and handling

2.5 Money

Jason (2016) shows the relationship between cost saving, sustainability and efficiency. Money factor such as operation cost act as the direct indication to business performance. Table 5 indicates the expected outcome from operation financial aspect. Each factor has to be evaluated to ensure a sustainable and healthy contribution. Cost do not only reflect on operation performance, but also gauge the competitiveness in the global market. Money factor also plays an important role in project feasibility decision making.

Table 5: Expected outcome for Money (MY)

Factors	Description
MY1	Achieving higher material cost reduction rate in operation
MY2	Improving effectiveness of labour cost in operation
MY3	Achieving higher utility / energy cost improvement rate in operation
MY4	Achieving higher operation / maintenance cost reduction rate
MY5	Achieving higher inventory cost reduction rate for material handling
MY6	Achieving higher waste management cost reduction rate

2.6 Environment

Many industry players have contributed significantly towards global economy without paying much attention to the environment. The criticality and attention of global warming and climate change have influenced the industry player to take environmental concerned matter into operation consideration. Environmental emission generated from the industry premises can be improved with new technology. Industry players can develop waste recovery system to convert waste into value-added product. Table 6 indicate the expected outcome from environment aspect.

Table 6: Expected outcome for Environment (EV)

Factors	Description
EV1	Improving air emission quality emitted into the atmosphere
EV2	Improving discharged water quality prior discharged into environment
EV3	Improving on reduction of noise pollution that will cause discomfort to employee
EV4	Improving scheduled waste management system to reduce unnecessary contact with employee and environment
EV5	Reducing carbon footprint within the operation premise.

Figure 3 summarises the relationship of outcome between L&G and five major components. First level consists of L&G expected outcome while second level consist of expected outcomes from the five major components (manpower, machine, money, material and environment). Note that the second level components are not the subset of the components in first level, instead, they are expected to affect or contribute to the first level components. It is expected that the outcome from five major components will contribute to reduction in carbon footprint (B), reduction in production wastage (E), reduction in interruption of material flow (G) and improve in product quality (I). Although not all first level components are evenly contributed by all five major components, expected outcome from second level component will positively contribute indirectly to the first level.
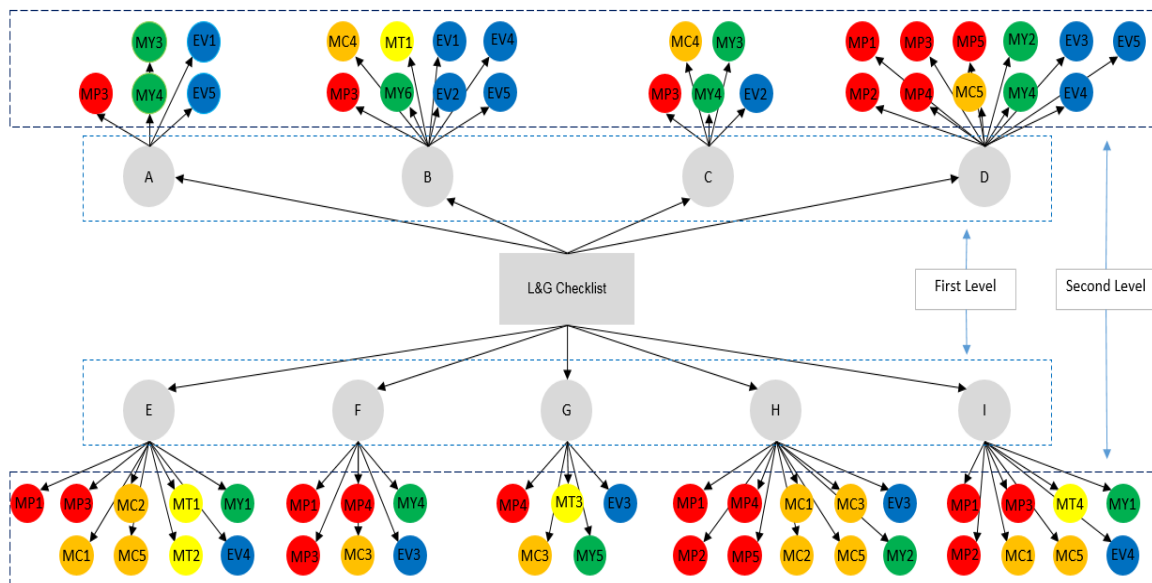

Figure 3: Relationship between expected outcome of L&G and major components.

3. Future works

With the expected outcome breakdown in Figure 3, a checklist will be developed based on the expected outcome in second level. Referring to Figure 1, data collect from checklist will be calculated with a mathematical model. Principal component analysis (PCA) is taken into consideration it is able to convert huge number of correlated variables into smaller set of uncorrelated variables known as principal component (PC) without losing the too much of information (How and Lam, 2017). The mathematical model is expected to evaluate the degree of L&G in a particular industry. Debottlenecking and optimization solutions will be developed once the calculation model is established.

4. Conclusions

Global competition and climate change have forced manufacturing industry to move towards lean and green manufacturing. The need to reduce operation cost without comprising environmental health has become a challenge globally. The development of checklist for lean and green approach, outcome-based approach is used to identify the relationship and suitability of data. Lean and green approach contains five major components which consist of manpower, material, money, machine and environment. Expected outcomes for all components (e.g. lean and green, manpower, material, money, machine and environment) are being list out individually. A two-level hierarchy network is being developed to consolidate a series of expected outcome to achieve lean and green motive. Lean and green checklist will be established based on the second level hierarchy network. This will be a tool which able to facilitate industry player in achieving higher performance in terms of lean and green perspective.

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