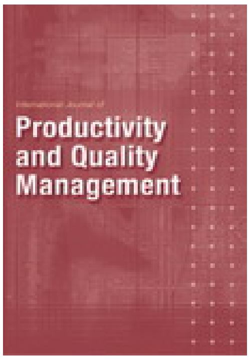

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Exploring the interrelationships between green manufacturing practices and Malaysian green sustainable performance

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Exploring the interrelationships between green manufacturing practices and Malaysian green sustainable performance

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Abstract: Green manufacturing (GM) is deliberately an integral part of green operations management. However, little is reported about the empirical investigation of GM practices and the associated sustainable performance within Malaysian industries. This paper aims to develop a conceptual multi-dimensional GM model and explore the relationships amongst these practices in order to eliminate the existing gap in operations management contemporary literature. To accomplish this, a structured questionnaire was designed and sent to key respondents, the managers. Two general hypotheses are postulated based on the developed model. Results were performed through techniques utilised from both advanced programs namely SPSS 23 and AMOS 23. Findings show that both hypotheses are supported as these are significant and there are positive linkages between GM and both financial and green performance. This paper is considered a portfolio and guide for Malaysian manufacturers in their trend to be sustainable.

Keywords: sustainability; model; questionnaire; structural equation modelling; SEM; green manufacturing.

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1 Introduction

Green manufacturing (GM) opportunities, challenges, drivers and barriers has been identified to reduce carbon impact with respect to environment. It used interchangeably with cleaner production, industry ecology, sustainability production and environmental conscious manufacturing. Abualfaraa et al. (2020) argued that GM practices focus on reducing the business' environmental impact. Besides, they claim that these practices are still new and lack clear and structured definition. Besides, Prabhu et al. (2020) proposed a new model recognised as green through lean tools (GTLT) in which it designed to implement GM in four several phases through the adoption of three fundamental lean tools namely 5S, A3 report and kaizen in garment manufacturing industries. Additionally, both Gaikwad and Sunnapwar (2020) investigate the status that both lean and green practices and tools are being used for improvements in three sustainable dimensions namely social, economic and environmental performance that directly affect overall business performance. GM is the concept of reducing and eliminating any risk of harm to the environment during the production process, beginning with the stages of raw material, to production operation into packaging stage, up to distribution and end of life stages (Sezen and Çankaya, 2013; Chuang and Yang, 2014; Digalwar et al., 2017). Holistically, the concept of GM covers all the technological approach including the physical approach that could lessen the carbon emission. Climate change is an undeniable issue for all. Scientists have concluded that human activities due to the burning of coal, oil and gas, are the causes of the global warming (IPCC, 2010). According to Afum et al. (2020), the decisions aligned by managers whether to embrace green advantages such as GM may yield least outcome without the collaboration of critical upstream supply chain partners (e.g., supplier integration) and downstream supply chain partners (customer integration). Some scholars claim that most manufacturing small and medium enterprises (SMEs) in developing countries rarely adopt GM practices due to misunderstanding this concept (Jamian et al., 2012). Furthermore, Zhan et al. (2018) argued that few studies have attempted to link GM practices and focuses on sustainable performance. Review of the contemporary literature show that most of the organisations are still not implementing green in their manufacturing processes, causing the reduction of the carbon emission is impossible. This raised the question, why is it hard for the manufacturers to adopt green in their operations. The ultimate purpose of this paper is to explore the relationships between GM practices and the sustainable performance within the Malaysian industries. By this, it tries to reduce the existing gap and further introduces the main GM practices that Malaysian manufacturers prefer to adopt. Authors believe that to inspire the GM practices to be widely implemented, a study on the financial performance as well as the green performance needed to perform. It is perceived that the positive result on the financial performance will eradicate any doubt among the manufacturers to pursue green in their operations. Therefore, the carbon emission will consistently reduce by the vigorous attempt of GM practices among manufacturers in Malaysia.

The structure of this paper is organised as follows: it starts with the introduction describing GM practices, illustrating the problem identified and main themes. Further, the extensive literature review on GM is introduced in Section 2. Methodology including research design, sample size data collection techniques and methods are introduced in section 3 whereas the Section 4 shows the results obtained eliminated from the empirical analysis as per structural equation modelling (SEM). Section 5 is related to discussion of the results, conclusions, limitations and future research directions.

2 Literature review

Literature review in this paper consists of different subsections concerned with GM, sustainability and practices. The main components of GM are described separately to show their importance while these are fully practiced by manufacturers.

2.1 GM concept

This section discusses the main themes of GM and the following subsection portrays the main components of GM used in this study. Migdadi and Elzzqaibeh (2018) evaluated the performance of GM strategies adopted by ISO 14001 certificate holders in Jordan. Singh et al. (in press) focused on GM aspects related to manufacturing industries. They investigated the critical success factors (CSFs) affect the implementation of GM. Bisoyi et al. (2019) focus on utilisation of GM technique for modulating a product that is sustainable and reusable. Saetta and Caldarelli (2021) presented the technological innovations for green production and demonstrate the need to act in several areas to make a production process that is sustainable from an economic, social and environmental point of view. They argued that both lean and green concepts have also been introduced in the foundry industry.

Dubey and Bag (2018) argued that green operations management includes integrating the principles of environment management to the field of operations management. Generally, wildfire in Australia, earthquake in the Philippines, sea foam in Spain, and recently corona virus in China and the world are the signs that environment is accelerating its devastation. The urge to protect the Earth is critical by reducing the chances of climate change. Even though the Earth needs greenhouse gas (GHG), acting as a blanket to keep it warm, the heat produce by human activities is excessively unreasonable. This will cause too much heat trapped into the atmosphere, which will increase the Earth's temperature. One way to reduce GHG is by reducing the carbon footprint. The metric to quantified carbon footprint is tonnes of CO_2 equivalents (t CO_2-eq.) (Chakrabarty, 2014). The Earth needs GHG, acting as a blanket to keep it warm. However, if human activities produce GHG excessively, it will cause too much heat trapped into the atmosphere, which will increase the Earth's temperature. One way to reduce GHG is by reducing the carbon footprint. The metric to quantified carbon footprint is tons of CO_2 equivalents (t CO_2-eq.) (Chakrabarty, 2014). Since it is significant to reduce carbon footprint, researchers are exploring methods for adaptation and mitigation on each and every stage of production processes, from upstream to downstream of the manufacturing industries. The integration between the manufacturing the environmental concern has led to the development of GM. It comprises of the flows of raw materials to the finished product while achieving environmental sustainability.

GM goals are "to reduce the amount of natural resources needed to produce finished goods through more energy, and materials efficient manufacturing processes that also reduce the negative externalities associated with waste and pollution" (Govindan et al., 2014). Existing studies confirm that the ultimate aim of GM is to reduce and to minimise the environmental impact and resource consumption during a product's life cycle (Govindan et al., 2014). Govindan et al. (2015) stated that since the launched of the ISO 14001, there is a speedy growth in manufacturing initiatives has been discovered with the extensions. Besides the government regulations, organisations are forced to adopt the ISO 14001, which helps them to integrate manufacturing processes into green practices. Organisations understand the environmental issues as opportunities for competitive advantage and marketplace success. In a world of ever-greater environmental consciousness, many corporations find that building environmental attributes into their portfolio of products help them win customers and drive revenues.

2.2 GM practices

2.2.1 Green design

A green product or service can be considered by several factors; for example, one key factor is to close the material loops through the design for environment (DFE), which includes design for remanufacturing, design disassembly and for recycling. Equally significant in green design are the application of cleaner production principles of preventive strategy and source-oriented approaches. These factors may include reduction of toxics use, enhanced durability, product-service combinations, updatability via software upgrades, manufacturability and others. All such efforts can lead to a more ecologically sound and to lower fossil carbon footprints products and services. Both Peng and Liu (2016) observed the effect of managerial environmental awareness on the eco-innovation. They assumed that green design is the most important practice to achieve the environmental sustainability. One of the main green practices applied in manufacturing sector is the green design; however, Bowen et al. (2001) stated that green design would only be successful if the people who are working in the field recognise the opportunity that will benefit them. A green product or service can be characterised by several factors; for example, one key factor is to close the material loops through the DFE, which includes design for remanufacturing, design disassembly and for recycling. Equally significant in green design are the application of cleaner production principles of preventive strategy and source-oriented approaches. Both Peng and Liu (2016) deliberate the effect of managerial environmental awareness on the eco-innovation. Moreover, Chuang and Yang (2014) considers the influence of green design, green process and green packaging. Their study are based on a small case study resulted from three different enterprises only. Thus, results are not conclusive to the overall manufacturing industries and cannot be fully generalised. Table 1 illustrates carbon foot printing profile with respect to manufacturing phases.

Table 1 Carbon footprinting profiles in manufacturing phases

Phase	*Emission*	*Percentage*
Raw material	0.5905	12.84%
Fuel	1.1905	25.89%
Utilities	2.1049	45.78%
Packaging	0.2223	4.83%
Waste	0.1519	3.30%
Transportation	0.3368	7.32%
Total	4.5969	100%

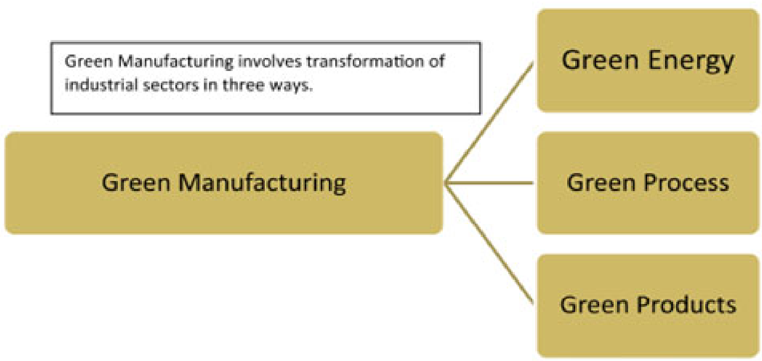
Govindan et al. (2015) stated that since launching ISO 14001, there is a speedy growth in manufacturing initiatives, which discovered with the possible extensions. They identified that many attention are given towards the drivers for the green supply chain management while lack focus on GM drivers. In their study, they only focused on two practice namely ‘DFE’ and the product-oriented environment management system (POEMS).

2.2.2 Green process

As it illustrated by Das et al. (2019), green process is considered as one of the main focus parts in GM. However, in this study, green process was selected as an element of the GM practice. Figure 1 illustrates this issue.

Reduction of the energy use during production operation is essential. Energy management and efficiency in production lines and manufacturing environments, which is estimated to be around 38% of the world’s energy consumption is gaining more importance. Because it is a quality, neutral way, not only to reduce production cost but also because of its role in ensuring the facility compliance with environmental regulations and best practices (Zhu et al., 2015). Numerically, in 1999, the automotive industry spent around $3.6 billion to cover production energy costs. Additionally, the effect of the carbon emissions (product of energy consumed) can add to the energy cost if a carbon-tax policy is enforced. In addition, the European community targets to reduce the primary energy consumption of 20% within the year 2020; accordingly improving GM requires a revolutionary approach in considering energy efficiency and saving aspects. This effort will provide many benefits such as direct costs reduction, regulations respect, processes with low energy consumption, positive product/process image; in this view, energy efficiency is estimated to be a competitive asset. Manufacturing system complexity demands the conceptual integration of the single machine tools, conceiving the shop floor as a unique macro-machine tool; consequently, the energy consumption should be optimised by considering, a holistic, system approach (Bruzzone et al., 2012). Xie et al. (2019) assessed the significant impact of green process innovation on the financial performance.

Figure 1 Focus areas of GM (see online version for colours)



Source: Adapted from Das et al. (2019)

2.2.3 Remanufacturing

Remanufacturing is the process of restoring recycled products to a 'like-new' functional state. It provides several benefits for original equipment manufacturers (OEMs), such as savings in labour, material costs and energy consumption. For example, in the 2008/2009 financial year, Fuji Xerox Australia remanufactured more than 230,000 equipment parts, which led to a cost saving of $6 million compared to sourcing new parts (Bulmuş et al., 2013). Remanufacturing is usually more environmentally friendly than traditional manufacturing since it is based on the restoring and recycling of old used products (Ilgin and Gupta, 2010). Operations and processes of remanufacturing similar to forward manufacturing affect the environment. Carbon emissions are considered a case example to illustrate this. Therefore, remanufactures must, similar to traditional manufacturers, figure out how to trade-off economic costs generated in the process of production, as well as environmental costs under carbon emission regulations.

2.2.4 Waste and disposal

According to Rusli et al. (2013), internal environmental practices such as recycling the papers and cartridge toners, adopting energy efficiency for heating, lighting, and manage the waste are highly being implemented inside enterprises. However, these execution were only implemented within the office management but does not covered the entire operation itself. Thus, this study will investigate the practices within the production process quantitatively.

Manufacturing firms consume the natural resources in highly unsustainable manner and release large amounts of GHG leading to many economic, environmental and social problems from global warming to local waste disposal (Sangwan, 2011). Besides, waste is considered as anything that does not add value to the product. The various wastes that are commonly found in industries are defined as different categories in lean manufacturing. If these wastes are reduced using the appropriate tools and techniques of lean which in turn can have the control over industrial pollution. The elimination of waste represents the ultimate solution to pollution problems that threaten ecosystems at the global level. It is also observed that energy saving plays a prominent role in controlling the pollution there by the reduction in generation of GHGs to the atmosphere is controlled. One of the benefits of GM would be reducing cost because in the end, the company may not have to shell out money to remove the waste when waste has already been eliminated on the first step. According to Rusli et al. (2013), internal environmental practices such as recycling the papers and cartridge toners, adopting energy efficiency for heating and waste management are highly being implemented in the firms. However, these executions were only implemented within the office management but do not cover the entire operation itself. Therefore, this study will investigate the waste practices within the production process quantitatively.

2.3 Green sustainable performance

In this study, green sustainable performance is observed and examined through two dimensions namely financial performance and the environmental performance. Researcher considers these of most significant and has an impact in the Malaysian environment. Details about these are as follows: Schmidt et al. (2016) has proved that stakeholders' pressure drive the implementation of the green practice. In their study, they found that the downstream of the supply chain are the one that highly adopted the green practices compared to the upstream due to the force brought by the stakeholders' expectations. Their objectives on financial interest could led to environmental interests. Furthermore, 'internal environment' practice was proved to be the top practice in green supply chain management (Rusli et al., 2013). However, their study on the 'internal environment' mainly covered on the green office practices such as toner and paper recycle and heating and lighting energy consumption. Sin et al. (in press) investigate the relationship between TQM practices and sustainability performance, taking into account the environmental, economic and social aspects. Jiang et al. (2021) proposes a research on the sustainable development performance of GM technology innovation based on artificial intelligence and blockchain technology. In their research conducted in the Chinese construction industry, Li et al. (2019) explored sustainable performance in terms of economic performance, environmental performance and social performance. The study performed by Parmar and Desai (2020) is established to determine the status of sustainable Lean Six Sigma (SLSS) practices execution in the industries. In a recent study by Gavareshki et al. (2020) to present a productive and sustainable integrated management system model, which can create or increase an added value in all organisational processes and sub-processes.

In order to measure the effectiveness of GM, the dimensions for the performance measurement need to be identified. Fynes et al. (2004) pointed out that performance is measured based on the accumulation or recombination of a unique asset, the reduction in costs, or a reduction in uncertainty. On the other side, Hervani et al. (2005) concluded that ISO 14031 performance management system is based on environmental condition, operational performance and management performance indicators. The green management needs to quantify its performance for their internal and external organisations reports (Luthra et al., 2016). Hence, this study also proposes a GM roadmap for performance measurement, which could be adopted by manufacturers. However, in SME in manufacturing sector, Rehman et al. (2016) study the GM within manufacturing companies in India, they explored the impact only on operational performance instead of the financial and green performance. The impact of GM on the performance measure is characterised through both green and financial performance.

According to Grob (1995), the knowledge and the appreciation towards the environmental issues is what green awareness is about. Since then, researchers have tried to identify the relationship between the green awareness and the impact of the green behavioural. This is because the higher the green awareness will cause better green behaviour and accordingly increasing the level of the green responsibility. In this study, the green behavioural scope will revise the adoption of green within the manufacturing processes.

The primary competing hypothesis justifying why organisations practice green is the hypothesis that everything needs to do with benefit, which is the profitability. The only issue rise is due to the long-term benefit that will cause the green manufacturer reluctantly adopt green. Organisation make strides toward environmental friendliness, on this assumption, since they become tied up with the ‘business case’ for sustainability, that is, they come to a belief that lessening energy use, minimising the waste, and various green practices will be advantageous for the primary concern. On the other hand, they appear to trust that being seen as green-concern-organisation will win their customers, and increase benefits that way. Moreover, when adopting GM, the financial benefit is no longer a question. Govindan et al. (2015) has shown that there is no doubt that organisations will experience better financial performance when it is rank as the top driver for them to go green. Managers are subject to the economic pressures, their goals are to cut unnecessary costs reduce waste and attract environmentally concerned consumers. Some of them actually put much effort into green practices that will do these issues. The fact that from green to gold is not clearly understood by the manufacturers. The reluctant to go green are the result of lack of awareness that the greening expenses could lead to higher profit. The awareness on the benefit of the expenditures to implement GM is yet to establish. Some wants to go green but they are groping in the dark, not sure what should be done to properly realise this practice. A high level of this awareness on environmental sustainability can be achieved under the influence of the education, organisational culture and governmental regulation (Pane and Patriana, 2016; Sottile et al., 2016).

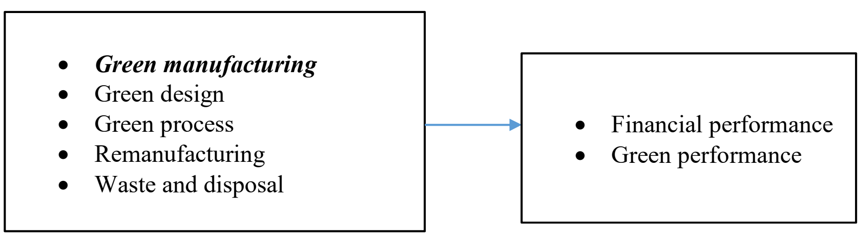
2.4 GM and sustainable performance linkage

Thomas (2020) argued that to attract more buyers is the vital benefit of sustainability. According to Toke and Kalpande (2019), both sustainability and green imprinting have realised special interest from various business castigations including information management, marketing, supply chain management, etc. Their recent research focuses on identification and analysis of the CSFs of GM behind successful achievement of environment sustainability in Indian manufacturing industry. Dubey and Bag (2018) argued that the archetype shift of policies in the direction of green economy is forcing the managers to consider the green initiatives extremely. Pang and Zhang (2019) concluded that GM has been drawing the attention of academia since the 1990s and reflected as one of the most vital fields for attaining the sustainable development. Leong et al. (2019) claim that there is no clear definition for green and proposed a model for lean and green integration. The recent research conducted by Sun et al. (2020) discussed measuring and linkages of risk management with green innovation practices for GM under the global value chain.

2.5 Conceptual model and hypotheses

Refer to the above literature review and based on the GM themes and philosophy, the proposed model involves multi- dimensions practices and green performance emphases on selected Malaysian industries. It is perceived that GM consists of four factors namely green design, green process, remanufacturing and waste and disposal. On the other side, the green performance is characterised by both financial performance and green environmental performance. Figure 2 displays the proposed conceptual model.

Figure 2 Proposed multi-dimensional model (see online version for colours)



Based on the proposed model, direct hypotheses are developed and formulated to investigate the impact of GM on the sustainable performance. Therefore, to accomplish and realise the main goals of this paper, two direct hypotheses are postulated to be empirically examined. These are:

H1 GM has significant and positive effect on financial performance.

In this hypothesis, GM practices are recognised as the exogenous which propose to have an influence on the financial performance aspects for the Malaysian industries reflected as the endogenous latent construct.

H2 GM has significant and positive effect on green performance.

The second postulated hypothesis also considers GM as the exogenous construct while green environmental performance is the endogenous construct.

3 Methodology

The methodology in this paper presents the complete design of the paper including the sampling frame, data collection, analysis methods and techniques.

3.1 Design

The research paradigm adopted in this paper is a positivistic paradigm. Authors' belief that the reality can be measured by using methodologically generalised by the theoretical framework to achieve the purpose of the study. Hence, the positivistic must take account for the shared belief of the previous successful scholars but it does not exclude any of the other possible assumptions of ontological, epistemological, and methodological perspective which might exist for any actual research project (Morgan, 2007). However, this paper is designed based on the theoretical framework and followed by an empirical investigation in quantitative ways. Authors started by identifying the existing gaps in GM, which assists in developing the proposed theoretical model through pooled and reviewed the related contemporary literature. Identifying the latent constructs, and the dimensions as per the variables under investigation is the second stage. Besides, the population of the Malaysian manufacturing industries, and sample size was determined through the scientific way. Therefore, the realisation for this study is performed through survey method, which later, the empirical data were developed and analysed through using techniques from the most common statistical method namely SEM.

The next steps concentrate on establishing the structured questionnaire through adopting and adapting process from previous relevant GM and sustainability literature. After the panels of expert have validate the developed questionnaire, decision is to proceed the research process with the data collection phase. Prior to the field test, two levels of data collection are performed, namely the pre-test and the pilot test. This is significant to prepare that the data collected are practically accurate so that later when run the analysis it will reduce the amount of errors and mistakes to occur. During the pilot test, the exploratory factor analysis done and this assisted to proceed into the real field test. During field test, the confirmatory factor analysis (CFA) was conducted and subsequently run the SEM analysis.

3.1.1 Sample size and data collection

Feldmann (2014) suggested a comprehensive sampling procedure, which contains six stages. These include introducing the target population, sampling frame and techniques, an appropriate sample size, sampling process and validation the selected sample. This study used structured questionnaire as a method to gather the primary data. Based on this, the sampling frame consists of three main sectors namely electric, electronic and automotive industries located in Malaysia. Researcher focuses on these industries because they have recorded as having the fastest growth rate among other sectors.

The sampling frame for this study is obtained from the Federation of Malaysian Manufacturing (FMM) Directory for year 2016 (47th edition). Besides, selection of the sample size depends on four factors, which are sampling error, population size, the variation of the population with respect to the characteristics of interest and the smallest subgroup within the sample for which estimates are needed (Salant and Dillman, 1994).

The target respondents are selected from both the management and the operation levels within the focused industries. This is because these managers have first-hand knowledge and information regarding the green issues, green innovation initiatives, and continuous green progress in environmental performance of their industries. It is observed that there is no specific guideline concerning determination of the appropriate sample size to analyse research model through SEM techniques. Therefore, authors followed the recommendations assigned by Hair et al. (2010). They argued that sample size can be decided based on the number of items in the designed questionnaire, and this should be at least five times the total items. The total number of items in this study is 68, so the desired sample size is ($68 * 5 = 340$). This means that there should be five observations for each item. They also suggested that if the sample size becomes too large greater than 500, SEM analysis will be sensitive and goodness-of-fit (GIF) will be poor for the model fit. Sample size larger than 30 and less than 500 are appropriate for quantitative research. Based on the objectives of this study, stratified random sample is considered appropriate for this type of research. Actually, two steps are required for the stratified sample to be considered. These are dividing the target population represented by the three industrial sectors subdivided with comparable characteristics called strata and the next step is selection of the sample from each stratum randomly. Using this sample type assists to ensure better sampling representativeness. To get a stratified random sample, the population selected was divided into strata according to sectors identified, and it deliberated as follows: strata sample size = [(strata size / total population) ∗ total no. questionnaires administrated].

3.2 Constructs

Four practices are reflected to conceptualise GM whereas other two dimensions to further describe sustainability concept. Table 2 depicts all items deliberated in this paper for the different practices. Green design has six items, green process has six items, remanufacturing has six items whereas four items are designed for waste and disposal. Five items for the financial performance and six items for the green performance.

3.3 Data analysis techniques

Both statistical technique for data collection (SPSS 23) and SEM through analysis of moment structure (AMOS 23) were considered appropriate for this type of studies, therefore, both programs are reflected to analyse the gathered data. Several techniques were utilised from these programs so that to achieve the outlined objectives. Therefore, and similar to other researchers, descriptive statistics, principal component analysis (PCA) and CFA all used.

Table 2 Practices and proposed items

Construct		*Indicators/items*	*# items used*
Green manufacturing practices			
Green design (GD)	1	Innovativeness	GD1–GD6
	2	Energy consumption	
	3	Close loop design	
	4	Waste management	
Green process (GP)	1	Improvement of activities to reduce energy consumption	GP1–GP6
	2	Improvement of process on the operations	
Remanufacturing (RE)	1	Effort in implementing remanufacturing (skills and cooperation with supplier)	RE1–RE6
	2	Collection and cleaning activities	
	3	Reconditioning and reassembly activities	
Waste and disposal (WA)	1	Waste management	WA1–WA4
	2	Resource recovery	
Green sustainable performance			
Financial performance (F)	1	Cost saving	F1–F5
	2	Profit	
	3	Market share	
	4	Sales	
Green performance (G)	1	Carbon emission (energy and waste)	G1–G6
	2	Hazardous materials	
	3	Green product development	
	4	Competitive advantage	

4 Results

Results in this paper include using the possible techniques so that to achieve the main objectives and answer the proposed questions in better manner. As discussed in the Section 3, both advanced programs such as SPSS and AMOS 23 are utilised by authors consistent with other scholars in similar studies.

4.1 Descriptive statistics

This section conveys the descriptive analysis of the main latent constructs including all items. Mean, standard deviation and variance are calculated using SPSS 23.

4.1.1 Descriptive analysis of GD

Table 3 displays the mean and standard deviation of GD items. The mean score of items ranges from 6.53 to 7.19 and the standard deviation ranges from 1.948 to 2.227. The mean score of item (our products are designed to last longer) was the highest, which, concerned with the designing of products and their shelf life and use.

Table 3 Descriptive statistics of GD items

#	*Items*	*Mean*	*Stand. deviation*	*Variance*
1	Our company emphasise design innovative products with concern about environment.	6.92	2.011	4.044
2	Our products are designed to reduce the consumption of resources.	6.81	2.051	4.208
3	Our products are designed for reuse, recycle and recovery of material.	6.72	2.227	4.959
4	Our products are designed to last longer.	7.19	1.948	3.795
5	Our products have been redesigned to reduce their environmental impact.	6.85	2.063	4.256
6	Our company goes beyond government regulations to implement green practices.	6.53	2.121	4.498

4.1.2 Descriptive analysis of GP

Table 4 displays the mean and standard deviation of GP items. The mean score of items ranges from 6.09 to 6.88 and the standard deviation ranges from 2.021 to 2.334. The mean score of item GP1 was the highest, which is related to Malaysian industries consumption of water, electricity, gas and the intention of these industries to lower the value of the consumption, which generates benefits to them as well.

Table 4 Descriptive analysis for GP items

#	*Items*	*Mean*	*Stand. deviation*	*Variance*
1	Our company constantly lowers the consumption of water, electricity, gas and fuel during production and disposal.	6.88	2.056	4.227
2	Our company generates cleaner or renewable technology to replace purchased energy (for example, solar energy).	6.09	2.334	5.447
3	Our company constantly redesigns the production and operation processes to improve environmental efficiency.	6.54	2.053	4.215
4	Our company constantly improves our products to meet environmental criteria such as waste electrical and electronic equipment (WEEE) and restriction of hazardous substances (RoHs).	6.61	2.182	4.759
5	Our company constantly improves production processes that avoid or reduce the use of hazardous products.	6.86	2.053	4.214
6	The company has adopted proactive strategies towards environmental sustainability.	6.79	2.021	4.086

4.1.3 Descriptive analysis of remanufacturing

Table 5 displays the mean and standard deviation of RE items. The mean score of items ranges from 5.90 to 6.53 and the standard deviation ranges from 2.009 to 2.22. The mean score of item (our company does collect and clean some of used parts/materials) was the highest among the other items in this construct and refers to the used materials and parts collection.

Table 5 Descriptive statistics for RE items

#	*Items*	*Mean*	*Stand. deviation*	*Variance*
1	Our company does have intention to implement remanufacturing.	6.31	2.009	4.035
2	Remanufacturing is one of the main operations in our company.	5.90	2.22	4.929
3	Our company lacks of competence to implement remanufacturing.	6.14	2.062	4.253
4	Our company does collect and clean some of used parts/materials.	6.53	2.146	4.606
5	Our company does recondition and reassemble some of used parts/materials.	6.47	2.183	4.764
6	Our company does have cooperation to outsource the remanufacturing processes with the supplier.	6.46	2.099	4.408

4.1.4 Descriptive analysis of waste and disposal

Table 6 displays the mean and standard deviation of WA items. The mean score of items ranges from 6.95 to 7.09 and the standard deviation ranges from 1.977 to 2.145. The mean score of item (our company effectively follows the waste treatment and disposal procedure) was the highest which is an indication of the perception that Malaysian manufacturers in adoption the methods assigned for waste treatment and disposal in their facilities.

Table 6 Descriptive statistics for WA items

#	*Items*	*Mean*	*Stand. deviation*	*Variance*
1	Our company constantly seeks ways to achieve zero waste.	6.95	2.145	4.599
2	Our company effectively follows the waste treatment and disposal procedure.	7.09	2	4.000
3	Our company manages resource recovery (recycle, reuse) as one of the waste management activities.	7.03	2.039	4.157
4	Our company effectively manages waste and disposal management activities.	7.05	1.977	3.907

4.1.5 Descriptive analysis of financial and green performance

Table 7 displays the mean and standard deviation of green sustainable performance in terms of both financial and green (environmental) items. The mean score of financial performance items ranges from 6.28 to 6.53 and the standard deviation ranges from 2.056

to 2.136. The mean score of item (our company has made huge cost savings by implementing green practices) was the highest, which imply the benefits and savings perceived because of practicing green. On the other hand, the mean score of green performance items ranges from 6.34 to 6.72 and the standard deviation ranges from 1.874 to 2.134. The mean score of the item (new and improved green products have been created based on environmental sustainability) was the highest, which reinforces the importance of green products and development.

Table 7 Descriptive statistics for financial and green performance items

#	*Financial performance*	*Mean*	*Stand. deviation*	*Variance*
1	Our company has made huge cost savings by implementing green practices.	6.53	2.056	4.227
2	Considering the economic situation, our profit has increased.	6.33	2.104	4.426
3	Considering the economic situation, our market share has increased.	6.37	2.073	4.297
4	Considering the economic situation, our sale has increased.	6.43	2.136	4.562
5	Considering the production volume, our production cost has decreased.	6.28	2.106	4.435
Items name	*Green performance*	*Mean*	*Stand. deviation*	*Variance*
1	Carbon emission has decreased considering the volume of production.	6.52	2.049	4.199
2	Consumption for hazardous materials has decreased considering the volume of production.	6.43	1.895	3.591
3	Wastes have decreased considering the volume of production.	6.4	2.015	4.06
4	Energy has been consumed efficiently considering the volume of production.	6.6	1.874	3.512
5	New and improved green products have been created based on environmental sustainability.	6.72	1.885	3.553
6	Compared to our competitors, we have been the fore-runner in environmental issues.	6.34	2.134	4.553

4.2 Principal component analysis

PCA is conducted for all practices. The general results of Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is 0.922 whereas Bartlett's test of sphericity is acceptable and have df = 2,213, approximate chi-square = 20,432. The resulted pattern matrix consists of six different factors related to the main latent constructs used. Values of factor loading and reliability through Cronbach alpha are depicted in Table 8.

Results indicated that all factor loadings are acceptable within the allowed range. Besides, Cronbach alpha values are greater than 0.7 which is treated good at this stage of analysis and so the items can be used in further analysis.

Table 8 Factor loadings and Cronbach alpha for items

Item ID	*Items*	*Factor loading*	*Cronbach's alpha*
GD1	Our company emphasise design innovative products with concern about environment.	0.866	0.904
GD2	Our products are designed to reduce the consumption of resources.	0.878	0.901
GD3	Our products are designed for reuse, recycle and recovery of material.	0.851	0.907
GD4	Our products are designed to last longer.	0.740	0.923
GD5	Our products have been redesigned to reduce their environmental impact.	0.896	0.898
GD6	Our company goes beyond government regulations to implement green practices.	0.849	0.907
GP1	Our company constantly lowers the consumption of water, electricity, gas and fuel during production and disposal.	0.775	0.923
GP2	Our company generates cleaner or renewable technology to replace purchased energy (for example, solar energy).	0.817	0.918
GP3	Our company constantly redesigns the production and operation processes to improve environmental efficiency.	0.877	0.907
GP4	Our company constantly improves our products to meet environmental criteria such as waste electrical and electronic equipment (WEEE) and restriction of hazardous substances (RoHs).	0.889	0.905
GP5	Our company constantly improves production processes that avoid or reduce the use of hazardous products.	0.880	0.907
GP6	The company has adopted proactive strategies towards environmental sustainability.	0.887	.906
RE1	Our company does have intention to implement remanufacturing.	0.800	0.869
RE2	Remanufacturing is one of the main operations in our company.	0.819	0.866
RE3	Our company lacks of competence to implement remanufacturing.	0.619	0.899
RE4	Our company does collect and clean some of used parts/materials.	0.844	0.861
RE5	Our company does recondition and reassemble some of used parts/materials.	0.859	0.857
RE6	Our company does have cooperation to outsource the remanufacturing processes with the supplier.	0.857	0.858
WA1	Our company constantly seeks ways to achieve zero waste.	0.874	0.938
WA2	Our company effectively follows the waste treatment and disposal procedure.	0.927	0.911
WA3	Our company manages resource recovery (recycle, reuse) as one of the waste management activities.	0.932	0.908
WA4	Our company effectively manages waste and disposal management activities.	0.934	0.908

Table 8 Factor loadings and Cronbach alpha for items (continued)

Item ID	*Items*	*Factor loading*	*Cronbach's alpha*
F1	Our company has made huge cost savings by implementing green practices.	0.884	0.943
F2	Considering the economic situation, our profit has increased.	0.942	0.929
F3	Considering the economic situation, our market share has increased.	0.950	0.926
F4	Considering the economic situation, our sale has increased.	0.946	0.927
F5	Considering the production volume, our production cost has decreased.	0.831	0.955
G1	Carbon emission has decreased considering the volume of production.	0.903	0.939
G2	Consumption for hazardous materials has decreased considering the volume of production.	0.912	0.938
G3	Wastes have decreased considering the volume of production.	0.920	0.936
G4	Energy has been consumed efficiently considering the volume of production.	0.917	0.937
G5	New and improved green products have been created based on environmental sustainability.	0.854	0.946
G6	Compared to our competitors, we have been the fore-runner in environmental issues.	0.866	0.945

4.3 Measurement model and assessment

After finalising the first step, the next stage is concerned with establishing the CFA. The final revised measurement model including the four practices of GM and sustainability factors is depicted in Figure 3. Based on Figure 3, RMSEA = 0.064, CFI = 0.903 and Chisq/df = 2.377. These values are within the acceptable limit. Therefore, the revised measurement model is considered appropriate at this stage.

CFA can be used to verify the uni-dimensionality. It is presented by the factor loading which must exceed the value of 0.5 for the newly developed items and 0.6 for an established item (Zainudin, 2015). In order for the items to achieve the convergent validity and the composite reliability, all values of AVE should be more than 0.5 (AVE > 0.5) and the CR values to be more than 0.6 (CR > 0.6). This is to assure that, all the items in the instrument are reliable to measure the constructs. The validity achieved when all items in the measurement model are statistically significant. Table 9 shows the results obtained for CR and AVE.

4.4 Structural model and hypotheses testing

After realising CFA and PCA, the next step is building the structural model towards testing the postulated hypotheses. Two direct hypotheses are postulated. GM is the exogenous latent construct whereas green sustainable performance. The full-fledged structural model is depicted in Figure 4.

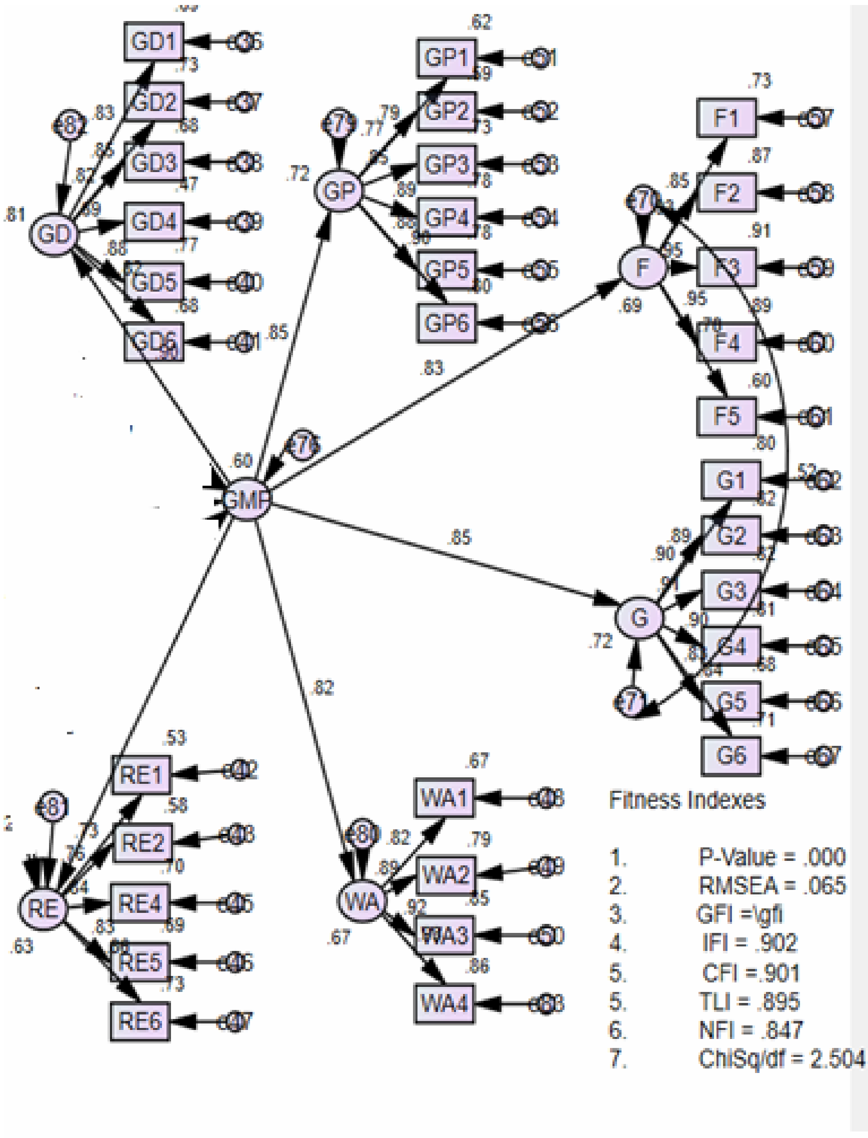
Table 9 Constructs factor loading, CR and AVE calculations

Construct	*Item*	*Factor loading*	*CR (minimum 0.6)*	*AVE (minimum 0.5)*
Green design	GD1	0.831	0.922	0.665
	GD2	0.850		
	GD3	0.818		
	GD4	0.684		
	GD5	0.875		
	GD6	0.820		
Green process	GP1	0.785	0.937	0.714
	GP2	0.764		
	GP3	0.848		
	GP4	0.884		
	GP5	0.884		
	GP6	0.896		
Remanufacturing	RE1	0.731	0.900	0.643
	RE2	0.763		
	RE4	0.828		
	RE5	0.827		
	RE6	0.854		
Waste and disposal	WA1	0.820	0.909	0.770
	WA2	0.891		
	WA3	0.919		
Financial performance	F1	0.848	0.950	0.794
	F2	0.932		
	F3	0.949		
	F4	0.943		
	F5	0.769		
Green performance	G1	0.886	0.951	0.764
	G2	0.901		
	G3	0.905		
	G4	0.896		
	G5	0.818		
	G6	0.836		

Table 10 Results of hypotheses

Hypothesis statement		*Estimates*	*P-value*	*Result of hypothesis*
H1	Green manufacturing has significant effect on financial performance	0.828	0.001	Supported
H2	Green manufacturing has significant effect on green performance	0.846	0.001	Supported

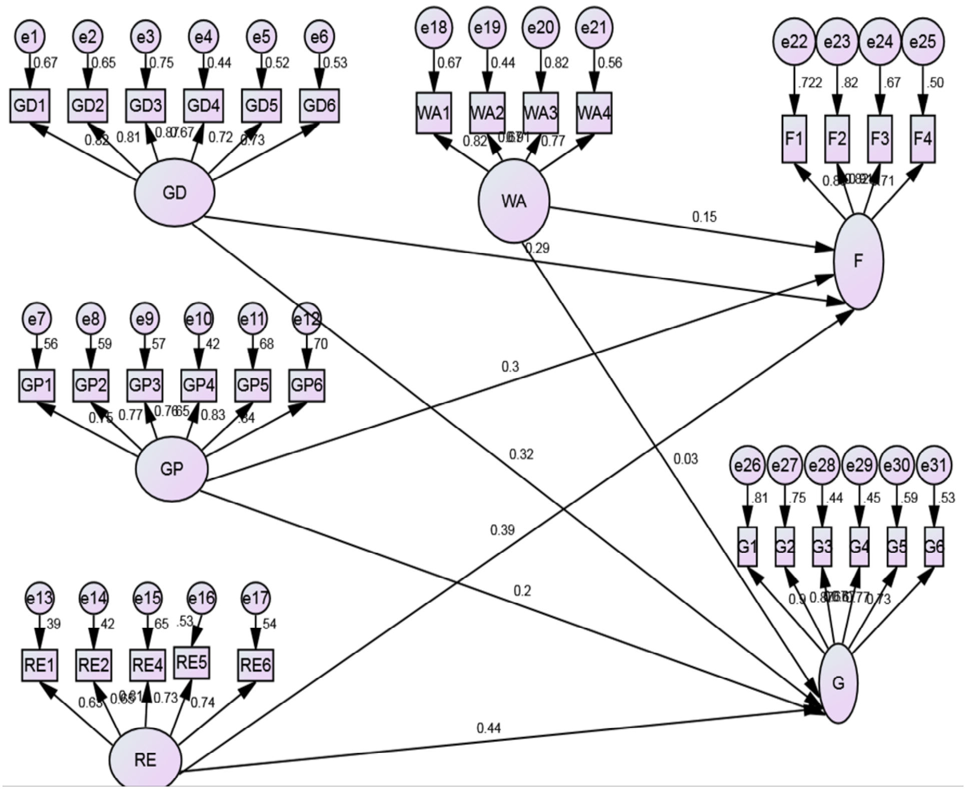
Figure 3 Measurement model of the main practices (see online version for colours)



Statistical significance is considered while probability value (P-value) is less than 0.05, and the critical ratio (CR) is more than 1.96. On the other hand, practical significance is identified when the value of β (standardised regression weight) is more than 0.2. Detailed results of the postulated hypotheses are reflected in Table 10.

Findings indicated that the hypotheses of the structural GM model are highly supported by the causal relationship.

Figure 4 Full-fledged structural model (see online version for colours)



5 Discussion and implications

This study treated with the new factors related to GM within the industrial country namely Malaysia. In order to be a developed nation, manufacturers have to adopt the best common practices and follow the world-class standards to still be competitive. It is deliberated that GM is one of the most philosophy and techniques that enable key managers to enhance their activities and ensure the sustainability. This realised upon capturing the real practices. This paper observes GM by means of assessment of four green practices namely green design, green process, remanufacturing and waste and disposal. These are separately explored with the financial performance. Each green practice does successfully efficiently contribute to the value of GM to be positively and statistically significant in relation to the financial performance. Based on the final refined structural model, the hypothesis related o these practices using GM practices as the exogenous latent construct and financial performance as the endogenous latent construct is supported hypothesis as it is both statistically and practically significant. Results for the link between GP and financial performance show that CR equals to 4.428, which is higher than the threshold, value, whereas for the link GD and financial performance, CR value equals to –2.843, and for RE to financial performance equals to 10.158. Finally, the link between WA and financial performance is also significant which has a value of CR =

–3.663. Findings is consistent with the study conducted by Zhu and Sarkis (2004) focusing on green design, and Xie et al. (2019) on green process, Giuntini and Gaudette (2003) on remanufacturing, and Hayami et al. (2015) on waste and disposal. Surprisingly, some scholars argued that there is no empirical research that addresses the impact of GM towards financial performances. For instance, Climent and Soriano (2011) claim that not numerous researchers agree that being green could contribute to financial performance. Additionally, Miroshnychenko et al. (2017) found that ISO 14001 adoption has negative influence on financial performance. They show that internal green practices (pollution prevention and green supply chain management) are the major environmental drivers of financial performance, while external green practices (green product development) play a secondary role in determining financial performance. On the other side, a recent study performed by Lucas and Noordewier (2016) discovered that environmental management practices, including pollution prevention actions, have a greater effect on financial performance. Endrikat et al. (2014) conducted a recent meta-analytical review of 149 studies on the linkages between corporate environmental performance (CEP) and corporate financial performance (CFP) reveals a positive relationship between CEP and CFP, approving former research established.

Furthermore, this paper examines the positive direct relationship between GM practices and the green performance within selected Malaysian industries.

It is obvious that from the contemporary literature review, few studies explored the practices with respect to the green environmental performance. Findings conclude that GM has a positive statistical significant effect towards green performance. This result is consistent with the study performed by Yang, et al. (2013) as they explored green supply chain but also address on the issues of GM portraying the factor of internal green practice. Sezen and Çankaya (2013) explored the linkage between GM and sustainability with the three dimensions namely environmental performance, economic and social, and find a positive relationship between these practices. They concluded that Turkish enterprises must incorporate environmental advantages into their management systems as these can lead to improved economic, environmental and social performance. On the other hand, Digalwar et al. (2013) proposed 12 measures for GM performance in the Indian industries, and environmental performance considered among these measures. In the Brazilian enterprises certified to ISO 9001, Soubihia et al. (2015) examined the linkage between green operational practices and the green performance. They supported that GM have a positive and significant relationship.

5.1 Limitations and future directions

Even though this paper is empirically designed, still there are some limitations similar to other research conducted in different sectors. This includes the industries selected, as these are not generalised to all manufacturing sector in Malaysia. Another issue is gathering the primary data through one specific point of time, this could affect the results. However, further factors can enhance the reliability of this study, which enable future researchers to further adopt within their environment. Generalisability of the results is another issue could attract other scholars. Additionally, conducting this research in different sectors such as services could be established. Authors did not investigate the linkages within the sustainable performance factors, which could be empirically explored in future research showing the real importance of these factors.

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