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Impact of Lean, Agile and Green (LAG) on business competitiveness: An empirical study of fast moving consumer goods businesses

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ABSTRACT

The adoption/utilisation of Lean, Agile and Green (LAG) practices in both the manufacturing and service sector is rising. However, there yet remain a research gap to precisely evaluate the relationship between LAG practices and business competitiveness (e.g, achieving reduction in cost, lead time and environmental recyclable waste). This research aims to explore this relationship, specifically in fast-moving consumer goods (FMCG) businesses. The hypothesised relationships are tested with data collected from 96 FMCG companies. Structural Equation Modelling is applied to evaluate different channels of achieving business competitiveness through the adoption of Lean, Agile and Green. The findings suggest that competitive outcomes vary with the adoption of LAG practices in specific product life cycle stages. This implies that awareness of the product life cycle concept is essential. A combination of LAG practices for the sole purpose of reducing environmental waste is negatively related to environmental waste reduction. LAG practices are more efficiently adopted when the adopters are equipped with expert knowledge on the paradigms and their individual practices. This research has approached the attainment of competitiveness in the FMCG businesses by analysing management efforts that improve cost performance, lead time and environmental sustainability aspects of business operations. The research has also considered the product life cycle stages in analysing the impacts of management efforts.

1. Introduction

The Global Business environment characterised by highly dynamic and cost-driven global competition (Gecevska et al., 2012) demands operational excellence (Gólcher-Barguil et al., 2019) and business competitiveness. For a competitive business environment, innovation needs to be embedded/encouraged in all dimensions – product, process and organisation (Gecevska et al., 2012; Breznitz and Cowhey, 2012; Casadesus-Masanell and Ricart, 2010; Salam and Khan, 2018). An increase in competition and the fluidity of customer expectations require the organisations to make efforts to gain competitive advantages in the market place (Pakdil and Leonard, 2014). Due to this increasing rate of competition, businesses in every sector are under increasing pressure to continually assess their business strategies in order to exploit the rapidly changing market drivers. Some of these drivers are discussed below.

1.1. Competition

The competitive rivalry is ever increasing in the market and such is the scenario for the fast-moving consumer goods (FMCG) sector. Oraman et al. (2011) emphasise that the FMCG sector is driven by strong competition. The list of competitive options included among others, the price which is affected by production costs, delivery speed, quality and product image (Tersine and Hummingbird, 1995). Furthermore, these competitive options and priorities change as products progress through their different product life cycle (PLC) stages. Tersine and Hummingbird (1995) argue that as no organisation is capable of excelling in all these factors simultaneously, therefore focus on a single or a combination of these factors provides a unifying guiding drive for competitiveness. Striving to be a low-cost producer in volatile and price-sensitive markets is a powerful competitive advantage (Collins, 2013; Mariano, 2015). Simultaneously, management of time, particularly lead time is believed to make a positive contribution to the

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competitive advantage of a firm (Al Serhan et al., 2015; Tersine and Hummingbird, 1995).

1.2. Product life cycles (PLC)

PLC is made necessary as a result of the need for improved awareness on the volumes required to be produced and the competitive priorities of each product, and the way these change over the product's life cycle (Luna and Aguilar Saven, 2004; Aitken et al., 2002; Sharma, 2013). The high level of demand fluctuations in the FMCG industry (Aljunaidi and Ankrah, 2014) makes FMCGs particularly vulnerable to PLC changes. According to Sharma (2013) companies, especially those in the FMCG sector who persisted with the consideration of the PLC concept had a better competitive advantage than those who did not.

1.3. Environmental sustainability

The concerns for environmental sustainability are of crucial importance and are becoming an integral part of corporate performance metric (Garza-Reyes et al., 2018; Nadeem et al., 2019) – one that stakeholders, outside influencers and even financial markets have started to monitor. As a result, there has been an increase in the influence of regulatory bodies and governments on corporate strategy. Businesses are put under pressure to take responsibility for the impact of their business decisions on the environment (Movahedipour et al., 2017) and apply measures to reduce such impacts. As manufacturers focus on environmental sustainability, the PLC concept becomes even more important (Nadeem et al., 2019; Madu et al., 2002).

Addressing the above-mentioned concerns require effective levels of leanness, agility and the deployment of environmental management practices, as these are advocated to play the foundational role in the gaining of competitiveness (Cabral et al., 2012; Espadinha-Cruz et al., 2011; Hasanian and Hojjati, 2016). However, evidence on the impacts of lean, agility and green adoption on business competitiveness are mixed and often ambiguous. Methodological inconsistencies, piecemeal adoption and contextual factors may be contributory factors to the variations recorded regarding the impacts of LAG on competitive measures.

The aim of this study is to explore the relationship between LAG and business competitiveness while focusing on additional sources of variations of the measures of competitiveness-cost, lead time, and the product life cycle (PLC) stages. Variations on reported impacts of LAG mean that firms are unclear about the adoption details of LAG. This study's central hypothesis posits that monitoring, analysing and reporting the impacts of LAG on cost and lead time, provides important and actionable information in business operations and that competitiveness is improved by a combination of appropriate LAG practices at PLC stages. For this purpose, the study begins with exploring the relationships between LAG and performance measures. First, it discusses the performance measures Cost (C), Lead time (Lt) and Environmental waste (W), and why they are suitable measures for this study. Further, an integrated framework is presented which includes LAG, PLC and performance measures C, Lt, and W. The study then uses structural equation modelling (SEM) to examine the relationships depicted in Fig. 1.

The novelty of this research lies in the fact that it examines the effects on C, Lt and W., while including PLC as part of the investigation. The PLC provides a rarely considered source of variation which may be unavoidable for FMCGs. This variation is shown by the different outcomes reached at the different PLC stages when the same lean practices are adopted. The key finding of this study is that LAG adoption yields different outcomes given different market conditions. Therefore, it is useful to be aware of the LAG practices that are best suited for the prevailing market conditions, such that preferable competitive outcomes are realised.

This paper comprises of five sections. The first section briefly introduces the scope of this research, the second section provides an overview of the performance measures of Lean, Agile and Green, which are advocated in this research as measures of competitiveness. The third section presents the hypothesis development and associated literature leading to the development of those hypotheses. A total of thirteen hypotheses are discussed covering the relationship between LAG and performance measures, including lean adoption in PLC stages. In the fourth section, the research methodology and data collection are discussed. The fifth section presents the theoretical and managerial implications and concludes this research with a summary of limitations and future research directions.

2. Performance measures

Given that a critical challenge in the FMCG industry is to competently support increasing customer demands, Farahani et al. (2013); Found and Rich (2007) and Aljunaidi and Ankrah (2014) believe that manufacturers are pushed to focus on cost reduction and that this issue becomes even more critical because customer loyalty is often in short supply in this industry, and that high competitiveness implies that this has to be realized at minimal cost. Also, extended lead times have been considered as obstacles in the FMCG industry (Farahani et al., 2013), reducing lead times could, therefore, improve competitiveness in the FMCG industry. Furthermore, given that businesses are facing increasing pressure to minimize the ecological impact of production activity, taking responsibility for the impact of their management decisions on the environment is now inevitable. Enterprises must now comply with environmental regulations. Consequently, environmental waste reduction is a reasonable consideration.

2.1. Cost reduction

Making efforts to reduce production costs is a powerful competitive advantage (Johnson, 2004); Fouskas and Giaglis, 2011; Muehlhausen, 2012; Porter, 1985; Williamson, 2015). For this research, it indicates the extent to which practices adopted contribute to the reduction of production costs. This is an essential factor to be reduced in production in order to stay competitive.

Ploy et al. (2011) state that cost as a manufacturing performance indicator is the ability to effectively manage production cost and its associated aspects such as overhead cost, inventory cost and value-added cost. Along with changes in product models in a production line, equipment (including machines) are relocated considering the overall costs of material handling and reconfiguration (Sanchez and Nagi, 2001). Hence cost can be considered in terms of material handling costs and reconfiguration costs. The authors also include the cost of purchase of resources, total cost of processing as well as that of all possible system reconfigurations as part of possible measures for cost. In other words, costs could be measured by what each practice takes out of the operating budget of a firm.

2.2. Lead time

The duration of lead time directly affects the operational and competitive abilities of a business (Maheshwari et al., 2010), hence, the reduction of lead times can be a competitive advantage (Pan and Yang, 2002; Villarreal and Salido, 2009). For this research it indicates the ability of the manufacturing enterprise to execute a particular job - from the date, it is ordered to the date it is delivered (Lederer, 2008) - quickly and as soon as the order is placed. Lead times needs to be minimized in production as excess time is waste, and leanness calls for the elimination of all waste.

Lead time is measured in exactly what it is defined by time. This is usually in days or weeks depending on the product and/or the company. Lead time is an important attribute of production and it can be reduced by applying various LAG practices.

Lean practices		Cost reduction							Lead time reduction							Waste reduction						
		0	1	2	3	4	5	NS	0	1	2	3	4	5	NS	0	1	2	3	4	5	NS
Time based competition (JIT)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Cycle time reduction	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Set up time reduction	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Cellular manufacturing	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Bottle-neck removal	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Focused factory	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Planning and scheduling	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Fig. 1. Snippet of survey questionnaire.

2.3. Waste

Waste is defined as a by-product of day to day activities which generates a significant threat to society (Begum et al., 2012). It is the amount of commercial, industrial and other material wastes produced in all forms of the production process including management activities which need to be reduced and how practices adopted correlates with the reduction of waste. In this research, practices which contribute more or less to the reduction of waste will be identified. Rehman and Shrivastava (2012) states that impact analysis helps identify the activities contributing high and low environmental impact, including the ratio of waste recovered, recycled, sold off and/or disposed of. The handling, treatment and disposal of wastes have costs attached to them and hence must be reduced in order to be competitive. Generated waste is used as a measure for green because it is related to aspects of environmental performance including clean and renewable energy generation, environmental impacts and emission of greenhouse gases (Begum et al., 2012). Greenhouse gas emissions could either be avoided or produced by waste management activity (Digest of Waste and Resource Statistics –, 2015 Edition, 2015).

EPA (2015) reports that the majority of waste disposed of in North London is sent to landfill, with the rest of it either recycled or incinerated. The government introduced a tax on every tonne of waste sent to landfill because landfill waste creates methane and a liquid called leachate which damages the environment through improper management. As of 2011, the cost of sending a tonne of waste to landfill was £48 (EPA, 2015). From 1 April 2016, the standard tax rate has risen to £84.40 per tonne of waste to landfill (EFW, 2015).

The following sections review the impacts of lean, agility and green on the measures of competitiveness i.e cost, lead time and waste. This review helped in the development of the questionnaire.

3. Hypotheses development

Fig. 1 is a research framework, showing how business competitiveness is related to LAG, cost, lead time, environmental waste and PLC. Specific hypotheses are discussed in the following sections. In developing the hypotheses, 150 questionnaires were distributed following a pilot study of members of the Institute for Operations Management which has approximately 2000 members. The sample size was calculated using the sample size method applied in Esan (1994), at a 95% confidence interval, recommending that 83 questionnaires should be distributed. Fig. 1 shows a snippet of the questionnaire. Reliability testing of the questionnaire was conducted and the constructs internal consistency and validity were measured using Cronbach's alpha and was found to be $\alpha = 0.76$ which indicates sufficient reliability (Inman et al., 2011).

3.1. Lean

Shah and Ward (2003) believe that the adoption of lean practices is linked to improving the measures of operational performance. The most usually cited advantages of lean adoption are improvements in quality and labour productivity, cycle time reduction, manufacturing costs and customer lead time (Shah and Ward, 2003). Many different Lean tools have been developed to assist manufacturing sector to improve their operations (Mirdad and Eseonu, 2014; Shah and Ward, 2003; Ashutosh et al., 2007), hence improving process flow and achieving cost-effective performance improvement through the elimination of wastes. Some of them are discussed herein.

3.1.1. Cost reduction

Mackelprang and Nair (2010) believe that cost performance is positively related with set up time reduction, pull system, uniform workload, lot size reduction and preventive maintenance. In other words, these practices identified by Mackelprang and Nair (2010) help in the reduction of manufacturing costs. Similarly, preventive maintenance helps improve performance costs by minimizing the average downtime of machinery due to failure which still had labour cost despite the stoppage (Nakamura et al., 1998).

According to Kumar et al. (2013), material handing accounts for 15%–75% of total manufacturing costs due to a poorly laid out facility. This implies that a poor cellular layout of the manufacturing facility may lead to an increase in total manufacturing costs. This then entails that a suitably re-engineered production process involving the appropriate physical layout of facilities and equipment could, in fact, mitigate the negative impact on manufacturing costs ascribed to material handling and related practices. When adopted to expressly provide customer satisfaction, planning and scheduling can be directly translated into the reduced cost (Eyong, 2009).

Liebesman (2009) believes that uniform workload which is the elimination of variability on assembly line production systems helps reduce costs. Group technology has also been identified by Vázquez-Bustelo and Avella (2006) as a practice that provides key advantages for production centres while lowering costs.

The multiple regression equation that relates the cost performance to the lean practices adopted is given by the constant and the coefficients of the unstandardized beta as:

$$\text{CR (Cost reduction)} = 0.434 + 0.088L_1 - 0.245L_2 + 0.001L_3 - 0.0127L_4 + 0.278L_5 - 0.008L_6 - 0.116L_7 + 0.056L_8 + 0.002L_9 - 0.129L_{10} + 0.176L_{11} + 0.106L_{12} - 0.220L_{13}$$

The equation shows that time base competition, setup time reduction, bottleneck removal, total quality control, quality circle, pull system/

kanban and preventive maintenance are positively correlated to Cost performance.

3.1.2. Lead time reduction

Lean practices enhance productivity by reducing lead times in a variety of ways. Reducing lead time for a fixed service level requires a reduction in average cycle time, set up time and the removal of bottlenecks (Singh et al., 2013). The symptoms of bottlenecks/constraints include congestion slowdowns, queue formation and shipping delays. The authors observed that when bottlenecks were removed or reduced the average velocity of the production traffic increased. Time-based competition, lot sizing (production in small/large batches), continuous flow production and bottleneck removal are lean practices identified by de Treville et al. (2004) to contribute positively in the reduction of lead times.

Sharma et al. (2015) performed multiple regression analysis to evaluate the impact of several lean manufacturing practices on lead time (The manufacturing practices being the independent variables). In their research, pull system was discovered to be a positive predictor (Nakamura et al., 1998; Sharma et al., 2015; Singh et al., 2013) while set up time reduction was observed to be a substantial positive predictor for lead time reduction meaning that a reduction in set up time leads to a significant reduction in lead time, hence improving the lead time performance. Sharma et al. (2015) expressed surprise at the negative coefficient observed for total productive maintenance (preventive maintenance) as it was contrary to popular belief with respect to lead time reduction. This observation is quite startling as the regular maintenance practices help prevent pre-emptive break downs of machinery, consequently reducing throughput time.

Focused factory and continuous flow production are also practices believed to reduce lead times as simplicity, repetition, experience and homogeneity of tasks are qualities which make that possible (Singh et al., 2013). Lean is expected to enhance the ability of an organization improve customer value and experience in terms of lower lead times which will enhance the competitiveness of the organization.

The multiple regression model for lead time reduction is given as,

$$LTR = -0.287 + 0.094L_1 + 0.084L_2 + 0.0980L_3 + 0.175L_4 - 0.022L_5 + 0.082L_6 - 0.019L_7 + 0.102L_8 + 0.024L_9 + 0.041L_{10} + 0.110L_{11} - 0.058L_{12} - 0.022L_{13}$$

The equation shows that time based competition, cycle time reduction, set up time reduction, cellular manufacturing, focused factory, total quality control, quality circles, continuous improvement, and pull system/kanban are positively correlated to lead time reduction.

3.1.3. Waste reduction

Nadeem et al. (2017) and Dieste et al. (2019a, 2019b) affirms a positive relationship between lean manufacturing and environmental performance. There is a similarity in the waste reduction techniques of both lean and green, with an emphasis on business and manufacturing process practices (Dues et al., 2012). Waste reduction through a transition in business practices is realized by an adaptation of company management culture (Mollenkopf et al., 2010 in Dues et al., 2012). This implies that a change/modification is needed in the company's vision to integrate lean and green practices as core importance in all of its support functions. Both lean and green emphasise the integration of product and process redesign to allow the product life/usage extension and/or to allow straightforward ways of recycling (Dues et al., 2012). Sroufe (2003) cited in Yang et al. (2011) contend that firms who employ lean practices to reduce internal wastes also adopt practices for improved environmental management and that environmental management encompasses activities from product development to final delivery and discarding of products.

Modi and Thakkar (2014) contend that effective preventive maintenance is a lean practice which eradicates machine breakdowns, defects, scrap and rework, mini stoppages and reduced speed. It can, therefore, be said that since it eliminates defects and scrap among other things, it will also reduce waste generated.

The multiple regression model for waste reduction shows that cycle time reduction, et up time reduction, focused factory and quality circles are positively correlated to waste eduction. The model is as follows, $WR = 7.226 - 0.056L_1 + 0.121L_2 + 0.039L_3 - 0.011L_4 - 0.180L_5 + 0.023L_6 - 0.092L_7 - 0.370L_8 + 0.103L_9 - 0.415L_{10} - 0.581L_{11} - 0.232L_{12}$

Thus, research and experiences with lean may encourage organizations to adopt lean for the purposes of cost reduction, lead time improvement and environmental waste reduction. Therefore consistent with prior research, this research hypothesizes:

H_1a. Cost reduction is positively associated with the adoption of lean practices

H_1b. Lead time reduction is positively associated with the adoption of lean practices

H_1c. Environmental waste reduction is positively associated with lean adoption

3.2. Agility

Lin et al. (2006) believe that agile enterprises, in general, have the capability of ensuring lower manufacturing costs, expanding market share, meeting the demands of customer, enabling the speedy introduction of new products, and reducing/eliminating non-value adding activities (as in lean production) and increasing firm competitiveness. Thus, the agile enterprise is seen as the winning strategy in the 21 st century as it helps equip companies to become market leaders in a highly competitive market with volatile customer requirements.

3.2.1. Cost reduction

Yusuf et al. (2004) believe that the agile supply chain impacts on cost leadership. The cost of agility may be associated with actions like purchasing flexible machines, effective information systems for real-time capture/sharing of information, enhancing capacity to tackle sudden demand (demand flexibility), extra employees to appropriately manage extra production volumes and reduced time of production, the selection, development and nurture of trustworthy suppliers to provide supply flexibility, the development of capacity for quicker production in terms of more fleet and the upgrade of technology (Ravet, 2011).

In order to bring products to the market quickly and cost-effectively, it is necessary to apply all existing resources notwithstanding their location and work together internally and with other companies (Sherehiy et al., 2007). Pasutham (2012) echoed the same tune, stating that operating costs can be reduced through the adoption of new information technology that enhances internal communication. According to van Hoek et al. (2001), operational cost savings can also be achieved through strategic postponement. von Lanzenauer and Pilz-Glombik (2002) argue that rapid information flows and the assurance of error-free and timely data helps achieve cost reductions and sustained competitive advantages.

3.2.2. Lead time reduction

Nakamura et al. (1998) and Singh et al. (2013) believe that excessively large lot sizes contribute to long lead times. It then follows that adopting the agility practice small batch sizes would help reduce lead time.

Aitken et al. (2002) state that several designers co-operate and simultaneosly work on the same project hence increasing the intellectual ability of the team and compressing lead times. The capacity to link and take full advantage of the tacit knowledge of designers and suppliers helps improve competitive advantage. By extension, research and development for new product development, supplier partnership and internal communication could be a catalyst for cutting lead times.

3.2.3. Waste reduction

Young et al. (1997) believe that there are considerable opportunities to cut down on waste, through innovations in product design and manufacturing processes, which will also lead to considerable cost savings and enhanced competitiveness. Hence it can be said that research and development for new products could lead to the waste reduction which in turn will lead to improved competitiveness.

It is expected that the adoption of agility practices improves business competitiveness through improving costs of production, lead time compression and environmental waste reduction. The set of hypotheses are:

H_1d. Cost reduction is positively associated with the adoption of agility practices

H_1e. Lead time reduction is positively associated with the adoption of agility practices

H_1f. Environmental waste reduction is positively associated with the adoption of agile practices

3.3. Green

The study of the relationship between green supply chain management practices and organisational performance is one of the most popular subjects of research (Zhan et al., 2018; Min and Kim, 2012 in Wang and Sarkis, 2013). Green supply chain management according to Wang and Sarkis (2013) represents a firm's effort on reducing irresponsible environmental behaviour. Environmental waste refers to the unnecessary use of resources (Hallam and Contreras, 2016).

3.3.1. Cost reduction

Most organizations express the business value of green adoption programs in terms of reducing cost through reduced energy and material utilization and reputation protection through voluntary commitments on greenhouse gas emissions, energy, labour, water, waste, renewable materials, poisonous substances, ecosystems and habitats, and several other issues (PricewaterhouseCoopers, 2010). Also, by consuming and disposing of less material, the cost associated with waste handling is reduced.

Green manufacturing also helps to achieve efficiency in production (i.e. use of less energy and water usage), lower the raw material costs (i.e. recycling waste instead of buying virgin materials), reduce environmental and work-related safety expenses (i.e. lower the cost of complying to regulations costs and potential liabilities), and improves the overall standing of the business (Ghazilla et al., 2015). Koechlin and Müller (1992) state that,

> '…contrary to a common misconception, environmental management keeps costs down rather than jacking them up.'

3.3.2. Lead time reduction

Nageswara Posinasetto (2014) posits that the link between green manufacturing and lead time have not been clearly established. However, he does not believe that the pursuit of green is contrary to a firm's interests regarding lead time. Furthermore, apart from the environmental benefits of green manufacturing, Fischer et al. (2016) believe that product quality and production lead time also improve with adoption of green manufacturing.

3.3.3. Waste reduction

Sanchez Rodrigues and Kumar (2019) advocate that by adoptiong Leand and Green, multiple improvements can be achieved simultaneously, suggesting that lean could lead to environmental benefits. Dieste et al. (2019a) found that environmental performance is improved by adopting the lean practices such as just-in-time and total quality management. Other published research also affirms that to achieve operational improvement and environmental performance, Lean and Green complement each other (Farias et al., 2019) and that these two concepts have synergy (Jakhar et al., 2018). According to Rehman and Shrivastava (2012), the unscientific management of waste material generated by commercial and industrial activities could lead to serious environmental concerns, therefore, immediate appropriate disposal arrangement is required. To achieve overall green disposal, there ought to be end-of-life (EOL) treatment (recycling), collection of equipment, use of biodegradable materials, also, packaging materials and their disposal ought to be environmentally friendly. For better housekeeping, Sroufe (2003) cited in Rehman and Shrivastava (2012) advocates various activities including segregation of waste. Employee training is one of the suggested improvements aimed at reducing waste and maintaining competitive advantage (Amani et al., 2015; Uhrin et al., 2017).

In general, green practices ultimately caters for the minimisation of environmental impact (Mangla et al., 2015) by the reduction of toxics, waste, pollution, the optimisation of the use of raw material and energy by the application of end-of-life, cradle to cradle and close loop approach (Pandey et al., 2018; Rehman and Shrivastava, 2012). Therefore, this research hypothesizes:

H_1g. Cost reduction is positively associated with the adoption of green practices

H_1h. Lead time reduction is positively associated with the adoption of green practices

H_1i. Environmental waste reduction is positively associated with the adoption of green practices

3.4. Product life cycle (PLC)

PLC is used to describe the behaviour of the product from development to its end-of-life or retirement in order to maximise the value of and the chances for improved profit in each stage of the cycle (Ryan and Riggs, 1996). While the product is in the market, these phases include introduction, growth, maturity and decline. The importance of the PLC is embedded in the fact that it points to market opportunities and threats that may have tactical implications. The PLC is a versatile structure for developing contingent hypotheses about appropriate strategy options (Hofer 1975 cited in Day, 1981) and guiding management toward the expectation of the outcomes of the core dynamics of the market being served.

Knowledge of the life cycle stage of each product will enable organizations to make decisions and employ different methods and strategies towards optimising performance (Aitken et al., 2002; Pham and Thomas, 2012). With this knowledge, a company is equipped with the capability to be competitive during all stages of the PLC. Due to the cumbersome nature that the tests of hypothesis could take for LAG in four different PLC stages, this research focuses on the introduction stage of the PLC and hypothesizes:

H_2a. Competitiveness is positively associated with lean adoption in the introduction stage of the PLC.

H_2b. Competitiveness is positively associated with lean adoption in the growth stage of the PLC

H_2c. Competitiveness is positively associated with lean adoption in the maturity stage of the PLC

H_2d. Competitiveness is positively associated with lean adoption in the decline stage of the PLC

4. Research methodology

This study adopts secondary data from Udokporo (2017). The data

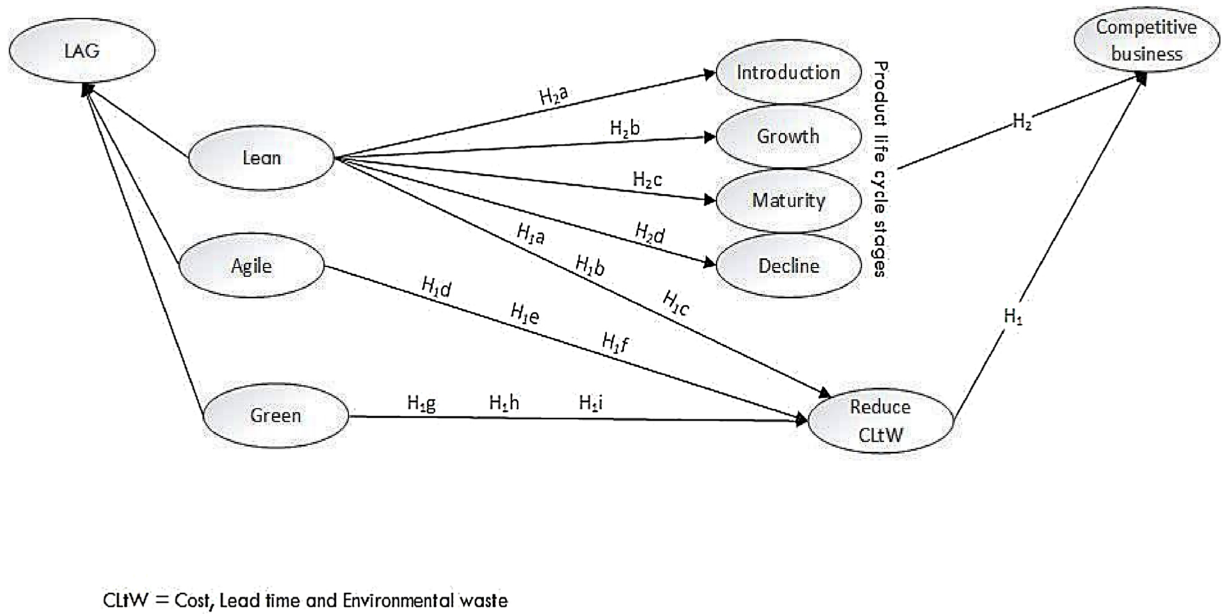

Fig. 2. Theoretical Model.

was gathered through a survey of 96 operations managers of FMCG companies in the United Kingdom. A 7-point Likert scale questionnaire was used to elicit information based on product life cycle stage about the contribution of the LAG practices on cost reduction, lead time reduction and waste reduction.

4.1. Structural model path diagram

The structural model depicted in Fig. 2 presents the formulated hypotheses. Prior to proceeding with the analysis of the structural model, it is essential to comprehend the structural path diagram. Structural equation modelling shows the graphical illustration of its mathematical representation, connecting the dependent variables to their corresponding explanatory variables within a set of equations.

A review of Fig. 1 shows that there are seven endogenous variables (4 PLC stages and 3 performance measure-cost, lead-time, waste) and three exogenous variables (LAG). Arrows originating from the exogenous variables are used to show structural regression coefficient, they indicate the effect of one (exogenous) variable on another at a given PLC stage (H_2a, H_2b, H_2c, H_2d) and on the performance measure (H_1a, H_1b, H_1c, H_1d, H_1e, H_1f, H_1g, H_1h, H_1i) as shown in Fig. 1, the arrows suggest that the variables are effected by their corresponding underlying factors. As such the path coefficients signify the magnitude of the expected change in the observed variables for every change in the corresponding dependent variable.

4.2. Structural model results

Fig. 3 shows the structural model with parameter estimates. The fit indices determines whether the model is acceptable or not. If the model is acceptable, the significance of the paths (or lack of it) is confirmed and established. Some of the rules for acceptance of a model are as follows:

- The upper confidence level of the root mean square error of approximation (RMSEA) should not exceed 0.08 (Hu and Bentler, 1998). Browne and Cudeck (1992) and Fullerton et al. (2003) believe that RMSEA should be less than 0.08. Steiger (1990) proposes that RMSEA for an acceptable model is ideally less than 0.05 while Tal-Saban et al. (2018) adopts a figure less than 0.06.
- The Goodness-of-Fit-Index (GFI) should be more than 0.90 (Byrne, 1994). The GFI is the sum of the squares of the differences between the observed and expected outcome frequencies, divided by the expectation.

Although many researchers disagree on what constitutes adequate validity for the acceptance of a model, Byrne (2001) believe that the RMSEA (the square of the residuals) is one of the most informative criteria in assessing a model fit. Hence, this research reports two types of fit indexes, the RMSEA (0.375) and the GFI (0.959). The RMSEA figure reported exceeds the threshold of 0.08, however, this could be explained by the table, showing that only the introduction stage is significant at $p < 0.05$, the other life cycle stages are not significant.

Cost reduction is positively associated with the adoption of lean practices (H1a): The null hypothesis $H0 : \beta = 0$, and the alternative hypothesis is $Ha : \beta \neq 0$, and the significance level is 5 %. The estimated coefficient of $\beta = 0.43$ ($t = 0.35$ $p > 0.05$) between lean adoption and cost reduction supports H_1a. The finding is consistent with earlier literature (Mackelprang and Nair, 2010; Kumar et al., 2013). As organisations adopt lean practices, the expectation is that production costs are reduced. Achieving production at a reduced cost is a competitive strategy (Farahani et al., 2013) and lean is certainly of ways to deliver cost reduction as supported by the hypothesis.

Lead time reduction is positively associated with the adoption of lean practices (H1b): The estimated coefficient of $\beta = -0.29$ ($t = -0.27$, $p > 0.05$) for the relationship between lean adoption and lead time reduction is significant at 5 % level of significance, as p-value = $0.92 > 0.05$. The β value suggests that the effect of lean on lead time is not significantly different from 0. There is a positive relationship between lean and lead time. The application of lean heralds the reduction of lead times as observed by McAleer and Humphreys (1997); de Treville et al. (2004); Sharma et al. (2015) and McLean (2017).

Environmental waste reduction is positively associated with the adoption of lean practices (H1c): Similarly, the estimated coefficient of $\beta = 7.22$ ($t = 4.53$, $p > 0.05$) for the relationship between lean and environmental waste reduction is significant, indicating support for H_1c. The support for the positive relationship between lean and environmental waste reduction is highlighted through the similarities between lean and green. Both paradigms share a common objective-waste elimination, though waste is defined differently by both paradigms and their waste reduction objectives also differ, they target the same type of wastes. For example, by-products produced as a result of production activity or scrap is waste according to both lean and green (Dues et al., 2012). Scrap which would otherwise go to the landfill is, in fact, environmental waste. Hence the adoption of lean is expected to reduce environmental waste. Expanding lean theory to consider environmental wastes may lead to the discovery of new uses for lean practices and tools (Hallam and Contreras, 2016).

Agile practices on cost reduction (H_1d): According to (Ravet, 2011), the cost of agility may be associated with actions and outcomes such as buying flexible machines, efficient information systems for real-time capture/sharing of information, improving capacity to tackle sudden demand changes (demand flexibility), extra employees to properly manage increased production volumes and reduced time of production, the development of capacity for quicker production in terms of larger fleet and the upgrade of technology.

The estimated coefficient of $\beta = 1.19$ ($t = 1.81$, $p > 0.05$) as shown in Table 1 for the relationship between the adoption of agile practices and cost reduction is significant, indicating support for H_1d. This finding is consistent with Sharp et al. (1999) and Lacerda and Furtado (2018) and Saeed et al. (2019)'s findings that agile approaches to manufacturing helps companies and institutions reduce costs, achieve greater engineering discipline. The adoption of agile manufacturing practices means facing the reality that customers must be served with small quantities of bespoke products of impeccable quality, delivered on-time, and at very low cost (Sharp et al., 1999).

Agile practices on lead time reduction (H_1e): The estimated coefficient of $\beta = 4.36$ ($t = 5.26$, $p < 0.05$) for the relationship between agile practices and lead time reduction is significant indicating support for H_1e. An agile enterprise is characterised as a fast and efficient learning organisation. Aitken et al. (2002) believe that the ability to enhance cooperation among staff members and exploit the tacit knowledge of employees in an enterprise would increase intellectual capacity and support the compression of lead times.

Agile practices on environmental waste reduction (H_1f): The estimated coefficient of $\beta = 5.82$ ($t = 6.69$, $p > 0.05$) for the relationship between agile practices and waste reduction is not significant. The p-value of 0.001 indicates that H_1f is not supported. Hence adopting agile practices for environmental waste reduction would be less than appropriate.

Cost reduction is positively associated with the adoption of green practices (H_1g): The estimated coefficient of $\beta = 3.40$ ($t = 3.92$, $p > 0.05$) supports H_1f that the adoption of green practises has a positive influence on cost reduction. This is consistent with earlier literature ((Koechlin and Müller, 1992); Fischer et al., 2016). The adoption of green practices may lead to a reduction in costs which benefits customers in the form of reduced product costs. For example, by consuming and disposing of less material, the need/cost of handling, treating and disposing of environmental waste is reduced. The waste reduction could take but is not limited to the following forms:

- Buying durable long-lasting materials
- Using products free of hazardous materials
- Using less packaging
- Implementing in-process recycling
- Water/energy conservation

Lead time reduction is positively associated with the adoption of green practices (H_ih): The estimated coefficient of $\beta = 2.14$ ($t = 2.39$, $p < 0.05$) for the relationship between green practices adoption and lead time reduction is not significant. The p-value of 0.00 indicates that H_1h is not supported. Hence adopting green practices for lead time reduction may be counterproductive. The main focus of green according to Rehman and Shrivastava (2012) is to reduce environmental

Table 1
Research hypotheses and test results.

	β	t-value	P-value
Cost reduction			
Lean	0.43	0.35	0.28
Agile	1.19	1.81	0.66
Green	3.40	3.92	0.63
Lead time reduction			
Lean	−0.29	−0.27	0.92
Agile	4.36	5.26	0.11
Green	2.14	2.39	0.00
Environmental waste reduction			
Lean	7.22	4.53	0.17
Agile	5.82	6.69	0.001
Green	3.24	3.18	0.06

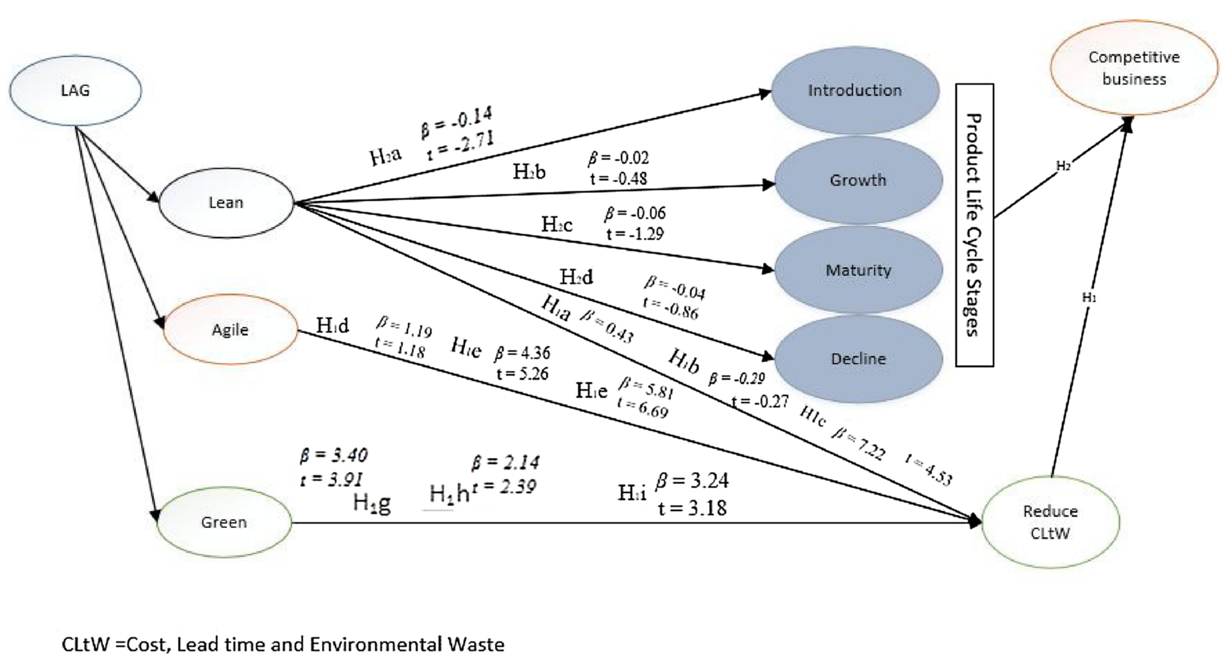

Fig. 3. Structural Model results.

Table 2
Hypothesis test results for lean adoption in PLC stages.

Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	8.60967	4.19205	2.05	0.0741
Introduction	1	−0.13608	0.05029	−2.71	0.0268
Growth	1	−0.02008	0.04207	−0.48	0.6459
Maturity	1	−0.05572	0.04319	−1.29	0.2330
Decline	1	−0.03998	0.04650	−0.86	0.4150

waste and pollution, lower the amount of waste that goes to landfill and so on.

Environmental waste reduction is positively associated with the adoption of green (H_1i): The estimated coefficient of $\beta = 3.24$ ($t = 3.18$, $p > 0.05$) is significant, indicating support for H_1i that the adoption of green practises has a positive effect on environmental waste reduction. This is consistent with earlier literature (Rehman and Shrivastava, 2012; Yacob et al., 2018).

Competitiveness with lean adoption in PLC stages (*H2a, H2b, H2c and H2d*): The hypotheses for lean adoption in PLC stages are tested in the same fashion as the previous hypotheses, which is that the true but unknown slope of the relationship between lean and PLC stages equals 0, the null hypothesis $H_0 : \beta = 0$. As a natural extension, the alternative hypothesis is H_a: $\beta \neq 0$. For H_2a, the estimated coefficient $\beta = -0.14$ *(The test statistic t:* $(\hat{\beta}_1-0)/SE(\hat{\beta}_1) = (-0.13608-0)/\ 0.05029 = -2.71$, $p < 0.05$*)* indicates that there is not enough evidence to conclude that the effect of lean on competitiveness in the introduction stage is significantly different from 0. Therefore, H_0 is rejected (Table 2).

However, the estimated coefficients for the H_2b, H_2c and H_2d and their corresponding p-values ($p >$ 0.05) as shown in Table 2 indicate that lean adoption supports competitiveness in the growth, maturity and decline stages of the PLC. The tests of hypotheses indicate different outcomes for lean at the different PLC stages. However, the omnibus F-test shown in Table 3 indicates that, overall, PLC stages have a significant effect on lean practices (p-value < 0.0001).

5. Discussion and conclusion

Rapidly growing competition and changes in customer needs place an immense pressure on the FMCG industry to develop business competitiveness and stay ahead of the game in the global market. LAG practices are believed to be major contributors to gain competitive business practices and their successful adoption is a key element leading to competitive advantage. The importance of developing competitive advantage cannot be overstated. It is believed that achieving a high competitive advantage positively affects financial performance and improves firm value (Wijayanto et al., 2019).

This study has evaluated the impact of LAG practices on performance indicators of cost, lead time and environmental waste by using a structural equation modelling approach. For this purpose, 13 hypotheses were developed and a structural model was developed to analyse the effect of LAG on cost reduction, lead time improvement and environmental waste reduction. Results of the structural equation modelling analysis showed that the overall model fit the data well and specifically support all of the study hypotheses except one.

Appropriate adoption of lean practices within the FMCG sector has led to improved competitiveness as indicated through the hypotheses on lean adoption. The adoption of lean heralds the reduction of lead times, costs and environmental wastes. This particularly supports the theoretical literature purporting that lean adoption is linked with improvements in measures for operational performance, labour productivity, cycle time reduction, manufacturing costs and customer lead time.

The hypotheses on agile practices adoption are supported for cost reduction and lead time reduction but not for environmental waste reduction. The lack of support might stem from the main focus of agility, which is on cost-effective and rapid satisfaction of customer demand. This means that the delivery of products to customers might involve the use methods that don't encourage environmental responsibility. For example, the use of some of the fastest means of transport such as air crafts which increases the carbon footprints. Therefore, from an organisational and production perspective, agile practices' best outcomes could be achieved when implemented as part of a broader competitive and operational strategy.

On green adoption, the hypotheses are supported except for the adoption of green for lead time reduction. However, green must not be seen as completely antithetical to lead time reduction as Fischer et al. (2016) believes that green adoption has a positive effect on lead time. It is worth mentioning that green strategies, in general, are capable of employing low cost or hybrid tactics for competitive advantage (Walsh and Dodds, 2017).

The hypotheses for PLC stages showed mixed but inconclusive results as the test was only conducted on lean adoption in the four PLC stages. However, this result is not surprising as products have different market characteristics while they go through their PLC stages and therefore would require different strategies to deal with/manage such products in specific PLC stages. Sometimes such strategies may be lean, agile, green or some combination of the three.

5.1. Managerial and theoretical implications

This research provides a comprehensive and enhanced understanding, for the organisations and their respective managers, of the effect of LAG practices on performance parameters - cost, lead time and environmental waste. The study can be adapted by managers to analyse their business practices while adopting Lean, Agile, and Green practices either as stand-alone or collectively, depending on what practices they currently have adopted. At the same time utilising the analytical aspects of the study would better equip the managers to gain in-depth insights that will help them make more informed and effective decisions while formulating their strategy to be more competitive.

Regarding the theoretical value, this research complements earlier research developed in this field by considering the stages of PLC in analysing the influence of LAG on performance parameters. Previous research such as those of Espadinha-Cruz et al. (2011) and Hasanian and Hojjati (2016) considered the exploration of LAG without the inclusion of PLC stages. Although they had gone further by considering the "resilient" paradigm, however, the inclusion of PLC was ignored which the authors believe are important factors to incorporate. By considering the PLC stages – Introduction, Growth, Maturity and Decline, this research provides knowledge which was previously scantily explored or unavailable for the most part. This research also encourages managers to develop a portfolio of what management strategies are suitable and under what circumstances.

5.2. Limitations and future research directions

While the objectives of this research were successfully accomplished, it is not free of limitations like other researches of similar nature. There is potentially the possibility of regional bias as this

Table 3
ANOVA for lean adoption in PLC stages.

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	26.10581	6.52645	46.41	< .0001
Error	8	1.12496	0.14062		
Corrected Total	12	27.23077			

research mainly focused on respondents from small to large scale FMCG industries who may not be actively engaged within the FMCG industry. The generalisations made in this research are based on the professional experience of such respondents as much as they can recall. Therefore, there may be a risk of error in the information provided and consequently the generalisations made. Future research can overcome this limitation and further validate this study by including large and diverse sample size. This would reduce the probability of the margin of error and make the results and their generalisations more accurate.

Common method biases occur when there are variations in responses caused by the survey instrument, which in this case is the questionnaire survey, rather than the actual proclivities of the respondents. It is possible for this kind of bias to occur in any given research, this research not being an exception. Maximum effort has been made to avoid such bias. It is recommended that careful evaluation of the conditions under which the data are obtained, to be made in order to assess the extent to which common method bias may be a problem. This can be accomplished by implementing statistical control methods.

Since the scope of this research was kept limited to evaluate the impact of Lean, Agile and Green practices only. However, the resilience factor has a strong impact on the competitiveness of the businesses. Future research is encouraged to incorporate the reliance aspect along with Lean, Agile and Green. Moreover, the developed hypothesis only included lean adoption aspect on PLC and not the Agile and Green adoption. Further research is highly encouraged to further expand the scope of this research.

References

Aitken, J., Christopher, M., Towill, D., 2002. Understanding, implementing and exploiting agility and leanness. Int. J. Logist. 5, 59–74.
Al Serhan, Y.N., Julian, C.C., Ahmed, Z.U., 2015. Using time to gain competitive advantage: a framework and analysis of propositions. Int. J. Commer. Manag. 25, 456–465.
Aljunaidi, A., Ankrah, S., 2014. The application of lean principles in the fast moving consumer goods (FMCG) industry. J. Oper. Supply Chain. Manag. 7, 1.
Amani, P., Lindbom, I., Sundström, B., Östergren, K., 2015. Green-lean synergy - root-cause analysis in food waste prevention. Int. J. Food Syst. Dynam. 6, 99–109.
Ashutosh, T., Chris, T., Peter, S., 2007. A framework for implementing cost and quality practices within manufacturing. J. Manuf. Technol. Manag. 18, 731–760.
Begum, S., Akbar, D., Rasul, M.G., 2012. Identification of an Appropriate Alternative Waste Technology for Energy Recovery from Waste Through Multi-Criteria Analysis. 6. .
Breznitz, D., Cowhey, P., 2012. America's two systems of innovation: innovation for production in fostering U.S. Growth. Innov. Technol. Gov. Glob. 7, 127–154.
Browne, M.W., Cudeck, R., 1992. Alternative ways of assessing model fit. Sociol. Methods Res. 21, 230–258.
Byrne, B.M., 1994. Structural Equation Modeling With EQS and EQS-Windows: Basic Concepts, Applications, and Programming. Sage Publications, Inc., Thousand Oaks, CA, USA.
Byrne, B.M., 2001. Structural Equation Modeling With AMOS: Basic Concepts, Applications, and Programming, 1st Ed. .
Cabral, I., Grilo, A., Cruz-Machado, V., 2012. A decision-making model for lean, Agile, Resilient and Green supply chain management. Int. J. Prod. Res. 50, 4830–4845.
Casadesus-Masanell, R., Ricart, J.E., 2010. Competitiveness: business model reconfiguration for innovation and internationalization. Manag. Res. 8, 123–149.
Collins, J., 2013. Strategy and Competitive Advantage.
de Treville, S., Shapiro, R.D., Hameri, A.-P., 2004. From supply chain to demand chain: the role of lead time reduction in improving demand chain performance. J. Oper. Manag. 21, 613–627.
Dieste, M., Panizzolo, R., Garza-Reyes, J.A., 2019a. Evaluating the impact of lean practices on environmental performance: evidences from five manufacturing companies. Prod. Plan. Control. 1–18 0.
Dieste, M., Panizzolo, R., Garza-Reyes, J.A., Anosike, A., 2019b. The relationship between lean and environmental performance: practices and measures. J. Clean. Prod. 224, 120–131.
Depart for Environment Food and Rural Affairs, 2015. Digest of Waste and Resource Statistics – 2015 Edition. England.
Dues, C., Tan, K., Lim, M., 2012. Green as the new lean: how to use lean practices as a catalyst to greening your supply chain. J. Clean. Prod. 40, 93–100.
EfW, 2015. landfill,RDF [WWW Document]. letsrecycle.com. URL http://www.letsrecycle.com/prices/efw-landfill-rdf-2/ (Accessed 5 May 2016).
Esan, E.O., 1994. An Introduction to Sampling Theory and Practice. JAS Publishers, Lagos.
Espadinha-Cruz, P., Grilo, A., Puga-Leal, R., Cruz-Machado, V., 2011. A model for evaluating lean, agile, resilient and Green practices interoperability in supply chains. In: 2011 IEEE International Conference on Industrial Engineering and Engineering Management. Presented at the 2011 IEEE International Conference on Industrial Engineering and Engineering Management. pp. 1209–1213.
Eyong, M., 2009. Creating A Competitive Supply Chain: Evaluating The Impact Of Lean & Agile Supply Chain.
Farahani, P., Akkerman, R., Wilke, J., 2013. A hierarchical demand-driven production planning and control framework for the FMCG industry: an SAP-based approach. 2013 IEEE International Conference on Industrial Engineering and Engineering Management. Presented at the 2013 IEEE International Conference on Industrial Engineering and Engineering Management 991–995.
Farias, L.M.S., et al., 2019. An ANP-based approach for lean and green performance assessment. Resour. Conserv. Recycl. 143, 77–89.
Fischer, X., Daidie, A., Eynard, B., Paredes, M., 2016. Research in Interactive Design (Vol. 4): Mechanics, Design Engineering and Advanced Manufacturing. Springer.
Found, P., Rich, N., 2007. The meaning of lean: cross case perceptions of packaging businesses in the UK's fast moving consumer goods sector. Int. J. Logist. 10, 157–171.
Fouskas, K.G., Giaglis, G.M., 2011. The impact of managerial perceptions on competitive response variety. Manage. Decis. 49, 1257–1275.
Fullerton, R.R., McWatters, C.S., Fawson, C., 2003. An examination of the relationships between JIT and financial performance. J. Oper. Manag. 21, 383–404.
Garza-Reyes, J.A., Salomé Valls, A., Nadeem, S.P., Anosike, A., Kumar, V., 2018. A circularity measurement toolkit for manufacturing SMEs. Int. J. Prod. Res p. In press.
Gecevska, V., Stefanic, N., Veza, I., Cus, F., 2012. Sustainable business solutions through lean product lifecycle management. Acta Technica Corvininesis - Bull. Eng. 5, 135–142.
Ghazilla, R.A.R., Sakundarini, N., Abdul-Rashid, S.H., Ayub, N.S., Olugu, E.U., Musa, S.N., 2015. Drivers and barriers analysis for green manufacturing practices in malaysian SMEs: a preliminary findings. Proc. CIRP 26, 658–663.
Gólcher-Barguil, L.A., Nadeem, S.P., Garza-Reyes, J.A., 2019. Measuring Operational Excellence: An Operational Excellence Profitability (OEP) Approach. Production Planning and Control, Taylor & Francis p. In press.
Hallam, C., Contreras, C., 2016. Integrating lean and green management. Manage. Decis. 54, 2157–2187.
Hasanian, S., Hojjati, S.M.H., 2016. A framework for supplier selection criteria in "LARG" supply chain based on a literature review. Int. J. Manag. Account. Econo. 3, 502–519.
Hu, L., Bentler, P.M., 1998. Fit indices in covariance structure modeling: sensitivity to underparameterized model misspecification. Psychol. Methods 3, 424–453.
Inman, R.A., Sale, R.S., Green Jr., K.W., Whitten, D., 2011. Agile manufacturing: relation to JIT, operational performance and firm performance. J. Oper. Manag. 29, 343–355.
Jakhar, S.K., Rathore, H., Mangla, S.K., 2018. Is lean synergistic with sustainable supply chain? An empirical investigation from emerging economy'. Resour. Conserv. Recycl. 139, 262–269.
Johnson, J., 2004. Flexible working: changing the manager's role. Manage. Decis. 42, 721–737.
Koechlin, D., Müller, K., 1992. Green Business Opportunities: The Profit Potential. Financial Times/Pitman Pub.
Kumar, N., Kumar, S., Haleem, A., Gahlot, P., 2013. Implementing lean manufacturing system: ISM approach. J. Ind. Eng. Manag. 6, 996.
Lacerda, L.L., Furtado, F., 2018. . Factors that help in the implantation of agile methods: a systematic mapping of the liteature. 2018 13th Iberian Conference on Information Systems and Technologies (CISTI). Presented at the 2018 13th Iberian Conference on Information Systems and Technologies (CISTI) 1–6.
Lederer, P.J., 2008. Lead Time Performance Measurement.
Liebesman, S., 2009. Dynamic Duo: lean and six Sigma improve profits and customer satisfaction. Quality Progress. pp. 56–58 42.
Lin, C.-T., Chiu, H., Tseng, Y.-H., 2006. Agility evaluation using fuzzy logic. Int. J. Prod. Econ. 101, 353–368.
Luna, E.F.G., Aguilar Saven, R.S., 2004. Manufacturing Strategy Linked to Product Life Cycle.
Mackelprang, A.W., Nair, A., 2010. Relationship between just-in-time manufacturing practices and performance: a meta-analytic investigation. J. Oper. Manag. 28, 283–302.
Madu, C., Kuei, C., Madu, I., 2002. A hierarchic metric approach for integration of green issues in manufacturing: a paper recycling application. J. Environ. Manage. 64, 261–272.
Maheshwari, B., Jagoda, K., Lonseth, R., 2010. Key issues in managing technology transfer projects: experiences from a Canadian SME. Manage. Decis. 48, 366–382.
Mangla, S.K., Kumar, P., Barua, M.K., 2015. Risk analysis in green supply chain using fuzzy AHP approach: a case study. Resour. Conserv. Recycl. 104 (B), 375–390.
Mariano, T., 2015. Cut costs: improve competitive advantage. ECS J. Solid State Sci. Technol. 28.
McAleer, E., Humphreys, P., 1997. Cellular management: a framework for the support services? Manage. Decis. 35, 464–473.
McLean, T., 2017. Reduce Lead Time in your Global Supply Chain with lean thinking: long lead times are the cause of many of the problems that plague supply chains. Material Handling & Logistics. pp. 16–18 72.
Mirdad, W.K., Eseonu, C., 2014. A Conceptual and Strategy Map for Lean Process Transformation. Industrial and Systems Engineering Research Conference.
Modi, B.D., Thakkar, H., 2014. Lean thinking: reduction of waste, lead time, cost through lean manufacturing tools and technique. Int. J. Emerg. Technol. Adv. Eng. 4.
Mollenkopf, D., Stolze, H., Tate, W.L., Ueltschy, M., 2010. Green, lean, and global supply chains. Int. J. Phys. Distrib. Logist. Manag. 40, 14–41.
Movahedipour, M., Zeng, J., Yang, M., Wu, X., 2017. An ISM approach for the barrier analysis in implementing sustainable supply chain management: an empirical study. Manage. Decis. 55, 1824–1850.
Muehlhausen, J., 2012. Does Cost Cutting Create Competitive Advantage?.
Nadeem, S.P., Garza-Reyes, J.A., Leung, S.-C., Cherrafi, A., Anosike, A.I., Lim, M.K., 2017.

Lean manufacturing and environmental performance – exploring the impact and relationship. In: Lödding, H., Riedel, R., Thoben, K.-D., von Cieminski, G., Kiritsis, D. (Eds.), Advances in Production Management Systems. The Path to Intelligent, Collaborative and Sustainable Manufacturing, IFIP Advances in Information and Communication Technology. Springer International Publishing, Cham, pp. 331–340.
Nadeem, S.P., Arturo Garza-Reyes, J., Anosike, A.I., Kumar, V., 2019. Coalescing the lean and circular economy. In: Proceedings of the International Conference on Industrial Engineering and Operations Management Bangkok, Thailand. March 5-7, 2019, IEOM Society, Bangkok, Thailand. pp. 1082–1093.
Nakamura, M., Sakakibara, S., Schroeder, R., 1998. Adoption of just-in-time manufacturing methods at U.S.- and Japanese-owned plants: some empirical evidence. IEEE Trans. Eng. Manag. 230.
Oraman, Y., Azabagaoglu, M.O., Inan, I.H., 2011. The firms' survival and competition through global expansion: a case study from food industry in FMCG Sector. Procedia - social and behavioral sciences. The Proceedings of 7th International Strategic Management Conference 188–197 24.
Pakdil, F., Leonard, K.M., 2014. Criteria for a lean organisation: development of a lean assessment tool. Int. J. Prod. Res. 52, 4587–4607.
Pan, J.C.-H., Yang, J.-S., 2002. A study of an integrated inventory with controllable lead time. Int. J. Prod. Res. 40, 1263–1273.
Pandey, R.U., Surjan, A., Kapshe, M., 2018. Exploring linkages between sustainable consumption and prevailing green practices in reuse and recycling of household waste: case of Bhopal city in India. J. Clean. Prod. 173, 49–59.
Pasutham, A., 2012. Supply Chain Performance Measurement Framework. Aston University.
Pham, D.T., Thomas, A.J., 2012. Fit manufacturing: a framework for sustainability. J. Manuf. Technol. Manag. 23, 103–123.
Ploy, S., Yang, L., Jie, F., 2011. Impact of Agile Manufacturing on Thailand Automotive Performance and Competitive Advantage.
Porter, M.E., 1985. Strategy and Competitive Advantage.
Ravet, D., 2011. Lean Production and Agile Organisation: The Link Between Supply Chain and Sustainable Development.
Rehman, M.A.A., Shrivastava, R., 2012. Green manufacturing (GM): past, present and future (a state of art review). World Rev. Sci. Technol. Sustain. Dev. 10, 17–55.
Ryan, C., Riggs, W.E., 1996. Redefining the product life cycle: the five-element product wave. Bus. Horiz. 39, 33.
Saeed, K.A., Malhotra, M.K., Abdinnour, S., 2019. How supply chain architecture and product architecture impact firm performance: an empirical examination. J. Purch. Supply Manag. 25, 40–52.
Salam, M.A., Khan, S.A., 2018. Achieving supply chain excellence through supplier management: a case study of fast moving consumer goods. Benchmarking 25, 4084–4102.
Sanchez, L.M., Nagi, R., 2001. A review of agile manufacturing systems. Int. J. Prod. Res. 39, 3561–3600.
Sanchez Rodrigues, V., Kumar, M., 2019. Synergies and misalignments in lean and green practices: a logistics industry perspective. Prod. Plan. Control. 30, 369–384.
Shah, R., Ward, P.T., 2003. Lean manufacturing: context, practice bundles, and performance. J. Oper. Manag. 21, 129–149.
Sharma, N., 2013. Marketing strategy on different stages PLC and its marketing implications on FMCG products. Int. J. Market. Financ. Serv. Manag. Res. 2, 121–136.
Sharma, V., Dixit, A.R., Qadri, M.A., 2015. Impact of lean practices on performance measures in context to Indian machine tool industry. J. Enterp. Inf. Manag. 1218–1242.
Sharp, J.M., Irani, Z., Desai, S., 1999. Working towards agile manufacturing in the UK industry. Int. J. Prod. Econ. 62, 155–169.
Sherehiy, B., Karwowski, W., Layer, J., 2007. A review of enterprise agility: concepts, frameworks, and attributes. Int. J. Ind. Ergon. 37, 445–460.
Singh, R.J., Sohani, N., Marmat, H., 2013. Effect of Lean/JIT practices and supply chain integration on lead time performance. J. Supply Chain. Manag. Syst. 2, 37.
Sroufe, R., 2003. Effects of environmental management systems on environmental management practices and operations. Prod. Oper. Manag. 12, 416–431.
Steiger, J.H., 1990. Structural model evaluation and modification: an interval estimation approach. Multivariate Behav. Res. 25, 173–180.
Tal-Saban, M., Ornoy, A., Parush, S., 2018. Success in adults with probable developmental coordination disorder using structural equation modeling. Am. J. Occup. Ther. 72 7202205010p1-7202205010p8.
Tersine, R.J., Hummingbird, E.A., 1995. Lead-time reduction: the search for competitive advantage. Int Jrnl of Op & Prod Mnagemnt 15, 8–18.
Udokporo, 2017. An Integrated Decision Support Framework for the Adoption of Lean. Agile and Green Practices in Product Life Cycle Stages.
Uhrin, Á., Bruque-Cámara, S., Moyano-Fuentes, J., 2017. Lean production, workforce development and operational performance. Manage. Decis. 55, 103–118.
US EPA, O, 2015. Why Should You Care About Preventing Waste? Small Business Guide [WWW Document]. URL http://www.epa.gov/p2/why-should-you-care-about-preventing-waste-small-business-guide (Accessed 2 September 2016). .
van Hoek, R., Alan, H., Martin, C., 2001. Measuring agile capabilities in the supply chain. Int. J. Oper. Prod. Manage. 21, 126–147.
Vázquez-Bustelo, D., Avella, L., 2006. Agile manufacturing: industrial case studies in Spain. Technovation 26, 1147–1161.
Villarreal, B., Salido, L., 2009. Improving order lead time: a case study. Coll. Teach. Methods Styles J. 5.
von Lanzenauer, C., Pilz-Glombik, K., 2002. Coordinating supply chain decisions: an optimization model. n.d.. Spektrum 24, 59–78.
Walsh, P.R., Dodds, R., 2017. Measuring the choice of environmental sustainability strategies in creating a competitive advantage. Bus. Strategy Environ. 26, 672–687.
Wang, Z., Sarkis, J., 2013. Investigating the relationship of sustainable supply chain management with corporate financial performance. Int. J. Product. Perform. Manag. 62, 871–888.
Wijayanto, A., Suhadak, Dzulkirom, M., Nuzula, N., 2019. The effect of competitive advantage on financial performance and firm value: evidence from indonesian manufacturing companies. Russ. J. Agric. Socio-Econ. Sci. 85, 35–44.
Williamson, M., 2015. Cartones Ponderosa Strengthens Its Competitive Advantage. PPI Resource Directory.
Yacob, P., Wong, L.S., Khor, S.C., 2018. An empirical investigation of green initiatives and environmental sustainability for manufacturing SMEs. J. Manuf. Technol. Manag. 30, 2–25.
Yang, M.G., Hong, P.B., Modi, S., 2011. Impact of lean manufacturing and environmental management on business performance: an empirical study of manufacturing firms. Int. J. Prod. Econ. 129, 251–261.
Young, P., Byrne, G., Cunningham, M., 1997. Manufacturing and the environment. Int. Adv. Manuf. Technol. 13, 488–493.
Yusuf, Y.Y., Gunasekaran, A., Adeleye, E.O., Sivayoganathan, K., 2004. Agile supply chain capabilities: determinants of competitive objectives. Eur. J. Oper. Res. 159, 379–392.
Zhan, Y., et al., 2018. Green and lean sustainable development path in China: Guanxi, practices and performance. Resour. Conserv. Recycl. 128, 240–249 Elsevier B.V.