An empirical examination of lean production, agile production and supply chain collaboration on manufacturing sustainability in Saudi Arabia

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By

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Declaration

I declare that the ideas, results, analysis, findings and conclusions reported in this thesis are entirely my own efforts, except where otherwise acknowledged. I also declare that this work is original and has not been previously submitted for any degree award.

Abstract

The contemporary constantly changing environment is a significant challenge that affects all organisations including manufacturing firms while implementing concepts underpinning a drive for sustainability, with government regulations, customer demands and supplier issues impacting these firms. Literature on sustainability performance has suggested that the combined influence of lean manufacturing and agile manufacturing can help organisations to overcome those challenges, yet this relationship has received little empirical attention to date. Furthermore, the extant literature has suggested that supply chain collaboration (SCC) at the customer and supplier level can affect sustainability performance in general in firms including those that have adopted lean production or agile production or both. Likewise, however, little empirical attention has been applied to date. A major area of concern in this context is the importance of the implementation of economic, environmental and social sustainability factors in firms and the complications that could arise while doing so. This research thus examines the complex situation created in manufacturing firms that adopt lean production and agile production, and how SCC intervenes. The nature and extent of the combined influence of lean production and agile production on sustainability performance were investigated alongside the impact of SCC as an intervention. Lean production and agile production were conceived as independent variables in a single model influencing economic, environmental and social sustainability performance factors as individually distinct constracuts and directly. SCC was conceived as a moderating variable to ascertain the extent of its effect on the direct individual relationship posited between lean production and agile production respectively and the three sustainability performance factors respectively. The research was conducted in the Kingdom of Saudi Arabia. Medium and large enterprises were chosen for study. A survey instrument was developed and administered online. A total of 700 manufacturers were identified to whom the survey instrument was sent in the form of a weblink, and 181valid responses were received. Structural equation modelling was used to analyse the hypothesised relationships in the theoretical model. The findings revealed that lean production and agile production in combination cannot influence the individual sustainability performance factors in a single model. Lean production dominated and influenced the three sustainability performance factors positively while agile production only acted as the covariant when the two production methods were used in combination. However, both lean production and agile production were found to individually and independently influence the three sustainability factors. SCC not only moderated the relationship between lean production and economic sustainability performance factors positively but moderated all the three relationships between agile production and the three sustainability performance factors negatively. This research contributes to the body of knowledge concerning the implementation of interventions to achieve the three sustainability performance factors in firms, namely lean production and agile production, and contributes important guidance for managers in manufacturing firms seeking to enhance these sustainability performance factors through lean and and agile production and when SCC intervenes.

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Chapter 1: Introduction

1.1 Research background

The concept of sustainability and the sustainability performance of industrial firms, which often reside within dynamic and potentially complex business environments, has gained significant attention from practitioners (Janmontree and Zadek, 2020). The extant literature indicates that manufacturing firms in particular are under pressure to respond to constant changes that occur in their environment and sustainability requirements (Teixeira et al. 2021; Orji and Liu, 2020; Choudhary et al. 2019; Leon and Calvo-Amodio, 2017). Such responses often include improving quality alongside reducing costs (Burgess et al. 2019; Ravet, 2011). However, many firm's responses are not always found to be adequate, not least because manufacturing firms are being expected to do more due to rising challenges which include a world that is volatile, uncertain, complex and ambiguous, with a high level of competition, a globalized economy, requirements for faster response times, and nowadays a significant rise in consciousness about ecological aspects (Henriksen et al. 2022; Ravet, 2011). Two important phenomena that are argued to hold the potential to help manufacturing firms in this situation are the ideas of lean and agile manufacturing and the strategies of supply chain management (Furlan et al. 2023; Kant et al. 2015; Womack et al.1990; Womack and Jones, 1996).

There is evidence in the literature that manufacturing firms that have implemented lean production or agile production are expected to derive operational advantages and enhanced performance outcomes (Chavez et al. 2022; Geyi et al. 2020). At the same time, the literature and practice indicate that many manufacturing firms are unable to cope with the changes occurring in their internal and external environments and produce goods and services in a sustainable manner and derive sustainability performance benefits (Pucker 2021; Eslami et al. 2019; Ravet, 2011). Literature has also produced contradictory results with regard to the link between implementing lean and agile technologies and sustainability. Some contributions (e.g. Sadeghi et al. 2022; Mayr et al. 2018) have argued that sustainability performance can be achieved through the application of technologies such as lean production and agile production. However, other contributions (e.g. Mohaghegh et al. 2023; Martínez-Jurado and Moyano-Fuentes, 2014) have argued that the current knowledge about implementing sustainable performance in manufacturing units that have adopted lean and agile technologies is not sufficient. Accordingly, the focus and requirement for greater understanding on the lean production-sustainability performance relationship and agile production-sustainability performance relationship has gained heightened importance.

Furthermore, while the literature has begun to link lean production and/or agile production to sustainability performance, although often incorporating only one sustainability parameter at a time (Alzoubi et al., 2020; Srinivasan et al., 2020), there is a paucity of research that has linked a comprehensive view of sustainability performance factors to lean production and agile production, together in a single study (Vaishnavi and Suresh, 2020; Ramana et al. 2013). The combined effect of lean production and agile production is yet to be well understood in regard to their influence on sustainability performance.

The literature has also indicated that achieving sustainability performance should be undertaken with the involvement of supply chain stakeholders including, for example, customers and suppliers, without which an understanding of the impact of lean production and agile production on sustainability performance would be incomplete (Ekren, 2022; Srinivasan et al., 2020). Supply chain collaboration has emerged as an increasingly popular phenomenon among firms to help achieve improved performance outcomes (Ataseven and Nair 2017; Chavez et al. 2015). Supply chain collaboration entails combining the ability of two or more independent firms to plan and implement supply chain activities (Cao et al. 2010), and notable advantages derived include improved stock levels, reduced lead times, and reduced transportation cost (Yilmaz et al. 2016).

Therefore, to understand and help address the problems faced by manufacturing firms seeking to improve their sustainability performance, this research has identified the need to examine the influence of the adoption of lean production and agile production alongside the concept of supply chain collaboration. The next section elaborates on the problems concerning the core issue of sustainability and the various factors related to sustainability performance that need to be understood to help alleviate those problems unresolved in the literature, and in practice, so far, including lean production, agile production and supply chain collaboration, leading to the definition of the research problem and research question.

1.2 Research problem and research questions

The research background has identified sustainability performance of manufacturing units as the central issue of this research. Taking a holistic view, sustainability performance issues are concerned with three different dimensions, namely economic sustainability performance, environmental sustainability performance and social sustainability performance (Negulescu et al. 2022, Erwin, 2021; Ravet, 2011). However, the literature indicates that there are many barriers faced by manufacturing units preventing them from achieving sustainable performance. These include the absence of system thinking, factors that are related to politics, resistance to change, and lack of supplier control to ensure sustainable behaviours among suppliers, alongside the wider problem of the concept of global capitalism and associated consumption prevailing among a significant proportion of consumers (de Paiva Duarte, 2015). Such barriers, in turn, cause problems to supporting a sustainable society, for instance the lack of a healthy environment for all (Haslam and Waterson, 2013). Other barriers include lack of environmentally sustainable manufacturing processes (Ghazilla et al. 2015), innovation in enterprises (Xie et al. 2010; Avlonitis and Salavou, 2007), performance of those enterprises in the small and medium sector (Terziovski, 2010) and lack of standards, metrics and systems pertaining to sustainable manufacturing practices (Escoto et al. 2022). Such barriers can all create uncertainty for practitioners despite their desire for their manufacturing firms to achieve a positive impact. A major challenge therefore is lack of clarity in the minds of practitioners of how to address the increasing pressures from customers, governments, non-governmental organisations, trade bodies and employees for improved sustainability outcomes (Escoto et al. 2022).

It is important to note however, that the literature not only identifies barriers but also enablers towards sustainability performance. For example, enablers that support the design of sustainable production processes, products, and services (Sudarsan et al. 2010), government support and legislation, investment support for sustainability, and quality improvement education and training and infrastructure and facilities (Mutingi et al. 2017) are all considered to enable sustainable manufacturing. However, the literature concerned with barriers and enablers to/for sustainable manufacturing is fragmented, and it has been suggested that many of the contributions have not explained the logic used to categorise barriers and enablers and define those categories in an acceptable manner (Alayón et al. 2022).

As alluded to above, across the world governments, organisations and citizens of different countries have become increasingly aware of and concerned with sustainability performance. This has driven firms in many industries to introduce sustainable practices, including supply chain sustainability in their operations strategies. Negulescu et al. (2022) highlight that after the Rio Summit of 2002, which was concerned with world-wide sustainable development issues, researchers have started to take significant steps in regard to both theoretical and practical aspects concerning the sustainability performance of firms. Many researchers have highlighted the advantages of adopting sustainable development practices concerning the three dimensions of sustainability, including the following examples:

- Economic sustainability performance advantages: Increased company market share, enhanced company image, improved the company's marketplace position and increased company profitability (Abdul-Rashid et al., 2017).

- Environmental sustainability performance advantages: Reduction of harmful emissions to the air, reduction of liquid waste, reduction of solid waste and decrease in consumption for hazardous, harmful and toxic materials (Inman and Green, 2018).
- Social sustainability performance advantages: Improved relationship with the community and stakeholders, improved work safety, improved work environment, improved living quality of surrounding community (Abdul-Rashid et al. 2017) and improved workforce satisfaction (Nath and Agrawal, 2020).

There is widespread acceptance that there are advantages in implementing sustainable performance strategies, yet research outcomes concerning the three sustainability performance factors have been found to be inconsistent and often lacking in depth of examination, and hence require wider investigation including and importantly it is reasonable to argue, on the deployment of three sustainability dimensions simultaneously. Janmontree and Zadek (2020) argue that much of the focus of prior research has been on the environmental sustainability dimension, and attention to economic and social sustainability performance has, despite the increased recognition of the importance of triple-bottom line thinking (Ruiz-Benitez et al. 2019; Kamble et al. 2019; Gimenez et al. 2012; Carter and Rogers, (2008), been much less attended to in the literature. Similarly, Rodrigues et al. (2016) argue that with regard to certain aspects of corporate sustainability, only environmental and economic sustainability performance have been discussed extensively in the literature, as well as in the practical domain, but social sustainability is rarely found in such exercises concerning sustainability performance - an observation also made by Zorzini et al., (2015) and Yawar and Seuring (2017). It has been suggested that these inconsistencies have resulted in contradictory conclusions, in turn resulting in problems concerning the successful implementation of practices supporting sustainable performance in manufacturing industries (Furlan et al. 2023).

Social sustainability is concerned with human rights, labour rights, and corporate governance and managing social resources that are linked to people's skills, efficacy and social values (Sarkis, 2010). Zainoddin et al., (2017) argues that social sustainability is a serious problem affecting firms that are interested in social sustainability as many of those firms are likely to have a narrow perspective on how corporate social sustainability can be enacted.

Regarding economic sustainability, Millimet et al. (2009) argue that restrictions imposed by the natural environment can affect the improvement and the stability of the economy of a country. An important observation made by the United Nations (2019) is the need for investment in research and development infrastructure that would enable innovations to be brought to bear, however in many countries, it is seen that scientific research and innovation are still lagging behind, and hence hampering economic sustainability. These aspects pertaining to economic sustainability need to be addressed. In addition, land loss, environmental damage, deforestation, climate change, biodiversity loss and air pollution are on the rise and environmental sustainability has become a serious issue that needs to be tackled (Zheng et al. 2021; Akter et al. 2018).

While much of the literature, as noted, has shown that social sustainability is the least investigated sustainability performance factor amongst the three (Cope et al. 2022; Sundström et al., 2019), the literature and preceding arguments also highlight that the three sustainability performance factors overlap to an extent and in certain ways are interrelated (De Matteis and Borgonovi, 2021; Di Vaio et al. 2021). As Zimmermann (2019) argues, the sustainability strategy of an organization must aim at attaining long-term benefits in terms of economic prosperity, ecological sustainability and social stability in their own right. However, most of the research efforts to date have either dealt with the three sustainability performance factors as a single composite construct, or in pairs, but not as a group of three independent dimensions. There is an important and urgent need in studies concerned with sustainability performance to exclusively examine the social sustainability performance, economic sustainability performance, and environmental sustainability performance as distinct constructs, rather than amalgamating them into a single construct as has been the case in many prior studies. Analysis in this way will provide a clear understanding of the impact of sustainability enablers on sustainability performance.

Achievement of sustainability performance is argued to be dependent on the production method or technology adopted by manufacturing units (Su et al. 2024; Venugopal, and Saleeshya, 2019; Ciccullo et al. 2018), for instance use of lean production or agile production (Furlan et al. 2023; Ravet, 2011). However, achieving sustainable performance in industries that have adopted lean production or agile production is not free of challenges. For instance, Martínez-Jurado and Moyano-Fuentes (2014) argue that lean production may not in fact lead to competitive advantage that is sustainable and can compromise flexibility, while agile itself does not guarantee first-rate supply chain performance and can at times in fact be wasteful and less efficient (Mohaghegh et al. 2023). This highlights another area that requires investigation as contradictions can cause confusion in the minds of managers and inconsistency in decision making on how to achieve sustainable performance in manufacturing firms (Smith and Lewis, 2011).

It is reasonable to infer from the above arguments that the three sustainability performance factors can provide much needed benefits to organizations, however the challenges faced by many organisations are not allowing those organisations to fully reap and enjoy those benefits. In addition, although both lean production and agile production are seen in the literature to have the capacity to positively influence the three sustainability performance factors, the constantly changing environment and other factors like government regulations, customer demands and supplier issues are not insignificant challenges that organisations, arguably manufacturing firms in particular, are facing. At the same time research that has included both lean production and agile production simultaneusly is not common. This implies that research and knowledge about the combined influence of lean manufacturing and agile manufacturing on the sustainability performance factors is sparse. In the absence of any knowledge about the combined performance of lean production and agile production on the three sustainability performance factors, new knowledge must be sought. A better understanding of the implications of the implementation of lean production practices and agile production practices would help manufacturing firms in their efforts to improve sustainability performance along the three different sustainability performance dimensions.

There is evidence in the literature to show that the influence of supply chain stakeholders can enhance the ability of the organisations to achieve a more stable sustainability performance (Martinez-Jurado and Moyano-Fuentes (2014); Geyi et al. (2020). The formation and maintaining of collaborative relationships are considered important for a sustainable supply chain (Govindan et al. 2016). Supply chain collaboration (SCC) seeks to achieve common goals that could be useful to multiple parties working together rather than independently (Cao and Zhang, 2011). SCC involves partners working in collaboration with each other, often establishing strong inter-organisational relationships thereby enabling them, for example, to share information, resources and risk (Min et al. 2005). At the same time however, examination of the literature indicates a lack of knowledge on how the concept of supply chain collaboration intervenes in the relationship between lean production and agile production on the one hand and sustainability performance factors on the other (Bouguerra et al. 2021; Hassani et al. 2020), which in turn is affect the progress of practitioners in enhancing their firms' sustainability performance.

The preceding arguments form the basis for the research questions investigated in this study. Given the gaps identified in the literature framed here, the research questions that this research seeks to answer are:

RQ1: What is the nature of the relationship between lean production and the three sustainability dimensions in the presence of agile production?

RQ2: What is the nature of the relationship between agile production and the three sustainability dimensions in the presence of lean production?

RQ 3: What role does supply chain collaboration play in facilitating the relationship between:

(a) Lean production and sustainability dimensions, and

(b) Agile production and sustainability dimensions

1.3 Research aim and objectives

The aim of this research was to examine the direct relationship between lean production and agile production on economic, environmental and social sustainability performance respectively, and the moderating role of supply chain collaboration on the relationship between lean production and agile production respectively and economic, environmental and social sustainability performance respectively, in the context of manufacturing firms.

Accordingly, the research objectives the study sought to achieve are:

- To conduct a critical review of the literature on lean and agile production and sustainability performance to identify existing gaps in the knowledge base;
- To develop a conceptual model identifying the intervening role of supply chain collaboration in the relationship between lean production and agile production and sustainability performance;
- To empirically test and verify the proposed conceptual model in the context of medium and large manufacturing firms located in the Kingdom of Saudi Arabia; and
- To provide a set of practical implications that can inform practitioners in manufacturing firms in their decision making related to their efforts to improve their firms sustainability performance, alongside a significant theoretical contribution to the literature on the enablers of economic, environmental, and social sustainability

1.4 Scope and limitations of the study

The scope of this study is limited to investigating the focused issue of the influence of lean production and agile production on the three sustainability performance factors in the presence of supply chain collaboration as an intervention. The research does not conceive lean production and agile production as a single construct but has defined them individually as influencing economic, environmental and social sustainability factors. The research has studied the direct effect of lean production and agile production on the three sustainability performance factors. That is to say that in this research the following direct relationships have been investigated:

- Lean production – Economic sustainability performance
- Lean production – Environmental sustainability performance
- Lean production – Social sustainability performance
- Agile production – Economic sustainability performance
- Agile production – Environmental sustainability performance
- Agile production – Social sustainability performance

In addition to the above, the study has introduced supply chain collaboration as an intervention in each one of the above relationships and has investigated its influence as a moderator of those relationships. The research does not seek to understand the interaction between the three sustainability performance factors. Finally, this research was scoped to be conducted on the manufacturing units in the Kingdom of Saudi Arabia belonging to the medium and large industry sector. The scope of this research was also limited to deriving the study data from employees in those industries holding positions equal to managers and above.

As far as the limitations of this study are concerned, it can be seen that the study was conducted over a broad range of manufacturing industries that are located only in the Kingdom of Saudi Arabia. It is possible the results of this research could have been different if the manufacturing units were categorized under their specialization. Similarly, this research has not included firms belonging to the small sized segment. Including such firms in the research could have provided a more comprehensive picture of the influence of lean production and agile production on the sustainability performance factors – this is a recommendation for future research. Finally, the research was conducted only in the context of the Kingdom of Saudi Arabia which should be noted in terms of the generalizability of the findings. Nevertheless, the study has developed a conceptual model the study of which can easily be replicated in other industry/geographical contexts.

1.5 Research methodology: an outline

The research questions set for this research required a robust investigation of the nature of the relationship between lean production and agile production and the three sustainability performance factors and the effect of possible interventions on those relationships. This pointed to the need to understand the nature of those relationships objectively, and entailed the necessity to develop a theoretical framework with hypothesized relationship between the various constructs identified in the framework. To test the various hypothesized relationships there was a need to collect data grounded on a positivist epistemology, objective ontology and a deductive research approach. This is in line with the established methodology literature for instance Saunders et al. (2023), Sekaran and Bougie (2019) and Pallant (2020). A survey instrument was developed based on instruments developed and tested already by other researchers who have conducted research in a similar field. The testing ground was the Kingdom of Saudi Arabia, with the main focus on medium and large manufacturing firms. The database of National Industrial Information Center (2021) was used to identify the targeted companies. The data was collected through an online facility by which the research instrument was posted on a website and the weblink was sent to the participants, a practice widely followed by researchers in recent times. Structural equation modelling method was used to analyse the data and derive finding which is in line with the data analyses conducted by other researchers while investigating topics concerning lean production, agile production, sustainability performance and supply chain collaboration (e.g. Geyi et al. 2020; El-Khalil and Mezher, 2020; Baridwan and Zaki, 2020; Hasan et al. 2023; Zhang and Cao, 2017). The findings were juxtaposed against prior literature, and contributions are set out in full in the final chapter.

1.6 Study contribution

This study contributes to the body of knowledge that concerns with sustainability performance of manufacturing industries in the Kingdom of Saudi Arabia that have adopted lean production and agile production or both or those thinking to adopt either of those methods keeping in view the influence of supply chain collaboration as an intervention. The study provides a number of new contributions to the knowledge. Chief amongst these contributions is that lean production and agile production do not work in combination in a single model as independent variables while influencing the three sustainability performance factors. However, it was found that when lean and agile methods are implemented together in a manufacturing firm then it is lean that was found to influence the three sustainability performance factors as a dominant method and agile method was found to be a covariant to lean production. Next, the research model was redefined by splitting it into two new configurations: one with lean production conceived as the independent variable, agile as covariant and the three sustainability factors as dependent variables; and the other with agile production conceived as the independent variable, lean as covariant and the three sustainability factors as dependent variables. Both the models showed that the independent variables influenced the three dependent variables significantly with the covariants contributing to the association with the independent variables. However, it was found that lean production is having a greater influence on economic, environmental and social sustainability performance factors when compared to agile production.

Further to this it was also found that the supply chain collaboration intervention was conceived to be a moderator of the relationship between lean production and the three sustainability performance factors as well as agile production and the three sustainable performance factors. Results showed that while supply chain collaboration acts as an intervention, then it is possible to differentiate customer side supply chain collaboration and supplier side supply chain collaboration. Such a differentiation brought significantly different results that were mixed. Overall, it was seen that supply chain collaboration moderated the relationship between lean production and economic sustainability performance only but moderated all the three relationships between agile production on the one side and the three sustainability performance factors on the other. It was also found that supply chain collaboration moderated negatively all the three relationships between agile production on the one side and the three sustainability performance factors on the other.

As far as theoretical contribution is concerned, this research has shown that the stakeholder theory, the resource based view, the theory of sustainable development, theory of transaction cost economics and the dynamic capability theories could be applied to the theoretical model. Thus the application of those theories in developing the study's unique proposed new model has shown that the application can be extended to concepts that relate lean production, agile production, sustainability performance and supply chain collaboration. With regard to practical contribution, this result has provided new knowledge to practitioners in the manufacturing industry about dealing with sustainability performance factors in a constantly changing environment and dynamic behaviour of supply chain stakeholders. The contributions of the study to knowledge and for practice are presented in detail in Chapter 7.

1.7 Structure of the thesis

This thesis comprises seven chapters as follows:

This chapter has provided brief background to the issue under study and presented the research questions, followed by the aim, objectives and methodology adopted. It also set out the study's scope and limitations and contributions to knowledge.

Chapter 2 provides a thorough and critical review of the literature concerning the three sustainability performance factors, lean production, agile production and supply chain collaboration. The literature review has covered areas concerning the definitions, factors affecting the above constructs, factors affected by the above constructs, the current knowledge available in the literature and the gaps found in the literature.

Chapter 3 presents and discusses the theoretical framework that has been developed to answer the research questions outlined in chapter one, developing the associated theoretical relationships through hypotheses based on the literature.

Chapter 4 outlines the research methodology developed for this research and required to answer the research questions. It covers the methodological philosophies that formed the basis for developing the methodology, the research framework, the research strategy, data collection process, sampling procedure, reliability and validity analysis and the structural equation modelling data analysis procedure adopted in this research.

Chapter 5 presents the entire data analysis and study findings, commencing with details of the final study sample, the procedures used to screen and cleanse the data, and analysis of the structural model.

Chapter 6 discusses the findings and evaluates the research findings by examining them in light of other relevant prior empirical work.

Chapter 7 indicates sets out the theoretical contributions this research makes to the body of knowledge concerning the sustainability performance factors, their implementation and the influence lean production, agile production and supply chain collaboration factors. It also sets out practical contributions that are expected to be useful to the practitioners. It details the limitations of this research as sets of our recommendations for future research that can extend the present research and further the knowledge on the enablers of economic, environmental and social sustainability performance.

Chapter 2: Literature Review

2.1 Introduction

This chapter is concerned with the critical review of the literature in regard to the concepts namely lean production, agile production, sustainability performance and supply chain collaboration. The chapter commences by providing an overview for lean production (sections 2.2 through 2.7) and agile production (sections 2.8 through 2.13). In each case, the overview sets out definitions, origins, and their associated elements/concepts. Then in each case, the overview includes identification of factors affecting each, how each has been conceptualized, and what approaches have been used in prior research. Section 2.14 then provides an overview of lean and agile in combination. Sections 2.15 through 2.19 provides a similar overview of sustainability performance, delineating the three areas of sustainability performance - economic, environmental and social. For each, the overview includes identification of the current scenario adopted by various researchers in establishing theoretical support for them, and how they have been conceptualised and what approaches have been used in prior research. Section 2.20 briefly discussed the importance of lean and agile production to sustainability. The review then moves on to provide an overview of supply chain collaboration in section 2.21. This includes definition, purpose, its configuration and components, and theoretical underpinnings.

The chapter then proceeds, in section 2.22, to provide a careful, systematic and detailed review of the prior research that has investigated the connections (relationships) between the four constructs: supply chain collaboration, lean production, agile production, and sustainability performance. The findings are presented in a series of sub-sections (2.22.2 through 2.22.7) based on the findings from applying the review protocol, namely - *given the volume of all literature associated with these four constructs* - carefully restricting the search terms to the named constructs; including empirical (primary data-based) studies and significant systematic review approaches and excluding purely conceptual work; restricting to work published in the English language; and restricting to papers mainly published in recognized high-impact outlets (journals). Based on the above analysis, the chapter concludes by summarizing and setting out current research gaps, and hence the focus of the present research, that is to say, the main gap the study seeks to address. The following sections thus provide a critical view of the current body of knowledge concerning the above.

2.2 Lean production: Overview and definitions

The literature shows that lean production is popular and many manufacturing firms across the globe have developed and implemented lean programmes at the level of manufacturing units, and indeed at the corporate level (Powell and Coughlan, 2020; Hines et al. 2004; Holweg, 2007). The literature indicates that lean production has been defined by various authors as evidenced by the selection of representative definitions provided in Table 2.1

Table 2.1, Illustrative of definitions of lean production

Definition	**Provided by**
A way by which the cost of production is lowered by minimizing waste. (rephrased)	Womack et al. (1990)
Lean thinking is a process which includes the following five steps namely value, the value stream, flow, pull and perfection. (rephrased)	Womack and Jones (1996)
A production system that uses fewer resources as input to generate a performance as output that leads to better customer satisfaction and higher market share than the competitors. (rephrased)	Katayama and Bennett (1996)
Lean production is a multi-dimensional approach that encompasses a wide variety of management practices, including just-in-time, quality systems, work teams, cellular manufacturing, supplier management, etc. in an integrated system. The core thrust of lean production is that these practices can work synergistically to create a streamlined, high quality system that produces finished products at the pace of customer demand with little or no waste.	Shah and Ward (2003, p.129)
Production of goods or services is lean if it is accomplished with minimal buffering costs.	Hopp and Spearman (2004, p.1027)
Lean production is an integrated manufacturing system that is intended to maximize the capacity utilization and minimize the buffer inventories of a given operation through minimizing system variability (related to arrival rates, processing times, and process conformance to specifications).	De Treville and Antonakis (2006, p. 102)
Organisations that use less material to generate their work, perform work with the least effort put in by the human resource, design and development produced with the least amount of time and utilize least energy and space are considered lean. Further, those organisations concentrate on the demand projected by the customers as well as produce products and services of a high quality in manner that is most effective and economical. (rephrased)	Dhamija et al. (2011)
Identification and taking out waste by a systematic approach dependent of continuous improvement, flow of the product, pull of the customer and pursuance to perfection. (rephrased)	Bhasin (2015; p.2)

The definitions of lean provided in Table 2.1, spanning the period 1990 to 2015, vary but have a number of prominent features in common. The commonalities are that lean is a process that involves continuous improvement; it focuses on customer satisfaction, the reduction of waste, the optimum use of resources and minimum costs (production/buffering), all in pursuit of enhanced and optimized performance.

2.3 Lean production – a philosophy

A careful examination of the literature indicates wide support for the view that the concept of lean production considered to be a philosophy (Moore, 2001; Bateman, 2002; Bhasin and Burcher, 2006; Leite and Vieira, 2015). The lean philosophy states that it is a way to do more but through the continuous reduction in human effort, as well as equipment time and space, because it focuses on providing customers with only what they want (Neves et al. 2018). Other researchers (e.g. Balamurugan et al. 2020; Salem et al. 2016) define the lean philosophy as a set of activities that determine the value of each activity in the production process and distinguishes those activities that add value from the ones that do not. Bhasin (2015, p. 2.) similarly defined lean management as "a systematic approach to identify and eliminate waste through continuous improvement; flowing the product at the pull of the customer in pursuit of perfection". Schonberger (2019, p.369) explained the lean philosophy as: ". . . not be about implementing a set of tools. Rather, we are told it must revolve around creating a lean or continuous-improvement culture, people-focused leaders, and raising lean literacy". The varying positioning of lean as a philosophy found in the literature clearly show that lean as a philosophy (or as a theory) is all about 'doing more with less' (Awad et al. 2022), thereby implying that lean philosophy (or theory) is underpinned by the notion that the lowest amount of resources should be used to produce the highest amount of efficiency and quality.

It is important to note that the philosophy is not without critique. Critiques of the lean philosophy suggest that as a theory lean does not address the impact of changes on the wider organization, and that lean organizations therefore remain susceptible to such impacts (Crute and Graves, 2001). In addition, it has been claimed that lean contributes to reduced flexibility and can lead to a lower ability to react to new conditions and circumstances (Dove, 1999). Despite these criticisms, lean as a philosophy (or a theory, or indeed as a method (Bocquet et al. 2019) has been widely adopted by firms operating in the manufacturing sector, with a corresponding broad interest as the subject of management researchers (Bhamu and Singh, 2014). Moreover, many contributions have indicated the utility of the lean philosophy in many sectors and areas of research (Caiado et al. 2020; Klein et al. 2022).

2.4 Concepts associated/connected with lean production

The literature shows that there are a number of concepts/methods that have been developed which are clearly associated with the philosophy of lean production, including Kaizan (continuous improvement), Just-in-Time (JIT), Total-Productive-Maintenance (TPM) and Value Stream Mapping (VSM) (Sá et al. 2022; Genç, 2021; Abd Mohammed et al. 2021). It can be seen in the literature that many authors have investigated lean production drawing on these concepts, and the importance of these concepts to lean production can be understood by examining their main attributes. Lean production, when "combined" (or when applying) these concepts can help its implementation yield better long-term results, improve an organization's output, and improve the performance of the firm, through a significant problem solving capacity (Ismyrlis, 2021). The literature, for example, shows that a combination of Lean and Kaizen called Lean-Kaizen approach and its adoption in an organization can improve the organisation's output by solving problems by detecting and implementing small improvements in system, process and product. Similarly combining JIT and lean production (which has been termed JIT/Lean (Kupanhy, L., 2012) enables the production of items in a manufacturing unit based only on what is needed, when it is needed and the quantity needed (Goetsch and Davis, 2022). These examples indicate that the implementation of lean production can, or may have to, depending on the context, draw on other concepts and methods such as Kaizen or JIT or TPM or VSM. A review of these concepts was therefore important and undertaken, to help establish in what ways they may affect lean production, and to help inform how they may contribute to lean production implementation.

The discussion is presented next with regard to four of those philosophies and methods namely just-in-time (JIT), total productive maintenance (TPM), value stream mapping (VSM) and Kaizen (continuous improvement) as examples only. This discussion is expected to provide the difference between considering lean production as an integrated construct and not represented through the individual philosophy or method associated with lean production.

2.4.1 Just-in-Time (JIT)

According to the literature JIT is itself a management philosophy (Htun et al. 2019), however according to Choi et al. (2023), there is still no universal definition of JIT. JIT was first developed by Toyota Motor Company, Japan, to support its production system - the Toyota Production System (TPS) (Ohno, 1988; Sugimori et al. 1977). Although there are many definitions found in the extant literature about JIT, the definition suggested by Womack and Jones (2003) is extensively adopted and defines JIT in its most basic for as a method that enables an organization to produce the right item at the right time, enabling an organization to reduce inventories, utilize space in a better manner and reduce waste. Examination of the literature indicates that a majority of the researchers in fact, consider JIT as a lean production tool (e.g. Andinyanga, 2022; Ghaithan, 2021; Madanhire, 2013), although others consider JIT as a stand-alone philosophy (Ismael, 2023; Shah and Ward, 2007, 2003; White et al. 1999; Upton, 1998; Goyal and Deshmukh, 1992), and others still simply suggest that JIT could be used in conjunction with lean production (Goetsch and Davis, 2022). That is, past researchers have conceived JIT varyingly, sometime as an independent variable (Ismael, 2023) and sometimes as part of lean production (Belekoukias et al. 2014).

2.4.2 Total productive maintenance (TPM)

According to Rajak (2023), TPM is a Japanese philosophy that is unique in nature and was introduced by Nippon Denso Co. Ltd. of Japan, in the year 1971. TPM is a production-driven methodology that focuses on continuous improvement, and is purported to be designed to optimize equipment reliability and effectiveness leading to the removal of equipment breakdowns (Rajak, 2023). Although TPM is often discussed, developed and researched in its own right (Ahmed et al. 2010; Saxena, 2022) which can imply that it is a separate philosophy, many researchers link it closely with lean production (Medynski et al. 2023; Rahamneh et al. 2022; Azid et al. 2019). As is the case with JIT, TPM has been conceptualized in different ways, for instance Belekoukias et al. (2014) identified TPM as a covariant of other lean related philosophies such as JIT, whereas Medynski et al. (2023) used TPM in conjunction with lean production.

2.4.3 Value stream mapping (VSM)

The concept of value stream mapping is now widely used in the manufacturing sector and is also linked to lean production by many researchers (Masuti and Dabade, 2019; Wang et al. 2020; Ghushe et al. 2017). The literature shows that researchers have investigated issues concerning VSM by identifying VSM as an independent variable (Belekoukias et al. 2014), but also as an integral element of lean production (Rahamneh et al. 2022), widely implemented where lean production is in force (Kathem et al. 2023). Rother and Shook (1999) argue that it is an efficient tool which when employed in or applied to a production process helps to demonstrate clarity in where value is, or is not, added. In addition, Antonio et al. (2023) argue that VSM deals with defining a future state through a process of mapping the reengineering process. The reengineering process involves streamlining and ensuring a more efficient information flow and process steps. Elimination of non-value added actions is achieved while implementing VSM through a process of identification and simplification of inefficient activities.

2.4.4 Kaizen

Berhe (2022) explains that Kaizen – otherwise known as Continuous Improvement - is a method that focuses on the continuous improvement of the traditional/existing way of working. It is positioned by Dimitrescu et al. (2018) as a philosophy concerned with optimizing processes in organisations and reducing waste at the workplace. Rewers et al. (2016) explain the term Kaizen indicates small and gradual improvements that occur as result of efforts undertaken by people in manufacturing units. Rewers et al. (2016) further say that Kaizen enables manufacturing units to improve individual operations and processes with an aim to eliminate waste and improve value-added activities and claim that Kaizen philosophy can be applied to any workplace scenario as it is simple. Roosen and Pons (2013) refer to Kaizen as part of the lean philosophy and indicates that no process can ever be perfect because of which operations in workplaces including manufacturing units must be improved continuously to eliminate waste.

Numerous studies have and continue to report the positive impact of Kaizen on manufacturing performance (Chan and Tay, 2018; Negrao et al. 2017; Belekoukias et al. 2014; Bradley and Willett, 2004). Although these examples indicate that Kaizen can be differentiated from lean production, that is to say as a separate independent construct (e.g. Belekoukias et al., 2014), many researchers hold that Kaizen can be a representation of lean production (Akhmatova et al. 2023; Rosak-Szyrocka, 2019; Antony et al. 2017), Patel et al. (2023) arguing that Kaizen is a component of lean.

Recent times research outcomes have pointed towards improvements in the successful implementation of lean production particularly with the adoption of Kaizen. For instance, Hương and Anh (2021) studied SMEs in regard to the successful implementation of lean production in Vietnam and found certain factors including Kaizen as supporting the successful implementation of lean production. Hương and Anh (2021) studied 10 typical industrial manufacturing enterprises who had adopted lean production that were struggling with limited resources, low technology level, and low production management capacity and found them to have successfully implemented lean production. Hương and Anh (2021) concluded that application of Kaizen in regard to leadership commitment, technology level, management competences, labor quality, employee awareness and supply chain integration were the factors that enabled the SMEs to implement successfully the concept of lean production.

This is supported by other researchers who have argued that an interaction between lean operations and continuous improvement (CI) is essential (Shah and Ward, 2003, 2007; Liker, 2004; Cua et al. 2001; Karlsson and Ahlstrom, 1996; Flynn et al. 1995a; Womack et al. 1991; Imai, 1986; Ono, 1988; Sugimori et al. 1977), and that there appears to be a lack of clarity on how this interaction unfolds with the passage of time (Knol et al. 2022).

2.4.5 Summary – Concepts associated with lean

The review presented in the previous four sections highlights that lean production is associated with a number of concepts which many see as a part of lean implementations and others see as independent concepts. Each one of these concepts could therefore be separately investigated. It is important to note at this juncture that it was decided that in this research lean production as a construct would be used as an overarching construct, and hence that represents all of the associated concepts. It was deemed that including each independently from lean would detract from providing knowledge on how lean as concept will perform in a model, and risk providing new knowledge in fragmented manner. Further to the discussion on associated concepts, the next section deals with the factors that affect lean production.

2.5 Conceptualisation of lean production and approaches used in prior research

Lean production has been conceptualized in the literature in different ways. For instance, Inman and Green (2018) conceptualized lean manufacturing processes as an independent variable that determines the operational performance of a manufacturing unit while studying a sample of 182 manufacturing managers in U.S. plants. Similarly, Baridwan and Zaki (2020) conceptualized as a determinant of performance of small and medium enterprises in Indonesia while investigating the role of supply chain management as a mediator. Klein et al. (2022), for example, conceptualized lean production as a set of lean management practices and investigated its influence on process effectiveness of a public institution. Klein et al. (2022) broke lean production down (as a management tool) and conceptualized it as a composite construct made up of five different lean management practices. Furthermore, Klein et al. (2022) positioned and operationalised lean production as an independent variable that influences the dependent variable process effectiveness directly. Similar conceptualization of lean production as an independent variable that influences other dependent variables, such as cost, speed, dependability, quality, and flexibility, and sustainability can be seen in the research efforts of Belekoukias et al. (2014) and Putri et al. (2022) respectively. García-Alcaraz et al. (2021) on the other hand, positioned lean production components as both independent and mediating variables. In their research, García-Alcaraz et al. (2021) used the 5S components of lean manufacturing as an independent variable, and used Single-Minute Exchange of Die (SMED) and Continuous Flow (COF) as mediating variables. García-Alcaraz et al.'s study (2021) was investigating lean production's effect on economic sustainability in the context of the manufacturing industry in Mexico.

Examination of the literature also indicates that lean production or lean as a concept has been positioned as a dependent variable, for instance in the research effort of Nguyen and Ngo (2023) who investigated the determinants of influencing the application of lean accounting in the context of garment industries in Vietnam. These various studies show that lean production as a concept has been conceptualized in various ways as a determinant (independent) variable, mediating (facilitating) variable, or outcome (dependent) variable, and there is no specific guideline as to conceiving it. The conceptualization position is based on the research question under investigation and the support the question derives in terms of the theoretical aspects concerning lean production.

Researchers have used both quantitative (positivist) and qualitative (interpretivist) research approaches to investigate the concept of lean production. For instance, Ismael (2023) used a quantitative research method and used survey strategy to collect data from the manufacturing industries in Saudi Arabia to examine the Impact of Integration between lean accounting and just in time technique on cost reduction in modern sustainable manufacturing environment. Inman and Green (2018) also used the quantitative approach and used a set of measures assessed along a five-point Likert scale for measuring lean. Nordin et al. (2014) on the other hand, used a qualitative study approach while investigating lean manufacturing implementation, developing a qualitative research design using case study method. Similarly, Aripin et al. (2023) used a qualitative research method and conducted research on the European automotive manufacturing plants and studied the leadership attributes for a successful lean manufacturing implementation. Using the case study method, a series of interviews with six informants from four countries were conducted by Aripin et al. (2023). The literature also shows that mixed method research strategies have been used to investigate lean production, for instance Andersen (2015) who studied the design of lean interventions to enable impact, sustainability and effectiveness using a mixed-method study, and Lima et al. (2023).

2.6 Agile production: an overview and definitions

The concept of agile production is increasingly considered important as a means for firms to ensure supply chain competitiveness (Baah et al. 2021; Susitha et al. 2024). Much research has been undertaken on agile production, with arguably a lions share regarding to the evolution of agile production practices within supply chains (Gunasekaran et al. 2018).

The following sections critically review the literature concerning agile production as a concept, including how agile production is defined, the theoretical underpinning on which agile production could be grounded, and approaches used in prior research to investigate agile production.

Table 2.2 provides a selection of prominent definitions of agile production found in the extant literature. Icacco Institute’s (1991) definition, which is arguably one of the most comprehensive, emphasises agility’s focus on the simultaneous achievement of speed (responsiveness) and flexibility.

Table 2.2, Agile production definitions

Definition	Provided by
It is a system of manufacturing that is known for its extraordinary capabilities that enable the industries to face the fast-changing needs of the marketplace. Example of capabilities could be internal capabilities that include hard and soft technologies, human resources, a management that is educated and information. Example of fast changing needs could be infrastructure, responsiveness, customers, suppliers, speed, competitors and flexibility. This system has the ability to rapidly shift among product models or between product lines as a response that occurs in real-time to the customer requirements. Here rapid shifting could indicate speed and responsiveness; shifting between product lines and amongst product models could indicate flexibility; and real-time response to customer requirement could indicate customer needs and wants.	Icacco Institute (1991)
Agility is about succeeding in business and gaining profits, get higher market share and clients in a situation where being competitive is major challenge. It is constantly changing, contextual, embracing change continuously and aggressively and inclined to achieve growth. It is not about making firms more efficient or cost effective.	Goldman et al. (1995)
The agile manufacturing concept enables companies to have the ability to: respond efficiently and speedily to meet a client's demand; produce non-stop high quality products that meet the expectations of the customer to the maximum; have a larger time period to the losers; and gain higher market share. Thus manufacturing firms must focus on not only better quality, productivity and lower cost but also on enhancing their ability to have an effective and faster response to changes occurring in the markets, production technology and information and computer technology.	Cho and Jung (1996; pp.333)
The ability of a manufacturer of products and services to respond as fast as possible in changing markets that are influenced by customer-based valuing of goods and services.	DeVor et al. (1997)
The ability to produce a wide range of cost-effective products that are of high quality with lead times that are short, in different lot sizes and developed to meet a particular client's specifications as the main way to survive and prosper in an environment characterised by competitiveness that could be changing continuously and unpredictably.	Gunasekaran et al. (2018)
The ability of an organization to respond rapidly to changes in demand, both in terms of volume and variety.	Christopher (2000, p. 39)
The ability to change operating states efficiently as a reaction to dynamic situations and changing demands placed upon it.	Narasimhan (2006)
The ability to capture emerging opportunities related to such characteristics of a company as perceptiveness, flexibility, intelligence and shrewdness	Trzcieliński (2011)

The definitions presented in Table 2.2 provide a generalized understanding of the concept of agile production and are useful in their own right, but also when seeking to explain agile production's relationship with other manufacturing concepts. While the definitions of agile production given table 2.2 vary to some extent, common attributes can clearly be seen. These are the ability to produce a wide range of products – of high quality, the ability to move/shift production rapidly amongst different product models/categories based on real-time demand, underpinned by flexible production technology and adaptability.

Based on a thorough review of the relevant literature, it is possible to identify a set of attributes (features) that can broadly represent the concept of agile production. These are presented in Table 2.3 provides the list of critical success factors identified by the researcher.

Table 2.3, Examples of critical success factors that affect agile production identified by the researcher

Example of critical success factor (CSF) represented by the item	Author/s
Cross functional products development teams	Conforto et al. (2014)
Flexible manufacturing	Adeleye and Yusuf (2006)
Technology leadership practices	Vinodh et al. (2010)
Implementing latest technology in production and guide employees	Geyi et al. (2020)
Flexible; Creative skills; Critical thinking skills	Geyi et al. (2020)
Training and development to employees	Baraei and Mirzaei (2019)
Adapting to change as an organizational culture	Baraei and Mirzaei (2019)
Innovate as per market needs	Gupta (2019)
Responsiveness to changing market requirements	El-Khalil and Mezher (2020)

The attributes identified by the researcher illustrate that agile production is overwhelmingly construed as an independent variable in agile production research studies. For instance, flexible manufacturing as a variable could affect a number of activities within a firm including meeting requirements of the customers that change over a period of time and enhance the business processes (Misra et al. 2009). Similarly, cross functional teams could accelerate decision making and fluid governance process (Darusulistyo et al. 2022).

The attributes presented in Table 2.3, found to be important in the agile production literature, are used in the present research (see section 4.11.1).

2.7 The theoretical support to agile production

Agile production as a concept has been discussed in the literature based on different theoretical underpinnings and empirical models. For instance, Geyi et al. (2020) used the dynamic capabilities theory to explain the operationalization of agile manufacturing while investigating agile capabilities as necessary conditions for maximising sustainable supply chains in the context of industries in UK. In another instance, Gyarmathy et al. (2020) argue that theories including resource-based view (RBV), transaction cost analysis (TCA), Porter's five market forces (PFMF), dynamic capabilities (DC) and Total Cost of Ownership analysis (TCO) have been used to explain agile production. Similarly, Abourokbah et al. (2023) used the resource-based view and dynamic capability theories while investigating the role of absorptive capacity, digital capability, agility, and resilience in supply chain innovation performance in the context of firms in Saudi Arabia engaged in processing activities (e.g. food and beverage, construction, mining and minerals, petroleum, chemicals, and pharmaceuticals). These examples, alongside other contributions, namely (Candace et al., 2011, Mohamud and Sarpong 2016, and Pezeshkan et al., 2015), indicate that the resource-based view and dynamic capability theory are the two widely applied theories in research concerning agile production especially when one deals with a turbulent and unstable business environment The application of a combination of those two theories has the potential to explain the operationalisation of agile production as a construct and its relationship to other concepts including sustainability and supply chain collaboration. This view is supported by Gyarmathy et al. (2020) who say that the current situation regarding the supply chain systems is complex and a single theory will not be enough to explain the interaction between agile manufacturing, supply chain systems and sustainability. Martínez-Sánchez et al. (2019) also used the RBV and dynamic capability theory, in their case investigating agile production, innovation and technological cooperation in the context of overlapping priorities of manufacturing firms. Thus, a critical review of the two theories was important and would be useful for this research.

2.7.1 Resource based view (agile production related)

As far as this research is concerned some of the important characteristics that concern agile production include the use of such resources as human resources that indicate the capability of a firm (Icacco Institute, 1991), capable of adapting to change indicating that resources need to be available when changes occur and demand higher resources (Barlow et al. 2011) and being competitive be a successful firm. These are direct variables of agile production. When linked with another variable namely sustainability performance factors, then explaining the possibility of such a relationship and answering any question arising out of the linkage of the two variables by RBV can be achieved (Alkhdour et al. 2025; Nurjaman et al. 2020). This requires an understanding of the RBV as a theory.

According to Barney (1991) RBV posits that a company's competitive advantage is situated primarily on the application of bundles of resources that are valuable, rare, inimitable and not substitutable. Martínez-Sánchez et al. (2019) argue that RBV has received considerable attention by researchers in the fields of business and management, production and innovation management. While RBV can explain the how resources are connected to competitive advantage, at the same time researchers argue that it does not explain certain situations. For instance, according to the resource-based view a firm can achieve competitive advantage if its assets and resources are used in distinctive ways (Chen et al. 2009; Day 1994; Barney 1991; Wernerfelt 1984). That is, when a firm employs resources that are rare, valuable and not easy to be replicated, then that firm achieves competitive advantage (Chen et al. 2009; Day 1994; Barney 1991; Wernerfelt 1984). According to RBV firms are assumed to have a variety of resources. The resources and environment around firms are always dynamic and this situation is applicable to any firm implementing agile production techniques. Further, agile production is a complex operation and achieving competitive advantage is challenging (Martínez-Sánchez et al. 2019) which implies that on its own, RBV, while highly relevant, may have shortcomings in explaining how to derive competitive advantage using agile production.

Sanchez (2008) strongly criticized RBV and identified seven conceptual deficiencies and logic problems in Barney's conceptualization of resources considered as strategically valuable resources as well as the framework Barney had identified as VRIO (Value, Rarity, Imitability, and Organization). For instance, Sanchez (2008) argues that RBV concept proposed by Barney (1991, 1997) is a theoretically sterile undertaking and criticizes RBV as a logical impossibility caused by excessive abstraction because it purports a strategy proposition that is not universalistic. Despite the shortcomings, the suitability of RBV for application to organisations like manufacturing units has been recommended by authors (e.g. Elwaked et al. 2025; Pereira and Bamel, 2021). For instance, Elwaked et al. (2025) assert that RBV defines resources of orgaisations as a mix of many things including attributes, processes, assets, capabilities, knowledge and information. Using those resources, an organization can develop and establish strategies that improve efficiency and effectiveness (Elwaked et al. 2025). Further, Barney (2021) highlights that organisations should associate themselves with capability-based approach to bring together diverse internal resources as well as capitalize on external opportunities that are unique. The above characteristics of RBV have enabled RBV to be a leading concept in strategic management in organisations and it is considered to be one of the most encouraging conceptual frameworks in management discourse (Barney, 2021; Pereira & Bamel, 2021). Researchers (e.g. Adnan et al., 2018; Pereira & Bamel, 2021; Collins, 2022) believe that RBV concept could be used to develop a strategy for improving the performance of organisations by using resources that are part of those organisations leading to gaining sustainable competitive advantage.

Furthermore, literature shows that RBV as a concept is based on three premises that are fundamental to the concept (Barney, 2021) namely:

- that organisations can be viewed as a bundle of resources that are potentially unique although some of the organisations might be blessed to be better endowed with the above resources than others (Elwaked et al.2025).

- resources of firms that are strategic in nature are distributed in a heterogenous manner across an industry sector (Arraya, 2016; Andersén, 2021; Nikmah et al. 2021). Such a heterogeneous distribution of strategic resources can significantly influence the competitive advantage of an organization (Cuthbertson and Furseth, 2022). This implies that the success of an effective organization depends on solely the differences in resource endowments a firm enjoys with respect to other competing firms leading to competitive advantage (Elia et al., 2021; Liu et al., 2023). RBV explains that competitive advantage derived from such resources cannot be duplicated by other competing firms.

- the organisation's resources are clearly found to be not moving perfectly across firms. This could be understood as a situation wherein those mobile resources are taken by the players. The effect of such resources taken by players is that an organization could see its competitive advantage declines over a period of time and other resources may be needed to maintain competitive advantage. Further, RBV suggests that differences in strategic resources between organisations could persist over a period of time leading to declining advantage over a period of time (D'Oria et al., 2021).

The above discussions critically discussed the utility of RBV as a theoretical support for linking variables like agile production and sustainability performance factors. Thus from the foregoing discussions it can be said that where agile production is thought to be driving sustainability performance factors in a firm RBV can be used to establish a relationship between the two. Whether RBV enables the establishment of such a relationship can be corroborated by the arguments of several authors referred above. It can be concluded that using RBV it can be seen that when a firm employs resources that are rare, valuable and not easy to be replicated, then that firm achieves competitive advantage (Chen et al. 2009; Day 1994; Barney 1991;

Wernerfelt 1984). Competitive advantage is an important sustainability performance factor and RBV insists that if the assets and resources of a firm are used in distinctive ways (Chen et al. 2009; Day 1994; Barney 1991; Wernerfelt 1984) then competitive advantage can be achieved as part of the sustainability performance of a firm.

Additionally, if one integrates the concept of supply chain collaboration then the situation becomes even more dynamic as supply chain systems are by nature dynamic (Martínez-Sánchez et al. 2019). Thus, another theory may be needed to augment the explanation that could be given by RBV to operationalize agile production that is sustainable and integrate supply chain collaboration into agile production. In this research the theory chosen to support RBV was the dynamic capability theory which is explained next.

2.7.2 Dynamic capability theory

While the previous section has touched upon some of the characteristics of agile production, the Icacco Institute (1991) has identified some more characteristics. Some of the other most important characteristics of agile production identified by Icacco Institute (1991) are capabilities, flexibility, speed, responsiveness, infrastructure, human resources, hard and soft technologies, a management that is educated and informed, competitors, suppliers, customers and ability to rapidly shift among product models or between product lines as a response that occurs in real-time to the customer requirements (Iacocca Institute, 1991). It can be seen that many of these characteristics of agile production can have lack of support of RBV when agile production is linked to sustainability factors. For instance, RBV is constrained by its limitation to be a logic based concept (Sanchez, 2008). However, when rapid changes are required to be adopted in a firm, RBV may not be in a position to explain the disturbance in the heterogenous distribution of resources in that firm, thus resulting in a possible disorder in distribution of resources in some sections of a firm leading to an adverse impact on competitive advantage. This can only occur when there are rapid changes that occur in a firm that has agile production method implemented in it. In this dynamic situation RBV may not be able to explain the relationship between agile production as a variable and sustainability performance factors as variables. So, some other theories need to be brought in to support RBV to establish the conceptual relationship between the two variables namely agile production and sustainability performance factors. One such theory that could be brought into support RBV concept is the dynamic capability theory.

According to Teece et al. (1997; p. 516) dynamic capability (DC) is defined as “the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments”. Teece et al. (1997) argue that agile production is considered as a dynamic capability that can produce sustainable competitive advantage and hence can be explained by DC theory. However agile is complex, structured, multidimensional, and usually involves long-term commitments to specialized resources and hence is not easy to achieve. This is a challenge for many firms (Chikwendu et al. 2020). As was noted above for RBV, the application of DC theory alone may not be enough, although argued to be useful, DC theory has been found to suffer its own limitations. For instance, Pezeshkan et al. (2015) argue that the relationship between DC and competitive advantage is inconsistent in the literature. D'Aveni and Ravenscraft (1994) posited that those firms that transform multiple times may not be able to replicate the transformation in the future. It is important that researchers keep in mind such limitations while applying the DC theory to any research involving agile production. In this respect, it is worthwhile to combine another theory with DC theory that could augment its limitations, for instance RBV, that considers the linkage between resources and competitive advantage.

Application of RBV and DC theory in combination in research that has investigated agile production and sustainability is found in the extant literature. Erwin (2021), for example applied both RBV and DC theories in research that investigated the impact of agile supply chain strategy on sustainability performance with company's sustainability reporting. Sharma et al. (2023) studied the supply chain enablers of green, resilient, agile, and sustainable fresh food using RBV theory. Similarly, Ahmed et al. (2019) analysed the factors affecting firms' agility and competitive capability using RBV and DC theories. Thus, it can be seen that evidence is available in the literature regarding the application of RBV and DC theories to research concerning agile production.

It is seen that dynamic capability theory has been argued to be sufficient enough to support RBV in explaining the relationship between the variables agile production on the one hand and sustainability performance factors on the other. However, there is a need to understand whether the use of dynamic capability theory could really make a difference to the relationship between agile production on the one hand and sustainability performance factors on the other. This aspect gains importance because of the limitations that surround agile production, RBV and dynamic capability theory. For instance, one of the limitations of dynamic capability theory is that the relationship between DC and competitive advantage is inconsistent in the literature (Pezeshkan et al. 2015). This has a direct effect on RBV because RBV fundamentally posits that it can explain whether the relationship between two variables can lead a firm to achieve competitive advantage using internal resources organized in a way that those resources are available at all points of time in a rapidly changing situation. However, researchers have argued that this universalistic character of RBV is a myth (Sanchez, 2008). Thus, if dynamic capability theory is used alongside RBV, then it is possible to overcome this limitation of RBV as DC argues that firms if they are ready to integrate, build, and reconfigure internal and external competences in a rapidly changing environment, then it is possible for researchers to apply RBV to agile production and achieve competitive advantage.

From the foregoing discussions it can be seen that the concept of dynamic capabilities could be used to support the RBV in regard to this research that involves the possible linkage between agile production and sustainability performance factors with the intervention of the supply chain concept. Despite its limitations, dynamic capability theory provides a strong support in areas where resources are not easily available to achieve competitive advantage through the application of RBV.

2.8 Factors affected by agile production

A careful examination of the existing literature shows that agile production has been identified many times as a construct that affects a number of factors in the context of manufacturing firms. Factors identified include sustainability performance (Sun et al. 2022; AlNawafleh et al. 2022; Firooz et al. 2021; Geyi et al. 2020), organizational culture (Firooz et al. 2021), firm performance (Reed, 2021), labour productivity, human resource management (AlNawafleh et al. 2022), procurement (Sun et al. 2022), environmental supply chain management systems, social supply chain management systems, economic, social and environmental performance (Ciccullo et al. 2018), innovation, environmental management, cost competitive advantage, differentiation competitive advantage (Lopez-Gamero et al. 2022), and operational performance objectives (including price (cost), speed, quality, flexibility, reliability and innovation) (Geyi et al. 2020). That agile production as a construct has been conceived to affect numerous factors in many different domains illustrates the contemporary importance of the construct. According to the literature the influence of agile production on sustainability performance factors however is not well understood, an argument proffered by Ciccullo et al. (2018) who contended that integration of agile supply chain and sustainability is understudied, representing a gap in the literature, and noting that for example, an investigation into this relationship might be expected to reveal amongst other things the trade-offs between sustainability performance factors (economic, social and environmental performance factors) when managers in firms want to take decisions about a specific supply chain practice. After reviewing the literature regarding the factors affecting and that are affected by agile production, the next section deals with the review of how agile production has been conceptualized in prior research.

2.9 Conceptualisation of agile production and approaches used in prior research

Agile production has been varyingly conceived in the literature. Firooz et al. (2021), for example, conceptualized agility as an independent variable influencing organizational sustainability, and van Kelle et al. (2015) similarly conceptualized the degree of agility present in a firm as an independent variable determining project success. Reed (2021) on the other hand, conceptualized agility (strategic) as a mediator between firm size and firm age on the one hand and firm performance on the other. Abourokbah et al. (2023) also conceptualized agility (supply chain) as a mediator, in this case between absorptive capacity and supply chain innovation performance. AlNawafleh et al. (2022) in their study on the relationship between electronic human resource management and labour productivity conceptualized organizational agility as a moderator. Betts and Tadisina (2009) also conceptualized agility (supply chain) as a moderator, of the relationship between collaboration level and supply chain performance. Studies have also positioned agility as a dependent variable. Gligor and Holcomb (2012) conceptualized supply chain agility as a dependent variable determined by supply chain orientation. Similarly, Wiechmann et al. (2022) conceptualized agile organizational structure as the dependent variable determined by a set of critical factors, including digital transformation, information system alignment, agile methods, Scrum and customer focus.

In addition to the above conceptualization positions of agility in priori research, agile production has been included in research as an independent variable, but as a variable whose relationship with the dependent factors is supported by some moderators. Reed (2021), for instance conceptualized environmental turbulence as moderating the relationship between strategic agility and firm performance, and Abourokbah et al. (2023) conceived a model in which supply chain agility was shown to influence innovation performance of a firm alongside supply chain resilience. These examples indicate that not only is agile considered to affect other constructs independently but also in combination with other factors. This in turn indicates the value of further research to identify such factors.

The above arguments show that agile production has been conceptualized varyingly by different authors in different contexts and serving different purposes. These observations from the literature provided some idea on how to conceptualise agile production for the present research. The next section deals with the measurement and research methods that have been adopted by various researchers to understand how the concept of agile production is/can be measured.

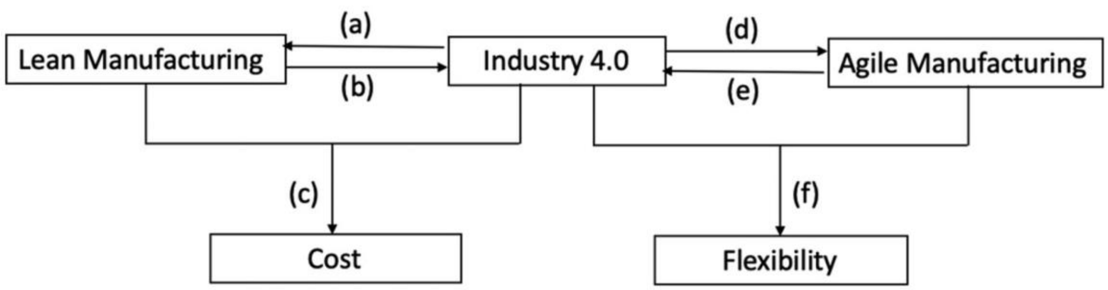
Both quantitative and qualitative research methods have been used in prior research when investigating the concept of agile production. Firooz et al. (2021), Reed (2021) and van Kelle et al. (2015) all used quantitative (positivist) research methods to collect data from the target populations they studied, as did Geyi et al. (2020) who used a Likert scale based research instrument to measure the construct agile practices, and El-Khalil and Mezher (2020) who used a 10 point Likert scale based research instrument to measure agility. Conversely, Pfaff (2023), Wiechmann et al. (2022) and Gunasekaran (1999) all used qualitative (interpretivist) research approaches to answer their research questions associated with agile production, namely interviews (Wiechmann et al. 2022), literature survey (e.g. Gunasekaran, 1999) and case studies (Pfaff, 2023), respectively.

In summary, it can be seen that literature on agile production as a construct has been well discussed but still there are gaps that need to be addressed. Some of the important gaps that need to be addressed are the conceptualization of agile production as a variable and its relationship with lean production, sustainability performance and supply chain collaboration.

2.10 Combining lean production and agile production

Evidence in the literature suggests that the differences that are found between lean production and agile production can be complementary to each other (Iqbal et al. 2020). Researchers argue that when both lean and agile production are integrated, customer satisfaction, production process flexibility, collaboration with stakeholders and increasing in company openness can be achieved. (Ustyugová and Noskievičová, 2013). Similar arguments are posited with regard to other features of lean and agile production methods. One example of the combined/integrated framework found in the extant literature is that presented by Ding et al. (2023), as Illustrated in Figure 21.

Figure 2.1, Example of a framework combining lean and agile production methods



Source: Ding et al. 2023

However, prior research has also argued that combining lean and agile production methods might in fact lead to problems in manufacturing (Iqbal et al. 2020; Ghobakhloo and Azar, 2018; Iqbal et al., 2018; Hallgren and Olhager, 2009), that is, that the differences that exist between lean and agile production methods can cause difficulties with a feature of lean conflicting with the corresponding feature in agile, and which could make planning and predictions on the manufacturing line difficult, as implied in Christopher and Towill's (2002) analysis presented in Figure 2.2.

Figure 2.2, Predictability of supply chain aspects concerning production methods

Lean lead time (Supply characteristics)	*Lean* Plan and optimize	*Hybrid* De-couple through postponement
Short lead times	*Kanban* Continuous replenishment	*Agile* Quick response
	Predictable	Unpredictable

Source: Christopher and Towill, 2002

Mari et al. (2015) set out differences between lean and agile production along eleven dimensions relating to the manufacturing context (Table 2.4)

Table 2.4, Differences between lean and agile production

Distinguishing attributes	Lean supply	Agile supply
Typical products	Commodities	Fashion goods
Marketing place demand	Predictable	Volatile
Product verity	Low	High
Product life cycle	Long	short
Customer drivers	cost	Availability
Profit margin	low	high
Dominant cost	Physical cost	Marketability cost
Stock-out penalties	Long-term contractual	Immediate and volatile
Purchasing policy	Buy material	Assign capacity
Information enrichment	Highly desirable	obligatory
Forecasting mechanism	Algorithmic	Consultative

Source: Mari et al. 2015

Figure 2.2 shows that when lean and agile are implemented in a firm in an integrated manner, then the quick response associated with agile could be difficult to predict, as opposed to planning and optimization of lean production method, which is inherently predictable. This can cause incongruence in production lines and there could be conflicts that could be a cause of concern.

Nevertheless, there are growing calls for investigating the combined performance of the two methods as much of the existing research effort has been restricted to investigating either one or other of the two methods by considering them as individual silos (Knol et al. 2018; Johansson and Osterman, 2017; Pinho and Mendes, 2017; Tarafdar and Qrunfleh, 2017; Tortorella and Fettermann, 2017). Researchers argue that given the nature of flexibility associated with agile production and cost efficiency associated with lean, there is a need to address both lean and agile production in one research instead of studying them separately as individual silos (Gunasekaran et al. 2008; Narasimhan et al. 2006; Naylor et al. 1999). This is an important area of research that promises to contribute to the body of knowledge related to both lean and agile production methods.

The literature shows that although research that has used both lean and agile concepts in combination simultaneously are sparse (Vaishnavi and Suresh, 2020; Ramana et al. 2013), a number researchers have suggested and examined possibilities of combining lean production and agile production in a single conceptual model to determine their combined influence on various factors concerning manufacturing, including supply chain and sustainability performance (Furlan et al. 2023; Amir, 2011). Table 2.5, constructed by Furlan et al (2023), summarises the various research outcomes that have been reached by researchers who have combined or contrasted the use of lean production and agile production within a single study.

Table 2.5, Examples of various research outcomes that have combined or contrasted the use of lean production and agile production within a single study.

#	Authors (Year)	Type of Contribution	Key Findings
1	Sadeghi et al. (2022)	Empirical (Quantitative)	Lean-agile strategy founded on sustainable supply chain leadership strategy is considered to be the top priority by these authors to enhance performance indicators of the case under analysis. The findings argue that even if lean and agile are considered independent strategies, lean-agile combined strategy is better.
2	Oliveria-Dias et al. (2022)	Conceptual	This study considers lean and agile supply chains as distinct and cannot be combined. The research is about the relationship between the lean and agile supply chain strategies on the one hand and information technologies on the other.
3	Hallgren and Olhager (2009)	Empirical (Quantitative)	Lean production and agile production are considered to be different in terms of drivers and outcomes. Main difference in performance outcomes is linked to cost and flexibility where cost is considered to be a lean production factor while flexibility is considered to be an agile production factor.
4	Krishnamurthy and Yauch (2007)	Empirical (Qualitative)	The researchers argue that firms must simultaneously pursue both lean production and agile production strategies by utilizing the concept of leagile.
5	Narasimhan et al. (2006)	Empirical (quantitative)	The authors have recommended lean and agile manufacturing to be distinguished. It is argued that lean production stresses on quality control, and reliability but agile production emphasizes on superior capabilities in terms of quality, delivery, and flexibility.
6	Bruce et al. (2004)	Empirical (Qualitative)	The authors have investigated the leagile perspective in the contexts of textile companies which have used both perspectives.
7	Fisher (1997)	Empirical (qualitative)	The authors have distinguished between lean production and agile production. It is argued that supply chains that deal with functional products from production to delivery should use lean production factors including efficiency, minimum inventory and lower cost. On the other hand supply chains that deal with innovative products from production to delivery should use agile production factors including responsiveness, flexibility and speedy.

Source: Furlan et al. (2023)

Wurzer and Reiner (2018), noted that when combining lean production and agile production, the intention of firms is to use their contradictory features to provide an integrated benefit of cumulative gain. Naylor et al. (1997) argued that a combination of lean and agile production will help manufacturing units to react to unpredictable demand of markets downstream as well as enabling the unit to support and level schedule upstream from the markets. However, recent literature has also suggested that the argument that in manufacturing units lean and agile production can co-exist is weak, (Ding et al., 2023). Ding et al's (2023) study that followed up their assertion, investigated the use of competitive advantage that could be derived by integrating lean and agile production in the context of industry 4.0 technologies. Hallgren and Olhager

(2009) in their study of firms doing business in different industry sectors found that lean and agile production are mutually exclusive, on the basis that the two production methods had different drivers and outcomes. Similarly, Qamar et al. (2020) found, through their investigation of the automotive industry in the UK that there is a clear and distinct separation between companies that achieve high levels of flexibility, and those that attain high levels of cost efficiency. Such findings led Ding et al (2023), to refute the idea that lean could result in high levels of flexibility, and likewise that a high level of cost efficiency can be achieved through agile production. Oyombe et al.'s (2022) study on the other hand, found leagile strategy having a positive influence on competitive advantage on the context of construction supply chains. It is interesting to note that in their study of impact of leagile hybrid paradigm practices on supply chain performance, Rahimi and Alem-Tabriz (2022) conceived lean and agile production as independent constructs, and the two constructs were shown to operate independently on supply chain performance, in a single model.

The above contributions indicate a lack of clarity on the outcome when lean and agile production methods are combined, and consequently it is also not clear whether it is better or necessary to only use lean and agile production independently or in a combined fashion to exploit their respective attributes. These contributions highlight a number of variants in conceptualisation in studies concerning lean and agile production.

Extension this analysis on lean and agile production Table 2.6 presents Sharp et al's (1999) comparison between lean and agile production, which is useful and has enabled researchers to propose ways forward to utilise the two, ultimately for the benefit of firms.

Table 2.6, Comparison of lean production and agile production

	Lean	**Agile**
Drivers	• Market • Economy of waste • Predictable markets • Make to forecast	• Customer • Economy of diversity • Unpredictable markets • Make to order
Focus	• Technology and Systems	• People and Information
Suppliers	• Fewer • High level of trust • (long-term) • Co-operative	• Selection from many • High level of trust • (short-term) • Shared risk/reward
Organisation	• Teaming • Flatter organization	• Multi skilling • Empowerment
Product	• Many options • High quality	• Customised • Fitness for purpose
Process	• Flexible • Automated	• Adaptive • Knowledge based
Philosophy	• Administrative	• Leadership

Source: Sharp et al. 1999; p.157

The comparison shows distinct differences which in turn point towards the following configurations a firm could look to adopt to gain maximum benefit:

1. A firm can fully implement only agile production and derive all the benefits provided by agile production.
2. A firm can only rely upon lean production and exploit the advantages provided by lean production.
3. A firm can implement an integrated production mechanism such as leagile where the advantages of agile production and lean production are "integrated" for achieving better performance.
4. A firm can choose to implement agile production as the dominant production method, supported partially by lean production where needed.
5. A firm can choose to implement lean production as the dominant production method, supported partially by agile production where needed.

While literature shows that the first three scenarios have prominently been addressed discussed in the literature (e.g. Sharp et al. 1999 (agile only); Awad et al. 2022 (lean only); Ding et al. 2023 (integrated model), the remaining two are not well discussed addressed thus far, and arguably this is a gap in the literature, and may have arisen simply due a preference to investigate each construct independently or as a 'merged' concept.

2.11 Sustainability performance: overview and definitions

This section provides an overview of the concept of sustainability and sustainability performance including their definitions given by various authors in regard to manufacturing units. Sustainability is a major concern of industries across the world (Medabesh and Khan, 2020; Pierre et al. 2019). The term sustainable manufacturing has been varyingly defined and tends to be derived from the World Commission on Environment and Development (WCED) (1987) definition of sustainable development (Eslami et al. 2019). Table 2.7 presents the latter, followed by definitions of sustainability in the manufacturing context.

Table 2.7, Definition of sustainable development, and definitions of sustainable manufacturing

Definition	**Provided by**
Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.	The World Commission on Environment and Development (WCED) (1987; p.1)
Sustainable manufacturing is a set of technical and organisational solutions contributing to the development and implementation of innovative methods, practices and technologies, in the manufacturing field, for mitigating the excess of environmental load and for enabling an environmentally benign life cycle of products	Garetti et al. (2012, p. 79)
Sustainable manufacturing can be defined as the ability to use natural resources in manufacturing intelligently in order to fulfill economic, environment and social aspects and thus, preserves the environment and improve the quality of life	Garetti and Taisch (2012, p. 85)
Sustainable manufacturing is a concept that is made of five aspects namely eco-design (life-cycle design), process design, energy management, waste management, and supply chain management	Kuo et al. (2022)
Sustainable manufacturing could be defined as the creation of products having economic value using processes that reduce negative impacts on the environment, save energy and natural resources and conserve natural resources and energy to ensure their availability in the future.	Hermawan et al. (2023)

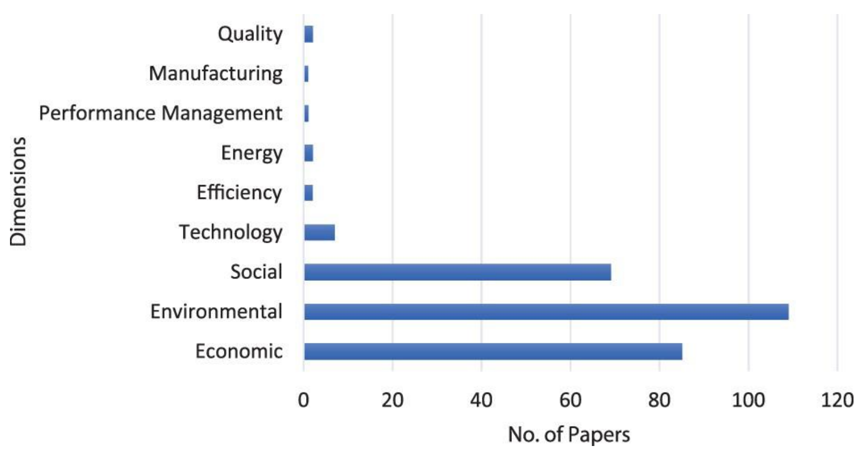
From these definitions of sustainable manufacturing, it is clear that sustainable manufacturing encompasses a number of aspects including meeting the demands of current generation and preserving for future generations resources to meet their needs, a focus on innovative methods thus contributing to the developmental aspects, mitigating excesses usage of or load on environment, fulfilling economic, environmental and social aspects, preserving the environment and improving quality of life of people. The definitions further indicate that sustainable manufacturing is a complex phenomenon, that needs to be addressed through the careful consideration of how sustainability performance of a manufacturing unit is achieved. The phenomenon of sustainable manufacturing although rapidly gaining momentum, poses challenges to manufacturing firms across the world (Eslami et al. 2019). To understand such challenges and how to mitigate them it is necessary to first review the extant literature.

2.12 The three areas of sustainability

According to the literature, the bulk of the research work that has addressed sustainability in manufacturing industries is focused on one or more of the three major sustainability performance dimensions, namely economic, environmental and social sustainability. The need to study each of the three areas arises for many reasons. These include a lack of in-depth understanding of each of the three areas that could help manufacturing firms to devise their own sustainable strategies (Eslami et al. 2019); lack of knowledge related to improving sustainability through adoption of latest technologies at all levels (system, process and product) (Kishawy et al. 2018); and lack of knowledge on how to keep continuously developing current "sustainable" technologies, benefiting and leading to a more sustainable manufacturing environment Kishawy et al. 2018).

Eslami et al's (2019) review on the dimensions of sustainability in manufacturing firms indicated that that the number of articles covering the three sustainability factors namely economic, environmental and social sustainability (across a wide range of literature types and sources) is comparatively higher than on other more specific factors that also affect sustainability (figure 2.3).

Figure 2.3, Status of research on economic, environmental and social sustainability factors



Source: Eslami et al. 2019

Examples of the three sustainability performance factors in the manufacturing context has also attracted the attention of the United Nations (UN) and governments across the world. The United Nation's sustainable development goals (SDGs) are concerned with the three factors, as reflected in UN's focus on poverty, inequality, climate change and environmental degradation (UN, 2023). Similarly, in the United Kingdom, and in Saudi Arabia (the location of the present study), governments have framed policies with regard to environmental sustainability that are concerned with the manufacturing units (Medabesh and Khan, 2020). All 193 member countries in the UN have adopted the UN sustainable development goals (UN, 2015).

The following sections, in turn, examine literature that has addressed economic, environmental and social sustainability performance, respectively.

2.13 Economic sustainability performance

According to Basiago (1999) the notion of economic sustainability was first introduced by Hicks (1946). One explanation of economic sustainability is that it is a system of production that takes cares of the present consumption levels without seriously affecting future needs (Basiago, 1999), and in simplest terms, the sustainability that the economic sustainability aims to achieve is the sustainability of the economic system itself (Basiago, 1999). An example of an instance of economic sustainability was the definition of Hicks (1946) given for income, explained as the amount one can consume during certain period of time and yet be well off at the end of that period of time. This can be applied to the manufacturing industry context also, whose income could be similarly defined for the purposes of explaining their economic sustainability.

Table 2.8, Definitions of economic sustainability

#	Definition	Author
1	Depending on the assumption of what a capital stock is, technological progress is and the rate of discount of a future utility is as well as having a finite level of resources, it is possible to achieve maximum level of utility over time, with utility levels being constant over time.	Solow (1974); Stiglitz (1974); Dasgupta and Heal (1974)
2	The capability of a company to offer its customers a service package that could be considered by its customers as better than the service package offered by other companies who are its competitors resulting in a profit for the company. The service package thus offered should be adaptable to any changes in the internal or external environment of the company in the future.	Demeter et al. (2009)
3	It is the maximization of the financial benefits of a firm for its internal and external stakeholders.	Leon and Calvo-Amodio (2017)
4	It is the capacity of a company to achieve its financial objectives in the short and long terms using such practices as lean production.	Siegel et al. (2019)
5	It concentrates on: linking a project's goals and outcomes to a firm's main economic drivers to create an interaction; how the project is expected to guide the firm; and how the project is expected to ensure the sustainability of the firm's business with regard to financial stability.	Brzozowska (2021)

2.13.1 Factors affected by economic sustainability performance

While the literature shows that there are factors that affect the economic sustainability in firms, at the same time it shows that there are factors that are affected by economic sustainability performance. Abdul-Rashid et al. (2017) identified company's market share, image, marketplace position and profitability as some of the factors that are affected by economic sustainability performance. Similarly, Inman and Green (2018) identified the amount of the goods delivered on time, inventory levels, scrap rate and product quality as factors affected by economic sustainability performance. Enshassi et al. (2016) identified scale and business scope, effects on the local economy, capital budget and finance plan as factors also affected by economic sustainability performance. Competitive advantage, generation of more revenue, contribution to the government exchequer, generation of additional economic benefit (economic value added), existing assets (addition to capital), reduction in overall risk and saving in investment and other costs, were factors found to be affected by economic sustainability performance by other researchers (Zheng et al. 2021; Raihan, 2019; Akter et al. 2018; Nwobu et al. 2017).

Despite these findings and observations, the literature indicates many avenues still not yet investigated with regard to the effect of economic sustainability on the performance of firms, representing gaps in the literature.

2.13.2 Factors affecting economic sustainability performance

The literature shows that several factors affect economic sustainability performance in the manufacturing sector. Kahn (1995) identified growth, development, productivity and trickle down as factors affecting economic sustainability performance. Earnings per share and Return on Equity (RoE) are considered to be factors affecting economic sustainability (Milne and Ralph, 1999), as are profitability and price earning ratio (Al-Tuwaijri et al., 2004). Sustainable supply chain collaboration, competitive advantage (Reyes-Soriano et al. 2022) and agile production (de Castro et al. 2022) have also been found to affect economic sustainability performance. Similarly, Awad et al. (2022) identified lean manufacturing practices and value creation as factors affecting economic sustainability performance.

The extant literature indicates that the current knowledge concerning the relationship between some of the abovementioned factors and economic sustainability performance is not well addressed in the literature. For instance, Akbar (2021) argue that researchers suggest that accomplishing economic sustainability is dependent on sustainable manufacturing practices, however Kim (2010) and Saleh et al. (2011) have highlighted that researchers have neglected this aspect and have not provided solutions to accomplish it. Literature shows that conflicting results have been achieved by researchers in regard to understanding the definition of sustainable manufacturing practice and economic sustainability that is context driven. In addition, it is also seen that literature lacks adequate research outcomes that have established a relationship between sustainable manufacturing and economic sustainability (Akbar, 2021). To overcome this gap Akbar (2021) conducted research on 140 fabricators in Pakistan to understand the relationship between sustainable manufacturing practice and economic sustainability and produced inconclusive results. The author showed that there is a partial influence of sustainable manufacturing practice on economic sustainability. Akbar (2021) studied products innovation, processes innovation, managerial innovation and advertising innovation as factors that measure economic sustainability. This implies that more research needs to be conducted to gain deeper insights into the concept of economic sustainability and the factors affecting it.

In similar lines Wiśniewski and Tundys (2022) conducted a research on sustainability factors in supply chain links using comparative analysis of those factors which included economic sustainability performance. The study presented and analysed the various actions taken while implementing sustainable development factors and elements in supply chains which include economic sustainable factors by taking into consideration the perspectives about the various links in the supply chain. Using a survey questionnaire strategy, the authors collected data from farmers, manufactures, retailers and online stores selling organic products (including natural cosmetics and household chemicals). 700 enterprises from Poland were selected for collecting data. The results of the research showed that various sustainability indicators have a role in selected links in the supply chain which included economic sustainability indicators. The importance of the sustainability indicators was determined using ranks which could be used to make decisions on prioritizing the implementation of sustainable development strategies in whole supply chain. However, results were fragmented with only the producers being ranked high due to the economic aspects of supply chain whereas the manufacturers were found to have a high ranking only in regard to the social aspects of the supply chain while the retailers had a high rank with regard to the environmental aspects of the supply chain. Thus the results showed that in various contexts the economic sustainability factor could be producing varying results on the supply chain links depending on the context. This shows the importance of contexts on the performance of the sustainability factors indicating the need for conducting research on those sustainability performance factors on supply chain links including economic sustainability performance factors. Therefore, it is necessary to conduct more research to understand the relationship between some of the factors mentioned here and economic sustainability performance in the context of manufacturing firms. Thus after reviewing the concept of economic sustainability performance the discussion next deals with the conceptualisation of economic sustainability performance as a factor in literature.

2.13.3 Theories concerning economic sustainability

The literature shows that researchers have used different theories to explain and investigate economic sustainability performance. Not surprisingly, Vitalis (2003) argues that economic sustainability could be explained by economic theory which states that when the preferences for the environment increase, then the right preservation levels could be automatically achieved. In another instance, Iftikhar (2022) argues that endogenous growth theory can be applied to explain economic sustainability performance because economic development focuses on productive capacity and the utilization of the knowledge the firm has, by large firms leading to possible investments in human capital and research. The literature also reveals that the Resource-Based View (RBV) can be applied to economic sustainability (Lockett and Thompson, 2001). Barney (1991) argues that RBV is concerned with resources that are valuable, rare, non-substitutable and inimitable. It is possible to achieve competitive advantage using RBV. Examples of resources include tangible (funds, technology, equipment) and intangible (skill, organizational process, information and knowledge) ones. Those resources help achieve improved efficiency, and effectiveness culminating in organizational capabilities (Barney, 1991). Giang et al. (2022), not surprisingly suggested that triple bottom line theory (TBL) is useful to explain the economic sustainability performance of manufacturing units. Literature shows that TBL as a theory can explain an entity's balanced development where the main objective of the entity is not profit alone (Lorenzoni et al. 2000). According to Lorenzoni et al. (2000), more and more firms are bringing in the concept of TBL into their operation to make it sustainable which is measured by economic, social, and environmental factors, not least because not focusing on sustainability performance can be a serious risk for firms as such firms may lose market share and pay a cost to regain customer confidence (Lorenzoni et al. 2000).

2.13.4 Conceptualisation of economic sustainability performance in prior research

The concept of economic sustainability has been varyingly conceived in the literature. Akbar (2021) conceptualized economic sustainability as a dependent variable while investigating its relationship with innovation performance and sustainable manufacturing in the context of manufacturing industries. Akbar (2021) further distinguished between internal sustainable manufacturing practices and external sustainable manufacturing practices, and economic sustainability was concerned with financial performance of the manufacturing units. The internal sustainability manufacturing practices concerned cleaner creation, employee relations and eco-efficiency, while the external sustainability manufacturing practices were supplier relations, community relations, customer relations, industrial relations and closed-loop production. Zheng et al. (2021), alternatively, conceived economic sustainability as the determinant of overall sustainable performance in their investigation of factors affecting sustainability performance (in this case, of financial institutions in Bangladesh). An interesting feature of Zheng et al's (2021) study is that the relationship between economic sustainability and sustainability performance was operationalized as mediated by environmental sustainability and social sustainability.

Samadhiya et al. (2022) adopted circular economy as the mediator between total preventive maintenance and I4.0 on the one hand, and economic sustainable performance (alongside environmental and social) on the other. Here, circular economy concerned the firm optimising usage of resources and elimination of wastage to accomplish harmonious, sustainable development (Ghisellini et al. 2016). Similarly, Diantimala (2018) positioned economic sustainability acts as a mediator, positing that sustainability disclosure involving economic, environmental and social sustainability mediates between firm characteristics (e.g. leverage, size, liquidity and profitability) and financial value.

Although not in the manufacturing domain, in their investigation on the influence of sustainability report disclosure as moderating variable towards the impact of intellectual capital on company's performance, Utama and Mirhard (2016) used sustainability disclosures as moderators. In their research, it was posited that sustainability reporting moderates the relationship between value added intellectual coefficient (VAIC) and return on equity and return on assets. Similarly, Gillani et al. (2020) investigated the moderating effect of financial sustainability on association between firm's financial determinants and firm financial distress. These prominent examples clearly show that economic sustainability has been conceptualized in various ways which leads to the inference that there is no one way to conceive economic sustainability in empirical research studies. Further to discussing the conceptualization aspects of economic sustainability the next section reviews the measurement aspects concerning economic sustainability.

2.13.5 Approaches used and measurement of economic sustainability performance in prior research

Literature shows that economic sustainability as a construct has been studied using quantitative, qualitative and mixed methods. For instance, Zheng et al. (2021) used a quantitative survey method to investigate and measure economic sustainability as an independent variable in the context of banks and non-bank financial institutions in Bangladesh. Specifically, Zheng et al. (2021) collected data about economic sustainability with a measurement instrument using a 5-point Likert scale and analysed the data using structural equation modelling. Similarly, Abdul-Rashid et al. (2017) studied 443 manufacturers with ISO 14001 certification in Malaysia and used quantitative research method and a survey questionnaire strategy to collect data about factors of sustainable manufacturing practices impacting sustainability performance. The survey questionnaire used multipoint Likert scale ranging from 'Strongly disagree' to 'Strongly agree' and the authors used Structural Equation Modelling to analyse the data. In the same vein it can be seen that Inman and Green, (2018) investigated the impact of Lean and green combine on environmental and operational performance using quantitative research method and collected data using a survey questionnaire. Likert scale was used to collect data with the points ranging from no implementation to complete implementation. Inman and Green, (2018) conducted the research on a sample of 182 manufacturing managers working for U.S. manufacturing plants and used PLS-SEM method to analyse data. However, Carag et al. (2023) on the other hand, used both qualitative and quantitative research methods, adopting a 7-point Likert scale based survey for collecting data during the quantitative phase of their study, and semi-structured interviews in the qualitative phase, in their research on development and validation of sustainability framework for SMEs. Sin et al. (2020) also chose to use a mixed method approach in their investigation on the perceptions of quality management and sustainability. Sin et al. (2020) examined hotel quality manager's perceptions of quality management and sustainability via the sequential-mixed methods approach. Their research, qualitative research method was used at the beginning in which interviews were conducted which was followed by quantitative research method that depended on and followed the qualitative research method.

In the quantitative research method phase Sin et al. (2020) conducted the research on 4 and 5-star hotel quality managers in Malaysia and used a survey questionnaire and PLS-SEM method to conduct data analysis.

The above discussions clearly show that researchers have used different measurement methods to collect data about economic sustainability and analyse it. It can be thus inferred based on the discussions above that conceptualization and measurement of economic sustainability as a construct is varied and wide and provides an opportunity for researchers to choose a particular method or methods depending on the context of study. Further to discussing the concept of economic sustainability performance the next section deals with environmental sustainability performance.

2.14 Environmental sustainability performance

Many definitions of environmental sustainability can be found in the literature. Morelli (2011) defined environmental sustainability simply as a condition that concerns human society, the condition signifying the balance, resilience and interconnectedness that enables human society to fulfill its needs, taking into account the capacity of those various ecosystems that support it, leading to continuous regeneration of the services required to meet those needs, and ensuring that such regeneration is not affected by the actions of human beings which diminish biological diversity. Goodland (1995; p.10-11) defined environmental sustainability as a set of constraints that affects the four major activities that regulate the scale of the human economic subsystem, namely the use of renewable and nonrenewable resources on the source side while on the sink side are the pollution and waste assimilation. Morelli (2011) and Goodland's (1995) definitions of environmental sustainability are found to be widely used in the literature. Sutton (2004) defined environmental sustainability as the capacity of an organization to maintain qualities that are valued in the physical environment, which include:

- human life;
- those capabilities that the natural environment has to maintain the living conditions of human beings and other living organisms (for instance air and water that are clean; climate that is suitable for people to live);
- elements that the environment that produce renewable resources (water, wood, wind energy and fish);
- the operations of the society that has to go on despite depletion of non-renewable resources; and
- quality of life of people which comprises the livability and beauty of the environment.

Ince (2018) argued environment sustainability is a method by which human needs are met and the health of the ecosystems are not compromised, a view indicating the limits of the human activities in nature. An example of this definition could be the growing agricultural and economic needs that emphasise on the need for mutual ties between people and nature. Dixit and Chaudhary (2020) explain that environmental sustainability is about responsible activity concerning the environment and stopping the depletion or debasement of the natural resources and securing them from long-term environment quality issues. Dixit and Chaudhary (2020) also argue that environmental sustainability is a condition of resilience, balance and interconnectedness which leads to the development of a method by which human beings could fulfill their needs, without compromising factors that are concerned with the environment. Moldan et al. (2012) positioned environmental sustainability as the maintenance of natural resources alongside nature's services at a convenient level.

The above definitions indicate that environmental sustainability is a broad term that encompasses a wide range of aspects that concern the human society, the resources and the environment itself. The definitions indicate the enormity of the challenges associated with maintaining the environment and sustaining it, an observation Supported by Little et al. (2016), who argue that it is a difficult challenge to identify a truly comprehensive and realistic way to (evaluate and) enhance sustainability. In addition, the definitions indicate that solutions are needed to overcome the problems faced during maintenance of the environment and literature shows that our understanding and use of this concept environment sustainability is not devoid of problems (Morelli, 2011). Accordingly, further research is needed to attain a better understanding of the environmental sustainability. The next sub-sections review the literature regarding the various factors that are affect by, and that affect environmental sustainability, respectively.

2.14.1 Factors affected by environmental sustainability performance

The literature indicates that enhanced environmental sustainability performance has the capacity to affect both firm-level and intra-firm/individual factors. For instance, studying the internal and external environmental factors affecting innovative leadership towards sustainable growth of manufacturing small and medium enterprises, Ngibe and Lekhanya (2020) found that external sustainable growth of manufacturing industries is influenced by environmental factors. Using a survey questionnaire, Ngibe and Lekhanya (2020) collected data from owners and managers of 384 small and medium enterprises situated in Natal, South Africa, the researchers found a direct relationship between internal and external environmental factors and sustainable growth. Results showed that external factors like competition, fast changes in technology and social factors had a positive effect on sustainable growth. With regard to the internal factors the authors found that capital and business performance, support from shareholders/boards of directors, employee support and business networking had a direct influence on sustainable growth of SMEs. However, the results produced by the researchers could not considered as conclusive and generalisable as the research was conducted in a particular province of South Africa environmental characteristics could be different from those existing in other countries. Similarly, investigating the determinants of an environmentally sustainable model for competitiveness Noorliza (2023). Exploring the human–environment connection in the context of the logistic industry, Noorliza (2023) investigated logistic professionals and logistic service providers and developed an environmentally sustainable model. Conducting a systematic literature review, the researcher examined environmental leadership that encouraged the organizational structure and green practices that helped manufacturing units to gain competitiveness and achieve sustained performance. However, the study suffered due to limitations including inadequate explanation about the relationship between environmental aspects and sustainability performance of manufacturing industries and lack of generalizability. The above review of the literature clearly points out that the relationship between environmental sustainability performance and sustainability needs further investigation to understand how the concept of environmental sustainability performance could be better understood in the context of the manufacturing industries.

Furthermore, on an intra-firm/individual level, Ince (2018) identified personal (personality and demographic factors) and organizational factors (organizational work life and sources of leader power) as factors that are affected by environmental sustainability. Under personality Ince (2018) identified extroversion, conscientiousness, agreeableness, openness and emotional stability as factors that get affected by the environment sustainability while work environment, working conditions and facilities were identified as factors affected by environment sustainability that were classified under quality of work life. As far as sources of power are concerned Ince (2018) identified legitimate, expert and referent as affected by it. Inman and Green (2018) identified reduction of air emissions, liquid waste, solid waste, reduction in consumption of hazardous, harmful and toxic material and environmental accidents and improved enterprise's environmental situation, as factors that measure an enterprise's environmental situation. These arguments demonstrate that there a number of environmental factors that could affect environmental sustainability performance of a manufacturing firm although all existing factors that are currently known to the human beings should be investigated to understand the relationship between environmental factors and sustainable manufacturing performance of organisations.

2.14.2 Factors affecting environmental sustainability

Literature shows that a number of factors affect environmental sustainability. Those factors include adoption of technology, business environment, skills related to management of enterprises and access to finance and competition (Msomi, et al. 2019; Ngibe and Lekhanya, 2019b), resources awareness and ability to enhance efficiency and operational effectiveness quickly (Snyman et al. 2014 and Chikozore, 2017). In addition lean production factors have been identified as affecting sustainability that include formal supplier certification programme (supplier management) (Shekarian et al. 2022), formal supplier certification programme (supplier management) (Shekarian et al. 2022), customer feedback on quality and delivery performance (customer value) (Awad et al. 2022), classification of products into groups with similar processing requirements (standardistaion) (Pawlik et al. 2022), grouping of equipment for producing the continuous flow of families of products (cellular manufacturing) (Kant et al. 2015), Employees working on the shop floor lead product and process improvement efforts (continuous improvement) (Barclay et al. 2021) and giving away a portion of every day to planned equipment maintenance activities (total productive maintenance) (Pawlik et al. 2022).

Additionally, literature shows that there are agile production factors that have been found to influence the environment sustainability performance of manufacturing industries which include, cross functional teams (Conforto et al. 2014), use of flexible production technology (Adeleye and Yusuf, 2006), leadership in the use of current technology (Vinodh et al. 2010), technology awareness (Geyi et al. 2020), flexible and multi-skilled employees (Geyi et al. 2020), providing continuous training and development (Baraei and Mirzaei, 2019), adoption of a culture of change (Baraei and Mirzaei, 2019), customer driven innovation (Gupta, 2019) and responsiveness to changing market requirements (El-Khalil and Mezher, 2020)

With so many factors affecting environmental sustainability performance, it has become a challenge for the enterprises to address every one of them to ensure that environmental sustainability is achieved. Moreover, the factors identified above provide an indication both of how formidable a task tackling environmental sustainability is, but also how it can be tackled if specific factors can be linked to specific purposes. In the context of the present research, the important aspect that needs to be understood is the usefulness of specific production methods in gaining any advantage to achieve environmental sustainability performance.

After discussing the factors affecting environmental sustainability performance of firms, the next section deals with the theories that could be drawn to support the concept of environmental sustainability performance and its relationship with its predictors and the predicted constructs.

2.14.3 Theories supporting environmental sustainability performance

There are a number of theories that have been suggested by researchers in regard to investigations of environmental sustainability performance. Zacher et al. (2023) identified five theories that could be linked to the concept of environmental sustainability which include the theory of planned behavior (TPB) of Ajzen (1991), the norm-activation model of Schwartz (1977), value-belief-norm theory of environmentalism of Stern (2000) and Stern et al. (1999), the social identity theory (Fritsche et al 2018) and social exchange theory (Thibaut and Kelley 1959). All five theories are concerned with the social and environmental psychology (Zacher et al. 2023). Naseem et al. (2023) used theories of comparative advantage and International Product Life Cycle (IPLC) in their investigation on elongating the role of renewable energy and sustainable foreign direct investment on environmental degradation. Aqib and Zaman (2023) identified human resource development theory, the theory of human capital accumulation and the theory of sustainable environment. As Aqib and Zaman (2023) explained, The theory of human resource development is concerned with human resource activities and is linked to the effect of positive or negative outcomes generated by the management's decision on a firm's output caused by employee actions, and Becker (1994) and Schultz (1989) argue that the theory of human capital accumulation is concerned with education and training that can boost worker output, and human resource aspects that are considered at the time of recruitment of workers. The theory of sustainable environment (Anand and Sen, 2000) argues that there will not be any deficit in the ethical behaviour of one generation with regard to the next, leading to the enjoyment of the same level of living standards due to the present actions in economics and environment, clearly a theory directly related to environmental sustainability performance.

Other theories have been identified, but it can be observed that they are very specific to the context. Islam and Iyer-Raniga (2023), for example, argued that many theories could be applied including product development theory, servitization theory, disruptive innovation theory, agency theory and stakeholder management theory, in regard to explaining the environmental sustainability performance but in the context of a circular business model. Similarly, Shatkovskaya et al. (2023) suggested the use of theory of sustainable development in their investigation of the legislation system as an element of state sustainable development in the twenty-first century.

The literature also identifies the theory of sustainable development, for instance Olawumi and Chan (2018). Taking cue from the arguments of Shi et al. (2019), it is reasonable to argue that theory of sustainable development provides a basis to explain the environmental sustainability performance of enterprises of all levels.

In its basic form, the theory of sustainable development can be stated as "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their needs (World Commission on Environment and Development, 1987; p. 6). While this theory is widely accepted across the world, it is important nevertheless to note there are criticism levelled against this theory, which Zahedi (2019) summarized as: -

- the theory lacks clarity at the conceptual level'
- human rights are not considered more important than generational needs,
- lack of precision in defining the needs of the next generation,
- there is no logical justification and moral obligation pertaining to ignoring the right of today's generation and requirements of the following generation,
- no legal enforcement support,
- one-dimensional and disproportionate with the requirements of the third world countries, and
- having an attitude that is judgmental and sloganistic.

The preceding observations from the literature indicate an extensive range that there are a number of theories that could be applied in order to explain the concept of environmental sustainability. This in turn leads to the inference that application of theories to the concept of environmental sustainability is complex and requires careful selection of the appropriate theory that aligns with the specific study focus and research questions.

2.14.4 Conceptualisation of environmental sustainability performance in prior research

Environmental sustainability, as a construct, has been varyingly conceptualized in the extant literature. Abobakr et al. (2022) conceived environmental sustainability performance as a dependent variable in their research on the impact of lean manufacturing practices on sustainability performance using a natural resource-based view. Solikhah and Maulina (2021) also conceived environmental sustainability performance as a dependent variable that is determined by a number of factors, namely financial performance, environmental awards, media coverage, compliance, pollution prevention, product stewardship and sustainable development. Guiao and Lacap (2022) on the other hand, positioned environmental sustainability as an independent variable, conceiving environmental sustainability awareness as the determinant of green purchase intention and brand evangelism. Similarly, Tabesh et al. (2016) conceived environmental sustainability as determinants of green supply chain management. Lestari et al. (2021) used environment regulations as a moderator of the relationship between customer pressure and green innovation. Zheng et al.'s (2021) study used environmental sustainability as a mediating variable while investigating the factors affecting the sustainability performance (environmental aspect) of financial institutions in Bangladesh. A similar conceptualization was put forward by Inman and Green (2018), who configured environmental sustainability performance as a mediating variable between lean manufacturing practice and supply chain management practice on the one hand and operational performance on the other. In yet another conceptualization, Ince (2018) conceived environmental sustainability performance as an associate construct of personal factors and organizational factors.

The above arguments show that environmental sustainability as a construct has been varyingly conceptualized in the literature depending on the area of investigation and hence there is no unity amongst researcher in the conceptualisation of environmental sustainability performance. The next section deals with its measurement and the way it has been investigated by researchers.

2.14.5 Approaches used and measurement of environmental sustainability performance in prior research

Environmental sustainability performance as a factor has been investigated using explanatory (quantitative) (e.g. Inman and Green, 2018; Zheng et al. 2021; Asio, 2021), exploratory (qualitative) (e.g. Carag et al. 2023; Goh et al. 2020) and mixed method (Sin et al. 2020; Khan and Quaddus, 2015) research approaches. Where researchers have used quantitative research method it is seen that commonly multi choice Likert scale measurement is used to measure items representing the environmental sustainability construct. Inman and Green (2018) conducted a survey with a five-point Likert scale to measure six environmental sustainability items in their study of the impact of lean and green practices on environmental performance in the US manufacturing plants. A similar approach can be seen in the studies of Guiao and Lacap (2022), Zheng et al. (2021) and Ince (2018). Evangelista (2014) on the other hand, conducted an exploratory case study while investigating the environmental sustainability practices in the transport and logistics service industry. Goh et al. (2020) conducted in-depth interviews as part of the qualitative research method while investigating sustainability policies and guidelines in the built environment. Sin et al. (2020) used a sequential-mixed method while investigating perceptions on sustainability and quality management in the Malaysian hotel industry.

As noted previously for economic sustainability, the use of a particular research method ultimately depends on the research question that was being addressed. After reviewing the literature concerning environmental sustainability performance, the next section addresses the social sustainability performance concept.

2.15 Social sustainability performance

An important part of sustainability is social sustainability performance, although review of the literature suggest it is not yet fully understood empirically in the literature. Eizenberg and Jabareen (2017), and

Vallance et al. (2011), for example, argue that the concept of social sustainability is not addressed in research with clarity and in a consistent manner.

Wang et al. (2022) define social sustainability practice as the degree to which a firm implements plans and programmes to enhance its staff member and communal performance. Brzozowska (2021) describe social sustainability performance as a concept that is concerned with a firm's culture, processes and procedures that take into account the gender, culture and other social aspects of a variety of stakeholders including supply chain partners, employees and other shareholders throughout the life cycle of a project (Salama, 2018). Sroufe and Gopalakrishna-Remani (2018) define social sustainability as the measure of the growth and development that improves the situations prevailing within firms to fulfill the various social goas for the firm. Another definition provided by Sachs (1999, pp. 32–33), states that social sustainability comprises achievements including a fair level of social homogeneity, equitable income distribution and a job that enables the creation of respectable livelihoods. In addition, Sachs (1999) argues that social sustainability requires equitable access to resources and social services, balancing between respect for tradition and innovation on the one hand and self-reliance, endogeneity and self-confidence on the other, and furthermore that it must be grounded on essential values of equity and democracy, with the word democracy implying effective appropriation of all human rights including political, civil, economics, social and cultural by the entire community.

While these definitions display both common and diverse aspects, overall the literature shows that there is no consensus on what should be the definition of sustainable development amongst the researchers (McGuinn et al. 2020). It is argued that despite its continuous usage and reference in academic research and public discussions, a common definition as well as conceptualisation of social sustainability has eluded researchers (McGuinn et al. 2020). The literature also suggests that a lack of clarity on how this concept relates to the other two sustainability dimensions - economic and environmental sustainability - is a key challenge associated with the concept of social sustainability (Boström, 2012).

Research has attempted to clarify the components or elements comprising social sustainability. Eizenberg and Jabareen (2017) developed a conceptual framework comprising four interrelated components namely equity, safety, physical urban forms and eco-presumption, concerning social sustainability which was expected to achieve a vision of a safer planet. Hutchins and Sutherland (2008) researched on certain indicators of social sustainability at the country level in the context of human health, equity, safety and quality of life. At the level of the firm and supply chain context, Hutchins and Sutherland (2008) identified employee factors for instance labour equity, safety and healthcare and philanthropic roles within the society as social sustainability dimensions. Steurer et al. (2005) argue that internal and external social improvements for stakeholders are social sustainability concerns of a firm. Internal social improvements for stakeholders are concerned with employees. External social improvements for stakeholders could be concerned with a number of different groups including communities or neighbourhoods and supply chain associates (Steurer et al. 2005). Within an organization, Pagell and Gobeli (2009) claim that employee well-being (for instance safety and health aspects) and human rights or equity may be the aims of social sustainability.

As far as the community or society is concerned, to be a responsible organization is the main aim of social sustainability (Orlitzky et al. 2003). The above contributions in the literature point to a diversity of arguments among the research community that try to explain the prevailing nature of what social sustainability could be, and indicating a lack of consistency on the part of the researchers in agreeing on a formal description of social sustainability performance. In addition, Hutchins and Sutherland (2008) for example note that there are vague statements such as 'philanthropic roles within the society', which do not provide practical clarity on what social sustainability could aim at. Accordingly, it is reasonable to deduce that social sustainability performance as a concept is still not well understood and there is a need to investigate its importance to the sustainability performance of firms. This is an important gap in the literature. While there is a large body of literature available that has dealt with sustainability performance of organisations, Golicic et al. (2020) claim that much of that literature is concerned with sustainability's economic and environmental aspects. Golicic et al. (2020) further argue that especially in the context of investigating the relationship between sustainability and performance outcomes, there is a lack of adequate research addressing this relationship. Wang et al. (2022) argue further that hardly any research has been conducted to understand the strategic role of social sustainability in enhancing a firm's performance, particularly financial performance. It is argued that without proper evidence of the direct relationship between practices promoting sustainability and organizational performance (e.g. financial performance), it is difficult for firms with a clear purpose and noble goals to execute social sustainability responsibilities (Wang et al. 2022).

2.15.1 Factors affected by social sustainability performance

Sroufe and Gopalakrishna-Remani (2018) posited that sustainability reputation and firm financial performance are two factors influenced by social sustainability performance. Alongside these high-level factors, the literature reveals a number of other factors that are affected by social sustainability performance. For instance, Amah and Oyetunde (2019) related consumer satisfaction and community satisfaction to social sustainability performance. Organisational image, trust, stakeholder's engagement plans, promotion of brand awareness, provision of better customers' satisfaction and provision of more employee benefits have similarly been identified as factors affected by social sustainability performance by a number of researchers (e.g. Zheng et al. 2021; Raihan, 2019; Akter et al. 2018; and Nwobu, 2017).

Improved relationship with the community and stakeholders, improved work safety, improved work environment and improved living quality of surrounding community were identified by Abdul-Rashid et al. (2017) as factor affected by social sustainability performance, and Nath and Agrawal (2020) identified improved workforce satisfaction and improved health and wellbeing.

2.15.2 Factors affecting social sustainability performance

A careful review of the literature reveals a number of factors that affect social sustainability performance. These include economic sustainability factors (Zheng et al. 2021), environmental sustainability factors (McGuinn et al. 2020), sustainable management (Sroufe and Gopalakrishna-Remani 2018), supply chain strategy (Qorri et al. 2018), employment, infrastructure capacity-building, community amenities, workers' health safety assessment (Enshassi et al. 2016), and diversity and product responsibility (Shaharudin et al. 2022). In addition, lean production and agile production factors have been proposed to affect social sustainability performance (Geyi et al. 2020; Uhrin et al., 2017; Wong and Wong 2014; Bonavia and Marín-Garcia, 2011).

Nevertheless, as Mani et al. (2018) note, it is clear from review of the literature that studies concerning social sustainability performance are still relatively scarce, and knowledge about relationship between factors that affect social sustainability performance and social sustainability performance is lacking in the literature (Shaharudin et al. 2022). This is a gap in the literature.

The next section discusses the theories that have been associated with social sustainability, and hence that could support the operationalisation of social sustainability performance as a factor for this research.

2.15.3 Theories that could be applied to the concept of social sustainability performance

As a concept Cornell and Shapiro (1987) argued that improved performance caused by social sustainability could be explained by corporate stakeholder theory. According to the stakeholder theory, an organization strives to improve and balance the expectations of its different stakeholders in a way that each stakeholder gets a certain level of compensation. It is argued that it is not only the organization the sole responsibility to be concerned with by that organisation, but also the needs of the society at large indicating a wider scope of corporate governance. Here stakeholders are considered to be shareholders, employees, lenders, customers, investors, suppliers, banks, competitors, governments and society (Younas, 2022). Cornell and Shapiro (1987) argued that organisations that have implemented socially sustainable practices are likely to have lower-cost claims resulting in better financial performance, and that firms in which there is a lack of socially sustainable practices can face problems of investors being discouraged as those investors could feel that investing in such firms could be risky (Alexander and Buchholz, 1978; Spicer, 1978). However, critiquing stakeholder theory, Jensen (2002) said that stakeholder theory suggests that the performance should be measured by the gains to its stakeholders, but this is not acceptable as there are other measures involved that need to be considered. Parmar et al. (2010) applied the stakeholder theory to address issues concerning the value created by an organisation, relationship between economic value and ethics and how businesses practice ethics.

Another theory that has been used by researchers in the investigation of social sustainability performance is the resource-based view (e.g. Khan et al. 2020). Barney (1991) argued that resource-based view could be applied to explain reputation which is considered as valuable resource that can lead to explaining the financial performance of an organization, which is considered part of social sustainability performance. Shaharudin et al. (2022) argue that the foundations of the resource based view (RBV) and the natural resource-based view (NRBV) need to be applied to explain the relationship amongst the variables. The basis of RBV has already been discussed in section 2.9.1. However, the NRBV is considered an extension of the RBV with the difference that it deals with environmental aspects (Hart, 1995) and arguably also resonates with social sustainability performance.

Other theories that have been suggested in the literature (e.g. Amah and Oyetunde, 2019) in regard to explaining the concept of social sustainability performance are cognitive dissonance theory (Festinger and Carlsmith, 1959), social exchange and the norm of reciprocity theories (Blau, 1964; Gouldner, 1960). Cognitive dissonance theory concerns seeking congruence between beliefs and behaviors of individuals (Amah and Oyetunde, 2019). Social exchange theory is more about psychological aspects (Zacher et al. 2023), as was previously noted. Norm of reciprocity theory is about reciprocal behaviour of stakeholders positing, for instance, that the more a firm exhibits alignment with the requirements of stakeholders as corporate social responsibility, the more favourable will be the customer evaluation of those stakeholders (Yoo and Lee, 2018). It is important at this juncture to note, as was explained by Cialdini et al. (1991) that norm of reciprocity has been criticized for lack of explanation about variation of norms within a societal group and the incompatibility of such norms (e.g. Krebs and Miller, 1985; Marini, 1984; Darley and Latané, 1970; and Krebs, 1970).

Perhaps not surprisingly given the more embryonic status of research on social sustainability performance, while a number of theories have been proposed to apply to the concept of social sustainability performance, stakeholder theory to date appears the most prevalent. Since the concept involves stakeholders including employees and the society at large, it appears stakeholder theory may be more suitable for explaining and operationalizing the concept. Stakeholder theory is all about the various stakeholders and their interests, and in addition, it is timely to note that both lean production and agile production involve stakeholders. The next section reviews the conceptualization of social sustainability as a construct in the literature, which, as noted for the previously reviewed constructs, is important for understanding and operationalizing the social sustainability concept.

2.15.4 Conceptualisation of social sustainability performance in prior research

As a concept, the literature shows that social sustainability performance has been conceptualized as an independent, mediating, moderating and dependent variable in prior research. Wang et al. (2022) used social orientation of the firm, a representation of social sustainability performance, as an independent determinant of financial performance. Similarly, Cope et al. (2022) identified social sustainability in terms of community as an independent variable that determined the perceptions of the natural environment of rural Utah community.

Zheng et al. (2021) in their research conceived social dimension as a mediator between the economic dimension and sustainability performance. the role of green finance in regard to the factors affecting the sustainability performance of financial institutions in Bangladesh. Similarly, Sroufe and Gopalakrishna-Remani (2018) conceived social sustainability performance as a mediator between sustainability management and firm financial performance in their research on management, social sustainability, reputation, and financial performance relationships. Chen et al. (2020), while studying the effects of employee involvement, stakeholder pressure and ISO 14001 in the context of lean manufacturing and environmental sustainability, used social sustainability aspect as a moderator of the relationship between promotion of green practices and environmental performance. Similarly, Haladu (2018) conceived social sustainability as a moderator of the relationship between specific firm characteristics and environmental sustainability reporting.

Shaharudin et al. (2022) identified social sustainability performance as the dependent variable determined by diversity practices, environmental practices, product responsibility, and safety and health practices. Similarly, Enshassi et al. (2016) conceived employment, infrastructure capacity-building, community amenities, workers' health safety assessment, direct employment, working conditions, public awareness, improvement of infrastructure, safety design, security consideration, provision of services, provision of facilities, communication to the public, operational safety and job opportunity as factors determining social sustainability.

As was the case for economic and environmental sustainability, it can be seen from the foregoing discussions that social sustainability performance as a construct has been varyingly conceived, implying that social sustainability performance can be operationalized in various ways and there is no unique way to position social sustainability performance. A further important observation is evident from the literature, which is that while conceiving social sustainability performance, researchers have largely used it as a single variable without any interaction with the other two sustainability variables namely economic sustainability performance and environmental sustainability performance.

2.15.5 Approaches used and measurement of social sustainability performance in prior research

Researchers have adopted various ways to assess and measure social sustainability as a construct. For instance, Juster (2022) used an explanatory study approach in understanding the determinants of sustainability of donor funded projects in Kenya and adopted a quantitative research method - a survey method was used as part of the quantitative research strategy and data was collected through a 5-point Likert scale. Here the researcher studied the social sustainability performance as a dependent variable influenced by management accountability and donor policies. De Matteis and Borgonovi (2021) studied the sustainability management model for local government in Italy through an explanatory study in which a quantitative research method was used and a survey was conducted. Similarly, Abdul-Rashid et al. (2017) used survey instruments in their research with 11-point Likert scale to measure social performance.

Other researchers have used the exploratory study approach in understanding the concept of social sustainability. Barna and Rebeleanu (2021), for example, employed an exploratory research method in their study on challenges of impact measurement in an emergent social economy in the context of Romania and used the in-depth interview method. Similarly, Di Vaio et al. (2021) used an exploratory study while investigating integrated thinking and reporting towards sustainable business models. In addition, Sin et al. (2020) used a mixed method while investigating the perceptions of quality management and sustainability in Malaysian hotel industry using interviews in the first phase of qualitative study and using surveys in the second phase of quantitative study. Thus, it can be seen that social sustainability performance as a concept has been measured in different ways by different researchers, an aspect that on the one hand shows inconsistencies in the literature in regard to measurement of the concept, but on the other highlights the possibilities for different approaches to take its development forward. This implies that researchers attempting to measure the concept of social sustainability measurement must carefully review the literature and the research questions being answered before arriving at a conclusion on how to measure the concept.

Based on the review of the literature presented in sections 2.17, 2.18 and 2.19 it can be stated that the concepts of economic, environmental and social sustainability performance although generally well investigated in the literature (particularly the environmental aspect), there are gaps that need to advance new knowledge about these concepts. While the literature evidences the availability of prior research in regard to various contexts and factors affecting or affected by sustainability performance, one of the areas that is not yet well addressed concerns the relationship between these three concepts on the one hand and lean production and agile production on the other. This aspect is discussed next.

2.16 Importance of lean production and agile production to sustainability

While the foregoing discussion has pointed out the need to study sustainability performance of manufacturing firms with regard to their challenges, barriers and enablers, two areas in the manufacturing sector that have been linked to sustainability performance in the literature are lean production and agile production (Mutingi et al. 2017; Singh and Vinodh, 2017). Literature (e.g. Yu et al. 2020; Kalyar et al. 2019; Chiarini, 2014) shows that implementation of lean production can support manufacturing firms to overcome barriers to sustainability. Similarly, many researchers (Khalfallah and Lakhal, 2021; Venugopal and Saleeshya, 2019; Singh and Vinodh, 2017; Mason-Jones et al. 2000) have found a relationship between agile production and sustainability. It is also found in the extant literature that sustainability is linked to supply chain management, for instance Sharma et al. (2021) who carried out a meta-analysis of sustainable supply chain management. Taking into account the above and considering the focus of this research which is concerned with the relationship between sustainability performance of manufacturing firms on the one hand and lean production, agile production and supply chain collaboration on the other, the review of the literature proceeds next to critically review the concept of supply chain collaboration and its relationship to the three phenomena namely lean production, agile production and sustainability performance.

2.17 Supply chain collaboration

The concept of supply chain collaboration is complex and research in this area is still evolving as supply chains are affected by a dynamic situation characterized, not least, by a high level of innovation (Chauhan et al. 2022).

Supply chain collaboration (SCC) is part of supply chain management (SCM) (Fu and Piplani, 2004; Mentzer et al. 2000). Supply chain management (SCM) itself has evolved over the past several decades and has covered a wide range of activities, from order management and warehousing management, to traffic management (Singh et al. 2018). SCM is widely understood to include physical distribution, inventory management, customer service, logistics, procurement and production planning, and hence fully embedded in the value chain (Singh et al. 2018).

Important to note at this juncture therefore, is the seeming complexity of supply chain management as a phenomenon, comprising multiple activities and the need therefore for a collaborative system to overcome such complexities (Arshinder et al. 2011). The apparent complexity led Chen et al. (2017) to suggest that the SCM area is understudied and more research is needed. The literature shows that supply chain collaboration plays an important role in supporting organisations to achieve better performance and customer satisfaction (Lee et al. 2000; Yang et al. 2000; Stank et al. 1999). Collaborative relationships are considered important for a sustainable supply chain (Govindan et al. 2016).

2.17.1 Defining supply chain collaboration

Prior research has broadly defined supply chain collaboration (SCC) as *"multiple firms or autonomous business entities engaging in a relationship that aims to share improved outcomes and benefits"* (Soosay and Hyland, 2015, p. 613). Others have defined collaboration through joint activities which include shared information, joint decision-making, resources and goal sharing, incentive alignment, collaborative communication and joint knowledge creation (Scholten and Schilder, 2015). However, collaboration is not just about developing close information exchange relationships at an operational level of activity, but also needs implementation in tactical and strategic levels in organizations across the supply chain (Barratt, 2004). Viewed from a relational position as a relationship between independent firms, supply chain collaboration is characterized by openness and trust, where risks, rewards and costs are shared.(Olorunniwo and Li, 2010). Cao and Zhang (2011, p. 166) defined supply chain collaboration, combining both a process and a relationship focus, as *"a partnership process where two or more autonomous firms work closely to plan and execute supply chain operations toward common goals and mutual benefits"*. Their definition is consistent with the work of Zacharia et al. (2011), also describing a combined process and relationship focus as follows: a way to integrate and implement external and internal knowledge and skills and assess both the capabilities namely absorptive capacity and collaboration process competence, which could affect the operational as well as relational results of those collaborations.

Authors have also articulated supply chain collaboration as a close cooperation among autonomous partners involved in joint efforts, which effectively meet end customer needs at lower costs (Holimchayachotikul et al. 2013). Similarly, it is argued to be a negotiated cooperation between independent parties, exchanging capabilities and sharing burdens, to improve collective responsiveness and profitability (Chan et al. 2012). Despite the many definitions of supply chain collaboration promoted by different scholars, it is evident as noted by Pradabwong et al, (2017), that most focus on the relationship, the process, and the gaining of mutual benefit through collaboration with supply chain partners. In addition, many authors have citied mutuality of benefit, reward and risk sharing, and the exchange of information as the foundation of such collaboration (Barratt, 2004).

It is important to note that the term supply chain integration (SCI) has often been used interchangeably with supply chain collaboration. While there is no overall consensus with the researchers on the definition of supply chain integration, many define it as a continuous and unbroken interaction that takes place between suppliers, manufacturers and customers in order to achieve strategic alignment and global optimisation (Devaraj et al. 2007). Flynn et al. (2010) defined supply chain integration as the level to which a manufacturing firm can collaborate with its supply chain partners and manage the processes within an organization and between organisations in a collaborative manner.

Singh et al's (2018) review on SCC identified a range of other terms used in the literature by various authors as interpretations or alternatives of the word collaboration (as presented in table 2.9), prompting Singh et al (2018) to note Arshinder et al's (2011) observation that there are clearly overlaps in the terminology used in the supply chain context. Whilst recognizing the complementarity (Arshinder et al, 2011) of terms, particularly integration and coordination, the present research focuses on supply chain collaboration.

Table 2.9, Various interpretations of the word collaboration used as part of SCC

Different interpretations of word 'collaboration'	**References**
Integration between parties	Bagchi et al. 2005; Frohlich and Westbrook, 2001; Pagell, 2004; Petersen et al. 2005; Vaart and Donk, 2008
Supply chain collaboration	Caridi et al. 2005; Holweg et al. 2005; Min and Roath, 2005; Shirodkar and Kempf, 2006; Stank et al. 2001; Vereecke and Muylle 2006
About alliances	Chung et al. 2008
Dyadic (e.g. buyer - supplier or buyer-manufacturer) relationships	Fynes et al. 2005a; Goffin et al. 2006; Kozan et al. 2006
Collaborative relationships	Hoyt and Huq, 2000; Johnston and McCutcheon, 2004
Partnerships	Gadde and Snehota, 2000; Spina and Zotteri, 2000
Supplier – retailer collaboration	Fu and Piplani, 2004

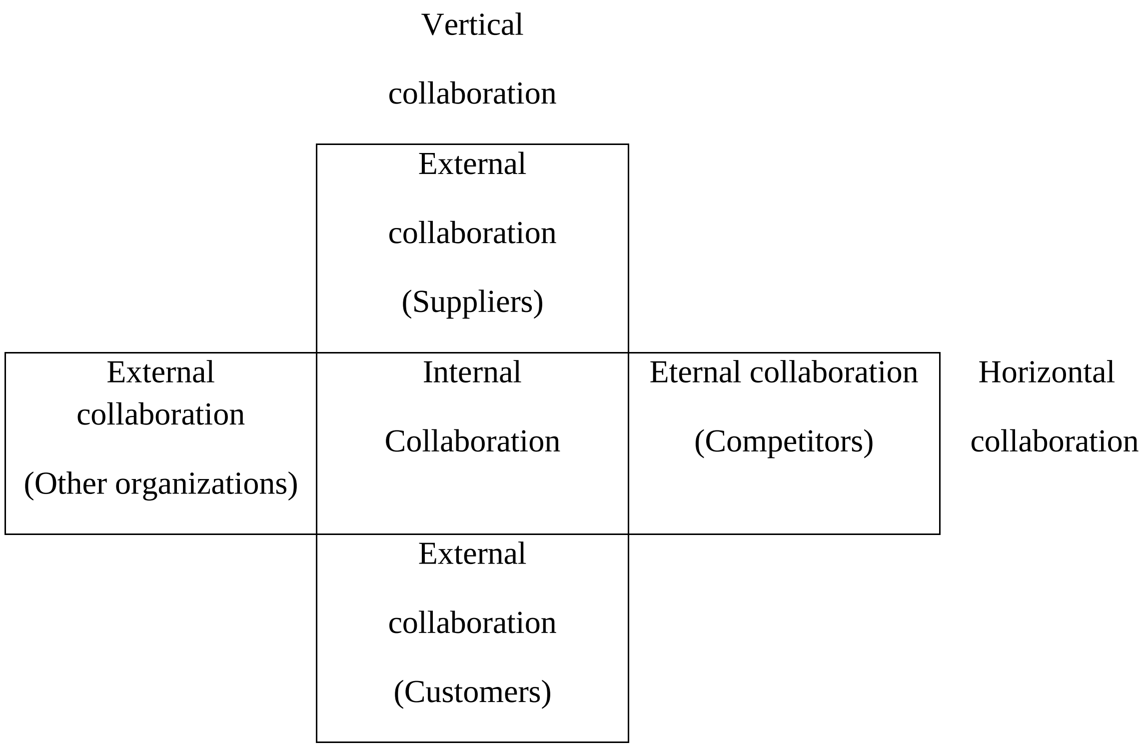
Source: Singh et al. 2018

An issue being investigated by researchers that is evident in the literature is the lack of knowledge on the relationship that could exist between supply chain collaboration and sustainability performance of firms (Wang et al. 2022). Examples of complex situations arising in assimilating supply chain collaboration with sustainable performance include pressure from regulatory authorities, stakeholder and interest group pressure, characteristics of a particular industry that determine the product and market complexity (Wong et al. 2015), investment foreign investors (Bardy et al. 2012) and environmental pollution (Golgeci et al. 2018).

2.17.2 Configurations of supply chain collaboration

Researchers have classified SCC as vertical, horizontal and lateral (Singh et al. 2018; Soosay et al. 2008; Simatupang and Sridharan, 2002). Bezuidenhout et al. (2020) define vertical collaboration as the alliance a firm achieves with suppliers and intermediaries thus gaining mutually useful goals. As Bezuidenhout et al. (2020) explained, there will be a common strategy adopted by partners in vertical SCC to make the supply chain more responsive and agile to customer demands that is dynamic in nature. Partners are known to have a long-term relationship in vertical SCC that will help them to focus on their core competencies and outsource the rest. Data sharing, better forecasting and planning are part of the vertical SCC (Barratt, 2004; Martin, 2004). Horizontal collaboration occurs when two or more organisations at the same level of the supply chain collaborate with each other actively. Through this collaboration those organisations share resources, share information and create a cooperative effort (Bezuidenhout et al. 2020). With growing complexity in the environment in which organisations operate, through horizontal collaboration, organisations can even collaborate with competitors to meet the dynamic requirements of the customers and aim to improve the overall supply chain performance. Advantages accruing out of horizontal collaboration include better purchasing power, reduction in fixed costs, decrease in logistics expenses and better access to markets enabled by a continuous supply in products (Soosay et al. 2008). Lateral collaboration is considered to be a combination of both vertical and horizontal collaboration amongst organisations which leads to a more flexible supply chain (Singh et al. 2018; Soosay et al. 2008). However, literature shows that the number of successful horizontal collaborative efforts in the industry is limited when compared to vertical collaboration (Ferrell et al. 2020) and vertical collaboration is still the dominant method used in SCC (Ho et al. 2019). A representative illustration of vertical and horizontal integration discussed by various authors in the literature is provided in figure 2.4.

Figure 2.4, Illustration of vertical and horizontal collaboration



Source: Barratt, 2004

As Nguyen et al. (2022) explained, an examination of the literature shows that current interest among researchers involved in SCC revolves around:

- drivers of successful supply chain collaboration (Salam, 2017; Zacharia et al. 2009; Soosay et al. 2008; Min et al. 2005).
- understanding the collaborative barriers (Mahmud et al. 2021; Ramanathan, 2014).
- examining supply chain collaboration benefits (Um and Kim, 2019; Pradabwong et al. 2017; Cao and Zhang, 2011).

As Nguyen et al. (2022) explains, there are challenges and gaps in the literature that are yet to be addressed by researchers. For instance, how country related characteristics including culture and technological advances affect SCC in the face of the discrepancies they create (Sim and Ali, 1998) is also an area identified that needs further investigation. Furthermore, research on SCC in regard to specific industry sector is claimed to be scant (Ralston et al. 2017). Some of the examples of industries that have been identified to not have received significant attention with regard to an understanding of the SCC include healthcare industry (Chakraborty et al. 2014), maritime logistics (Seo et al. 2016), thin-film transistor liquid crystal display (Liao and Kuo, 2014), and even the fast-moving consumer goods (Salam, 2017). Lack of industry specific studies is still regarded as a major gap in the literature (Ho et al. 2019). Addressing these gaps could reveal new understandings of the SCC concept, in turn supporting better exploitation of the SCC concepts by the industry.

The foregoing discussion provides an idea of the various aspects that concern SCC and the gaps found in the literature. The next section reviews the various components that comprise SCC.

2.17.3 Components of SCC that affect SC performance

Nguyen et al. (2022) argue that prior studies have not been able to achieve consistency as far as identifying the SCC components and hence further investigation is needed. Nevertheless, a review of the literature reveals a number of components that are frequently put forward. These include knowledge creation jointly (Um and Oh, 2020; Seo et al. 2016), sharing of resources (Hang and Hang, 2018; Nagehan et al. 2017), alignment of incentives (Pradabwong et al. 2017; Simatupang and Sridharan, 2005), synchronization of decisions (Ho et al. 2017; Talavera, 2014), sharing of information (Ye and Wang, 2013; Sezen, 2008), goal congruence (Um and Kim, 2019; Cao and Zhang, 2011) and collaborative communication (Seo et al. 2016; Cao and Zhang, 2011).

The following sections briefly review these components, considered the most useful for the present, drawing on the frequently cited conceptualisations of Nguyen et al. (2022) and Cao and Zhang (2011).

The literature shows that information sharing implies the extent to which an organization shares various types of information that is relevant, accurate, complete and confidential in timely manner with its partnering organisations in the supply chain. (e.g. Sheu et al. 2006; Cagliano et al. 2003; Angeles and Nath, 2001). Information sharing is considered to be vital for SCC. According to Baba et al. (2021) information sharing as a component of SCC helps organisations to improve performance. Although information sharing can help each organization in its performance, the benefits accruing out of the shared information amongst collaborators or partners in the supply chain can be even more valuable (Baba et al. 2021). Zhang and Cao (2018) explain that goal congruence is the degree to which supply chain actors/partners understand their own objectives could be satisfied by achieving the supply chain objectives. Accordingly, it is measured as the degree of goal agreement among supply chain partners (Angeles and Nath, 2001). Where true goal congruence occurs between supply chain partners, supply chain partners can be assured that their objectives are likely to be fully aligned with those of the supply chain, and that their goals could be accomplished by working towards achieving the objectives of the supply chain (Lejeune and Yakova, 2005). Zhang and Cao

(2018) define decision synchronization as the process by which supply chain partners coordinate decisions that pertain to planning and operations, and optimize the benefits accruing through the supply chain. Tseng et al. (2019) explained decision synchronization as the characteristic of the supply chain partners that estimates the intensity of SCC. Examples of decisions coordinated by the supply chain partners include procurement, placing orders, delivering orders, scheduling of production, managing demand, strategizing, replenishing inventory and managing the distribution channel (Lockamy and McCormack, 2004). Ma et al. (2020) define incentive alignment as the benefits obtained jointly by sellers and customers during business transactions. Simatupang and Sridharan (2005) define incentive alignment as a process adopted by supply chain partners through which costs, risks and benefits are shared. Frequently mentioned examples of incentive alignment include saving on reduced inventory costs, sharing of costs (e.g. loss on order changes), evaluating and publicizing each other's performance through co-development of systems, and sharing any risks that can affect the supply chain (e.g. Das et al. 2006; Simatupang and Sridharan, 2005; Melville et al. 2004; Grandori and Soda, 1995, Clemons and Row, 1992; Sako, 1992; Womack et al. 1990). Resource sharing is positioned within supply chain collaboration by Zhang and Cao (2018) as the process of exploiting and investing in capabilities and assets with partners in the supply chain. Examples of such resources identified by Harland et al. (2004) include those classified as physical resources, for instance equipment required to manufacture, facility and technology. Collaborative communication in its simplest form, is a process through which messages are transmitted between partners of a supply chain (Zhang and Cao, 2018). Existence of such communication between partners in a supply chain indicates the closeness of the inter-organisation relationship (Goffin et al. 2006; Tuten and Urban, 2001). Communication among the supply chain partners is argued to be the backbone of organizational continuity (Galaskiewicz, 2011). Review of the literature clearly indicates that there is a significant number of contributions that have addressed various aspects and antecedents of supply chain communication and the impact of supply chain communication in general on organizational performance. Wee et al. (2016) argue that when supply chain partners perceive and act on the need for interrelated skills and assets, joint knowledge creation occurs. Knowledge exploration (search and acquisition of new knowledge that is relevant) and knowledge exploitation (assimilating and relevant knowledge) are the two widely used types or aspects of knowledge creation addressed in the literature (Bhatt and Grover, 2005). The literature shows that joint knowledge creation occurs when supply chain members need to develop a knowledge base in collaboration with each other, which, in turn, leads to dissemination and sharing interpretations of that knowledge, enabling those organizations to create new benefits or values. Examples of such new benefits/values include brand image building, new product development, channel relationship establishment and responding to clients' needs (e.g. Luo et al. 2009; Johnson and Sohi, 2003; Slater and Naver, 1995).

The preceding discussion of components of SCC provides a clear picture of the various aspects that concern with the supply chain partners and the foci of their collaboration with each other. Nevertheless, various gaps in the literature have also been pointed out. Boubker et al. (2023) argue that there is knowledge gap in the literature with regard to the association between collaboration and supply chain performance, which needs further study. The literature also shows that there is a lack of integrated SCC knowledge relating to the supply chain network of partners that can help the partners to reduce the continuous supply chain problems they face, including functional silos, lack of transparency of knowledge as well as information and lack of adequate development of appropriate upstream and downstream relationships (Wee et al. 2016).

2.17.4 Theories associated with SCC

A number of theories are found in the extant literature that support the conceptualization and operationalization of SCC. These are transaction cost economics, the resource-based view (RBV) and the relational view. Each is reviewed next in the context of SCC.

2.17.4.1 Transaction cost economics

The theory of transaction cost economics (TCE) states that transactions between business partners are best transacted using the market mechanism where incentives to generate low costs are strong (Nagle et al. 2020). Long (2022) argues that TCE is about bounded rationality, opportunism, environmental uncertainty, and asset specificity. The Literature holds that TCE is a very relevant theory that can explain relationships among firms (Barringer and Harrison, 2000; Williamson, 1975). Grover and Malhotra (2003) argue that application of TCE to supply chain shows that there always will be a transaction cost in any supply chain interaction. This is possible because of the assumption that supply chain is affected by bounded rationality (Simon, 1957a) and opportunistic behaviour (Williamson, 2008). TCE is based on the premise that the decision to utilize either the vertical integration or market mechanisms depends on the relative monitoring costs that are caused by bounded rationality and uncertainties caused by partners' self-interest and opportunism (Kaufman et al. 2000). Here market mechanism or hierarchies like vertical integration are considered to be two prominent methods to organize transactions. However, the literature also shows that supply chain collaboration is considered the third thing that can be used as part of organizing transactions. Such an organization, according to the literature, helps companies to avoid the problems generated by hierarchies and markets (Koh and Venkatraman, 1991). For instance, Freeland and Sivan (2018) argue that control through hierarchical structure can alienate and demotivate employees, whereas organization structure that can motivate employees (Sesay et al. 2017). Similarly, markets are found to be less efficient in certain transactions, where firms as organisations are found to be better suited to handle those transactions

(Freeland and Sivan, 2018). These examples shows that supply chain transactions can thus be explained by TCE where transactions take place.

Literature shows that TCE has made valuable contributions to the understanding of sourcing, and also predicting the likely success of various supply chain arrangements, both in theory and practice. McIvor (2009) argued that TCE is one of the most influential theories applied in research concerning supply chain management, although a limitation of TCE that is important to recognize is its inability as a standalone theory to comprehensively explain the complexities of sources. Another criticism of TCE is that it neglects bounded rationality, differential capabilities, learning and path dependence (Foss and Klein, 2010), limitations that need to be kept in mind in SCC research. This may explain why Furubotn and Richter (2000) argued that what matters is the economic result and not the level of transaction costs.

At this point it is important to understand what transaction is and what transaction cost is in regard to TCE. The main aspect of transaction cost economics is the transaction cost. This cost is concerned with creating, utilizing, maintaining, modifying and governing the organization of an economic activity. The transaction costs are apportioned as market, managerial and political transaction costs. These include legal, administrative, information collection and many other costs (Garfamy, 2012).

In addition, Commons (1934) and Pitelis (1998) have defined transaction as an elementary economic unit of analysis that occurs within the entire organization. It has the ability to open up an organisation like a black box. This will help the organization to analyse the markets as systems comprising directly interdependent and institutionally behaving agents. This is expected to lead the firm to conceptualise hierarchies, markets and other possible coordination that leads to the formation of an inseparable continuum of forms of interactions. Further, the concept of transaction costs was proposed as early as the 1930s by Coase (1937) as related to economic analysis. According to Coase (1937) transaction costs are the costs that employ a price mechanism, and such a mechanism could be made of many components including:

- supervising the performance in an organization
- signing contracts with those who would be involved in the business activities of an organization like the supplier.
- looking for market information like competitor pricing of products.
- resolving such things as breach of contract problems
- conduct negotiations like purchase price of raw material.
- finding partners to transact like vendors who would supply raw material for a firm.

Further, the transaction cost is concerned with creating, utilizing, maintaining, modifying and governing the organization of an economic activity. The transaction costs are apportioned as market, managerial and political transaction costs. These include legal, administrative, information collection and many other costs (Garfamy, 2012).

In addition, Williamson (1998) argues that transactions costs in economic activity are like friction in physics. According to Williamson (1998) the characteristics of a transaction affect the level of transaction costs. Coase (1937) argues any trading process will need the transaction subject that will require investment of time, energy and economic costs to be paid with the price so that the completed market exchange is deemed to be transaction cost. This implies that the cost of making an exchange of an item that does not present itself directly in the materials production process could be considered as part of transaction costs. As a corollary it can be said that when the transaction costs are high, it makes the trading entity lose motivation to conduct transactions and creates obstacles in the smooth progress of trading activities (Boudreau et al., 2007).

Many researchers have suggested and applied TCE in SCC research. Ketokivi and Mahoney (2020) for example, applied TCE in their research on transaction cost economics as a theory of supply chain efficiency, concluding that TCE supports supply chain efficiency. Similarly, Bremen et al. (2010) applied TCE in their study on transaction costs in global supply chains of manufacturing companies. TCE provides the basis for explaining the transactions that occur as part of an economic activity in any SCC.

While there are recommendations to apply TCE theory in order to explain various variables, for instance, agile enablers and outcomes (Nagaaba, 2020), TEC is widely suggested to be applied where supply chain concept is involved as a significant variable (Long, 2022). Some of the areas where this can be seen include the relationship between buyer and supplier (e.g. Carr & Pearson, 1999; Heide & Stump, 1995); strategic sourcing and outsourcing decisions (e.g. Arnold, 2000; Dekkers, 2011; McIvor, 2009; Williamson, 2008); supply chain efficiency (Ketokivi and Mahoney, 2020) and supply chain and finance integration (Dekkers et al. 2020).

Grover and Malhotra (2003) also argue that TCE is one of the most widely cited theories in supply chain management and operations research. Literature shows that when there is a focus on the relationship between economic entities there is a common interest that develops in TCE and supply chain management (Zipkin, 2012). From the foregoing discussions it is clear that where an organization is involved in economic activity labelled as transactions, it is nearly impossible to remove supply chain activities, which in turn lead to the generation of transaction costs in exchange relationships. It is necessary therefore to reduce such transaction costs in such economic organisations. TCE thus helps in the research of supply chain activities.

Coase (1937) says transaction costs are the costs that employ a price mechanism. In regard to this research that focuses on the sustainability performance factors which includes economic sustainability performance factor, it is now clear that involving supply chain collaboration will invariably lead to incurring transaction costs. This in turn can affect the economic sustainability of a firm. Thus it can be concluded that in order to understand, explain and relate the supply chain collaboration concept with agile production as well as economic sustainability of a firm, it must be recognized that TCE is a prominent underpinning basis.

2.17.4.2 Resource based view (SCC related)

The underlying premise of RBV was presented in section 2.9.1. The important concepts of RBV are resources, capabilities and strategic assets (Barney, 1991). According to the literature the changes occurring in regard to the performance of a firm could be explained by the strategic resources which include core competence (Kosiol et al. 2023; Prahalad and Hamel, 1990), absorptive capacity (Lippsmeyer and Langemeier (2023); Cohen and Levinthal, 1990) and dynamic capability (Vitari and Raguseo, 2016; Teece et al. 1997). Further, when resources are mixed in a unique way, firms may gain advantage on competing firms who cannot do so (Dyer and Singh, 1998). This implies that if a firm has scarce resources and assets and also excels in capabilities and core competencies, the firm could achieve a sustained market advantage (Knudsen, 2003). In such situations application of RBV becomes useful to explain the relationship between resources and performance.

In the context of SCC, according to RBV, investing in assets, such as relation specific assets, can encourage partnering firms to build competitive advantage for the firm from rare, valuable and non-substitutable assets that are difficult to be imitated (Barney, 1991). Cao and Zhang (2011) claim that resource-based view (RBV) has been widely recognized as a theory to explain SCC, and Wang et al (2022), argue that the number of researchers using RBV in SCC research is increasing. Hitt et al. (2016) explain that RBV could be used to analyse the relationship between supply chain strategic resources of a firm and the firm's ability to gain competitive advantage.

The literature, for example Gligor and Holcomb (2014) and Hunt and Davis (2012), evidences the application of RBV to the fields of operations management and supply chain management. Further, Nishant et al. (2016) recommend use of RBV as the basis to examine the concept of chain performance as they argue it provides one of the best conceptual bases. Filho and Moori (2020) likewise posit that supply chain management associates positively with RBV.

Touboulic and Walker (2015) have suggested that RBV provides support to the argument that firms wanting to gain competitive advantage should carry out supply chain operations based on sustainability factors. Shibin et al. (2017), likewise argue that one of the important aspects of supply chain management is about its long-term viability for which there is a need to assess the economic, environmental and social factors. combining the arguments of Cao and Zhang (2011) with that of Shibin et al. (2017) it is reasonable to posit that SCC and sustainability issues could be dealt with using RBV.

Despite all of its perceived advantages, RBV has been noted as having limitations, not least that the central concern of RBV is that it is an analysis and investment in resources that should direct a firm to adopt a strategy (Barney, 1991) that will differentiate it and its products from its competitors (Peteraf and Barney, 2003), however, the literature shows that many other external factors will impact the overall performance of a firm, not only its resources. As Ray et al. (2004, p. 24) argued, *"simply examining the relationship between a firm's resources and capabilities and its overall performance can lead to misleading conclusions".*

2.17.4.3 The relational view

According to Dyer and Singh (1998), the relational view explains competitive advantage gained by a firm through the concepts of dyads and networks of firms as units of analysis. The relational view is argued to be a complement to the industry structure view and resource-based view (Wieland and Wallenburg, 2013). The theory states that when the extent of the partners' investment is higher in (a) inter-firm knowledge sharing routines and (b) relation specific assets, the higher will be the potential for relational rents. The concept relational rent was coined to indicate the result of the combination of resources and capabilities of a firm, and that are considered highly valuable when combined in a unique way (often called supernormal individual firm profits) (Dyer and Singh, 1998). Bai et al. (2021a, 2021b, 2021c) explain that the relational view posits that a firm gains collaborative advantage because of inter-firm specific assets, complementary resource endowments, exchange of substantial knowledge and effective governance. Dyer and Singh (1998) claim that there can be situations when competitive advantage can only be gained when idiosyncratic contributions specific to the collaborating organisations are jointly made by those organisations.

It is important to note at this point, that evidence of researchers drawing on the relational view in research concerning sustainable supply chain management is to be found in the extant literature, for instance, Theißen et al. (2014), Blome et al. (2014), Albino et al. (2012), Paulraj (2011), Gold et al. (2010) and Simpson and Power (2005). Blome et al. (2014) situated their assumptions using relational view as well as knowledge-based view because the researchers thought that the firms could gain by higher and balanced levels of collaboration along two sides of supply chain namely supply-side and demand-side. This is expected to lead the firms to generate synergistic relational rents with regard to sustainability as well as market performance, with the authors defining sustainability performance as an improvement related to resource consumption taking into account the environmental view.

Although the literature shows that the concept of SCC could be addressed by a number of other theories including extended resource based view (Cao and Zhang, 2011), organizational theory, social capital theory, trust theory, market oriented environmental sustainability theory (MES) and supply chain management theory (Wang et al. 2022), majority of the researchers have tended use the relational view and the RBV to explain the phenomenon of SCC.

2.18 Relationship amongst SCC, lean production, agile production and sustainability performance

In the extant literature, the importance of SCC in lean production (Garcia-Buendia et al. 2023), agile production (Erwin, 2021) and sustainability performance (Wang et al. 2022) has been well articulated. In this section, building on the preceding articulation of the constructs lean production, agile production supply chain collaboration and sustainability performance, a careful, systematic and detailed review of the prior research that has investigated the connections (relationships) between the four constructs is presented.

2.18.1 Protocol and inclusion/exclusion criteria

The purpose of this part of the review was to specifically identify the content of the prior research that has examined connections between lean and agile production, supply chain collaboration and sustainability performance. A systematic approach to selecting the literature through defined inclusion/exclusion criteria was adopted. The approach which has been adopted in prior research in the sustainability and operations domains (Durach et al 2017), seeks to ensure a reliable knowledge base from which to identify important directions for future research, namely important gaps that need further investigation.

Having identified all potential studies for inclusion through the application of carefully chosen search terms (keywords) reflecting the constructs of interest, the following inclusion/exclusion criteria were applied:

- including empirical (primary data-based) studies and significant systematic review approaches;
- excluding purely conceptual work;
- restricting to work published in the English language; and
- restricting to papers mainly published in recognized high-impact outlets (journals).

The application of this protocol - first checking the title and abstract, and for those filtered positively then checking the full-text - resulted in 70 studies identified. The studies were then reviewed to identify specifically, the nature of the approach taken, the connections that had been the focus of the study (scope) and their configuration (i.e. independent/dependent variables, and direct, and/or presence of mediation or moderation), and the associated main findings.

Based on this analysis, the findings are presented in the following sub-sections in the relationship themes:

- relationship between lean production and SCC;
- relationship between agile production and SCC;
- relationship between leagile and SCC;
- relationship between SCC and sustainability performance;
- relationship between lean production and sustainability performance; and
- relationship between agile production and sustainability performance.

2.18.2 Relationship between lean production and SCC

The systematic review identified seven contributions, all empirical studies, that focused on or included investigation of the relationship between lean production and SCC (or a specific aspect of, or associated closely with SCC). Seven adopted a quantitative approach.

Three of the studies adopted an aspect of performance (e.g. financial, operational and/or competitive) as the dependent variable. Of these, only Srinivasan et al's (2020) study, of 152 manufacturing firms, adopted supply chain collaboration as one of the study variables. This study found that a lean approach exhibited a positive influence on operational performance (but not financial), and that supply chain collaboration positively influenced the lean approach. The other two studies incorporated aspects of or closely associated with SCC. Jayaram et al (2008) examined the effect of relationship building on lean manufacturing and lean design respectively, and in turn the effect of these latter two variables on financial performance, based on a sample of 150 independently owned first tier suppliers to General Motors, Ford, and Chrysler. They found that relationship building did have a positive effect on lean manufacturing and design, and that lean design did predict financial performance, but, surprisingly, not lean manufacturing. Based on a data set from 232 Australian manufacturers, Prajogo et al (2016) adopted supply logistics integration as an independent variable and found that whilst it had no direct effect on competitive operational performance, the relationship was fully mediated by inbound supply performance and internal lean production processes, and that lean production had a positive effect on inbound supply performance.

Two studies examined aspects of SCC on a form of lean approach. Moyano-Fuentes et al (2012), collecting evidence from the Spanish automotive industry, found that while increasing levels of cooperation with suppliers did not affect the intensity of lean production adoption, greater cooperation with customers and the more information integrated with them did have a significant effect. So and Sun's 2010 and 2011 studies, obtained data from 558 manufacturers in 17 different countries. The 2010 study examined supplier integration strategy (SIS) for lean manufacturing, and found sub-factors of SIS – information sharing, e-business systems, and policy-based supplier selection had a positive influence on long term lean manufacturing adoption in small and medium-sized firms. Using a variety of measures for their independent and dependent variables, in their 2011 study, So and Sun found that electronic-enabled supply chain integration had a positive effect on the perceived advantage of lean production approaches.

One study, Qrunfleh and Tarafdar (2013) adopted supply chain responsiveness as its outcome variable, and found that strategic supplier partnership fully mediates the relationship between a lean supply chain strategy and supply chain responsiveness, which in turn is associated with enhanced firm performance. It can be inferred from the above that knowledge about the conceptualization of the relationship between lean production and SCC is still not conclusive and more investigation is needed.

2.18.3. Relationship between agile production and SCC

As far as the relationship between agile production and SCC (whichever direction) is concerned, literature shows that many researchers have dealt with this subject intensely. For instance, three studies were identified through the literature review that have investigated the relationship between agile production and SCC. Two of them used quantitative research while the third used qualitative research method. The study by Srinivasan et al. (2020) of 152 firms, conceptualized that environmental factor (e.g. technological and market turbulence, competitive intensity and supplier uncertainty) act as independent variables and affected operational and financial performance (dependent variables). While testing the relationship Srinivasan et al. (2020) positioned SCC, lean and agile as mediating variables. Their findings showed that environmental factors positively influence the performance factors with SCC, agile and lean production acting as positive mediators of the relationship between environmental factors and performance factors.

However, Qrunfleh and Tarafdar (2013) posited a model in which agile and lean were conceptualized as supply chain strategies and affecting firm performance (conceived as dependent variable), mediated by SCC (closely represented by strategic supplier partnership, postponement and supply chain responsiveness). Qrunfleh and Tarafdar (2013) conducted quantitative research and collected data from 205 senior executives and managers in the purchasing and supply chain functions from manufacturing firms in the USA through a survey. Investigating the concepts of agile supply chain and lean supply chain as independent variables, it was found by the authors that the relationship between a lean supply chain strategy and supply chain responsiveness is not supported. However, the relationship between an agile supply chain strategy, postponement and supply chain responsiveness was supported and found to affect firm performance positively through the mediation of SCC parameters. In yet another study by Yusuf et al. (2014), the authors conducted a quantitative research method and collected data from 137 firms across diverse industrial sectors characteristic of the oil and gas supply chain and found that agility (independent variable) and performance advantage of being resident in a cluster (dependent variable) are positively related. The authors established that diffusion of agility in the oil and gas supply chains indicates a positive relationship between agile production and SCC. The above discussion shows that research outcomes in regard to relationship between agile production and SCC were not conceptualized uniquely and various possibilities of conceptualizing the concepts of agile production and SCC are possible.

2.18.4 Relationship between leagile and SCC

Two papers were studied with regard to the relationship between leagile and SCC. Both of those papers used qualitative method.

By using data from 299 Australian firms, Fadaki et al. (2020) introduced a new supply chain leagility approach and investigated the uncertainty impact as the key design driver of supply chains on leagility. The study revealed that higher performance is possible on reducing the deviation from a balanced supply chain in which aspects of both leanness and agility are equally embedded.

Another study, by Oyombe et al. (2022), assessed the moderating influence of strategic partnership on relationship between leagile strategy and competitive advantage in the context of construction supply chains, using data from 260 companies in Kenya. The study showed that strategic partnership does not moderate the relationship between leagile strategy and competitive advantage. Additional, both leagile strategy and strategic partnership positively and significantly influence competitive advantage as independent variables.

2.18.5 Relationship between SCC and sustainability performance

The literature review was based on 21 papers that had addressed the relationship between SCC and sustainability performance. All of the papers were empirical studies. 15 of them used quantitative research methods while the remaining 6 used qualitative research methods. Out of the 15 quantitative studies 12 studies had some common factors used as independent variables which included internal integration (Munir et al. 2020; Mao et al. 2017; Cheng et al. 2016), sustainability factors (Ahmadi-Gh and Bello-Pintado, 2022; Li et al. 2017; Albino et al. 2012), SCC (Pan et al. 2020; Cao and Zhang, 2011), supplier integration (Du et al. 2018; Danese, 2013) and customer integration (Du et al. 2018; Chavez et al. 2015; Danese and Romano, 2011). Three papers used uncommon independent variables which included misalignment (misalignment to the ideal profile of SCC) (Blome et al. 2014), information sharing quality (Panahifar et al. 2018), additive manufacturing adoption (Delic et al. 2019).

While two papers have used SCC as the independent variable, those papers tested its influence on firm performance (Cao and Zhang, 2011) and manufacturing enterprise performance (in terms of environmental performance and economic performance) (Pan et al. 2020). Conducting a web survey in the USA on many different manufacturing firms numbering 211, Cao and Zhang (2011) confirmed the presence of a positive relationship between SCC and firm performance. Pan et al. (2020) in contrast argued that green supply chain management concerned with SCC, influences positively both economic and environmental performance of an enterprise.

Another important construct of SCC is the concept of internal integration in performance. Three research efforts were identified in this review that used internal integration as the independent variable and influenced sustainability performance. For instance, Munir et al. (2020) conducted a study in four countries and tested the relationship between internal integration and operational performance. Collecting data from 931 assembly manufacturing plants, across four continents and 22 countries, the authors found that internal integration positively influences operational performance of a firm. Similarly, Cheng et al. (2016) examined the relationship between internal integration as the independent variable and operational performance (dependent variable) of a firm and found that internal integration does not influence operation performance of a firm. The research work of Cheng et al. (2016) included data collection from 931 companies from 22 countries situated in Europe, the Americas and Asia which belonged to different sectors. However, the results of the research produced by Cheng et al. (2016) showed that external integration (an SCC associate) mediates positively between internal integration and operational performance of firms that inter-plant coordination (an SCC component) drives external integration positively and internal integration influences inter-plant coordination positively as well as operational performance through mediation of inter-plant coordination. It was also seen that internal performance indirectly affects the operational performance through the mediation of both inter-plant coordination and external integration.

In another instance Mao et al. (2017) conducted quantitative research by collecting data through a survey from a sample of 115 persons working in different sectors. Through their study they found that internal and external integration positively influence environmental performance. However, while external integration was found to influence financial performance positively, internal integration was found to influence financial performance negatively.

As far as supplier integration was concerned, two researchers conducted quantitative study to test the relationship between supplier integration on the one hand and company performance (Danese, 2013) and innovation performance (Du et al. 2018) on the other. Danese (2013) conducted their study in three industry sectors. A sample of 186 units were approached to collect data. The researchers tested the relationship between supplier integration, a construct associated with SCC on the one hand and efficiency, schedule attainment and flexibility on the other. Constructs namely efficiency, schedule attainment and flexibility were categorized as firm performance (buyer performance). The independent variable supplier integration was found to be positively related to efficiency, schedule attainment and flexibility. Similarly, the research outcomes produced by Du et al. (2018) showed that the relationship between the supplier integration (independent variable) and green innovation performance (dependent variable) is partially supported indicating a positive relationship between the independent variable and the dependent variable.

Furthermore, three researchers investigated the relationship between customer integration as an independent variable on the one hand and quality, delivery, flexibility, cost, efficiency and innovation performance (all dependent variables) (Du et al. 2018; Chavez et al. 2015; Danese and Romano, 2011) on the other. Du et al. (2018) found a positive relationship between customer integration (independent variable) and firm performance (dependent variable). Details about the research conducted by Du et. (2018) are already furnished in the previous paragraph. Chavez et al. (2015) collected data from 228 companies and found that customer integration (considered to be a component of SCC) positively influences quality and flexibility of a firm, which is considered to be in a way a sustainability performance factor. Similarly, Danese and Romano (2011) investigated 200 companies and collected data from them through a survey. It was found by the authors that customer integration positively influences efficiency performance.

In addition to the above three other researchers examined the influence of sustainability on the performance of the firms mediated by factors that concern SCC. For instance, Ahmadi-Gh and Bello-Pintado (2022) studied the effects of different sustainability practices on sustainability outcomes and competitive advantage to know whether manufacturing will be sustainable. Conducting a survey in 263 manufacturing companies across three industry sectors in 15 countries, Ahmadi-Gh and Bello-Pintado (2022) collected data from those companies. The results showed that supplier collaboration practices (treated as independent variable for the sake of the discussion here) have partial positive effects on sustainability outcomes (treated as dependent variable for the sake of the discussions here) and the adoption of supplier collaborative practices is mediated by the effective implementation of practices.

In a similar vein Li et al. (2017) used market-oriented environmental sustainability as an associate of sustainability performance is conceived an independent variable and linked it to export market performance as the dependent variable mediated by knowledge integration. In addition to this international buyer involvement was used as a moderator of the relationship between market-oriented environmental sustainability and knowledge integration. 305 private, domestically funded manufacturers that exported to overseas markets were approached to collect data using a quantitative research method. The results of the study showed that market-oriented environmental sustainability positively influences knowledge integration (an associate of SCC) which in turn positively influences export market performance.

Further, Albino et al. (2012) conducted a quantitative study with regard to 500 companies included in the U.S. 500 Newsweek's 2010 Green Ranking distributed in various industrial sectors. The data related to collaborations in environmental activities were available in companies' websites or reports for 347 out of the 500 companies. Albino et al. (2012) tried to find out the nature of the relationship between environmental collaborations (independent variable) and environmental performance (dependent variable). The sub-variables of environmental collaborations are the suppliers, customers, other companies, NGOs, government, and universities and research institutions. These are associated with the SCC and influence the environmental performance that includes sub-variables namely Newsweek Green Score (NGS), Environmental Impact Score (EIS), Green Policies Score (GPS) and Reputation Survey Score (RSS). The results indicate mixed outcomes. The influence of environmental collaboration is positive on some of the environmental performance factors.

Thus it can be seen that the research work of Albino et al. (2012) provides a significant clue on the SCC influence on sustainability with regard to environmental performance which is pertaining to sustainability performance.

While the above discussions have discussed the results of many research studies concerning the relationship between SCC and sustainability, there were six studies that adopted qualitative studies to understand the concepts of SCC and sustainability. Cloutier et al. (2020) studied the collaborative mechanisms for sustainability-oriented supply chain initiatives in regard to state of the art, role assessment and research opportunities aspects through a systematic literature review of 404 articles, which is a qualitative research method. The research identified seven collaborative mechanisms that included relationship management, contractual and economic practices, joint practices, technological and information sharing practices, governance practices, assessment practices, and supply chain design. As can be seen supply chain design and sustainability factors (e.g. contractual and economic practices, technological and information sharing practices, governance practices and assessment practices) were identified as themes that need to be considered for research. Similarly, Asif et al. (2020) studied 25 articles through a systematic review, the importance of adoption of green supply chain management practices through collaboration approach in developing countries and found that high priority drivers namely government regulations, customer demands and supplier performance can be important factors of green supply chain management practices. Those drivers could be considered as SCC components in regard to environmental supply chain management practices that are carried out using collaborations. Secondly, the research found that those drivers can affect eco-design, green purchasing, green manufacturing and reverse logistics in developing countries. These results were posited based on a systematic literature review.

A third systematic literature review by Chen et al. (2017) was also considered for this research which was based on the content analysis of 90 articles. The outcome of the review by Chen et al. (2017) concerning SCC for sustainability showed that there is a need to conduct more research in the area of SCC for the purpose of sustainability in the business field. The study showed that current research outcomes focus more on environmental and economic considerations, while there is a lack of consideration about social concerns.

A fourth research work of meta-analysis (qualitative research method) by Chang et al. (2015) was also reviewed by the researcher which was concerned about supply chain integration (SCI) and firm financial performance with a focus on positional advantage mediation and moderating factors. Analysing 170 previous investigations with regard how discrete dimensions of SCI enhance firm financial performance through three types of intermediate firm performance factors, the authors found that each dimension of SCI indeed improves financial performance. The authors also found out that superior customer value positional advantage has a stronger mediating effect than operational performance associated with lower cost positional advantage in the relationship between SCI and financial performance. It was also discovered by the authors that time, relationship quality, and collectivist national culture strengthen the associations between some dimensions of SCI and firm performance.

In another meta-analysis of 40 articles conducted by Ataseven and Nair (2017) with regard to assessment of supply chain integration and performance relationships, the authors found that there is a clear impact of internal integration, supplier integration, and customer integration on a firm's financial performance. Next, it was found that specific relationships between supply chain integration and performance require further study using contingency framework to understand the role of moderating factors. In the last article authored by Danese et al. (2020), which was a systematic literature review of 116 articles the authors investigated the fit in supply chain integration in regard to the context, practices and performance links. The authors argued that the most applied forms of fit are mediation and moderation in the various articles is concerning various contexts, practices and performance links. Secondly many of the popular research articles reviewed included the moderating role of uncertainty/complexity in influencing SCI benefits and the role of SCI as a prerequisite for other operations and supply chain management practices. The authors showed that future research opportunities exist in several areas, including adoption behavioural operations SC management aspects, antecedents of SCI applying the institutional theory and study of cultural aspects of different nations as a moderator of the relationship between SCI and performance. In addition, the authors also listed promising research opportunities that are concerned with less used fit forms like the profile deviation and fit as matching. Furthermore, combinations of multiple fit forms which could assist in addressing some issues in SCI including balance between upstream and downstream integration and optimal profiles were argued to be unresolved by the authors.

2.18.6 Relationship between lean production and sustainability performance

A total of 31 papers were studied with regard to the relationship between lean production and sustainability performance. Out of those 31 papers, 12 used quantitative research, 3 used mixed method research and 16 used qualitative method.

As far as this systematic review is concerned with regard to the relationship between lean production and sustainability performance, literature shows that empirical research has been conducted by many researchers using quantitative study (e.g. Jum'a et al. 2022; Chavez et al. 2022; Pearce et al. 2021; Rupasinghe and Wijethilake, 2021; Nath and Agrawal, 2020; Yu et al. 2020; Kamble et al. 2019; Dey et al. 2020; Rathore et al. 2018; Inman and Green, 2018; Garza-Reyes et al. 2018; Sartal et al. 2018). Those researchers showed that lean production has been considered as a determinant of sustainability performance. For instance, Rathore et al. (2018) considered lean process as the independent variable and argued that it drives sustainability performance. Taking into consideration the secondary data collected from 51 Indian firms' reports published by those firms, the researchers argued that factors of lean process including institutional pressure, sustainability practices, supply chain coordination and current practices influence dependent variables of sustainability performance. Those variables included innovation capabilities and sustainability performance. The result showed a positive relationship between lean process and sustainability performance depending upon the nature of innovation capabilities. Nath and Agrawal (2020) related lean production as an independent variable to operation performance. This relationship was mediated by four factors, one of which is sustainability performance. Conducting their research on 311 Indian companies, the authors found through their empirical study that lean indirectly affects the dependent variable operational performance of the firms mediated by sustainability performance positively.

Further, Rupasinghe and Wijethilake (2021) conducted their empirical study on 106 SMEs in Sri Lanka and posited that lean production directly affects all the three different sustainability performance (economic, environmental and social) factors. They however argued that such a performance is positively related if only two factors namely interactive use of sustainability control system and diagnostic use of sustainability control moderate the relationship between lean production and sustainability performance. Next, collecting data from 392 supply chain managers of manufacturing companies in Jordan, Jum'a et al. (2022) argued that there is a direct positive relationship between lean practice as an independent variable and the three sustainability performance factors namely economic, environmental and social. They also argued that sustainability oriented innovation mediates the relationship between lean practices and sustainability performance positively. In similar lines Dey et al. (2020) argued that lean management practices as an independent variable has a positive influence on the dependent variable economic performance of SMEs in UK. Conducting a survey on 119 SMEs the authors established that there is also a positive relationship between lean management practices as an independent variable and economic performance using some mediating variables including CSR practices, sustainability performance and sustainability oriented innovation. They found that sustainability oriented innovation has a positive influence on economic performance and sustainable performance has a negative influence on economic performance. It was also found that lean management practices have no relationship with sustainability oriented innovation. This implies that lean management practices as a variable have no indirect path that can affect economic performance through sustainability oriented innovation. However lean management practices were found to have a positive influence on CSR practices while CSR practices had a positive relationship with sustainability performance.

Furthermore, Inman and Green (2018) investigated empirically lean production as an independent variable affecting the dependent variable operational performance positively. They also argued that apart from the direct positive relationship between lean production and operational performance there can also be some mediated paths driven by lean production. For instance, Inman and Green (2018) found out that there is positive indirect relationship between lean production and operational performance using two other mediating variables namely environmental performance and green supply chain management practice. While the mediation by environmental performance was found to be positive, the mediation by green supply chain management practice was found to be negative. The study was conducted in the USA and data was collected through a survey from 182 manufacturing firm managers belonging to various sectors. In addition, Pearce et al. (2021) conducted quantitative research on 132 fruit farming operations in South Africa and investigated the relationship between lean management practices and sustainability performance both directly and indirectly. Cluster analysis was performed and it was found that two distinctive clusters of farms were identified namely high and low lean practice clusters. It was found that the two clusters significantly differed in practice implementation of lean management practices. It was also found that the two clusters had significant differences in terms of sustainability performance. Additionally, the authors found that lean management practice is an independent variable that affects sustainability performance in the primary production of horticulture industry.

One more research on lean by Garza-Reyes et al. (2018) found that there was a positive correlation between some of the lean methods and environmental performance factors. The authors conducted a quantitative empirical study on 250 management officials working in various sectors of the industry, conducting a correlation analysis, to find whether the relationship between lean methods (including TPM, VSM, autonomation, Kaizen/CI and JIT) and environmental performance factors (including materials use, energy consumption, non-product output and pollutant releases) is positive or negative. The authors showed that there is a positive correlation between TPM and JIT with all the environmental performance factors namely materials use, energy consumption, non-product output and pollutant releases. Kaizen/CI had positive correlation with materials use and pollutant releases. Similarly conducting quantitative empirical research using secondary data from two sources in Spain (9-year panel data that gave 5672 observations) from two official sources, Sartal et al. (2018) investigated the lean principles and tested whether those lean principles are ecofriendly. In the context of manufacturing firms in Spain they found that lean principles determine environmental sustainability performance positively. Particularly they found that Jidoka and Respect for People (RfP) had a positive influence on environmental sustainability performance. However, another lean principle JIT was found to have a major trade-off with the green goals.

One paper studied Industry 4.0 as a determinant of economic, environmental and social sustainability development mediated by lean production. Studying large enterprises four industry sectors in India, Kamble et al. (2019) collected data from managers of those large enterprises, 205 in number and found that lean production mediates positively between industry 4.0 and sustainability performance. Similarly, Chavez et al. (2022) studied (104 enterprises) the relationship between internal lean practices and operational performance. The relationship between internal lean practices and operational performance was mediated by sustainability performance factors and environmental and social sustainability performance factors. The results showed that internal lean practices as an independent variable influences operational performance through both the mediators and directly. In one other paper by Yu et al. (2020) the authors conducted empirical research (241 Chinese companies) using a quantitative research method. Investigating the relationship between innovativeness and triple bottom line (TBL, a sustainability performance factor), the authors found that the relationship between innovativeness, the independent variable and TBL, the dependent variable, is positive and is moderated positively by lean production.

Further to the 12 papers that were found to be using quantitative research study, 16 authors were found to use the qualitative research method to understand the relationship between lean production and sustainability performance. Amongst these 16 authors, 10 of them (e.g. Teixeira et al. 2021; Bhattacharya et al. 2019; Dieste et al. 2019; Henao et al. 2019; Siegel et al. 2019; Ciccullo et al. 2018; Leon and Calvo-Amodio, 2017; Cherrafi et al. 2016; Alves and Alves, 2015; Martínez-Jurado and Moyano-Fuentes, 2014) chose the plain literature review or systematic literature review as the method and came out with outcomes that provide knowledge on the relationship between lean production and sustainability performance. Teixeira et al. (2021) used a bibliometric analysis and structured analysis of the literature and reviewed 227 publications. The outcome of their research demonstrated the capability of lean and green and argued that their combined influence on sustainability outcomes enhances those outcomes and sustainability performance. Similar outcomes were provided by other researchers including Bhattacharya et al. (2019), Dieste et al. (2019), Henao et al. (2019), Siegel et al. (2019), Cherrafi et al. (2016), Alves and Alves (2015) and Martínez-Jurado and Moyano-Fuentes (2014). Bhattacharya et al. (2019) reviewed critically 80 articles and found that lean-green integration impacts sustainability performance with mixed results, that is some of the authors of the 80 articles reviewed disagreed that the integration does not impact sustainability performance while the others agreed on that concept. Cherrafi et al. (2016) investigated through a literature review of 118 papers on how to integrate three concepts namely lean manufacturing, Six Sigma and sustainability. The outcome of their research was determination of the gaps that exist in the literature and to extract the theoretical elements of an integration model. Seven major gaps were identified that could be used for further research. Amongst those seven gaps two were considered useful for this research. The first gap was the need to develop an integrated model that involves lean/Six Sigma and sustainability performance that could be applied to SMEs and functions. The second gap was developing an integrated metrics and measurement system to enable the industries in the SME sector to measure lean/Six Sigma and sustainability performance. Further, the researchers proposed a model that integrated lean/Six Sigma and sustainability performance as an example of integration of the three concepts although the model was not tested empirically.

Dieste et al. (2019) conducted a systematic literature review of 72 documents and generated a matrix that provided a link between some key lean practices to specific environmental measures. Possible relationships between various lean practices and the improvement of specific green performances where also enlisted. In addition, the authors also highlighted the relationships between lean and green production approaches that were state of the art relationships. In similar line Henao et al. (2019) initially reviewed 679 papers and categorized them under three categories namely direct relationship between lean manufacturing and sustainable performance (69 papers), indirect relationship between lean manufacturing and sustainable performance (160 papers) and no relationship between lean manufacturing and sustainable performance (450 papers). Their findings showed that relationship between lean manufacturing and performance largely has focused on operational and economic performance.

Further, using a systematic literature review, Siegel et al. (2019) in the context of small and medium enterprises, the authors identified and analyzed data on the challenges, success factors, tools and techniques, sustainability aspects, frameworks and benefits of Lean Green in manufacturing. The authors found important shortcomings in the knowledge and application of lean green as well as sustainability still exist. However, the authors point out that the three sustainability performance factors namely economic, environmental and social can be merged using the continuous improvement initiative that is lean production so that organisations in the SME sector sustain and utilise the advantages of both paradigms together.

Cherrafi et al. (2019) used literature review and their experience of over 40 years to develop a model and test it for understanding the relationship between lean production and environmental performance. The authors found through the implementation of their models on two case study orgnisations, one in the aerospace sector and the other in the automotive sector that reduction in the consumption of resources improves their environmental performance. The authors proposed a model utilizing Gemba–Kaizen to reduce any environmental impact without large capital investment by ensuring the involvement of everyone in an organization. It also pointed out that the organizations that integrate the specific the lean manufacturing concept Gemba–Kaizen can derive quantitative benefits leading the better working conditions and improved team spirit. Using an integrated model, Cherrafi et al. (2019) argued that it is possible to improve the environmental sustainability performance.

Furthermore, Alves and Alves (2015) conducted a simple (versus systematic) literature review on lean manufacturing, production management, sustainability and organisational culture and proposed a model and its implementation procedure in a company to gain knowledge on the importance of integrating the principles of lean manufacturing and sustainability in association with cultural transformation at a company. The authors proposed a model for implementation in a company. Integrating lean production concept with sustainability concepts and introducing the cultural transformation in an organization, it was argued that it is possible to eliminate waste in a production environment as well as generate productivity gains.

In addition, Martínez-Jurado and Moyano-Fuentes (2014) reviewed 125 articles to gain knowledge about the linkage between lean management, supply chain management and sustainability. The outcome of their literature review showed that research interest in the topics concerning lean production and sustainability have continued to be high and become wider since 1998. While there has been a high growth in the interest shown in the areas concerning lean production and sustainability, at the same time it was seen that the research concerning the topic of lean supply chain management and sustainability has been moderate. The research provides an idea about the contradictions and inconsistencies found in the literature as well as discussed potential opportunities and challenges that could be researched upon in future. For understanding the contradictions, inconsistencies and new areas of research, it is recommended that the paper could be directly referred.

Further, adopting a systematic literature review approach, Ciccullo et al. (2018) reviewed 73 papers in topics concerning integration between lean and sustainable and agile and sustainable supply chain paradigms and identified 6 different types of integration of the paradigms namely lean production, agile production and sustainability. The authors argue that it is critical to design and implement a system of practices that are aligned with the environmental and social requirements of different stakeholders that are of importance to a firm on the one side and adopt lean (e.g. efficient and waste free) and/or agile production (e.g. fast and flexible to the needs of the marketplace) on the other. The authors point out that there is a need to conduct research on how to develop conceptual and empirical studies to decide the need to integrate the three paradigms mentioned above.

In yet another effort that was based on a systematic literature review Leon and Calvo-Amodio (2017) claim that the relationships between lean and sustainability is important to explain how the integration of the two factors namely lean and sustainability can be achieved and deploy them too. Reviewing 57 papers the authors found that there is a lack of consensus on the definitions of lean and sustainability in the literature showing diverse perspectives that are greatly influenced by context in which those concepts were developed. The authors also noted that contradictions were found in the relevant literature on the relationship between lean production and sustainability. It was also noted that those contradictions arise from the various views taken for analysing the effect of lean production on environmental performance.

Amongst the authors who have adopted qualitative study in their research were six others amongst which 4 used case studies (Cherrafi et al. 2019; Choudhary et al. 2019; Longoni and Cagliano, 2015; Piercy and Rich, 2015), one used the method of TODIM as part of the multi-criteria decision-making (MCDM) model (Bai et al. 2019) and one used the iterative structural method (Ruiz-Benitez et al. 2019). The case study method used by Cherrafi et al. (2019) studied two cases namely large aerospace manufacturer based in the US who was using lean production method to reduce electricity usage. The second case studied was an injection molding company based in Morocco specializing in production of multiple automotive polymeric appearance parts. This company wanted to improve the customer value and sustainability performance with the top management interested in using lean production to improve operational and environmental performance and reduce the negative environmental impacts of its processes. The authors conducted interviews with cell workers and supervisors as part of the two case studies. A survey was part of the case studies used by the authors. The model developed by them helped the two cases to reduce the consumption of resources and improve their environmental performance.

Similarly, Choudhary et al. (2019) conducted a case study on a U.K. packaging-manufacturing SME. The authors applied the Green Integrated Value Stream Mapping (GIVSM), integrates both lean and green transformational initiatives. The authors found that GIVSM could be applied to deploy lean and green paradigms simultaneously and thus generate a synergistic effect for improving both operational efficiency and environmental performance. They also demonstrated that continuous improvement framework with sustainable procurement can help overcome misalignments in lean-green integration.

As far as the research of Longoni and Cagliano (2015) is concerned, it was seen that the authors used the inductive case study methodology to extend the application of operations strategy theory and sustainability development theory to 10 cross-industry cases. The authors performed within and cross-case analyses. The main of the researchers was to study the cross-functional executive involvement and worker involvement in lean manufacturing and sustainability alignment. The finding of the research was that cross-functional executive involvement and worker involvement are important to produce a positive effect on the strategic alignment of the lean manufacturing statement and bundles with environmental and social goals and practices.

Further, the case study research conducted by Piercy and Rich (2015) focused on the relationship between lean operations and sustainable operations. Using a longitudinal multi-year (up to four years observation), multi-case analysis of 5 manufacturing units in the UK. Two types of companies were chosen in the manufacturing sector in order to conduct cross-comparative research study. Using their study, the researchers found that introducing lean operations enable organisations to meet a wide range of sustainability performance aspects beyond environmental benefits. Examples of benefits that could be derived include transparency, community engagement, workforce treatment and supply monitoring. In addition, the researchers posited that lean implementation and sustainability performance are in fact interlinked.

Apart from the 16 papers reviewed above with regard to literature review (10 papers) and case studies (4 papers), there were two other papers that were using special methodologies which were reviewed. For instance, Bai et al. (2019) used the TODIM method to implement a multi-criteria decision-making (MCDM) model developed for the evaluation of lean manufacturing processes. While studying the investment ideas in lean manufacturing practices in companies the authors brought in the environmental and operational perspectives. Using this method, the authors collected empirical data from six manufacturing organisations in 4 different sectors namely aerospace, automotive, pharmaceutical and textiles. The impact of lean production on operational and environmental performance and ease of implementation were studied. The research outcome showed that those companies that ranked high in regard to operational and environmental performance and ease of implementation attracted investment.

In another study Ruiz-Benitez et al. (2019) used the Interpretive Structural Modeling (ISM) approach. Using this approach, the authors identified the existing relationships between lean and resilient supply chain practices and their impact on the three different dimensions of sustainability. While using ISM the authors used the aerospace industry to investigate whether the ISM approach will be useful to find out the impact of lean production as well as resilient supply chain practices on the economic, environmental and social sustainability performance of the aerospace firm. As part of the methodology 15 experts pertaining to 14 different manufacturing plants in the sector were selected as they were ready to participate. Participants were from various levels of the aerospace manufacturing industry that enabled the representation from various levels of the industry. It was also seen that the number of participants in each level was similar. The results of the research showed that there exists a relationship between lean and resilient supply chain practices and they impact sustainability.

Apart from the above quantitative and qualitative studies, there were authors of three papers (Rathore et al. 2018; De et al. 2020; Burawat, 2019) who used mixed method in their research. For instance, Rathore et al. (2018) used a mixed method research in order to understand the mediating role of innovative capabilities in the interplay between lean processes and sustainable performance. The research was conducted in the automobile industry in India. The authors adopted a two-pronged strategy for data collection. While the data for institutional pressure and supply chain coordination studied by the authors was collected using a quantitative research method (survey), at the same time the data regarding a firm's innovative capabilities was collected in the form of annual reports and company websites. In addition, data concerning sustainability practices and lean practices adoption were collected in the form of primary and secondary data. Furthermore, reports published by the automobile firms (secondary data) on sustainability were used alongside the use of structured questionnaires to collect primary data from the company's managers. The results of the data analysis showed that the relationship between lean firm and its sustainable performance is mediated by its innovative capability.

Similar to the research of Rathore et al. (2018), De et al. (2020) investigated the impact of lean and sustainability oriented innovation on sustainability performance of small and medium sized enterprises using a mixed method research on 35 manufacturing SMEs belonging to the eastern part of India. As input criteria the authors used lean production and sustainability criteria while economic, operational, environmental and social aspects were set as the output criteria. Using the method of Data Envelopment Analysis-based Framework, the authors were able to identify inefficient SMEs and were able to identify one SME as a benchmark for improving others. Subsequently, qualitative research method was used to suggest improvement measures for the inefficient SMEs. The results showed that combined effect of lean and sustainability oriented innovation helps achieve SMEs' supply chain sustainability.

However, adopting the mixed method research by collecting data from the manufacturing SMEs in Thailand, Burawat (2019) tested the structural relationship amongst certain factors namely transformational leadership, sustainable leadership, lean manufacturing and sustainability performance. Using a qualitative research approach, Burawat (2019) collected data from the middle and senior managers (40 participants) of the manufacturing industry in the SME sector in Thailand. Research methods used included participant observation, non-participant observation and in-depth interview. Adopting a quantitative approach in the same research the author collected data using survey from 598 respondents belonging to 374 companies.

The results of the quantitative study showed that lean manufacturing as a variable mediates in two relationships partially: one is between transformational leadership and sustainability performance partially and the other is between sustainable leadership and sustainability performance. Similarly, while adopting the qualitative approach, the author collected data through in-depth interviews. Analysis of the qualitative data showed that lean practices are appropriate for automotive industry though with less implementation in other industries.

The foregoing systematic review of the relationship between lean production and sustainability performance provide a good idea about the level of research that have been undertaken by various researchers through the review of 31 papers.

2.18.7 Relationship between agile production and sustainability performance

In order to understand the relationship between agile production and sustainability performance a systematic review of six papers was undertaken. Out of them 3 authors (e.g. Bouguerra et al. 2021; Nath and Agrawal, 2020; Geyi et al. 2020) had conducted quantitative empirical study while 3 (e.g. Sharma et al. 2020; Ivory and Brooks, 2018; Ciccullo et al. 2018) had used qualitative research study.

Bouguerra et al. (2021) investigated the multinational enterprises in Turkey to gain knowledge on whether agile organizations contribute to environmental collaboration or not. Adopting a quantitative study and by collecting data from 249 managers belonging to 66 multinational enterprises in Turkey, the authors found that there is a positive relationship between operational agility (independent variable) and environment collaboration (dependent variable). In addition, the authors related operational agility indirectly to environmental collaboration through individual creativity and flexible work arrangements. Individual creativity and flexible work arrangements acted as mediators between operational agility and environmental collaboration and such mediation was found to produce a better influence of operational agility on environmental collaboration than the direct relationship between operational agility and environmental collaboration.

Nath and Agrawal (2020) related agile production as an independent variable to operation performance, a dependent variable. This relationship was mediated by four factors, one of which is sustainability performance. Conducting their research on 311 Indian companies, the authors found through their empirical study that agility indirectly affects the dependent variable operational performance of the firms mediated social sustainability orientation, basic social sustainability practices as well as agility is indirectly affecting social sustainability performance via social sustainability orientation and basic social sustainability practices.

Furthermore, Geyi et al. (2020) adopted the quantitative study to understand the relationship between sustainable supply chain as an independent variable and two dependent variables namely operational performance and sustainability performance criteria. In addition, the authors also tested the mediating effect of agile practices between sustainable supply chain on the one hand and operational performance and sustainability performance criteria on the other. The research was conducted on a variety of manufacturing firms in the UK. 311 participants provided responses to the questionnaire distributed by the authors and the list of participants included many different levels from the top management to the lower executive level. The authors found that through the direct relationship, sustainable supply chain as an independent variable was able to positively influence both operational performance and sustainability performance criteria. In addition, agile practices as a mediating variable also enabled a positive influence on operational performance and sustainability performance criteria by sustainable supply chain.

With regard to qualitative research, it can be seen that Ivory and Brooks (2018) studied the management of corporate sustainability with a paradoxical lens in the context of strategic agility. The authors relied upon paradox theory to identify two particular pathways namely the organisation-wide acceptance of paradox and paradoxical resolution. The authors specifically apply the paradox theory to introduce strategic agility as a concept to tackle navigation through the paradoxical pathways. Ivory and Brooks (2018) claim that strategically agile firms are better positioned to navigate the paradoxes faced by those firms. An example of a paradox could be economic priorities and social or environmental priorities. The authors point out in paradoxes that involve economic sustainability and social sustainability, most often economic sustainability takes precedence. Going through the literature, the authors argue that such situations could be handled better using strategic agility. The authors claim that strategic agility is made of three organisational meta-capabilities namely strategic sensitivity, collective commitment, and resource fluidity. The finding of the authors based on simple literature review shows that firms use strategic sensitivity and collective commitment to reach goals like firm wide acceptance of paradox as a concept. In addition, the authors found that it is possible to achieve paradoxical resolution through the use of strategic agility elements like collective commitment and resource fluidity.

Furthermore, as explained earlier in section 2.22.6, Ciccullo et al. (2018) reviewed 73 papers in topics concerning integration between lean and sustainable and agile and sustainable supply chain paradigms and identified 6 different types of integration of the paradigms namely lean production, agile production and sustainability. As far as agile production is concerned, the authors argue that it is critical to design and implement a system of practices that are aligned with the environmental and social requirements of different stakeholders that are of importance to a firm on the one side and adopt agile production (e.g. fast and flexible to the needs of the marketplace) on the other. The authors point out that there is a need to conduct research on how to develop conceptual and empirical studies to decide the need to integrate the three paradigms mentioned above.

In addition, using the method of a systematic literature review Sharma et al. (2020) investigated the importance of integrating lean, agile, resilient, green and sustainable (LARGS) concepts in the area concerning supply chain management. Analysing the outcomes produced by 160 relevant articles published during 1999–2019, the authors aimed to bring out the main research issues and possible future research directions in LARGS paradigms in supply chains. The main outcomes included the finding of the authors regarding the areas that have not been investigated in the literature. Examples include: Interrelationships among agile, lean and green concepts on the one hand and supply chain performance on the other; integration of resilient, lean and sustainability concepts; connections between agile, resilient and sustainability concepts; combination of agile, resilient and sustainability concepts; combination of resilient, green and sustainability performance; bringing together agile resilient, lean and sustainability concepts; bringing together the concepts of agile green, lean and sustainability; combining agile, lean, resilient, green and sustainability concepts; and LARGS practices with supply chain performance. In addition to the above the authors also brought out a few different performance measures that could be used while integrating lean, agile, resilient, green and sustainability performance concepts in the management of supply chain. Those measures include competitive advantages, operational performance, overall performance, social performance, economic performance and environmental performance.

2.19 Summary and gaps in the extant literature

The review of the literature presented in the previous sections, and in particular the detailed review of the body of mainly prior empirical work that has derived findings relating to sustainability performance and what we know about its relationship with lean and agile production and supply chain collabotration, as presented in section 2.22, leads to a number of important observations regarding gaps in the knowledge that needs addressing.

The concept of sustainability performance has become a main concern for manufacturers working within dynamic and complex business environments (Janmontree and Zadek, 2020; Gunasekaran et al. 2019; Singh and Vinodh, 2017). Manufacturing companies are operating today under significant competitive pressure that requires using flexible resources that can be adjusted to meet changing customer demand. An important issue, at the same time, is that they must improve the triple bottom line objectives (TBL), that is, that pertain to economic, environmental and social impact. Thus, such companies need to respond to constant changes that occur in their business environment and sustainability performance requirements (Teixeira et al. 2021; Orji and Liu, 2020; Choudhary et al. 2019; Leon and Calvo-Amodio, 2017). The strategies of lean production and agile production and supply chain management can help the companies in this situation (Furlan et al. 2023; Kant et al. 2015; Womack et al.1990; Womack and Jones, 1996). There is evidence in the literature that operational advantages and performance outcomes of firms can be improved by implementing lean production and agile production (Chavez et al. 2022; Geyi et al. 2020) At the same time, the literature indicates that many companies are currently unable to adapt to internal and external changing conditions in business environments and produce goods and services in a sustainable manner and, therefore, derive sustainability performance benefits (Pucker 2021; Eslami et al. 2019; Ravet, 2011). Literature has also produced contradictory results with regard to the link between implementing lean production and agile production and sustainability performance. Some contributions (e.g. Sadeghi et al. 2022; Jum’a et al. 2022; Rupasinghe and Wijethilake, 2021; Bouguerra et al. 2021; Nath and Agrawal, 2020; Geyi et al. (2020); Garza-Reyes et al. 2018; Mayr et al. 2018) have argued that sustainability performance can be achieved through the application of technologies such as lean production and agile production. However, other contributions (e.g. Mohaghegh et al. 2023; Martínez-Jurado and Moyano-Fuentes, 2014) have argued that the current knowledge about implementing sustainable performance in manufacturing units that have adopted lean and agile technologies is not sufficient. Therefore, the requirement for greater understanding and investigating of the relationships between lean production and agile production on the one hand and manufacturing sustainability performance on the other has gained heightened importance, and is a gap in the literature that needs to be addressed.

Furthermore, while the literature has linked lean production and/or agile production to sustainability performance, although often incorporating only one sustainability performance factor at a time (Alzoubi et al., 2020; Srinivasan et al., 2020), there is a lack of research that has linked a comprehensive view of sustainability performance factors, namely economic, environmental and social to lean production and agile production, together in a single study (Vaishnavi and Suresh, 2020; Ramana et al. 2013). In addition, the combination of lean production and agile production is yet to be well understood in regard to their influence on sustainability performance. Ciccullo et al. (2018), for example, concluded that there is a need to conduct research on how to develop conceptual and empirical studies to decide the need to integrate the three paradigms of lean and agile and sustainable supply chain. Hence, it is reasonable to conclude that there is a need to further investigate in this area.

The literature has also indicated that achieving sustainability performance should be undertaken with the involvement of all relevant stakeholders throughout supply chain (e.g. Pan et al. 2020; Albino et al. 2012; Cao and Zhang, 2011) including, for example, customers (e.g. Chavez et al. 2015; Danese and Romano, 2011) and suppliers (e.g. Du et al. 2018), without which an understanding of the impact of lean production and agile production on sustainability performance would be incomplete (Ekren, 2022; Srinivasan et al., 2020). Supply chain collaboration as the supply chain management strategy has become very popular among firms to help achieve improved performance outcomes (Ataseven and Nair 2017; Chavez et al. 2015). Supply chain collaboration involves combining the ability of two or more independent firms to plan and implement supply chain activities (Cao et al. 2010), and notable advantages derived include improved stock levels, reduced lead times, and reduced transportation cost (Yilmaz et al. 2016). The literature has also examined aspects of supply chain collaboration on the lean production and agile production in manufacturing industries. The literature showed that the greater cooperation and information integrated with customers significantly affect lean production approach (Moyano-Fuentes et al 2012). The strategy of supplier integration including information sharing, e-business systems, and policy-based supplier selection positively influence lean production adoption in long term (So and Sun, 2010). Hence, the integration of supply chain collaboration to lean production can strengthen the impact of lean production on sustainability performance, which in turn is associated with enhanced firm performance. Similarly, in Qrunfleh and Tarafdar's (2013) study, the relationship between agile supply chain strategy, postponement and supply chain responsiveness was found to affect firm performance positively through the mediation factors of supply chain collaboration. Therefore, to understand and help address the problems faced by manufacturing firms seeking to improve their sustainability performance, this research has identified the need to empirically examine the influence of the adoption of lean production and agile production alongside the concept of supply chain collaboration as a moderator, a configuration which represents a gap in the literature.

This chapter has comprehensively reviewed the literature on the different aspects concerning lean production, agile production, sustainability performance and supply chain collaboration amongst industries. Literature review shows a number of gaps exist and there is need to fill those gaps. Furthermore, the review has dwelt on the various challenges faced by the stakeholders and industries in achieving a sustainable performance addressing which appears to be daunting task. Additionally, the theoretical relationships amongst those three factors have been critically reviewed which has provided avenues for improving the body of literature concerning sustainability performance in industries that have opted for lean production and agile production. Furthermore, the chapter has critically reviewed the need to collaborate amongst the industries and stakeholders to achieve sustainability performance. An important area of collaboration that promises to provide some way forward to achieve sustainability performance is the supply chain collaboration amongst industries. In the absence of well investigated studies the integration of supply chain collaboration into the relationship between lean production, agile production and sustainability performance has become a bottleneck which requires study. Thus, this chapter provides the basis to develop an empirical relationship between lean production, agile production and sustainability performance on the one hand and intervention of SCC into that relationship on the other. The development of a proposed theoreticl model is presented and discussed in the next chapter.

Chapter 3: Theoretical Framework

3.1 Introduction

This present research concerns manufacturing firms and their concerns about sustainability performance. The literature indicates that sustainability performance is a challenge in many industries including manufacturers (Medabesh and Khan, 2020). Little et al. (2016) argued that it is a difficult challenge to identify a comprehensive and realistic way to evaluate and enhance sustainability. Although the literature suggests that lean production and agile production are two concepts that could support manufacturing industries to achieve sustainability performance, the direct relationships between lean production and agile production on the one hand and sustainability performance factors on the other has not been well established in the extant literature (Pearce et al. 2021; Pushina et al. 2020; Melin and Barth, 2018; Ciccullo et al. 2018; Satolo et al. 2017). In addition to this gap in the literature, another important concern of the present study is the influence of supply chain collaboration (SCC) on the relationship between lean production (Tortorella et al. 2017; Jasti and Kodali, 2015; Anand and Kodali, 2008) and agile production (Tse et al. 2016; Swafford et al. 2006) on the one hand and sustainability performance (Dey et al. 2019) on the other.

This chapter commences the process of addressing these gaps by developing a theoretical framework describing anticipated links between lean production, agile production, sustainability performance and SCC, in a single model. The sections that follow hence discuss the relationship aspects concerning lean production, agile production, sustainability performance and SCC, and presents proposed hypotheses concerning the relationships that need to be examined empirically. It must be noted here that sustainability performance has been broken down into three factors namely economic, environmental and social and each is linked to lean production and agile production. The proposed relationship between lean production and the three sustainability performance factors is first discussed, followed by agile production and the three sustainability performance factors, and then the proposed influence of SCC in the proposed model.

3.2 Conceptual framework

The conceptual framework presents the proposed relationship between lean production, agile production, sustainability performance (i.e. economic, environmental and social sustainability performance) and supply chain collaboration (see Figure 3.1). The model suggests that the presence of lean production practice and agile production practice respectively, have a positive impact on sustainability performance (economic, environmental and social, respectively). Moreover, the model predicts that supply chain collaboration enhances the effectiveness of lean production practice and agile production practice on each of the three sustainability performance dimensions. That is, the model examines the moderating effect of supply chain collaboration on the relationship between lean and agile production and sustainability performance. Table 3.1 summaries the hypotheses developed for the study.

Figure 3.1, Conceptual model developed for the research (source: developed by author).

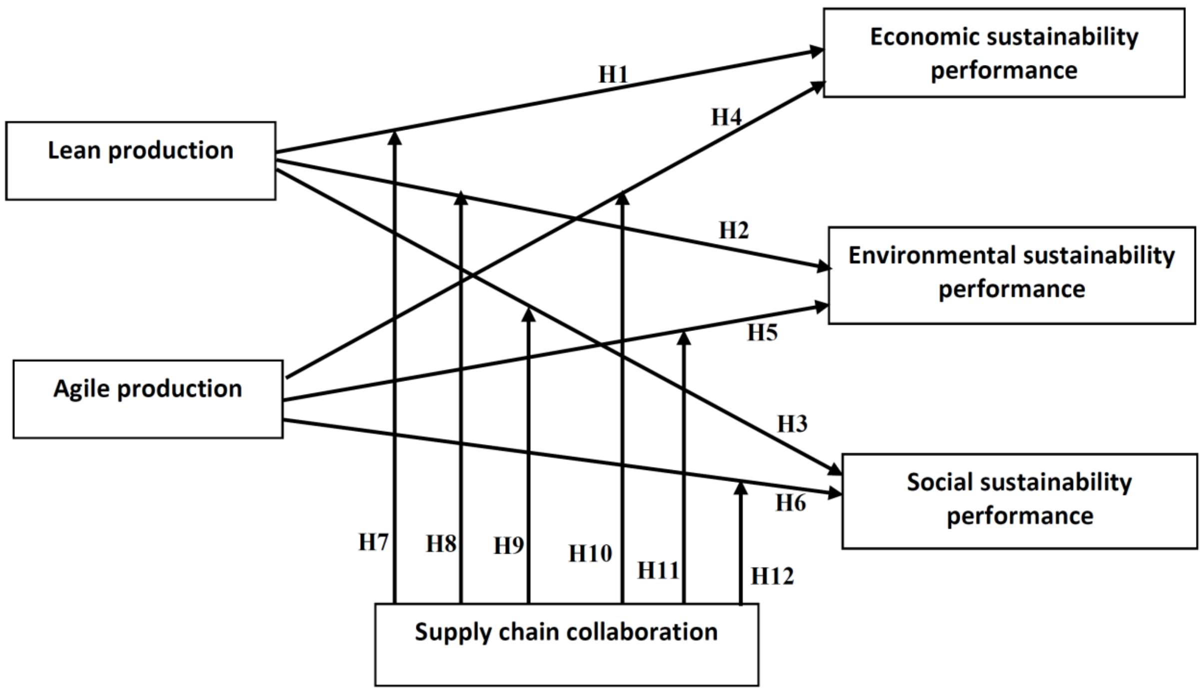


Table 3.1, List of hypotheses

Hypothesis code	Hypothesis
H1	Lean production practice is positively related to economical sustainability performance
H2	Lean production practice is positively related to environmental sustainability performance
H3	Lean production practice is positively related to social sustainability performance
H4	Agile production practice is positively related to economical sustainability performance
H5	Agile production practice is positively related to environmental sustainability performance
H6	Agile production practice is positively related to social sustainability performance
H7	Supply chain collaboration moderates the impact of lean production practices on economic sustainability performance
H8	Supply chain collaboration moderates the impact of lean production practices on environmental sustainability performance
H9	Supply chain collaboration moderates the impacts of lean production practices on social sustainability performance
H10	Supply chain collaboration moderates the impacts of agile production practices on economic sustainability performance
H11	Supply chain collaboration moderates the impacts of agile production practices on environmental sustainability performance
H12	Supply chain collaboration moderates the impacts of agile production practices on social sustainability performance

In the following sections, following discussion on the choice of how to conceptualise lean and agile (independently or combined) in the model, the inter-relationships (hypotheses) between the constructs are developed.

3.3 Conceptualising lean production and agile production in the conceptual framework

An important consideration that needed to be addressed in developing the conceptual model relates to the possibility of firms using both lean and agile production methods, and hence the inclusion of both in the conceptual development. As established through the review in chapter 2, whilst there is disagreement within the literature on whether the two approaches can co-exist, with some authors positing that the evidence for lean and agile production co-existence in manufacturers is weak (e.g. Ding et al. 2023; Qamar et al. 2020; Hallgren and Olhager, 2009), the dominant position observed in the literature supports the argument that lean and agile production in the manufacturing context can co-exist (e.g. Ding et al. 2023; Kant et al. 2015; Galankashi and Helmi, 2016). However, there are also differences within the research community on whether lean and agile production should be treated as a single construct (i.e. leagile) or as two independent constructs. For instance, Oyombe et al. (2022) and Fadaki et al. (2020) conceived leagile as a single construct and measured it using a single instrument. Rahimi and Alem-Tabriz (2022) and Srinivasan et al. (2020); Nath and Agrawal, (2020) and Sukwadi et al. (2013) however conceived lean and agile production as independent constructs and linked them independently to supply chain performance. A decision on this aspect was needed in the present study. The options available for the research were:

- To conceive lean production as an independent variable and link it to sustainability performance factors in a single model without the intervention of agile production. Examples of this conception could be found in the extant literature (e.g. Awan et al. 2022; García-Alcaraz et al. 2021);
- To conceive agile production as an independent variable and link it to sustainability performance factors in a single model without the intervention of lean production. Examples of this conception could be found in the extant literature (e.g. Bouguerra et al. 2021; Geyi et al. 2020 and Hartini and Ciptomulyono, 2015);
- To conceive a model in which both lean and agile production are conceptualised as a single construct (leagile) and link it to sustainability performance factors. In this case, except for a few examples (e.g. Oyombe et al. 2022; Fadaki et al. 2020; Galankashi and Helmi, 2016), not many research studies were found in the literature; or
- To conceive a model in which both lean and agile production are conceptualised as two independent constructs and link them independently to sustainability performance factors (as was the case for

example, in the studies by Rahimi and Alem-Tabriz (2022); Srinivasan et al. (2020); Nath and Agrawal (2020) and Sukwadi et al. (2013).

This research was guided by the model suggested by Christopher (2000) which independently linked lean production and agile production to manufacturing performance factors, in a single model. As noted above, using lean and agile as independent constructs also finds support in the research conducted by Rahimi and Alem-Tabriz (2022); Srinivasan et al. (2020); Nath and Agrawal (2020) and Sukwadi et al. (2013). Treating the two constructs independently not only facilitated a greater level of discriminatory power amongst the study's constructs in the modelling but was considered important for theory development in the fields of lean, and of agility, respectively.

3.4 Relationship between lean production and sustainability performance

The main objective of lean manufacturing is to eliminate all things that do not add value to a product, thus considered as a waste (Powell and Coughlan, 2020) and deliver high quality products at low costs produced with highest productivity (Franchetti et al., 2009; Ohno, 1988). The two main pillars that make the lean framework, as mentioned previously are Jidoka automation with human touch and just-in-time (JIT) (Dennis, 2007). The goal to be achieved is the highest quality of a product, at the lowest cost, in the least time by eliminating waste. Many researchers have stressed the need to link the concept of sustainability to lean manufacturing (Jum'a et al. 2022; Awan et al. 2022; García-Alcaraz et al. 2021; Martínez-Jurado and Moyano-Fuentes, 2014). Since the term sustainability performance implies the performance of the economic, environmental and social sustainability performance, it was deemed important to investigate the relationship between lean production and each one of the three sustainability factors. The following sub-sections deal, in turn, with the relationship between lean production and economic, then environmental, then social sustainability performance respectively

3.4.1 Relationship between lean production and economic sustainability performance

In the absence of a clear understanding of the nature of the relationship between lean production and economic sustainability performance, manufacturing units may be underperforming due to lack of competitiveness, the latter being an important purpose more broadly served by lean production. The literature shows that several factors affect economic sustainability performance in the manufacturing sector. Kahn (1995), for instance identified growth, development, productivity and trickle down as factors affecting economic sustainability performance. Although there is no overall consensus amongst researchers on a unique set of factors that affect the economic sustainability performance of a firm (Awad et al. 2022; de

Castro et al. 2022; Reyes-Soriano et al. 2022; Al-Tuwaijri et al. 2004; Milne and Ralph, 1999), and it is reasonable that many of the aforementioned factors could indeed determine economic sustainability performance, at the same time evidence indicates that lean production can positively affect economic sustainability performance. Nath and Agrawal, (2020), for example, empirically investigated lean management and economic sustainability performance using data from 311 practitioners from Indian manufacturing firms. The results suggest that lean management has positive and direct effect on economic sustainability performance. In similar lines, Dey et al. (2020), conducting a survey on 119 SMEs within manufacturing industries in the UK, argued that lean management practices as an independent variable has a positive influence on the dependent variable economic performance of SMEs. Siegel et al. (2019), defining sustainability performance, argued that it is the capacity of a company to achieve its financial objectives in the short and long terms using such practices as lean production. These contributions imply that a manufacturing unit that has adopted lean production methods will be able to drive economic sustainability performance of that firm.

Such a relationship can also be supported by lean philosophy and RBV. The lean philosophy states that lean is a way to do more, involving the continuous reduction in human effort as well as equipment time and space because it points towards providing customers with what they want (Neves et al., 2018). The RBV is concerned with resources that are valuable, rare, non-substitutable and inimitable. It has been shown that it is possible to achieve competitive advantage through the application of lean practices (Lewis, 2000). Examples of the associated resources include tangible (funds, technology, equipment) and intangible (skill, organizational process, information and knowledge) ones. Those resources, applied to reduce waste, help achieve improved efficiency and effectiveness culminating in organizational capabilities (Barney, 1991).

Based on above arguments, a direct and positive relationship between lean production and economic sustainability performance is very reasonable - as the level of lean production in a firm increases, the level of economic sustainability performance of that firm should also increase. This position is supported by Jum'a et al. (2022) and Nath and Agrawal, (2020). Thus:

H1: Lean production practice is positively related to economic sustainability performance

3.4.2 Relationship between lean production and environmental sustainability performance

Ince (2018) defines environment sustainability as a method by which human needs are met and the health of the ecosystems are not compromised. This view indicates the limits of the human activities in nature. Dixit and Chaudhary (2020) explain that environmental sustainability is about responsible activity concerning the environment and stopping the depletion or debasement of the natural resources and securing them from long-term environmental quality issues. The literature suggests that environmental sustainability performance is affected by a number of factors including the adoption of clean technologies, the prevailing business environment, skills related to management of enterprises, access to finance, competition (Msomi, et al. 2019; Ngibe and Lekhanya. 2019b), and lean production factors (Shekarian et al., 2022; Awad et al., 2022; Pawlik et al., 2022; Barclay et al., 2021; Kant et al., 2015).

The literature shows that the relationship between lean production and environmental sustainability has produced contradictory results and there is therefore a lack of clarity on the nature and extent to which lean production influences environmental sustainability. For instance, Rodrigues and Kumar (2019) and others (e.g. Sartal et al., 2018; Dües et al., 2011; Franchetti et al., 2009) found that lean manufacturing adoption may cause a negative effect on environmental sustainability. However, Jum'a et al. (2022) and others (e.g. Nath and Agrawal, 2020; Rodrigues and Kumar, 2019; Rupasinghe and Wijethilake, 2021; Dieste et al. 2019; Garza-Reyes et al., 2018; Cherrafi et al., 2017; Pampanelli et al., 2014; Aguado et al., 2013) found a positive relationship between lean production and environmental sustainability performance.

For environmental sustainability there is a need to maintain natural resources at a convenient level (Moldan et al. 2012) which implies some level of standardization. Lean production involves classification of products into groups with similar processing requirements (standardistaion) (Pawlik et al., 2022). Such a classification can help to ensure consumption of natural resources to the minimum extent needed to produce identical/similar products through shared resources, resulting in elimination of waste and use of the resource to the optimum extent. Thus, there exists a natural relationship between lean production and environmental sustainability. It is important to acknowledge that in some instances a negative impact of such a relationship has also been suggested, the literature for example showing that lean production and green production are divergent in some cases (Carvalho et al. 2017; Dües et al. 2011; Rothenberg et al. 2001; Simons and Mason, 2003). This could happen if lean production aims at greater levels of productivity and efficiency that may not be consistent with environmental sustainability performance (Dieste and Panizzolo, 2018).

This research adopts the position that lean production positively influences environmental sustainability performance, a position which is supported by Jum'a et al. (2022), Rupasinghe and Wijethilake, (2021), Dieste et al. (2019), Garza-Reyes et al. (2018), Cherrafi et al. (2017), Pampanelli et al. (2014) and Aguado et al. (2013). It is also supported by lean theory and RBV, an argument supported by Martínez-Sánchez et al. (2019). As mentioned above, RBV is concerned with resources that are valuable, rare, non-substitutable and inimitable, and lean production focuses on waste reduction and improving the efficiency of production processes, and hence reducing and optimizing natural resource utilization, which are also principles within the RBV (Barney, 1991). Wong et al (2018) argue that in the absence of waste reduction and elimination, resources are at risk of becoming increasingly scarce. Conversely, it is reasonable to argue that waste reduction and elimination - the pillars of lean - preserves resources thereby improving environmental sustainability performance. Garza-Reyes et al. (2018) argues that lean production is considered inherently ecological meaning that lean production supports environmental sustainability performance. A pertinent example is to eliminate unnecessary transportation of products or raw materials. Similarly, Sartal et al (2018) report based on their investigation on Spanish manufacturers that the quality (jidoka) and respect for people have an influence on environmental performance (CO_2 emissions) positively. Thus it is posited that lean production positively influences the environmental sustainability performance:

H2: Lean production practice is positively related to environmental sustainability performance.

3.4.3 Relationship between lean production and social sustainability performance

Sachs (1999, pp. 32–33) argued that social sustainability comprises achievements including a fair level of social homogeneity, equitable income distribution and a job that enables the creation of respectable livelihoods. Sachs (1999) also argued that social sustainability requires equitable access to resources and social services, balancing between respect for tradition and innovation on the one hand and self-reliance, endogeneity and self-confidence on the other. The literature indicates that a number of factors affect social sustainability performance including sustainable management (Sroufe and Gopalakrishna-Remani 2018), supply chain strategy (Qorri et al. 2018), employment, infrastructure capacity-building, community amenities, workers' health safety assessment (Enshassi et al. 2016), and diversity and product responsibility (Shaharudin et al. 2022). The literature also indicates that there are lean production factors that affect social sustainability performance. While conducting research on multisector manufacturing industries in Malaysia, Xiang and Nor (2021) found that the lean factors namely manufacturing planning and control practices, human resources practices and supplier relationship practices were not statistically significantly related to social sustainability performance, and similarly Resta et al., (2016) found a negative relationship in their investigation of five industry sectors. However, Uhrin et al., (2017), Wong and Wong (2014) and Bonavia and Marín-Garcia (2011) all found a statistically significant relationship between lean production and social sustainability performance. Despite the contradictory results found in the literature, this research, based on the balance of evidence, as provided by the findings of Jum'a et al. (2022), Nath and Agrawal, 2020; Uhrin et al., (2017), Wong and Wong (2014) and Bonavía and Marín-Garcia (2011), posits that lean production is positively related to social sustainability performance.

Theoretical support for establishing such a positive relationship is also provided by stakeholder theory. Since lean production has a focus on and explicitly recognizes the importance of involving stakeholders, particularly (but not exclusively) the employees, it is reasonable to argue that lean can positively influence social sustainability. Bonavia and Garcia (2011) for example, found that the implementation of lean production was associated with higher levels of training and employment security, the latter an important element of social sustainability from the employee perspective. Based on the literature reviewed in section 2.19.3, it appears that any relation between lean production and social sustainability could be explained partly by the stakeholder theory. For instance, the application of lean tools linking processes and materials to minimise waste and maximise value addition (Kaswan and Rathi, 2019; Ferng and Price, 2005), create a clean and well organised workplace (5s) (Díaz-Reza et al 2024) and ensure safety (TPM) (Sraun and Singh, 2017) can lead to an improved work environment, health, well being and safety for the workforce (Díaz-Reza et al 2024). Thus, the following hypothesis is postulated:

H3: Lean production practice is positively related to social sustainability performance.

3.5 Relationship between agile production and sustainability performance

Agility is about succeeding in business to help secure profits, with a view also to enhancing market share and satisfying clients through an ability to combine speed and flexibility of response to their needs (Aslam et al. 2018; Eckstein et al. 2015; Lee, 2004; Naylor et al., 1999). Agility is about being able to constantly change, embrace change continuously and aggressively, and is inclined to achieve growth (Aslam et al. 2018; Eckstein et al. 2015). The phenomenon of agile production has been shown to affect a number of factors including sustainability performance, however the current understanding of the relationship between agile production and sustainability performance is arguably incomplete (Geyi et al. 2020; Hartinia and Ciptomulyono, 2015). While there is evidence in the literature to indicate that agile production influences sustainability performance (e.g. Bouguerra et al. 2021; Nath and Agrawal, 2020; Geyi et al. 2020; El-Khalil and Mezher, 2020), Cicullo et al. (2018) stated that the influence of agile production on sustainability performance factors in understudied and needs understanding better. In order to fill this gap in the literature, in the sub-sections that follow the expected relationship between agile production and economic sustainability performance, environmental sustainability performance and social sustainability performance, respectively are proposed.

3.5.1 Relationship between agile production and economic sustainability performance

The literature indicates that economic sustainability is an important factor for achieving competitive advantage (Erdil et al. 2018) and furthermore that firms that have adopted agile production would like to achieve competitive advantage (Suarez et al. 1995). This implies that economic sustainability is an important derivative of agile production, an argument supported by Searcy (2012), who argued that the traditional metrics used to measure performance objectives of costs, speed, quality, flexibility, dependability and innovation are no longer sufficient on their own, and firms also need to deliver on sustainable performance. Such arguments indicate the need to integrate agile production with economic sustainability performance.

Nevertheless, there are contradictory results to be found in the extant literature. For instance, Geyi et al., (2020), El-Khalil and Mezher (2020), Nath and Agrawal, (2020) and (2020) Nabass and Abdallah, (2019) found a direct and positive relationship between agile production and economic sustainability performance. However, Ojha (2008) found a negative relationship between agile production and economic sustainability performance while Shin et al., (2015) found no relationship between the two constructs. Theoretical support for establishing the relationship between agile production and economic sustainability performance is provided by RBV theory (e.g. Sharma et al. (2023), Bhandari et al. (2022) and McDougall et al. (2019)). RBV explains how resources are connected to competitive advantage, a common goal that needs to be achieved while discussing agile production and economic sustainability performance. The above arguments lead to posit that a direct and positive relationship between agile production and economic sustainability performance is very plausible. Thus:

H4: Agile production practice is positively related to economic sustainability performance.

3.5.2 Relationship between agile production and environmental sustainability performance

Environmental sustainability performance concerns many aspects including waste, carbon, and other pollution particles, healthy climate in terms of air, water, and energy quality (Negulescu et al. 2022) and energy (Jeong et al. 2021). Furthermore, there are stakeholders who are affected by firms with regard to environmental aspects including employees, environmental pressure groups, the government, clients, financiers, suppliers and the citizens. Those stakeholders are concerned about environmental issues, and firms need to focus on gaining support from such stakeholders in order to achieve sustainable performance (Dzomonda, 2022). This includes firms that have adopted agile production (Geyi et al., 2020).

Lack of regulations, awareness, and knowledge have affected firms to implement measures to improve environmental sustainability performance (Rashed et al. 2022). Evidence in the literature indicates that environmental sustainability performance is positively affected by agile production (e.g. El-Khalil and Mezher, 2020; Geyi et al. 2020; Nath and Agrawal, 2020). As mentioned earlier, it can be seen that flexibility is one aspect of agile production (Darusulistyo et al. 2022). Geyi et al. (2020) argued that environmental sustainability performance is affected by technology awareness with Adeleye and Yusuf (2006) going one step further and claiming that use of flexible production technology – a core element of an agile production system - positively affects environment sustainability performance.

As far as theoretical support for establishing this relationship is concerned, environmental sustainability performance could be explained by theory of sustainable development. The theory of sustainable development states that “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their needs (World Commission on Environment and Development, 1987; p. 6). Application of the theory of sustainable development to studies concerning environmental sustainability performance is supported by Shi et al. (2019) who say that this theory could be applied to enterprises at all levels. In the manufacturing context, environmental sustainability performance concerns such aspects as decreased consumption for hazardous, harmful and toxic materials and improved enterprise’s environmental situation (Inman and Green, 2018). Linking these aspects to agile production is supported in the extent literature. For instance, many researchers have argued that agile production could be linked to many environmental sustainability performance factors including reduction in solid wastes, decrease in use of natural resources, increased energy efficiency, reduction in water usage, reduced air pollution, decrease in consumption toxic chemicals, decrease in frequency for environmental accidents and improvement in an enterprise environmental situation (El-Khalil and Mezher 2020; Paulraj et al., 2017; Esfahbodi et al., 2017; Blome et al., 2014; Zhu et al., 2013; Wong et al., 2012). In order to test this relationship, the following hypothesis is postulated:

H5: Agile production practice is positively related to environmental sustainability performance.

3.5.3 Relationship between agile production and social sustainability performance

Agile production has been argued to positively affect social sustainability performance (Geyi et al. 2020; El-Khalil and Mezher 2020; Nath and Agrawal, (2020). However, research on social sustainability performance is sparse, with much prior attention being paid instead to economic and environmental sustainability performance of firms (Golicic et al. 2020). Similar sentiments were expressed by Wang et al. (2022) who argue that the strategic role of social sustainability in enhancing a firm’s performance, particularly financial performance is not well investigated. While agile production is argued to support sustainability performance, the relationship between agile production and social sustainability performance needs to be better understood (Geyi et al. 2020).

As far as explaining agile production and its relationship with social sustainability performance is concerned, this research relies upon the stakeholder theory. Social sustainability performance, involves such aspects as employment, infrastructure capacity-building, community amenities, workers' health and safety assessment (Enshassi et al. 2016), diversity and product responsibility (Shaharudin et al. 2022). Since agile production has a focus on stakeholder involvement, the employees and customers, for example, continuous training and development and customer driven innovation - the aspects of agile (Geyi et al., 2020), it is reasonable to argue that agile production can positively influence social sustainability (employment, workers' safety and community amenities). For instance, Sumukadas and Sawhney (2004) indicated that workforce involvement such as training, information sharing, power sharing, reward, effected on satisfaction and performance. In addition, Wu et al., (2016) claim that understanding the expectations of customers can help in rendering sustainability initiatives to succeed and it is not easy to employ sustainability practices successfully without a strong understanding of, involvement with and knowledge of customer and other stakeholders (Geyi et al. 2020). This proposes that agility capabilities are likely to emerge during a period of greater social changes, for instance, agile production capabilities can evolve as a result of organisations' responses to customer demand for sustainable products. Thus, explaining the relation between agile production and social sustainability using stakeholder theory provides the basis for the following hypothesis:

H6: Agile production practice is positively related to social sustainability performance

3.6 Influence of supply chain collaboration (SCC) on the relationship between lean production and agile production respectively, and sustainability performance

Supply chain strategy is an important issue in industries operating in a competitive market, and each one of those strategies can have particular requirements of its own. Furthermore, it is required that when those strategies are deployed, they are properly managed (Galankashi and Helmi, 2016). The literature is replete with contributions on different supply chain strategies of various kinds (Furlan et al. 2023; Berthot, 2023; Varga and Kovács, 2016; Kant et al. 2015). Yet there is paucity of research that has integrated various supply chain strategies – one of which is supply chain collaboration - with the internal operational activities of a firm and examined their effect of the different internal drivers of performance (Galankashi and Helmi, 2016). There is a need to study the various influences of different supply chain strategies on internal operational activities, as identifying, categorizing, implementing and maximizing the benefits of those operational activities has been a challenge for researchers and practitioners alike (Fawcett et al., 2014; Wieland and Wallenburg, 2012).

Issues that can cause ambiguity in the minds of manufacturing industry managers, for example in deciding on which one of the approaches namely lean production or agile production or both should be used as part of the operational activities, have been identified by Furlan et al (2023) as:

- introduction of new products;
- improving existing processes and products;
- increase the productivity of factories;
- increase the efficiency and robustness of the supply chains;
- the context in which the firm is conducting its business; and
- the nature of the problems faced by the firm.

In this context, it is important to gain an understanding of which supply chain strategies need to be adopted when organisations are faced with the above question. Taking the example of a firms that wants to introduce new products and improve existing processes the firm has to decide (Furlan et al. 2023):

- whether to introduce the product based on breakthrough innovations or leverage the existing technological platforms; the new technology could be incompatible with the existing one but potentially better performing; and/or
- whether the processes should be improved incrementally or new technologies should guide the improvement; and/or
- How to enhance the efficiency and strength of supply chains; this may need a decision on whether to work with the current suppliers or find out new sources of supply.

The answers to the above problems are largely dependent on the context facing the firm (Snowden and Boone, 2007). For instance, where the problems are supposed to have been defined, identified without difficulty and documented and solutions to those problems are available, then it is worthwhile to adopt a solution which leverages the existing technological platforms. In this situation Womack et al. (1990) suggest the adoption of lean production as the approach. In this context, what supply chain strategy needs to be used is an important decision an organization must decide.

However, where the situation is complex, problems are not known and uncertainty surrounds the situation, the cause and effect relationship as well as solutions to the problems do not exist as of now, it is wise to explore new solutions (Snowden and Boone, 2007; Kurtz and Snowden, 2003). In this situation, Sutherland (2014) argue that adoption of agile production approach may be a better choice. In this context also, the manufacturer has to decide how to develop it supply chain strategies.

In yet another instance, Furlan et al. (2023) argue that companies can adopt a third approach when faced with complex environments, that is adopt the approach of improving the existing (using lean production approach) and explore new solutions (using agile production approach). This implies that firms increasingly need to become ambidextrous that is to say that those firms need to carry out incremental improvements and employ agile approaches. Supply chain strategies that can be adopted to support the effect of internal operational approaches on sustainability performance, as was established in the previous chapter, require further investigation.

The conceptual model includes a moderating effect of supply chain collaboration (SCC) on the relationships between lean production and agile production respectively and sustainability performance. In sections 3.6.1 and 3.6.2, based on the literature, the six hypothesized relationship (H7 to H12) are presented.

3.6.1 Influence of SCC on the relationship between lean production and sustainability performance (economic, environmental and social)

There is evidence in the literature to suggest that SCC influences sustainability in firms that have adopted lean production (Riofiandi and Tarigan, 2022; Ruiz-Benitez et al. 2019). In sections 3.6.1.1 through 3.6.1.3 that follow, the moderating effect of SCC on the relationship between lean production and economic, environmental and social sustainability performance respectively, is introduced.

3.6.1.1 Influence of SCC on the relationship between lean production and economic sustainability performance

Of late, researchers and practitioners alike have shown great interest in the potential SCC has in improving the performance of a firm leading to the achievement of competitive advantage (e.g. Ahmadi-Gh and Bello-Pintado, 2022; Pan et al. 2020; Du et al. 2018; Ataseven and Nair, 2017; Cheng et al. 2016; Mao et al. 2017 Chavez et al. 2015; Danese and Romano, 2011). Ataseven and Nair (2017) found that there is a clear impact of internal integration, supplier integration, and customer integration on a firm's financial performance. Du et al. (2018) found a positive relationship between customer integration and firm performance. Literature also shows that empirical research efforts on the influence of lean on sustainability performance in the context SMEs is needed (Kosasih et al. 2022). Prior research has argued that firms need to use resources efficiently while employing lean production throughout the supply chain that could lead to enhanced sustainability (namely economic, environmental and social sustainability dimensions) (Madsen et al. 2019; Masoumi et al. 2019; Lee, 2019; Tasdemir and Gazo 2018; Wu et al. 2015).

There is evidence to suggest that SCC has been used by researchers to influence lean production (economic performance) as a predictor (e.g. Riofiandi and Tarigan, 2022; Bento et al. 2020; Moyano-Fuentes et al. 2012) while some others have used it as a mediator between lean and firm economic performance (e.g. Vanichchinchai, 2019; Qrunfleh and Tarafdar, 2013). However, hardly any evidence is found in the literature where SCC has actually been tested as a moderator of the relationship between lean production and sustainability performance, including economic performance, with rare exceptions like Kosasih et al. (2022) who identified lean as affecting sustainability performance both directly and indirectly, with SCC moderating the relationship. In all the above research efforts it can be seen that supply chain collaboration has been used as supplier involvement in lean practices. Taking into account SCC aspects, supplier and customer, firms can also involve customers to, for example, contribute to determining product requirements and product development accurately so that data from customers can be integrated directly with firm system. For instance, Moyano-Fuentes et al (2012), similarly found that greater cooperation with customers and more information integrated with them did have a significant effect on the intensity of lean production adoption.

The argument that SCC could act as a moderator is supported by the theory of transaction cost economics (TCE) (Nagle et al. 2020). The theory could be applied to both the customers and suppliers. For instance, to achieve increased company profitability as part of the economic sustainability performance (Abdul-Rashid et al., 2017) low cost needs to be achieved in lean production and this involves the customers. Low costs could affect the quality of a product and the purchasing intentions of customers. Hence applying the TCE it is possible to argue that when firms take customers into confidence, those firms could generate low costs where incentives are strong to generate such low costs. Similar arguments can be made with regard to suppliers (Barringer and Harrison, 2000; Williamson, 1975). For instance, firms could achieve decreased inventory levels as part of the economic sustainability performance (Inman and Green 2018) when firms keep collaborative relationships with suppliers (Riofiandi and Tarigan, 2022). These aspects clearly point out the need to conceive SCC as an important moderator of the relationship between lean production and economic sustainability performance. Thus, it is postulated that:

H7: Supply chain collaboration moderates the impact of lean production practices on economic sustainability performance.

3.6.1.2 Influence of SCC on the relationship between lean production and environmental sustainability performance

SCC as a concept has been directly linked to environmental sustainability performance by a number of researchers (e.g. Ahmadi-Gh and Bello-Pintado, 2022; Pan et al. 2020; Mao et al. 2017; Albino et al. 2012; Chaabane et al. 2012). There is evidence in the literature that suggests that sustainability performance is directly driven by lean production and that SCC can act as a moderator of the relationship between lean production and environmental sustainability performance (Kosasih et al. 2022). As explained above, the arguments concerning possibly employing SCC as an independent variable affecting sustainability performance including environmental performance directly, or SCC affecting the relationship between lean production (quality management) and environmental sustainability performance as a mediator have already been established by researchers (Mao et al. 2017). Famiyeh et al. (2018) argued that firms have started establishing supply chain management in response to customer demand for environmentally sustainable products and services. Moderation of the relationship between lean production and environmental sustainability performance finds use if firms want to enhance the relationship. For instance, firms desiring to engage customers to get performance feedback on quality and delivery as part of lean production (Inman and Green, 2018) would like to ensure that environmental sustainability performance is achieved in terms of improved environmental situation by enhancing the relationship with those customers using SCC such as working with customers as partners (Lai et al., 2012). In another instance, for environmental sustainability there is need to maintain natural resources at a convenient level (Moldan et al. 2012). Lean production involves classification of products into groups with similar processing requirements (standardistaion) (Pawlik et al., 2022) can help to ensure consumption of natural resources to the minimum extent needed to produce identical/similar products through shared resources, resulting in elimination of waste and use of the resource to the optimum extent. Here, So and Sun (2011), SCC increase the perceived advantage of lean production approaches. Therefore, lean production increase maintaining natural resources (environmental sustainability performance). To assign SCC as a moderator of the relationship between lean production and environmental sustainability performance this research relies on the RBV. According RBV, investing in assets (e.g. relation specific) can encourage partnering firms to build competitive advantage for the firm will owns rare, valuable and non-substitutable assets that are difficult to be imitated (Barney, 1991). Cao and Zhang (2011) claim that resource based view (RBV) has been widely recognized as a theory that could be used to explain SCC's moderating influence on the link between internal practices and performance. Applying the previous arguments, it is possible to posit that SCC and sustainability relationship can be explained by RBV. Thus the hypothesis that is posited is:

H8: Supply chain collaboration moderates the impact of lean production practices on environmental sustainability performance.

3.6.1.3 Influence of SCC on the relationship between lean production and social sustainability performance

As in the case of the SCC moderation of the relationship between lean production and economic and environmental sustainability performance, support for SCC moderation of the relationship between lean production and social sustainability performance is also found in the literature. Already it has been established that many researchers have argued that SCC can drive economic, environmental and social sustainability performance in firms in a lean environment (Baridwan and Zaki, 2020; Vanichchinchai, 2019). Social sustainability revolves around such aspects as labor practices, human rights, product responsibility and society (Popovic et al. 2018). Gargalo et al. (2021) argue that social sustainability performance indicates a company's concern towards its stakeholders namely its suppliers and employees. That there could be a moderating effect of SCC on the relationship between lean production and social sustainability performance however requires further empirical validation. For instance, Abdul-Rashid et al., (2017) argue that companies as part of their social sustainability practice would like to have improved relationship with the community and stakeholders which could include both suppliers and customers. Towards this there is a need to have a lean practice, for instance key suppliers managing the inventory of a firm and its customers giving feedback on the performance quality and delivery (Inman and Green, 2018) supported by SCC. SCC could include such actions as working as a partner with firm's customers and keeping cooperative relationships with suppliers (Lai et al., 2012). In such situations SCC can be argued to moderate the relationship between lean production and social sustainability performance because inclusion of suppliers and customers as part of the SCC has the potential to help managers direct customer and supplier concerns about social sustainability into the implementation of the specific lean production practices, an argument supported variously by Gargalo et al. (2021), Masoumi et al. (2019). Conception of such an operation of SCC to enhance the relationship between lean production and social sustainability performance is supported by RBV, as was explained in the previous section., the following hypothesis is posited.

H9: Supply chain collaboration moderates the impacts of lean production practices on social sustainability performance.

3.6.2 Influence of SCC on the relationship between agile production and sustainability performance (economic, environmental and social)

There is evidence in the literature to suggest that SCC influences sustainability in firms that have adopted agile production (Bouguerra et al. 2021; Geyi et al. 2020). In sections 3.6.2.1 through 3.6.2.3 that follow, the moderating effect of SCC on the relationship between agile production and economic, environmental and social sustainability performance respectively, is introduced.

3.6.2.1 Influence of SCC on the relationship between agile production and economic sustainability performance

Previous work that considered sustainability and agile production has only focused on specific mediation dimensions such as supply chain (El-Khalil and Mezher, 2020). Thus there are examples in the literature to show the various ways in which the concept of SCC is conceived in regard its relationship with agile production and sustainability performance. Nevertheless, despite agreement on SCC's positive effect on enhancing the impact of other production interventions on performance, literature shows that no conceptual model has conceived SCC as a moderator of the relationship between agile production and economic sustainability performance.

For instance, Zhu and Wu (2022) argued that industrial structures have changed from resource-intensive to technology-intensive (agile). It is possible to posit that agile features including use of flexible production technology (Geyi et al., 2020) could be argued to influence economic sustainability performance factors like increase in a company's market share (Abdul-Rashid et al., 2017) and agile manufacturing could be affected by uncertainties. In such situations the relationship could be made robust by bringing in SCC on the customer side for instance having close contact with customers. In fact, involving customers could lead a firm to adapt flexible production technology (Bolwijn et al. 1986) as accommodating customers' demand is an important criterion of agile production and hence reduce uncertainties. This in turn could lead to better economic sustainability performance of the firm, for instance cost effective production. This argument is supported by Cicculo et al., (2018) who argue that SCC in an agile environment is also based on the sensitivity of a volatile consumer demand which could impact the cost aspect (economic sustainability criterion) of the products produced by a firm. A similar argument could be made with regard to supplier side of the SCC. For instance, cooperative relationship with suppliers is expected to improve strategic sensitivity, resource fluidity, and leadership unity of an agile firm (Doz and Kosonen, 2010) in the face a contradiction between stability and market changes. This in turn, could increase the company's market share, an economic sustainability factor (Abdul-Rashid et al., 2017). Thus it can be seen that introduction of SCC in the relationship between agile production and economic sustainability performance as a moderator has the potential to enhance the economic sustainability performance of a firm. This relationship is also supported by RBV that is concerned with resources (funds, technology, equipment, skill, organizational process, information and knowledge) that are valuable, rare, non-substitutable and inimitable (Barney, 1991). Examples of resources include tangible (funds, technology, equipment) and intangible (skill, organizational process, information and knowledge) ones. Those resources help achieve improved efficiency, and effectiveness culminating in organizational capabilities (Barney, 1991). Thus it is reasonable to infer that when economic sustainability performance is under focus, then to achieve better utilization of the resources as part of the agile production and improve the efficiency of an organization, it is necessary to introduce the SCC in the relationship between agile production and economic sustainability performance as a moderator. The hypothesis that is posited is:

H10: Supply chain collaboration moderates the impacts of agile production practices on economic sustainability performance.

3.6.2.2 Influence of SCC on the relationship between agile production and environmental sustainability performance

It is important to recognize here that there could be an effect of SCC on the relationship between agile production and environmental sustainability performance in a similar way as was the case for economic sustainability performance. This inference is possible because some researchers have argued that SCC has the potential effect on environmental sustainability performance of firms, for instance Mao et al. (2017), who found that internal and external supply chain integration positively influence environmental performance. In another instance, Albino et al. (2012), environmental collaboration with suppliers, customers, NOOs and government has a positive influence on the environmental performance factors. Furthermore, Chen et al. (2019) argued that intensely participating in environmental protection initiatives by suppliers, supports the relationship of sustainable practice and sustainable performance in the firms.

Previous studies have introduced plenty of evidence showing that agile production affects performance outcomes; however, there is little about the link between agile production and collaborative processes toward environmental sustainability (Bouguerra et al. 2021). Geyi et al. (2020) argued that agile production focuses on people and technology that work well by working with customers and adapting change which indicates the integration of supply chain in the relationship between agile process and environmental sustainability. Market sensing is a capability of agility for understanding customer’s expectations, and quickly leverage on the customers understanding and information technology to develop sustainable supply chain practices (Wu et al., 2016). Multi-stakeholder partnerships and collaboration across supply networks are also indirect capabilities of agile production for advancing sustainable objectives in manufacturing (Geyi et al. 2020). Furthermore, the combination of network collaborative and market sensing dimensions of agile production facilitate sustainability practices (Geyi et al. 2020). The above explanations clearly suggest that integration of supply chain collaboration in the relationship between agile production and environmental sustainability can improve the chances for sustainability initiatives to succeed.

Flint et al., (2011) explain that collaboration with suppliers could extend suppliers' perceptions into consumer value leading to co-innovativeness on the part of the suppliers (innovation is an agile feature). Further, Erwin (2021) claims that to improve supply chain perceptibility it is necessary that SCC leads to information exchanging activities, for instance active involvement in product design process (Lai et al., 2012). Thus it can be seen that there is a triad of agile production-environmental sustainability performance-SCC. Moderation implies that agile production-environmental sustainability performance should improve with the introduction of SCC. For instance, in a situation where a firm that has adapted agile production and wants to improve its environmental situation by using flexible production technology (an agile feature), then it is possible to argue both customer and supplier supply chain can be deployed. Applying the recommendation of Lai et al., (2012) which says that customers could be actively involved in a firm's product design process (SCC) and keeping cooperative relationships with suppliers (SCC) it is possible improve environmental sustainability performance in terms of improving that firm's environmental situation in an agile context. This operation of the SCC can be considered as a moderation of the relationship between agile production and environmental sustainability performance.

This moderation function of SCC could be explained by the resource-based view and dynamic capability theory which are the two widely applied theories in research concerning agile production especially when one deals with a turbulent and unstable business environment (Mohamud and Sarpong 2016, Pezeshkan et al. 2015; Candace et al. 2011). RBV talks about a company's competitive advantage that is situated primarily on the application of bundles of resources that are valuable, rare, inimitable and not substitutable. Dynamic capability indicates the ability of a firm "to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Teece et al. 1997; p. 516). Some researchers (e.g. Pereira-Moliner et al., 2021; Fraj et al., 2015; Aragon-Correa and Sharma, 2003) argue that environmental management could be thought of as a dynamic capability. Environmental management could be considered as that aspect of the management that comprises a set of environmental, organizational and technological practices involving the development of sustainable product and service designs and a more sustainable model. Environment management is a dynamic capability dependent on and connected to other capabilities, such as innovation and agility (Lopez-Gamero et al. 2022). Through environmental management firms could adapt to: turbulent environment and aim to gain competitive advantage in the market (Fraj et al., 2015; Aragon-Correa and Sharma, 2003); and new environmental demands from stakeholders including customers and suppliers. So where a firm's internal and external environments are challenging and turbulent, then if the firm's resources are valuable, rare, inimitable and not substitutable, then that firm could gain competitive advantage provided it is able to integrate, build and reconfigure its internal and external competences. Environmental sustainability improves in such a situation. Thus the following hypothesis can be posited:

H11: Supply chain collaboration moderates the impacts of agile production practices on environmental sustainability performance.

3.6.2.3 Influence of SCC on the relationship between agile production and social sustainability performance

Social sustainability performance was also found to have support in the literature to be linked to SCC (e.g. Jadhav et al. 2019; Awasthy and Hazra, 2019). For instance, Jadhav et al. (2019) indicated that supply chain collaboration and communication can directly affect social sustainability performance, and in addition, that the construct of collaboration and communication was the most effective method for enhancing external supply chain social sustainability performance. Social sustainability involves improvement in: the relationship a firm has with a community and stakeholders; safety; work environment; living quality of surrounding community (Abdul-Rashid et al., 2017); workforce satisfaction; and health and wellbeing of the workforce (Nath and Agrawal., 2020).

The potential of operationalising SCC as a moderator could be explained by actual examples concerning agile manufacturing firms. For instance, Geyi et al. (2020) argue that agile production plays a role in social sustainability performance. An example of agile production affecting social sustainability could be the customer driven innovation (an agile feature) leading to improved relationship with the community and stakeholders (social performance). In such a relationship if one can introduce SCC in terms of involving customers actively in product design process, the social sustainability performance of the firm could be enhanced. Here SCC moderates the relationship and not modify the relationship. Such a conception could be supported by stakeholder theory. It states that the relationship between a firm and its stakeholders may influence or get influenced by the activities carried out by that firm (Freeman, 1984). Thus introducing SCC to the agile production – social sustainability performance relationship could be thought of using stakeholder theory. Using this theory any activity like product design process in a firm could be linked to the stakeholder collaboration, to achieve social sustainability performance . Thus the hypothesis that could be posited is:

H12: Supply chain collaboration moderates the impacts of agile production practices on social sustainability performance.

3.7 Conclusion

The foregoing discussions provided the basis to construct the conceptual model using the hypothetical relationships postulated above. The developed conceptual model incorporating the six variables that are present within these hypotheses, was provided in figure 3.1 (above).

This chapter has enabled the researcher to conclude on the various relationships that have been assumed. This conclusion leads the inference that this model could be used to determine the methodology that needs to be developed for this research as well as answering the research questions. The various relationships postulated in this chapter as hypotheses are supported by both theory and extant literature. Thus this chapter provides the basis to develop the research methodology described in the next chapter.

Chapter 4: Research Methodology

4.1 Introduction

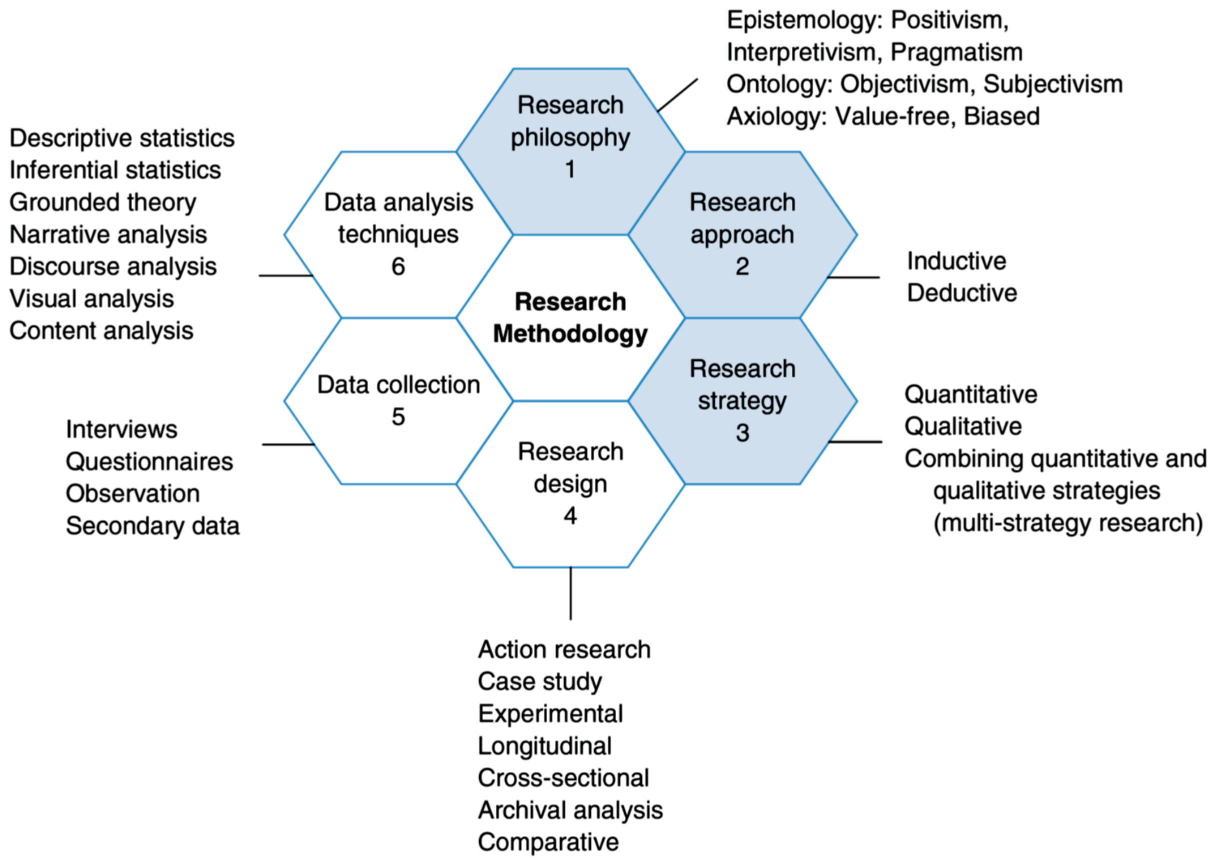
This chapter deals with the various aspects concerning the research methodology used in this research. The research methodology chosen was guided by the research questions. In developing the research methodology, this chapter reviews the literature concerning the philosophical issues that govern methodology, namely: choice of the epistemology, the ontology, the research approach, the research strategy, and the data collection method and the data analysis methods. These aspects are critically reviewed and the methodology chosen for this research is described.

4.2 Research philosophy

Philosophical issues are important aspects that need to be defined while developing the research methodology. A research philosophy is a system of beliefs and assumptions made on the part of the researcher leading to the development of knowledge in a particular field (Saunders et al. 2023). Literature shows that a research philosophy is needed for several reasons, most importantly, to gain clarity in research designs (including deciding on the type of evidence needed, collecting it and interpreting it), to make decisions on which design works or designs work best and determine the research design to be adapted depending on the limitations governing different subject or knowledge structures (Easterby-Smith et al. 2002).

Research philosophies help the researcher to think about the researcher's own role as a researcher (Wilson, 2014). To understand how the research philosophies are concerned with the research methodology, the researcher relied upon the Honeycomb research methodology framework developed by Wilson (2013) (figure 4.1). It can be seen from figure 4.1 that research philosophy is concerned with epistemology, ontology and axiology (e.g. Saunders et al. 2023, Wilson, 2014; Cohen et al. 2007). Epistemology is concerned with the nature of knowledge (Greener, 2022), ontology is concerned with assumptions about the nature of reality and axiology is about the role of values and ethics (Saunders et al. 2023). Each one of these three aspects are discussed next to understand their importance to this research.

Figure 4.1, Honeycomb research methodology



Source: Wilson, 2013

4.3 Epistemology

Epistemological perspectives include positivism, interpretivism, constructionism, critical realism, and pragmatism (Saunders et al. 2023; Sekaran and Bougie, 2019). While each one perspectives have their own definitions, strengths and weaknesses, the most commonly used perspectives in research are positivism and interpretivism (Alharahsheh and Pius, 2020; Kuhn, 2015). Thus, this research will discuss these two perspectives only. Both positivist and interpretive research perspectives have been widely used by researchers involved in research concerning sustainability, lean production, agile production and supply chain collaboration.

4.3.1 Positivism

Regarded as a philosophical stance of scientists belonging to the natural science discipline, positivism enables the scientist to deal with observable reality within a social environment resulting in the production of generalisations (Alharahsheh and Pius, 2020).

Positivism has other characteristics also which include emphasizing on the importance to what is given in general, minimization of the interference of human bias in pure data, facts and research outcomes and focus on pure data as well as facts (Saunders et al. 2023; Scotland, 2012). Positivism implies that researchers will be distant from the subject under investigation thus ensuring that researcher bias does not influence the subject while providing data or information to the researcher, or at the interpretation stage of data analysis. This is possible because of the objective nature of the data collected and the interpretation of researchers being stripped of personal values and bias. Furthermore, positivism is found to be associated with rigour and replicability of research and reliability of observations (Sekaran and Bougie, 2019).

Sustainability performance is concerned with economic, environmental and social sustainability implemented in an organization. Sustainability performance is an observable reality. Examples include increased company market share (economic sustainability) (Abdul-Rashid et al., 2017), air emissions reduction (environmental sustainability) (Inman and Green, 2018) and improved workforce satisfaction (social sustainability) (Nath and Agrawal, 2020) all of which could be reality that is observable. Research concerned with sustainability therefore could be based on the positivist epistemology. For instance, Mamede (2019) studied the use of sustainable performance measures in the context of the SMEs using positivist epistemology. The researcher produced causal explanations and predicted that in Portugal, environmental and social performance is explained by industry sector activity using numbers and observable and measurable facts. Similar examples can be found in the extant literature of researchers using the positivist epistemology in research concerning sustainability performance (e.g. Leseure, 2023; Gold and Schleper, 2017). It is also seen in the literature that organisations implement sustainability with the belief that it is a means to optimize profits and reputation building through a reactive stand vis-à-vis external stakeholder pressure (Prasad and Mills, 2010; Adler et al., 2007; Frankental, 2001). This sustainability tends to require the measurability of inputs and outcomes to be justified using positivist epistemological stance (Gold and Schleper, 2017).

It is seen from the literature that positivist epistemological position is associated with objective ontology, deductive research approach and quantitative research methodology (Saunders et al. 2023). However, its limitations include the claims of superiority over other research philosophies, it cannot be absolutely objective as it is not possible for the researcher to completely isolated from the object being studied and give rise to dispute (Purnamasari, 2016; Lowe et al 1983). The choice of positivist epistemology is seen to depend on a number of aspects that need to be borne in mind by the researcher. Further to discussing the positivist epistemological aspects of the research philosophy that a researcher should adopt, the next section discusses the interpretivist aspects.

4.3.2 Interpretivism

Interpretivist research aims at creating better and richer understanding of the social world and contexts and enables the researcher to interpret the phenomenon under study in a new way (Pervin and Mokhtar, 2022; Creswell, 2007). It is argued to focus on complexities of the world, richness of the understanding of the phenomenon under study, meaning-making and generate multiple interpretations of the underlying knowledge (Pervin and Mokhtar, 2022; Creswell, 2007). Thus, interpretivism is considered to be explicitly subjectivist in nature (Saunders et al. 2023). Berrone et al. (2023) claim that interpretive view is the correct way to synthesize the various ways by which sustainable development goals can be achieved leading to a nuanced understanding of the complex and multidimensional nature of those goals. Furthermore, interpretive research combines interpretation with induction into general findings (Eisenhart, 1998). This, according to Berrone et al. (2023) leads to an integration of theoretical and empirical knowledge. Where research involves the examination of diverse set of research outcomes that are characterized by multiple concepts, method and theories, literature shows that it is advisable to use interpretive research (Suddaby et al., 2017).

It can be seen that interpretivist epistemology is associated with subjective ontology, inductive research approach and qualitative research methodology. A number of researchers have adopted interpretive epistemology in research concerned with sustainability. For instance, Lehman and Kuruppu (2017) used interpretive epistemology in their research on social and environmental accounting research and brought out new knowledge regarding interpretation and creation of change in social practice. Branstrator et al. (2023) argued that interpretive paradigm provides epistemological innovation within the field of citizen science and validates the experiences actually gained by people who have lived through those experiences and embodied knowledge. In addition, these authors point out that interpretive epistemology fosters agency and empowerment within sustainability discourses.

Some of the limitations perceived of interpretivist research include lack of theory and being “mere storytelling” (Ahrens and Chapman, 2006, p. 820). For instance, Ahrens and Chapman (2006) argue that theoretical work is a pervasive and ongoing activity throughout an interpretive study. Additionally, it is argued that this ongoing activity draws on theory as a set of ideas used to define and explain the phenomenon under study of the field of interest thus making it difficult to reference the validity of the research or the basis on which the research is being conducted (Silverman, 2010; Ahrens and Chapman, 2006). Cohen et al. (2011) claim that interpretive inquiry involves the researchers to gain a deeper understanding and knowledge about a phenomenon within the complexity of the context. This can make the research highly contextual and lacking in generalizability.

4.3.3 Choice of the epistemological stance for this research

A comparison of the two epistemological positions discussed above is provided in table 4.1.

Table 4.1, Comparison of positivist and interpretive epistemological positions

#	Metatheoretical assumptions about	Positivism	Interpretivism
1	Epistemology	There is an objective truth that exists beyond the human mind.	Knowledge about the world is constituted with an intent and constituted with the support of a person's lived experience.
2	Ontology	The researcher and reality are independent.	The researcher and reality are inseparable, that is life and world.
3	Research object	The qualities that are inherent to the object under investigation exist separately from the investigator.	The object under investigation is interpreted taking into account the meaning structure of the investigator's lived experience.
4	Method	Relies upon statistical methods and content analysis.	Relies upon such aspects as phenomenology and hermeneutics.
5	The theory of truth	Has correspondence to the theory of truth. That is there is a one-to-one correspondence between research statements and truth.	Has truth as an intentional fulfillment. That is interpretations made by the researcher related to the object being investigated match the lived experience of the investigated object.
6	Validity	Belief of the researcher that data measures reality certainly.	Belief of the researcher that knowledge claims need to be defended.
7	Reliability	The researcher has the ability to replicate the findings.	The researcher need not replicate results but there is recognition that results are subjective and researchers need to address the implications arising from subjectivity of the results.

Source: Weber, 2004

Considering the fact that this research is about investigation of sustainable performance of manufacturing firms that have implemented either lean production or agile production or both in form or the other and supply chain collaboration, certain scientific methods can be adopted to study using observable and measurable facts. In addition, in manufacturing firms it is possible to collect data using numbers, and phenomena could be predicted. The findings from this type of inquiry are obtained efficiently and are acceptable to the end users as well as the academic community. Positivism was deemed to be appropriate ease the study is seeking to explain and predict the impact of lean and agile production on sustainability performance, and moreover to examine the moderating effect of supply chain collaboration on this relationship. Thus, it was deemed that reliable conclusions were more likely to be achieved if the researcher remained detached from the study participants, which would help reduce the potential bias that may otherwise arise from direct interaction (I.e. interpretivist) between the researcher and participants. This pointed towards the use of a positivist epistemology for this research.

4.4 Ontology

Widely used ontologies in research are objective and subjective ontology. As explained earlier ontology is about assumptions about the nature of reality (Saunders et al. 2023). Further, ontology helps the researcher to perceive the social world or what could be thought of the world. It could be a world that is comprising external to social actors or the views and actions of social actors who could create social phenomena. A choice of a particular ontology therefore depends on how the researcher would like to view the world and its actors (Wilson, 2014). These aspects are discussed next under the heading's objective and subjective ontologies.

4.4.1 Objective ontology

Researchers involved in the study of sustainability performance and the factors that influence it have adopted either the objective or subjective ontology. Objective ontology considers that social reality is external to the researcher and others who are called as social actors. Social entities appear to be physical entities of the natural world and their existence is independent of how people think of them, name them or gain awareness of them. Furthermore, it is assumed that since social actors cannot influence the existing social world, objectivism believes that there is only one true social reality that could be experienced by all social actors. Such a social world is made of solid, granular and relatively constant things. They include social structures into which each entity of the population is born (Burrell and Morgan 1979). Objectivists discover truth using observable and measurable facts. Through those facts objectivists draw law-like generalisations about reality considered as universal. Researchers adopting objectivist ontology aim to keep their research free of values which imply that the researchers would like to keep their beliefs and values away from the research and hence do not bias their research outcomes. For instance, in regard to sustainability performance reporting the process of accounting could be viewed through the lens of objectivism (Hines, 1989:56). It is argued by Hines (1989) that reality pre-exists accounting and that the empirical reality is objective and external to the subject (Chua, 1986:611). The objectivist ontological approach has been used by many researchers involved in sustainability. For instance, Isoh et al. (2020) used objectivist ontology while studying the impact of entrepreneurial intentions and actions on environmental sustainability in the context of the SMEs in Cameroon. Similarly, Ramos (2020) studied the topic of individual, economy, and global society taking into account the cases of innovation and transformation for a sustainable tomorrow using objectivist ontology.

Limitations of objectivism include the following. Objectivists are accused of mistaking their foundationalist root because structures present are not completely independent of social action. Additionally, objectivism is criticized on the assumption that objective basis exists for directly observing and assessing social structures in-depth. As mentioned earlier objectivism is associated with positivist epistemology, deductive research approach and quantitative research methodology. After discussing the objectivist ontology, the next section deals with the subjective ontology.

4.4.2 Subjective ontology

Saunders et al. (2023) explain that subjectivism is about assumptions of the arts and humanities which assert that social reality is constructed using perceptions and the resulting actions of social actors (that is people). It is further argued that social phenomena the order and structure of which is being studied are generated by the researchers themselves and the social actors. This happens by employing language, conceptual categories, perceptions and follow-up actions. Researchers relying upon subjective ontology believe that there is no underlying reality to the social world and what is seen as reality is not beyond what people attribute to it. Furthermore, because each one of the persons experiences and perceives reality varyingly, there is a necessity to consider multiple realities rather than a single reality that is considered as common for everyone (Burrell and Morgan 1979). In addition, it is argued that subjectivists believe that reality is created by social interaction and through such interactions, social actors produce partially shared meanings and realities.

As far as its limitations are concerned, subjective ontology is criticized as follows. Subjectivists cannot delink themselves from the subject being studied and hence bias could affect the findings of the research. Secondly subjective qualities are not ascribed to the substance or the matter and hence could only be applied to things in so far as they are objects of experience and should therefore be totally neglected by the physical description of nature (Johansen, 2011).

It can be seen that both objectivist and subjectivist ontologies could be used based on what the researcher is investigating and what the research questions are. A comparison of the objective and subjective ontologies is provided in table 4.2.

Table 4.2, Comparison of objective and subjective ontologies

#	Questions	**Objectivism**	⇔	**Subjectivism**
1	What is the nature of truth?	Order	⇔	Chaos
2	What is the world like? • What are firms like?	Existence of one reality that is true.	⇔	Existence of multiple realities and all are considered true.
	• What is the meaning of	Universal	⇔	Relative
3	being in firms? • What is the feeling of being	External to the researcher	⇔	Socially constructed in which the researcher is a part.
4	a manager or the managed?		⇔	

Source: Saunders et al. 2016

Following the discussions given above on the different ontological stance, the next section deals with the axiological aspect concerning this research.

4.5 Axiology

Creswell and Clark (2018) argue that axiology deals with philosophical assumptions that are concerned with the nature and effect of values that occur in knowledge production. It is concerned with questions like what is valued and accepted to be desirable or good for humans and the community of people (Biedenbach and Jacobsson, 2016). Axiology enables a researcher to identify the intrinsic value of an objective phenomenon. As far as the subjective phenomenon is concerned axiology deals with the influence of what is defined and attached by social factors on the subjective phenomenon being investigated. That is to say that an objective lens of the world will deal with a value free approach to the investigation of a phenomenon while a subjective lens of the world takes into account the values of the social actors involved in the investigation of a phenomenon (Handema et al. 2023). Thus, the philosophical aspect of axiology will be important to a researcher while making choices related to the research where consideration of the roles that value plays in a specific knowledge production process as well as the ability of the investigator to make value judgements are required (Paulinus and David, 2013). It can be seen that axiology deals with the question of the nature of ethics of ethical behaviour (Kivunja and Kuyini, 2017). Considering the fact that this research is about the influence of lean production and agile production on sustainability performance of manufacturing firms in the presence of supply chain collaboration, it can be argued that the axiological aspect will be guided by the role value plays in regard to the participants in the research. After discussing the three aspects concerning the research philosophy the next section deals with the rationale behind the choice of the ontological stance that needs to be adopted by the researcher.

4.6 Choice of the ontological stance for this research

The central issue that is being studied in this research is sustainability performance of manufacturing firms. Manufacturing activity comprises well defined processes and activities that produce unambiguous outcomes in terms of products. Every stage in a manufacturing activity data is collected in the form of numbers and decisions are made. Similarly, if a manufacturing firm wants to introduce concepts of sustainability performance then there is a need for adopting measures that provide an objective indication of the results achieved. Researchers investigating any relationship between sustainability performance and lean production or agile production or supply chain collaboration have to decide whether to be part of the phenomenon or remain aloof and investigate the phenomenon. With a subjective ontological stance, the researcher needs to be part of every step of implementing the sustainability performance concepts remaining inside the firm to gather data whereas with an objective ontological position the researcher resides outside of the manufacturing activity yet collects data from a distance. Since activities inside a manufacturing firm tend to produce objective outcomes, people who are part of the manufacturing firm would be able to provide with objective responses. Hence it is reasonable to argue that for research that investigates the implementation of sustainability performance aspects in a manufacturing firm and/or where lean production method or agile production method has been implemented, that research could be grounded on an objective ontology that satisfies the conditions provided in table 4.4. A subjective ontological stance is only needed when the researcher wants to understand, for example, the structure of the firm or who is in the firm, what should be the role of those persons and whether there is any need to study the actual functioning of the people involved. In line with the positivist philosophy, an objective stance was deemed to be the most appropriate ontology for the study. The next section deals with the study's research approach.

4.7 Research approach – induction vs deduction

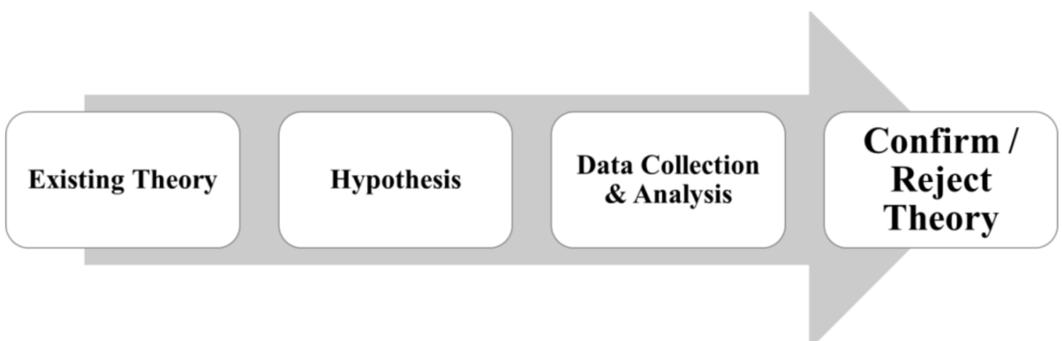
The type of research approach is another aspect that a researcher needs to pay attention to while applying or developing theories (Saunders et al. 2023). Most research projects will either test a theory or develop a theory (Barroga et al. 2023). Where a researcher aims to test or verify an existing theory this is a deductive approach. Where a researcher is concerned with developing a new theory about possible relationships between constructs that are linked to the research question, that research approach is inductive. Where the researcher is aiming to either developing or constructing a new theory that is rationalized or modifying or deconstructing or rationalizing an already existing theory that is linked to the research questions, then such research is often abductive (Ganesha and Aithal, 2022; Saunders and Lewis, 2017). Each of the three approaches are briefly discussed next.

4.7.1 Deductive research approach

Cohen et al. (2017) argue that deductive research approach is rooted on syllogism, a contribution of Aristotle to formal logic. In its original form syllogism was premised on a major concept of an a priori or self-evident proposition, a minor concept of providing a particular instance and a conclusion.

The assumption that is underlying syllogism is that a valid conclusion can be deduced using orderly and logical steps that are formal in a way the researcher proceeds from the general to the particular and a valid conclusion could be deduced (Cohen and Manion, 1980). Although currently researchers do not use syllogism in its original form, a modified deductive research approach is used in the modern world. Thus, empirical evidence that is based on authority became the standard and when more authorities are quoted, that much stronger the researcher's position becomes while deducing a conclusion (Cohen et al. 2017; Ketokivi and Mantere 2010). A representation of the flow of deductive research is provided in figure 4.2.

Figure 4.2, Representation of the flow of deductive research approach



Source: Ganesha and Aithal, 2022

According to Sekaran and Bougie (2019) for a scientist the concept of a theory is considered to be an organized set of assumptions that can be used to generate predictions that could be tested. A researcher who has adopted deductive approach starts with a general theory and funnel down the theory to specific hypotheses that could be tested. Then specific observations are collected to test the hypotheses through the process of funneling. There are established theories that explain sustainability performance. Examples of theories that are applied to explain sustainability and the factors that influence it include triple bottom line theory (Lorenzoni et al. 2000), economic theory (Vitalis, 2003), RBV (Khan et al. 2020), theory of planned behavior (TPB) of Ajzen (1991), norm-activation model of Schwartz (1977), value-belief-norm theory of environmentalism of Stern (2000) and Stern et al. (1999), the social identity theory (Fritsche et al 2018), social exchange theory (Zacher et al. 2023) and norm of reciprocity theory (Blau, 1964; Gouldner, 1960). Those theories provide a starting point to understand and explain sustainability performance in manufacturing units and its influencing factors. Further, there are a number of examples of researchers who have used deductive approach to examine the sustainability performance in manufacturing firms including Alketbi and Ahmad (2023), Wiśniewski and Tundys (2022) and Lasiyono (2019).

Advantages of using deductive approach include that the steps used in deductive approach are clear, easy to implement and make it easy to comprehend the reasoning behind a deduction, that is the conclusion. Using this approach, it is possible to generalize the inferences and make general statements that could be used to understand a wide range of happenings. Also it is free of subjective opinions or beliefs of the researcher and hence conclusions will not be biased due to researcher interference. Hence the outcomes are objective.

It is important to note that the deductive approach is recognized to have certain limitations, which include (Sharma, 2023): may lacks creativity and prevents thinking outside the box, and since deductive approach relies on the assumption that the person making an argument has complete knowledge of the topic at hand as well as all relevant information, in reality this assumption could be wrong leading the inaccurate conclusions.

Saunders et al. (2023) associate deductive approach to positivist epistemology, objective ontology and quantitative research method.

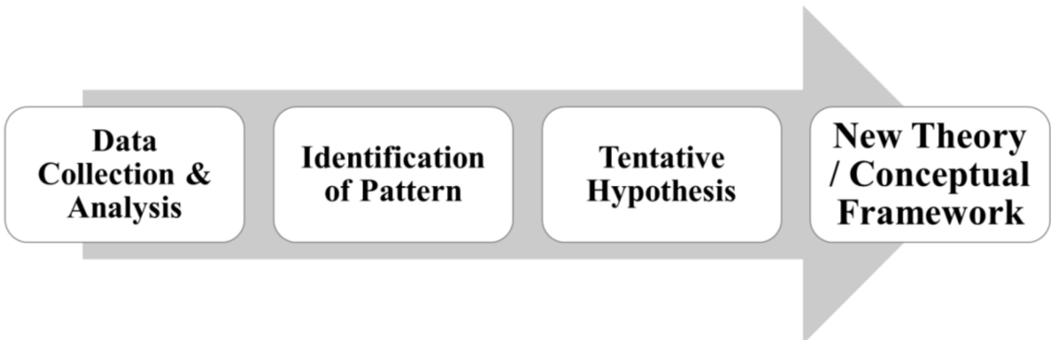
4.7.2 Inductive research approach

Sekaran and Bougie (2019) argue that inductive research approach works in the opposite direction to that of deduction and any researcher adopting this approach will move from the specific to a more general conceptualization. For instance, the observation that manufacturing units one, two and three that have implemented economic, environmental and social sustainability were accepted by stakeholders as sustainable. This leads to a proposition that all manufacturing units that have implemented the three sustainability performance concepts are accepted to be sustainable by stakeholders. Steps involved in inductive research approach are (Creswell and Creswell, 2022):

- gather information (e.g., interviews, observation).
- generate open-ended questions of participants or records field notes.
- analyze data to identify themes or categories.
- examine the themes or categories to generate broad patterns, generalizations or theories.
- develop generalizations, or theories by comparing with past personal experiences and literature.

The representation of flow of inductive research approach is depicted in figure 4.3.

Figure 4.3, Representation of the flow of inductive research approach



Source: Ganesha and Aithal, 2022

Advantages of using inductive research approach include (Stanton, 2023):

- helps in identifying patterns and trends in the collected data and information.
- encourages creativity and innovation.
- enables researchers to indulge in problem-solving.
- improves the decisions made by researchers while investigating phenomena.

Disadvantages of using inductive research approach include (Stanton, 2023; Saunders et al. 2023):

- can lead to incorrect conclusions as observations of researchers may not reflect the underlying reality accurately.
- personal bias of the researcher could affect conclusions and hence conclusions may not be objective or accurate.
- results could be based on subjective assessment of the researcher and hence building theory could be flawed.
- can be affected by oversimplification of complex problems, important information that is missed by the researcher and hence could affect decisions made by the researcher in arriving at conclusions.

4.7.3 Choice of the research approach

In this research in order to understand the theoretical relationships between the factors identified that affect the core issue of sustainability performance the researcher has produced a theoretical framework, as explained in chapter 3. That is the relationship between lean production and agile production as well as supply chain collaboration on the one hand and sustainability performance on the other has been developed. There was hence no need to discover a theory or modify a theory. Accordingly, the deductive approach was applied in this research. The next section discusses the chosen research method.

4.8 Research method

Widely used research methods include quantitative, qualitative and mixed method research. The choice of the research method depends on the comprehensive knowledge a researcher has on the different research methods, which in turn systematizes scholarly research and improves the quality of the research outcome (Saunders et al. 2023; Barroga et al. 2023). Each one of the different research methods is discussed next.

4.8.1 Quantitative research method

Creswell and Creswell (2022) claim that the inquiry related to quantitative research was the research strategy widely used during the late 19th century and throughout the 20th century that invoked the postpositivist worldview. While conducting such inquiry the strategies that will be implemented by researchers include true experiments and quasi-experiments. Literature shows that researchers using the quantitative research involve deductive research approach and verify and falsify hypotheses that were developed for the research (Borgstede and Scholz, 2021). There are a number of features of quantitative research which include (Das, 2022; Wisconsin University, n.d.):

- reliance on the assumptions made prior to testing.
- observations form the basis of investigation of an unclear or new phenomenon.
- investigation of the application of the theories that explain the phenomenon.
- develop hypotheses and explain those hypotheses to relate to the observation.
- prediction of results after testing the hypotheses.

Advantages of quantitative research include:

- save time and money using statistical tools (Bryman, 2001).
- interpretations of findings could be generalized (May and Williams, 1998).
- uses sampling methods which represent the larger population (Cohen and Morrison, 2011; Shank and Brown, 2007).
- replication of the research in different contexts (Shank and Brown, 2007).

Disadvantages of quantitative research include:

- Difficult to get an in-depth view of phenomena because the researcher is detached from the subject (Christensen and Johnson, 2012; Berg, 2007; Shank and Brown, 2007).
- Where there is strict order to follow as in quantitative study, in such studies there is support available to apply many ways of knowing; for instance, when the research proceeds in the order of reviewing the literature, formulating the research question and hypotheses, collecting data and analyse the collected data and summarise the results make the researcher to be inflexible (Creswell, 2009, Lichtman, 2006).
- The method does not: support innovation; help derive analytical outcomes; support in developing creative thinking; as predetermined work strategies are used (De Vaus, 1996).

Some of the examples of quantitative research method used in studies concerning sustainability performance include the study by Lima et al. (2023) of socio-technical framework for lean project management implementation in the regard to generating sustainable value in the context of digital transformation using quantitative research method. Similarly, Hasan et al. (2023) investigated the mediating role of manufacturing performance in the relationship between sustainability and lean manufacturing practices in a lean production environment quantitative research method. AlNawafleh (2022) studied E-HRM and how to use it to enhance the sustainability performance of universities in the presence of labour productivity and organizational agility using quantitative research method.

Furthermore, it is seen in the literature that a number of strategies could be used to implement quantitative research method that include descriptive, experiment, quasi-experiments, causal-comparative, correlational design and survey research (Creswell and Creswell, 2022; Cooper et al. 2007; Neuman and McCormick, 1995). While the choice of a particular strategy depends on the research problem being investigated, it must be noted that the pros and cons of each one of the strategies must be considered before making a choice. A brief about the various strategies that are used by different researchers provided in table 4.6.

The tabulations provided in table 4.6 show that different research strategies need to be used by researchers depending on the research question that is being addressed and the phenomenon being investigated. As far as the current research is concerned the investigation is about sustainability of manufacturing firms that have adopted lean production standard or agile production standard or both in the presence of supply chain collaboration. The research question led the researcher to investigate whether there is significant relationship between lean production and agile production on the one hand the and three sustainability performance factors on the other with supply chain collaboration acting as an intervention. This in turn led the researcher to study the literature on sustainability performance factors which pointed towards the necessity to understand how the manufacturing units have understood the concept of sustainability performance and the environment in which such sustainability performance needs to be implemented. This required the researcher to search for a conceptual relationship between the environment in which the manufacturing units throve and the sustainability factors. Having lean production and agile production as the environment in which the manufacturing units were situated, the researcher established a conceptual relationship between lean production and the three sustainability factors on the one hand and agile production and the three sustainability factors on the other. In order to test the relationships, the researcher aimed at gaining knowledge about how the relationships work in the manufacturing industries. Each manufacturing unit had to be approached. While the strategy of approaching each manufacturing unit in a territory that has hundreds and thousands of manufacturing units was nearly impossible, it was also found difficult to collect data from each unit individually using any of the quantitative research methods mentioned in table 4.6. Furthermore, using descriptive observational research was not easy as this would have entailed the researcher to be in each unit physically. The descriptive survey research provided a good alternative to the researcher if sampling technique were to have been adopted as this would have meant that the research approaches the manufacturing units either by online method or e-mail or telephonic interviews could be adopted. This method also provided the researcher with an efficient way of collecting data from the manufacturing units using a questionnaire.

The strengths of survey research method including that it is an efficient method that can be used to collect data from a large population, generalizability, can support data collection for correlational and causal analysis, and the various options that are available with regard to the choice of the mode of data collection make it an optimum choice of this method. In comparison the only weakness of this research method that needs to be taken care of is the low response rate. The strengths and weaknesses of other research methods do not seem to fit the current research as well in comparison to the survey research.

4.8.2 Qualitative research method

The origins of qualitative research could be traced to anthropology, sociology, evaluation and the humanities. According to Creswell (1994) qualitative research involves discovery. Creswell further describes qualitative research as an unfolding model that would occur in a natural setting leading to the researcher developing a level of detail that would be possible due to the high involvement of the researcher with the phenomenon and is based on actual experience. There are a number of features of qualitative research method which include (Creswell and Creswell, 2022):

- collected data is based on talking directly and actually to people and witnessing those people behaving in their actual workplace and when they are acting within their context.
- the focus of the researcher is on understanding the meaning the participants have with regard to a particular problem or issue and not the researcher's.
- this method involves an emergent research process and initial plan cannot be tightly dictated.
- involves of researcher's reflexivity.

Advantages of qualitative research include:

- provides opportunities for researchers to understand participants' experiences, opinions and feelings in-depth and derive meanings from those attributes of the actions of those participants. As far as to the thinking about truth and reality is concerned, meanings are also constructed on the basis of people's perception of the world surrounding them, their experiences, interaction with happenings and situations in their lives (Xiong, 2022).
- enables researchers to get deeper insights into phenomena or experience of human beings in a more holistic manner in specific context. Can be applied to interdisciplinary fields with a broad range of epistemological assumptions that are interpretive in nature and research methods that lead to a better understanding of human experiences (De Vaus, 2014; Denzin and Lincoln, 2005).
- offers specific data collection methods to decipher the respondents' inner experience in addition to indicating how meanings are drawn throughout the culture, that cannot be brought out by mere numbers associated with quantitative research (Xiong, 2022). Data collected through qualitative research methods are multifaceted and enable the researchers to generate rich information about individual perspectives (Polit and Beck, 2012).
- Theory emerges from data (Leedy and Ormrod, 2014).

The perceived disadvantages of qualitative research include:

- Interpretations of research findings could be affected by the researcher's own personal experience and perspectives. This calls for the need to take into account the contextual issues and their influence on the findings (Xiong, 2022).
- Qualitative research approach is criticized for the lack of generalizability of the findings. This renders the similarities that exist between bodies of knowledge or contexts more important in finding out whether the results of one setting could be applied to another leaving the judgement to those who are intending to apply those results.

- Analysis of data is complex and time consuming (Lune and Berg, 2012), In such situations, the findings derived may not be rich enough and compelling for further research or applying them in practice or policy making.
- Qualitative studies use subjective method to analyse data which may be wrong, inaccurate and misleading (Bernstein, 1974 in Cohen and Morrison, 2011, p21).

While disadvantages of qualitative research are formidable, yet the insights provided by qualitative studies cannot be provided by other methods. Hence it is worthwhile to consider qualitative research if researchers are aiming to answer research questions such as 'how".

A number of researchers have used qualitative research method in their research. For instance, Sonar et al. (2022) conducted a qualitative study on the role of lean, agile, resilient, green, and sustainable paradigm in the context of supplier selection. Carvalho (2011) investigated the divergencies and synergies of lean, agile, resilient and green paradigms and the effect of those paradigms' practices within supply chain attributes. Thus, it can be seen from the literature that a number of researchers have adopted qualitative research method while investigating the concept of sustainability of firms where lean and agile production methods are implemented and supply chain is an important part of it.

4.8.3 Choice of the research method

Amongst the research methods that have been discussed in the previous sections, the choice of the research method that is most suitable for this research was guided by the recommendations of Creswell and Creswell (2022). Table 4.3 provides how the methods compare with each other. This table guided the choice of the appropriate research method for this research.

Table 4.3, Comparison of the features quantitative and qualitative method research

Quantitative method	Qualitative method
This method is used in the following situations where: • hypotheses are stated before testing. • testing the theories by evaluating the relationship between variables is involved. • measurement of the variables using research instruments is required. • collection of numeral data is required. • analysis using statistical methods is necessary. • theories are tested deductively. • researcher bias should not be present. • generalization and replication of findings are involved.	This method is used in the following situations where: • hypothesis is developed. • approach used is exploratory. • individuals or groups ascribe to a social or human problem. • emerging questions and steps are involved in research. • participant's own settings are involved in data collection. • analysis of data builds inductively and moves the research from the particular to the general. • researcher makes interpretations of the analysed data.

Source: Creswell and Creswell, 2022

The current research investigated the sustainability performance of manufacturing units' knowledge about which lacks clarity. Many researchers have posited that sustainability performance as a concept could be represented by three elements namely economic sustainability performance, environmental sustainability performance and social sustainability performance. Each one of these elements have been identified as quantifiable phenomenon by many researchers (Zheng et al. 2021; Asio (2021); Akbar (2021); Sin et al. 2020; Ince (2018); Enshassi et al. (2016) and hence could be measured using numbers. In addition, these three sustainability performance factors have been investigated with regard to their theoretical relationships with several factors including lean production, agile production and supply chain collaboration (chapter 3). While this points towards a greater understanding of the conceptualization of the three sustainability factors, at the same time many other aspects concerning the three sustainability factors including measuring those factors numerically, the nature of their operation, the type of their function and the various ways they could be related many factors have been discussed extensively in the literature. The above arguments clearly point out that if at all there is any aspect that needs to be investigated about the three sustainability factors is their relationship to those factors for instance lean production, agile production and supply chain collaboration have not been investigated or only limited investigations has been carried out In addition, it is seen that many of those factors that could be theoretically related to the sustainability factors like lean production, agile production and supply chain collaboration, have been well discussed, described and investigated in the literature. This implies that linking those factors to sustainability factors is consistent and does not suffer from any limitations, as adequate theoretical support and literature support is available. Thus, it can be argued that the choice quantitative research method is the most suitable research method that can be employed in this research. After discussing the various aspects that are concerned with the research methodology the next step proceeds to discuss the actual research process and design that has been developed for this research.

4.9 Quantitative research design and data collection method

Sekaran and Bougie (2019) explain that a quantitative research design comprises certain elements including purpose of study, types of study, research strategy, extent of researcher interference, study setting, unit of analysis, time horizon, data collection method, sampling design, measurement and measures. The purpose of study could be exploration, description or hypothesis testing or case study analysis. As far as this study is concerned the purpose is to test hypotheses that will lead to the explanation of certain relationships between the factors including lean production, agile production, sustainability performance and supply chain collaboration. There are generally six different recognized types of quantitative research designs, as shown in Table 4.4.

Table 4.4, Comparison of quantitative research strategies

Descriptive-Observational Research	Descriptive-Survey research	Correlational	Causal comparative	Quasi-experimental research	Experimental
• Focuses on specific aspects of behavior that can be quantified through some measure. • A number of different characteristics are used to quantify observational study including counting of occurrence of the behaviour, frequency of occurrence, accuracy, intensity, proficiency, or mastery of the behaviour. • An instrument is used to rate a particular criterion of the phenomenon under study on a continuum (Mertler, 2021; Leedy and Ormrod, 2013) • Could be used depict the complexity of human behavior (Mertler, 2021).	• This method could be used to describe characteristics of a group or population (Fraenkel et al., 2012). • Data is collected about the phenomenon under study using a survey or questionnaire. • Respondents provide data about attitudes, opinions, behaviors, experiences, or other characteristics which would be representative of a population. • Sampling will be used to make the collection of data efficient. • Enables the researcher to study the relationship between two constructs (Fraenkel et al., 2012; McMillan, 2012).	• Used to ascertain whether there is an association between two constructs or variables and if so to what extent the two constructs are associated could be ascertained with this method (Cohen et al. 2017). • Researchers aiming to answer questions concerning two constructs or two datasets use correlational study (Cohen et al. 2017). • For instance, correlational studies could be used to answer questions like is there a relationship between two constructs or datasets or variables? If so, in what direction does the relationship act and what is the magnitude of the correlation between the two variables (Cohen et al. 2017).	• Similar to correlational research; the researcher aims to discover causes for the occurrence of a phenomenon through the process of comparing two groups of subjects, one wherein the phenomenon is related to the variable under study with the phenomenon that is not related to the variable. • Bridge the gap that exists between different descriptive research methods and true experimental research (Cohen et al. 2017).	• Participants are not randomly assigned to the group. • Random assignment to treatment condition not possible. • Participants from the same population are drawn and assigned to two group. • Types of experiments used are time-series design, counter balanced design and matching pretest–posttest control group design. • Usually used in school settings (Mertler, 2021).	• Participants are randomly assigned to treatment conditions. • Has at least one comparison group. • Threat to validity is controlled by random assignment and a comparison group. • This is a powerful experimental design because it combines random assignment, the use of a pretest, and the presence of comparison group. • Conducted in laboratories and not on the field (Mertler, 2021). • Useful in situations where predictive hypotheses are examined and not open research questions (Saunders et al. 2023).

As can be seen in Table 4.6, two of the types of study include causal and correlational. Correlational studies are concerned with delineating the important constructs that could be associated with the problem under investigation. Causal studies on the other hand are concerned with delineating cause and effect relationships (de Masta et al. 2023). In this research the researcher aims to find out whether there is a cause and effect relationships amongst the four variables identified for investigation using path analysis. As far as the study setting is concerned, the study was conducted in the field, that is to say, drawing date from the natural (non-contrived) setting. On the contrary, in contrived lab settings research will be conducted in a setting that is artificial in nature.

The unit of analysis is concerned with the entity being studied. It refers to the extent of aggregation of the data collected at a stage that is the subsequent data analysis stage. In this research the unit of study was the manufacturer (Sekaran and Bougie, 2019), falling under the category of medium and large industries established across the country of Kingdom of Saudi Arabia organization. In this research, the survey strategy was chosen due to the advantage it offers in data collection. Survey research enabled data collection in an economical way from a sizeable population, and it is generally easy to implement, explain and understand. It is a widely used strategy amongst researchers although it has limitations which should be acknowledged, which include the limit a researcher will encounter with regard to the number of questions any survey questionnaire could contain. Despite limitations, surveys are widely used in research because of their utility in research, for instance in areas including sustainability performance (Abdul-Rashid et al. 2017), lean production (Inman and Green, 2018), agile production (Nath and Agrawal, 2020) and supply chain collaboration (Mandal, 2017). A detailed description of the survey strategy is provided in the next section.

Another important aspect that needs to be considered is the extent of researcher interference in research that could lead to findings that are biased. Interference can be minimized using causal studies where the researcher will not hinder the natural work setting of the participants in the research. In correlational studies the researcher delineates the relevant variables, gathers data related to the phenomenon under study and analyses that data to derive findings. Here the researcher does not tamper with the responses of the participants. In comparison, if a researcher is conducting an experiment, then the researcher tends to manipulate the responses and change variables leading to greater interference in the study and the findings thus derived could be intentionally altered. Such interference could cause reliability problems (Saunders et al. 2023). This study is a causal study and tests hypotheses and hence researcher interference in the study is expected to be negligible.

In addition, research designs need to specify the time horizon of study which is generally intone of two types, namely cross-sectional or longitudinal. In regard to cross-sectional studies data is collected just once over a period of time. This data is considered sufficient enough to answer the research questions. In longitudinal studies, the researcher collects data more than once, collected over several weeks or months, and is used when data collected just once would not enable the researcher to answer the research question (Sekaran and Bougie, 2019). In this research the data was collected using the cross-sectional method as research questions did not require any data to be collected at different points of time.

With the research design confirmed, the next step was to define the specific data collection method to operationalize the survey strategy adopted.

4.10 Survey strategy

Elements of the survey strategy include development of a questionnaire that will act as the data collection technique, determining the target population for study, collection of the quantitative data, and preparing and analysing the data (Saunders et al. 2023). A questionnaire was developed based on already developed measurement scales for the associated constructs that were tested and validated in prior research. Thus, the next section discusses the development of the survey questionnaire.

4.10.1 Use of questionnaires as survey strategy and survey administration

Questionnaires are methods used for collection of a large data set and are distributed to participants who are asked to respond to the same set of questions in a pre-defined order (Sekaran and Bougie, 2019; Ekinci 2015; De Vaus 2014). Examples include face-to-face and telephone questionnaires as well as internet questionnaires. Saunders et al. (2023) explain that questionnaires help researchers to collect data about attitude of people, opinions of people and organizational practices and such data help researchers to identify and describe the variability of a variety of phenomena. There are different modes and media used to enable the participants to complete a questionnaire. and different mediums could be used to distribute and return the questionnaire. Self-administered questionnaires are widely used by researchers which are distributed online to the participants. Online distribution could be through a web browser and is usually via a hyperlink. The hyperlinks can be accessed through computers, tablets or smartphones, or via a QR code scanned into their smartphones. Questionnaires can also be distributed by mail or by hand and responses received through mail or by hand. Questionnaires can also be completed by researchers through telephone or face-to-face where the researcher or a representative of the researcher meets the respondent and asks questions face-to-face (Saunders et al. 2023; Cohen et al. 2017).

The advantages and disadvantages of mail or self-administered questionnaires and online/web-based questionnaires are summarised in table 4.5.

Table 4.5, Advantage and disadvantages of mail/self-administered questionnaires and web based surveys

Mail or self-administered questionnaires		Web-based questionnaires	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
• Can be given straight to the participants who can then record their responses using the instructions. • An individual can conduct surveys in a cost effective manner. • Cover a large geographical area. • Participants can complete the survey at their convenience. • Ensures anonymity. • No researcher bias. • Effective. • Can generate acceptable response rates.	• Participants' emotions, physical characteristics, reactions and settings cannot be observed (e.g. lying, habits, status). • There could be a lack of control over the order in which the questionnaire items are responded to. • Questionnaires could be incomplete. • Difficult to include visual aids (e.g., look at this picture and tell me what you see) or contingency questions or complex questions or open-ended questions in the questionnaire. • May not be suitable for people who may be ill-literate.	• Can be designed as static or interactive web/email surveys. Example of static web/email could be like the presentation of a page of paper but on the computer screen. Example of an interactive web/email could be a survey that has contingency questions and can provide different questions to different respondents with prior answers. • Least expensive. • Fastest. • Flexible designs. • Visual aid and audio or video-based questions. • Wider reach.	• There can be coverage issues. For instance, sampling, unequal access to and use of the internet. Some members of the participants like old, low-income, less literate and non-urban could find difficulty in accessing the internet. Also many participants may have multiple e-mails and hence there could be a possibility of the same person answering the questionnaire more than once. • Respondent privacy could be an issue. Need for secure websites with password or pins with high confidentiality. There is a need for respondent verification which is somewhat difficult if a person has more than one e-mail address.

Source: Cohen et al. 2017; Neuman, 2013

Literature indicates that the method of survey distribution has an important bearing on the response rate (Fincham, 2008). It must be borne in mind that response rate could vary depending the way the way the survey is conducted. For instance, examples found in the literature regarding the response rate achieved by some researchers through various survey strategies are

- Postal questionnaire: 10% – 50% (Neuman, 2014).
- Web and postal questionnaires: 10% - 20% (Saunders et al. 2023).
- Telephone questionnaires: Fallen from 36% to 9% (Dillman et al. 2014)
- e-mail surveys with multimode approaches: around 70% (e.g. Yun and Trumbo, 2000 reported 72% using multimode approach).

However, Saunders et al. (2023) argue that a number of interventions can be used to enhance response rate depending on the researcher's data collection method, for instance adopting multimode approaches could be used (e.g. face-to-face interviews, telephone calls based surveys, or smartphones based surveys (Guerra et al. 2024). From table 4.7, it can be seen that web-based questionnaires offer greater advantages than the mail/email surveys. Taking into account the advantages made available by the web-based questionnaires, this research adopts the web-based questionnaire method. Taking into account the above arguments this research adopted the web survey strategy but used multimode approach to send the weblink through e-mail and social media.

4.10.2 Types of questions

Literature shows that commonly two types of questions are used by researchers namely open-ended and closed questions (Sekaran and Bougie, 2019). Open-ended questions are those that could be used by respondents to respond in any way they want to, for instance asking participants to identify free of influence factors they believe would affect sustainability performance. Advantages of open-ended questions include easiness of design; least difficulty faced by respondents in recognizing and understanding the questions as possible answers' list is not provided; no need to guess like in multi-choice responses; use of reasoning and thought by respondents to answer questions; encourages deep learning; and there is a possibility of formative and summative assessment (Gharehbagh et al. 2022). The disadvantages surrounding the use of open-ended questionnaire include lack of versatility; consumes a good amount of time answer; low level validity concerns; content problems could be present; low objectivity; low level reliability concerns; difficulty in incorporating corrections if mistakes are committed while responding; and low performance of the questionnaire as it is difficult to administer if the questions are required to cover content comprehensively (Gharehbagh et al. 2022; Seif, 2021; Jalili et al. 2017).

Using closed questions, respondents are given choices to make from a set of alternatives provided by the investigator, for example asking respondents to rank a set of sustainability performance factors by assigning importance to those factors in an order of their preference, or asking respondents to indicate their opinion over a five-point scale regarding a statement concerning a sustainability performance factor.

Closed questions can be used to develop a questionnaire using nominal, ordinal, Likert or ratio scales. Advantages include easy to answer; takes smaller period of time to answer; responses easier to analyse; faster to respond to; responses could be pre-coded and fed into the computer easily for analysis; and comparison of answers is easier. Disadvantages of closed questions include forcing people to take into account categories; possibility of participant's choice not part of the alternatives given; choices may be leading the respondents; and wording of statements or questions could be influencing responses (Diop and Hutchings, 2012).

Given that this research aimed to collect data about four specific variables namely lean production, agile production, sustainability performance and supply chain collaboration with a view to statistical testing of hypotheses, closed Likert scale type questions were selected. Cohen et al. (2017) explain that Likert scales enable the researcher the convenience to measure opinions, quantity and quality. Although Likert scales have limitations, for instance deriving a degree of sensitivity and subtlety from the data than those data can bear and lack of a check on whether the responses provided are really matching the truth the respondents want to tell as some of the respondents could intentionally falsify the responses (Cohen et al. 2017).

4.11 Questionnaire development

The questionnaire was based on previously validated scales developed by prior researchers. The survey instrument was expected to be used to collect data from employees belonging to certain levels like managers and above in the manufacturing sector located in the Kingdom of Saudi Arabia (see section 4.12 for study sampling). Although the language used in Saudi Arabia is Arabic, it is widely known that English is the common second language widely used in the manufacturing sector, particularly by those holding managerial/ senior managerial positions. The population of respondents for the study were part of the top management staff who easily understood English as those staff were well educated and used English for transacting business in their firm. Thus, it was considered prudent to use English as the language in the building the survey instrument. Likert scale type questions were developed. Literature shows that 5-point scales or 7-point scales provide improved reliability and validity of the survey instrument over instruments with less than 5-point scales (Dawes, 2008; Malhotra and Peterson, 2006).

Literature shows that most of the research efforts that have used multi-choice scales have used either a 5-point or 7- point scale (Colman and Norris, 1997). While there is no conclusive evidence in the literature to say that one scale is better than the other Nunnally (1967) says that a 7-point scale would produce a better result when compared to the 5-point one. Criticising this, Matell and Jacoby (1971) claimed that the number of response points do not matter with regard to the reliability and validity of an instrument. In the absence of conclusive evidence on which one of the scales is most suitable for research in this research both 5-point and 7-point scales were used as consistent with the specific prior validated construct adopted in the prior research.

4.11.1 Measures of the constructs and questionnaire structure

The questionnaire comprised seven sections. Apart from section A, the rest of the sections had a direct link to the research model provided in figure 3.1. The list of constructs under investigation, the type of scale used, the number of items measuring each construct and the prior studies from which those items have been extracted are provided in table 4.6. The items were suitably modified and adapted for this research.

Table 4.6, List of items used to measure the constructs in the research model in figure 3.1

No. of items	Name of the construct	Item code	Items	Scale	Authors
11	Lean production*	LP1	Our key suppliers deliver to our plant on Just-in-time basis	5-point Likert scale	Inman and Green (2018)
		LP2	We adopt a formal supplier certification programme		
		LP3	We take active steps to reduce the supplier's number in each category		
		LP4	Our key suppliers manage our inventory		
		LP5	Our customer gives us the performance feedback on quality and delivery		
		LP6	Our production is pulled by the finished goods shipment		
		LP7	Our products are classified into groups with similar processing requirements		
		LP8	Our equipment is grouped for producing the continuous flow of families of products		
		LP9	We work to reduce setup times		
		LP10	Our employees working in the shop floor lead the product and process improvement efforts		
		LP11	We give a portion of every day to planned equipment maintenance activities		
10	Agile production*	AP1	We have decentralized decision making	5-point Likert scale	Geyi et al. (2020)
		AP2	We have cross functional teams		
		AP3	We use flexible production technology		
		AP4	We have leadership in the use of current technology		
		AP5	We have technology awareness		
		AP6	We have flexible and multi-skilled employees		
		AP7	We provide continuous training and development		
		AP8	We adopt culture of change		
		AP9	We force on customer driven innovation		
		AP10	We response to changing market requirements		
7	Supply chain collaboration ***	SCC1	We are in close contact with our customers	7-point Likert scale	Lai et al., 2012
		SCC2	Our customers are actively involved in our product design process		
		SCC3	Our customers involve us in their quality improvement efforts		
		SCC4	We work as a partner with our customers		
		SCC5	We maintain cooperative relationships with suppliers		
		SCC6	We keep close communications with our suppliers about quality and design		
		SCC7	We strive to build long-term relationships with our suppliers		
8	Economic sustainability performance **	EconSP1	increased company market share	5-point Likert scale	Abdul-Rashid et al., (2017)
		EconSP2	Enhanced company image		
		EconSP3	Improved the company's marketplace position		
		EconSP4	Increased company profitability		
		EconSP5	Increased amount of the goods delivered on time		Inman and Green (2018);
		EconSP6	Decreased inventory levels		
		EconSP7	Decreased scrap rate		
		EconSP8	Increased product quality		
6	Environmental sustainability performance **	EnviSP1	Air emissions reduction	5-point Likert scale	Inman and Green (2018)
		EnviSP2	Liquid waste reduction		
		EnviSP3	Solid waste reduction		
		EnviSP4	Decreased consumption for hazardous, harmful and toxic materials		
		EnviSP5	Reduced environmental accidents number		
		EnviSP6	Improved enterprise's environmental situation		
6	Social sustainability performance **	SocSP1	Improved relationship with the community and stakeholders	5-point Likert scale	Abdul-Rashid et al., (2017)
		SocSP2	Improved work safety		
		SocSP3	Improved work environment		
		SocSP4	Improved living quality of surrounding community		
		SocSP5	Improved workforce satisfaction		Nath and Agrawal. (2020)
		SocSP6	Improved health and wellbeing		
			* Exogenous constructs		
			** Endogenous construct		
			*** Moderator		

Section A there were five questions to collect data on job title, number of years' experience, industry sector, number of employees, age of the company.

Section B concerned the variable lean production which was conceived as an independent variable influencing the three sustainability performance variables found in the research model in figure 3.1. Further, in the context of the manufacturing industries in Saudi Arabia, lean production was measured using a 11 item research instrument which is in line with the research approach of Inman and Green (2018). The items were measured using a 5-point Likert scale with 1 indicating the point 'not fully implemented" and 5 indicating the point 'fully implemented'.

Section C concerned the variable agile production which was conceived as an independent variable influencing the three sustainability performance variables found in the research model in figure 3.1. Further, in the context of the manufacturing industries in Saudi Arabia, agile production was measured using a 10 item research instrument which is in line with the research measures publications of Geyi et al. (2020). The items were measured using a 5-point Likert scale with 1 indicating the point 'not fully implemented" and 5 indicating the point 'fully implemented'.

Section D concerned the variable supply chain collaboration which was conceived as moderating variable influencing the relationship between lean production and agile production on the one hand and the three sustainability performance variables found in the research model in figure 3.1. Further, in the context of the manufacturing industries in Saudi Arabia, supply chain collaboration was measured using a 7 item research instrument which is in line with the research measured used by Lai et al., (2012). The items were measured using a 7-point Likert scale with 1 indicating the point "strongly disagree" and 7 indicating the point 'strongly disagree'.

Section E concerned the variable economic sustainability performance which was conceived as a dependent variable influenced by both lean production and agile production found in the research model in figure 3.1. Further, in the context of the manufacturing industries in Saudi Arabia, economic sustainability performance was measured using an 8 item research instrument which is in line with the research measure proposed by Abdul-Rashid et al. (2017) and Inman and Green (2018). The items were measured using a 5-point Likert scale with 1 indicating the point 'not at all significant" and 8 indicating the point 'significant'.

Section F concerned the variable environmental sustainability performance which was conceived as a dependent variable influenced by both lean production and agile production found in the research model in figure 3.1. Further, in the context of the manufacturing industries in Saudi Arabia, environmental sustainability performance was measured using a 6 item research instrument which is in line with the research publications of Inman and Green (2018). The items were measured using a 5-point Likert scale with 1 indicating the point “not at all significant” and 5 indicating the point “significant”.

Section G concerned the variable social sustainability performance which was conceived as a dependent variable influenced by both lean production and agile production found in the research model in figure 3.1. Further, in the context of the manufacturing industries in Saudi Arabia, social sustainability performance was measured using a 6 item research instrument which is in line with the research publications of Abdul-Rashid et al. (2017) and Nath and Agrawal (2020). The items were measured using a 5-point Likert scale with 1 indicating the point “not at all significant” and 5 indicating the point “significant”.

The structured instrument design consisted of a cover page that informed the participants about the purpose of the questionnaire and the aim of the research (Appendix 1). The second part was the Consent form. Through this form, the participants were requested to confirm that they have read the Participant Information Sheet included with this questionnaire and hence were informed about the research. The participants chosen were over 18 years of age. This part, also, was used to confirm that no personal identifying data is collected in this study, therefore participants know that once they have submitted the answers they are unable to withdraw their data from the study. Additionally, the participant’s data can be anonymized, stored and used in future research in line with Brunel University’s data retention policies. Finally, the participants agreed to take part in this study. The remainder of the questionnaire followed the structure as described above (Sections A through to G). The instrument was initially tested using pre-test before it could be used in the main survey. Details of this test are provided next.

4.11.2 Pre-test

Pre-test/pilot testing is an essential part of the self-completion questionnaire development (Flynn et al., 1990; Bryman and Bell, 2015). The process allows the researcher to determine the adequacy of instructions included in survey to respondents (Bryman and Bell, 2015). It also ensures that the questions are understood by the participants and there is no ambiguity in the questions (Saunders et al., 2012). Therefore, pre-test of the questionnaire was conducted before the actual survey to ensure the content validity of the questionnaire to avoid repetitive items and to ensure that all items are clear and understandable (Sekaran and Bougie, 2013; Cohen,1988). The survey was evaluated by two academics in the field of Operations and SCM to ensure an acceptable level of face validity. They were asked to comment on the overall appearance, representativeness and suitability of the survey questions. The comments provided enhanced the wording and position of some questions and resulted in adding more information to the cover letter. An initial pilot test was also carried out by two practitioners. Before the pre-test stage, the instrument consisted of 49 items. The pre-test/pilot test resulted in deleting three questions, adding two questions and some minor modification in a few other questions including editing and improving the language and the grammar used in constructing the items. Finally, the survey instrument consisted of 48 items.

It must be noted here that after the initial pre-test with academics and initial pilot test with the two practitioners no follow-up larger pilot test was carried out on the survey instrument because the feedback and information received from the pre-test and initial pilot test was deemed to be comprehensive and informative enough to have confidence in the design of the questionnaire, and noting that the items used in the instrument had already been tested for reliability and validity by other researchers from whose publications those items were extracted. Secondly the number of manufacturing units available in the Kingdom of Saudi Arabia that fall under the category of medium and large enterprises where the employee number is greater than 100 is limited. Thus, conducting a pilot survey would limit the number of actual participants taking part in the main survey because usually participants who have taken part in the pilot survey would be excluded from the main survey (van Teijlingen and Hundley, 2002).

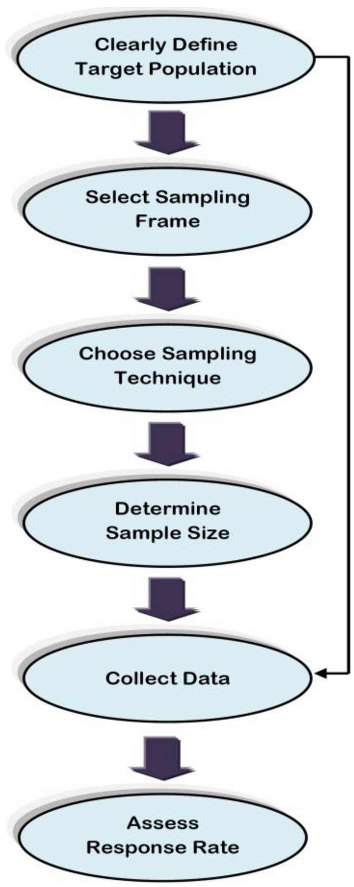
In addition, usually in research publications concerning the investigations on sustainability performance, lean production, agile production and supply chain collaboration, the sample sizes used by many researchers is low, for instance between 100 and 400. El-Khalil and Mezher (2020) investigated the mediating impact of sustainability on the relationship between agility and operational performance. No pilot study was conducted. The study included a survey of a total of 212 respondents. Respondents were top managers at 152 manufacturing facilities. In this case if a pilot study had been conducted by the researchers the total sample available for the main survey would have gone down, leading to errors in statistical analysis. For instance, reliability and validity problems would creep in as those statistical tests depend on larger sample sizes. Similarly, Chen et al. (2020) studied the lean manufacturing and environmental sustainability in China. No pilot survey was conducted. The main survey questionnaire was distributed to 306 manufacturing companies in China. The number of responses received was 220 from managers who were the participants in the research. In another instance, Teixeira et al. (2021) studied how to combine lean and green practices to achieve a superior performance in Portugal. Researchers contacted 4017 organizations by e-mail. However, only 533 agreed to participate in this research, of which only 261 responses were considered valid for use. Here again no pilot study was conducted. In yet another study of supply chain integration, risk management and manufacturing flexibility conducted by Chaudhuri et al. (2018) on manufacturing industries, in five countries (out of 1951 manufacturing plants in China, India, Japan, Malaysia and Taiwan

814 agreed to participate and 342 valid responses were obtained). Here again no pilot test was conducted. Thus, not conducting a pilot study in this research, based on prior research, appears to be wholly acceptable.

4.12 Study sampling

The sampling method chosen for this research followed the procedure suggested by Taherdoost (2016). Each step is described in turn.

Figure 4.4, Sampling process



Source, Taherdoost, 2016

The survey was conducted in the territory of the Kingdom of Saudi Arabia which is one of the fastest growing countries in terms of manufacturing sector in the world. The GDP contributed by the manufacturing sector in Saudi Arabia increased from Saudi Riyal (SAR) 81,911 million in the fourth quarter of 2021 to SAR84,906/- in the first quarter of 2022 (Central Department of Statistics and Information, 2022). In addition, manufacturing industries are fully backed by the Government of Saudi Arabia in terms of financial and administrative support. The government spares no effort in providing the required infrastructure to the industries to ensure that those industries do profitable business and contribute to the economy. New industrial cities have been created in Saudi Arabia by the government to encourage more entrepreneurs to establish businesses. According to The National Industrial Information Center (2021) there are more than 10,000 factories in the Kingdom of Saudi Arabia in different sectors. Among those, there are 1390 factories that have an employee strength that is either equal to or greater than 100 employees as shown in Table 4.7.

Table 4.7: Industry sectors (≥100 employees in Saudi)

Industry	Total	Industry	Total	Industry	Total
Other manufacturing	21	Manufacture of motor vehicles, trailers and semi-trailers	18	Manufacture of paper and paper products	54
Printing and reproduction of recorded media	8	Manufacture of beverages	67	Manufacture of coke and refined petroleum products	14
Water collection, treatment and supply	3	Manufacture of electrical equipment	54	Manufacture of other transport equipment	5
Electricity, gas, steam and air conditioning	3	Manufacture of wearing apparel	14	Manufacture of rubber and plastics products	134
Manufacture of furniture	38	Manufacture of leather and related products	3	Manufacture of other non-metallic mineral products	258
Manufacture of machinery and equipment N.E.C.	54	Manufacture of basic pharmaceutical products and pharmaceutical preparations	22	Manufacture of fabricated metal products, except machinery and equipment	155
Manufacture of computer, electronic and optical products	4	Manufacture of food products	209		
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	16	Manufacture of textiles	23		
Manufacture of basic metals	110	Manufacture of chemicals and chemical products	103		

Source: National Industrial Information Center (2021), Kingdom of Saudi Arabia

An essential criterion that was applied to the selection of Saudi Arabia as a territory for testing the hypotheses was the keen interest the various manufacturing firms are showing to adopt sustainable practices, for instance, implementing lean practices and agile practices, circular economy and adopting industry 4.0 standards (Al Falah and Ghouri, 2023; Ghaithan et al. 2021), although not always without challenges (Ghaithan, 2021). One of these challenges is the serious shortage of necessary skills required in local human resource, leading the Saudi government to take extra steps for human resource development (Othayman et al. 2020). According to Maware et al. (2022), there is a shortage of skilled personnel in Saudi Arabia who understand the concept of continuous improvement and how it can be applied to enhance the success of an organization. However, prior research provides multiple justifications for Saudi Arabia as a suitable context for studying lean, agile, and sustainable manufacturing

Firstly, Saudi Arabia is undergoing rapid industrialization with ambitious targets to increase manufacturing output by 200% by 2035 (World Bank, 2025). In addition, Saudi Vision 2030 explicitly aims to diversify the economy, reduce reliance on oil, and promote sustainable development, creating a strong motivation for adopting lean and agile principles to enhance efficiency and reduce waste in manufacturing (Alshammari et al. 2025).

Secondly, there has therefore been a rapid growing awareness of the environmental and social impacts of industrial activity, that has led to an increased focus on sustainability within Saudi Arabia's manufacturing sector (Arous et al., 2025). This aligns with global trends pushing for lean and green manufacturing practices, making it relevant to study how Saudi companies can leverage these approaches to achieve their sustainability goals (Abualfaraa et al. 2022; Alshammari et al. 2025).

Thirdly, the specific market conditions in Saudi Arabia, including the food manufacturing sector, require firms to adapt their operations for improved sustainability, making it an ideal setting to study the application of lean and agile principles. The unique market dynamics and the drive for TQM and lean practices to enhance sustainability create a relevant research context (Alshammari et al. 2025).

Fourthly, Saudi Arabia is also rapidly exploring Industry 4.0 technologies, generally and in the conext of sustyainability gains, and it is recognized that often the platform for integrating these technologies are lean and agile practices, further highlighting the importance of studying lean and agile to enhance sustainability in manufacturing (Ghaithan et al. 2021; Piprani et al. 2024).

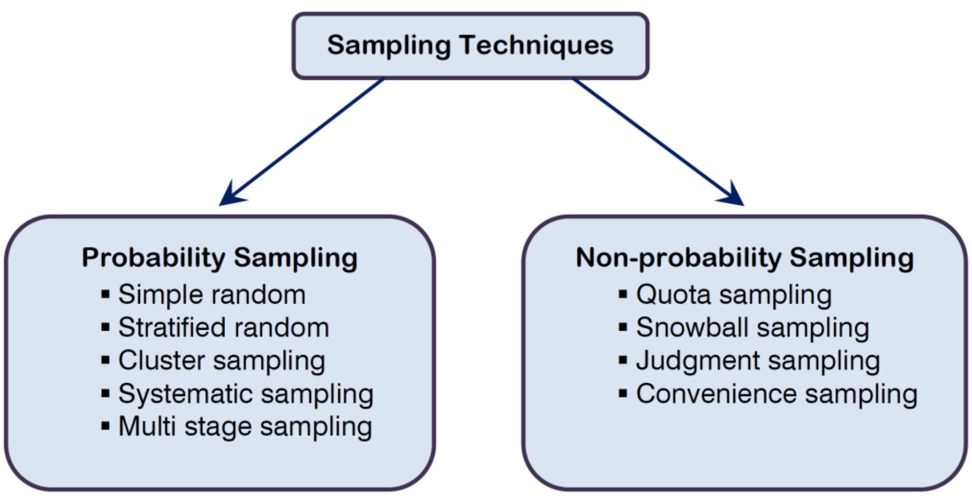
Within the manufacturing firms, the knowledge corresponding to the sustainability performance aspects of the firm were expected to be with employees at the rank of managers and above as it is a complex subject. Adding to this is the fact that lean production and agile production are operations strategies, knowledge about the implementation of which is expected to be only managers and above. Therefore, in this research the target population was employees of manufacturing firms whose designations were falling under the categories manager and above.

The number of factories with 100 employees and more is only 1390, which happens to be the target population for this research. Although classifications of firm size differ, at the time of conducting the research, manufacturers with >=100 employees in the Saudi Arabian industrial context was considered to be medium and large (National Industrial Information Centre, 2021; The Small and Medium Enterprises General Authority "Monsha'at", 2024). The rationale for choosing medium and large manufacturing companies (>=100 employees) was that the successful implementation of corporate social responsibility could be influenced by the firm's size (McWilliams and Siegel 2001) and the firm's financial performance (Wang and Sarkis, 2013). Therefore, firms are more likely to generate stronger social and environmental impacts (Gualandris and Kalchschmidt, 2016).

Considering the size of the population of manufacturing companies was estimated at around 1390, it was necessary to use a sampling strategy as an important part of the research. It is widely recognized and accepted that surveying every element in the population of a study is generally impractical (Saunders et al, 2012) and can increase errors and hence compromise overall accuracy (Barnett, 2002). Accordingly, based on a review of target sample sizes for studies of a similar nature in literature (e.g. Jum'a et al. 2022, Yu et al. 2020, Belekoukias et al. 2014), a target sample mailing size of 700 was used in the study.

An important aspect of sampling is identifying the type of sampling strategy a researcher has to adopt. Sampling represents the percentage of data drawn out of the total population for the research (Saunders et al., 2019; Bryman and Bell, 2011). There are different types of sampling strategies a researcher can look at before choosing the right one for his or her research. Literature shows that different types of sampling strategies have been developed by researchers a comprehensive picture of which is given in figure 4.5.

Figure 4.5, Sampling strategies



Source: Taherdoost, 2016

Choice of a sampling strategy depends on how a researcher wants to answer the research question (Saunders et al. 2023). For instance, where the question of 'what' is involved and the researcher is interested in providing statistical explanations or making estimates based on statistical analysis or interpretations about the target population based on the sample accessed to collect data or test a theory, probability sampling is used. On the other hand, if the researcher is studying a question of 'how' then the researcher may be aiming to uncover knowledge and provide indepth and rich information where appropriate with the support of reasoned judgements using non-probability sampling method (Saunders and Townsend, 2018) . Thus if the research questions set for this research are examined, it can be seen that statistical explanations will require to be provided and theories have to be established. This implies that the researcher is directed to use the probability sampling method.

Further, from figure 4.5 it can be seen that amongst the five different probability sampling methods the random sampling method was found good enough for the following reasons (Taherdoost, 2016). In this type of sampling strategy, every sample randomly chosen has an equal probability of being included in the sample. Sampling represents the percentage of data drawn out of the total population for the research (Saunders et al., 2019; Bryman and Bell, 2011). The simple random probability sampling technique was used to collect data from a representative population of the manufacturing companies. Thus, all "manufacturing companies" had the probability of being a part of the target sample of 700. Moreover, random sampling was used for data collection to ensure that the data was collected efficiently without the intervention of any manual effort leading to collection of more accurate data. Although there are some limitations that surround this method, for instance obtaining the sample can be high and that standard errors of estimators could be high, the main advantage of this method is that the probability of a subject of a target population becoming part of the sample is completely unaffected by other members of the target population (Cohen et al. 2007; Ghauri and Gronhaug, 2005).

Once the sampling strategy has been chosen, the online method of conducting the survey was chosen and it was possible to access a majority of respondents (senior management staff) who were well educated and could operate the internet on everyday basis in their lives without any difficulty. A hyperlink was generated using Qualitric and the hyperlink was sent to the manufacturing companies operating in the Kingdom of Saudi Arabia via emails and social media channels such as WhatsApp, since social media is considered to be a powerful distribution tool (Merolli, 2014). Once media were chosen for distributing the survey instrument, then the sample size was calculated which is discussed next.

4.12.1 Sampling strategy – target response size

The formula usually suggested by Cochran (1977; pp. 23-24) for calculating the sample size is:

- $n_0 = [t^2 \text{ x } s^2] \div d^2 \rightarrow (1)$

- where n_0= sample size;
- t = the t-value for a particular confidence level (confidence level usually used by researchers is 95%);
- s = estimate of standard deviation (calculated as s = number of points on the scale ÷ number of standard deviations) [e.g. if a researcher used a 7-point scale, then 6 standard deviations exist (3 to each side of the mean)]; and
- d = acceptable margin of error [calculated using the formula (number of points on primary scale multiplied by acceptable margin of error).

From the above the following could be derived to determine the sample size.

- t = 1.96 (for a confidence level of 95%)
- s = 7 ÷ 6 = 1.17
- d = 7 x 0.03 where 0.03 is the assumed margin of error = 0.21

From equation (1) it follows that:

$n_0 = [(1.96)^2\ (1.17)^2] \div (0.21)^2 = (3.84)\ (1.37) \div (0.044) = 5.26 \div (0.044) = 119.55$ Thus sample size of managers for this research is estimated as 120.

While 120 appears to be an acceptable figure as a final sample, however Cochran (1977) argues that a correction formula (equation 2) needs to be applied for the results obtained using equation (1) to ensure that the figure calculated is accurate if the sample size calculated exceeds 5% of the total population. Thus

$n = (n_0) \div [1 + (n_0 / \text{Population})] \rightarrow (2)$

where n is the new sample size calculated after correction;

Population is the actual population size = 1,390; and $n_0 = 120$.

Therefore, n = (120) ÷ [1+ (120/1,390)] = (120) ÷ (1+0.086) = 110.5≈ 111.

From the figure obtained using the correction formula given in equation (2) if the sample size is taken as 120, then verifying whether it is >5% of the total population 1390 shows that it is. That is to say 5% of 1,390 is 69.5 and 120 is greater than 69.5. Thus, there is a need for a correction factor to be used in determining the sample size. The final acceptable target sample size therefore is 111.

The total number of usable responses received for this research was 181, which thus is expected to improve the accuracy of the results (Creswell, 2009). This respresnets a response rate of 26%. For instance, 181 responses reduce the margin of error. This is explained as follows.

Equation (1) it can be rewritten as

- $d^2 = [t^2 \times s^2] \div n_0 \rightarrow (3)$

That is $d^2 = [5.26] \div 181$

and d = Square root of [5.26/181] = Square root of [0.029] = 0.17

However, d = [number of points on the Likert scale x margin of error]

Therefore margin of error = d/(number of points on the scale) = (0.17/7) = 0.0243

The percentage of margin of error = (0.0243) (100%) = 2.43%.

It can be seen that a response of 181 responses indicates a margin of error of 2.43% which is lower than the 3% margin of error assumed at the beginning. That is to say that the increase in number of responses is expected to improve the accuracy of the results obtained through statistical analysis.

4.13 Reliability

Further to specifying the sampling strategy, the next step taken was to understand how the reliability and validity tests were to be conducted. Pallant (2020) explains that reliability is a measure of a scale that indicates to what extent it is free of random error. Two tests are conducted usually to test the reliability of the scale namely test and retest reliability and internal consistency. Pallant (2020) adds further that the test-retest reliability of a scale can be examined using the correlation between a pair of items used to measure a construct and between an item used to measure a construct and the rest of the items used to measure the same construct. Additionally, Cronbach's alpha is found to be a commonly used measure of internal consistency in literature (Cohen et al. 2017). It measures the consistency of the various answers provided by the participants to all the items in the questionnaire or a variable. This also indicates the correlation between those items as well as the extent to which those items independently measure a variable. Acceptable values of Cronbach's alpha range between 0.6 and 0.8 with alpha values of 0.6 considered as indicating reliability as poor, 0.7 indicating reliability as acceptable and 0.8 and above considered as indicating reliability as good (Sekaran and Bougie, 2019). Literature shows that an alpha value of 0.7 or above is commonly suggested by researchers as acceptable (DeVellis, 2003). It must be noted here that the maximum value of Cronbach alpha cannot exceed 1.0 (Robinson et al. 1991a, 1991b).

4.14 Validity

Pallant (2020) defines validity as a measure of a scale that enables researcher to measure the degree to which the scale measures actually what it is expected to measure. Pallant (2020) argues further that there is no single clear cut indicator of the validity of a scale. Holmes-Smith et al. (2006) argue that validity indicates the accuracy of a measure and could be found to be present in a measure when the measure happens to be a perfect indicator of the variable intended to be measured. The important types of validity measurement widely used in empirical research include content validity, criterion validity, discriminant and construct validity (Saunders et al. 2023).

4.14.1 Content validity

This describes the correspondence between each one of the items of a construct and the concepts through assessment, often undertaken by expert judges. The validity can also be tested through pre-tests with multiple sub-populations (Hair et al. 2018). This was employed in this research to test the content validity (also called face validity). This has been explained in section 4.11.2. Similarly, a pre-test was conducted which is explained in section 4.11.2. Content validity was established through the above process.

4.14.2 Criterion validity

Also known as convergent validity (Zikmund et al. 2013), criterin validity is measured by correlational analysis. According to Hair et al. (2018) items in a questionnaire that are used to measure a particular construct should converge meaning that those items must share a high proportion of variance amongst themselves. This is measured by the degree to which two items used to measure the same construct are correlated, that is inter-item correlation and item-to-total correlation. High correlation indicates that there is convergence of measuring the construct by the various items and that the items measure the intended concept. This can also imply that the reliability of a questionnaire could be an indicator of convergent or criterion validity (Hair et al. 2006). Robinson et al. (1991a) suggest that acceptable values of item-to-total correlation should exceed 0.5 while inter-item correlation should exceed 0.3. Furthermore, Cohen (2013) recommends that correlation values need to be classified as small (correlation between 0.1 and 0.29), medium (correlation between 0.3 and 0.49) and large (correlation between 0.5 and 1). This thumb rule was used in data analysis.

4.14.3 Discriminant Validity

Zikmund et al. (2013) define discriminant validity as a measure that indicates low correlation between dissimilar concepts. One of the methods frequently used by researchers to determine discriminant validity due to its accuracy is the structural equation modelling (Gerbing and Anderson, 1988). Holmes-Smith et al. (2006) suggest that where constructs are interrelated, it is important to measure the discriminant validity. Furthermore, Holmes-Smith et al. (2006) consider that large correlations between latent constructs, for instance, 0.8 or 0.9 could indicate lack of discriminant validity. Other measures used to measure discriminant validity include Average Variance Extracted (AVE), pattern and structure coefficients and Chi-square difference test (Zaiţ and Bertea, 2011; Holmes-Smith et al. 2006). While there are many methods to check discriminant validity, Campbell and Fiske (1959, p. 81) suggest that at least two methods should be used to check the discriminant validity. Thus, in this research the AVE and correlation between the latent constructs (not exceeding 0.9) were used to test the discriminant validity.

4.14.4 Construct validity

Literature shows that construct validity is expected to show that the instrument indeed is able to measure the concept that is grounded on theory. Some of the ways construct validity could be established are correlational analysis, convergent validity and discriminant validity. Others argue that establishment of the convergent validity and discriminant validity is a means of establishing construct validity (Campbell and Fiske 1959; Peter 1981).

The above definitions and statistical measures were used in chapter 5 as part of the data analysis. Further to discussing the reliability and validity criteria, it was next considered important to discuss the data analysis aspects. Thus, the next section deals with the data analysis aspects.

4.15 Data analysis

The complete data analysis has been spread over several steps. Analysis was concerned with testing of the descriptive statistics including minimum, maximum, frequency, mean, standard deviation, skewness, kurtosis and Pearson correlation using SPSS. Descriptive statistics provide a few advantages including detailing the characteristics of the sample, examining the variables for any violation of the assumptions associated with the statistical tests used and achieving particular research objectives (Pallant, 2020). Following the descriptive statistics, the reliability (item-to-item correlation and item-to-total correlation) and validity of the research instrument were tested alongside analysing the data using structural equation modelling using AMOS software. SEM is a technique used to estimate a series of interrelated dependence relationships simultaneously in a model (Hair et al. 2018). While descriptive statistics, reliability and validity aspects have been described above, there is a need to understand structural equation modelling. This is described next.

4.15.1 Structural equation modelling (SEM)

Hox and Bechger (1998) explain SEM as a general statistical modelling technique that is widely used in behavioural sciences. It is also one of the common methods used for analysing data in quantitative studies in behavioural sciences (Chen and Pearl, 2015). Using SEM are becoming increasingly popular in the field such as lean production, agile production, manufacturing sustainability performance and supply chain collaboration (e.g. Inman and Green, 2018; Nath and Agrawal, 2020; Abdul-Rashid et al. 2017; Mandal, 2017). Therefore, this research used SEM for data analysis stages. SEM can be used in several statistical analyses including numerous multivariate procedures, regression analysis, discriminant analysis, factor analyses and canonical graphical path diagrams. Hox and Bechger (1998) argue that it is a mixture of factor analysis and regression or path analysis. It is a method that could be used to estimate a set of regression equations simultaneously (Janssens et al. 2008). SEM consists of a set of statistical techniques that can be used to examine certain variables, namely latent and observable variables (Boomsma et al. 2012). The measurement model is considered to provide the knowledge about relationship between the latent variables and observed variables while structural model can provide the knowledge about interrelationship between constructs (Mundra and Mishra, 2020).

Path analysis is the step that enables a researcher to estimate the structural relationships between the latent variables (Janssens et al. 2008). It provides the procedure for the researcher to determine the cause and effect relationship between the exogenous and endogenous variables and interpret the various numbers including the regression weights, the R squared value and the statistical significance of the relationships. Exogenous variables are independent variables (lean production and agile production) (Janssens et al. 2008), while endogenous variables are dependent variables (economic sustainability performance, environmental sustainability performance and social sustainability performance). Measurements using SEM include construct reliability (squared multiple correlation), discriminant validity, regression weights, correlation matrix, residual covariance, standard residual covariance, model fit (Janssens et al. 2008). These aspects have been discussed in Chapters 5. AMOS, as a common statistical package, was used to implement SEM (see section 5.9). This research, in addition to using the SEM, also measured the average variance extracted (AVE) and unidimensionality. AVE provides a measure of the presence or the absence of common method bias in addition to discriminant validity. Method bias can be occurred when measures use the same method that can lead to highly inflated correlation between constructs (San-Martín et al. 2020). For example, it occurs when both independent and dependent variables are given by the same source at any instant of time (Serenko, 2008) and because of self-reporting (Meade et al. 2007). Unidimensionality checks whether a model has a set of variables which have only one underlying dimension in common (Janssens et al, 2008, Gerbing and Anderson, 1988). The actual measurements with respect to common method bias and unidimensionality are provided in Chapter 5.

Rationale for using SEM:

According to literature, SEM is a multivariate statistical technique that enables a researcher to test complex theoretical models that comprise observed and latent variables (Abu-Bader and Jones, 2025). The model developed in this research is a multivariate model (Ch 3 figure 3.1) with lean production and agile production acting as independent variables while the three sustainability performance variables act as the dependent variables and the SCC acting as the moderating variable. The six variables which are the latent variables are measured using observed variables represented by the individual items used in the questionnaire to measure them. Thus SEM automatically qualifies as a tool to analyse the theoretical model in figure 3.1.

Turulja and Bajgorić (2020) argue that SEM provides better benefits when compared other tools like Multiple Regression (MR) in terms of evaluating the impact and relationships between the different variables at the same time in addition to incorporating the latent constructs into the analysis at the same time. Furthermore, when compared to the other usual techniques used in research to analyse data for deducing theories, for instance linear regression, SEM enables a researcher to test a number of dependent variables and their relationship with the independent variables using a model (SEM) that has the ability to operationalize theory. That is to say SEM is constructed using a theoretical framework established a priori (Maroco, 2014, Hair et al., 2005). Additionally, SEM is able to represent the relationships by parameters which provide the magnitude of the influence of certain variables like the independent variables on another variable called the dependent variable as per the hypotheses developed for testing a model so that the structure of the model is determined (Zucoloto et al. 2015). Apart from the above, SEM is able to evaluate the multiple fitness of the model to the data (for instance the goodness fit of the model to the data) as well as the statistical significance of the parameters measured by it by unifying several multivariate statistical methods in a mono methodological framework.

Although SEM can be criticized for certain assumptions it makes while evaluating models, for instance linearity of data, normality of data, nonnull covariances, absence of multicollinearity in the SEM, independence of observations, multiple indicators and absence of outliers, yet SEM has been able to provide a significantly better analytical results than other methods (Zucoloto et al. 2015). This is the rationale that was used in this research to deploy SEM to evaluate the theoretical model.

4.16 Research Ethics

During the process of data collection in social science research, potential harm can occur to participant's development, prospects of career or future employment (Diener and Grandall, 1978). Therefore, appropriate measures should be taken to protect participants and their organizations' confidentiality and anonymity. Furthermore, ethical conduct while researching business topics is important in literature (Saunders et al. 2019). Ethical conduct involves the code of conduct or societal norm of behavior expected while conducting research on the part of the researcher, participants, or respondents and the organization supporting or sponsoring the research (Saunders et al. 2019). While this research involves human participants, ethical approval from the organization concerned with the researcher, which is Brunel University London, is required.

As this study sought individuals' information (e.g. job title) and firms' formation (e.g. annual turnover), important actions were taken to protect the participants' confidentiality and anonymity during the process of the data collection. A cover letter (see Appendix 1) highlighting the purpose and importance of the study was included in the questionnaire. The letter also emphasised that participants' response and any comments would be treated with strict confidentiality, in accordance with the procedures of Brunel University London's Code of Research Ethics. Additionally, the letter pointed out that participants' answers would be used solely for the purpose of this research. Ethical approval of the study was received from Brunel University London through a BREO application prior to data collection (see Appendix 2).

4. 17 Chapter Summary

This chapter provides an overview of the most appropriate methodology that was applied to test our proposed conceptual framework in the research depending on the research questions set. The positivist epistemology and objective ontology approach were adopted. Consequently, the deductive reasoning approach and quantitative research method were followed. This led to quantitative research design which comprised certain elements including purpose of study, types of study, research strategy, extent of researcher interference, study setting, unit of analysis, time horizon, data collection method, sampling design, measurement and measures. In addition, the chapter explains the questionnaire development and validation process, by including the result of the pre-test. The statistical analysis technique of SEM was selected for data analysis stages. AMOS, as a common statistical package, was used to implement SEM. Hence, chapter 4 provides the foundation for the data anlysis provided in chapter 5.

Chapter 5: Data analysis

5.1 Introduction

Chapter 4 explained the methodology used in this research, including the research design, research philosophy, research process, and data collection mechanisms. A quantitative research method employing an online survey distributed to the managers of the manufacturing companies in the Kingdom of Saudi Arabia was used. In this Chapter, analysis of the data collected using the SEM multivariate technique to examine the proposed conceptual model and text the study hypotheses is presented. A total of 181 useable responses were collected. The empirical data analysis begins with several tests conducted to clean the data, including reliability, correlation analysis, and the normality test.

The structure of Chapter 5 is as follows. The response rate and profile of the respondents are presented in sections 5.2 and 5.3 respectively. Section 5.4 covers the descriptive analysis of the variables. Reliability analysis and validity analysis and other related analyses are covered in sections 5.5 and 5.6 respectively. Section 5.7 introduces the evaluation of the measurement model and section 5.8 specifically presents the confirmatory factor analysis. The structural analysis of the initial model is explained in section 5.9. In section 5.10, the model fit of the overidentified model is presented, followed in section 5.11 by the path analysis. Section 5.12 presents the analysis of the Lean Production model as the predictor. Section 5.13 cover the analysis of the Agile Production model as the predictor. Section 5.14 presents the moderation by supply chain collaboration on the relationship between lean production and sustainability performance, and section 5.15 the moderation by supply chain collaboration on the relationship between agile production and sustainability performance. Sections 5.16 and 5.17 discuss the result of unidimensionality test for lean model and agile models respectively, followed by section 5.18 which covers the average variance extracted (AVE) of the data used for analysis of the structural models. Section 5.19 then presents the final models, with summary of the chapter presented in section 5.20.

5.2 Response rate

The online survey was distributed to the mangers of 700 manufacturing companies in the Kingdom of Saudi Arabia through a hyperlink. A total of 261 responses were received, indicating a response rate of 37.28%. According to Sekaran and Bougie (2016) a response rate of 30% is acceptable in surveys. Out of the 261 responses received, 80 responses were rejected because of partial completion, and hence a total of 181 responses were found to be valid for use in the analysis. This respresents a response rate of 26% which is considered very good in the context of survey based reaserach (see section 4.10.1). The data was cleaned for any errors and prepared for analysis in line with the explanations given in chapter 4. The screening and cleaning process involved checking for data editing and coding errors, data keying errors and missing values. SPSS was used to analyse frequencies and each variable was checked for any discrepancy related out of range scores, that is to say checking the minimum, maximum, mean and standard deviation. The questionnaire was constantly referred during this process. These aspects are described in the following sections.

5.3 Respondent profile (Demographics)

The survey included five questions to ascertain important demographic characteristics of the respondent group. These were job title, number of years' experience, industry sector of the company, number of employees, and age of the company. Table 5.1 summarises the profile of respondents.

Table 5.1 Respondents profile

Job title	Freq.	%
General Manager	27	15%
CEO	11	6%
Operations/Production Manager	**121**	**67%**
Supply Chain Manager	22	12%
Total = 181		
Number of years' experience in the role	**Freq.**	**%**
1-5 years old	**48**	**27%**
6-10 years old	**47**	**26%**
11-15 years old	**44**	**24%**
16-20 years old	17	9%
21-25 years old	15	8%
26 years old and above	10	5%
Total = 181		
Industry sector	**Freq.**	**%**
Primary sector (agriculture, mining, etc.)	17	9.3%
Chemicals, rubber, plastics, non-metallic products	**55**	**30.3%**
Textiles, wearing apparel and leather	2	1.1%
Wood, cork and paper	11	6%
Metals and metal products	39	21.5%
Machinery, equipment, furniture	10	5.5%
Pharmaceutical products and preparations	1	0.5%
Food and beverages	28	15.4%
Electrical, electronic and optical products	16	8.8%
Printing and media	2	1.1%
Total = 181		
Number of employees in the company	**Freq.**	**%**
100-300	**145**	**80%**
301-500	16	8.8%
501-700	6	3.3%
701 employee and above	14	7.7%
Total = 181		
Age of the company	**Freq.**	**%**
1-10 years old	18	9.9%
11-20 years old	**45**	**24.8%**
21-30 years old	**43**	**23.7**
31-40 years old	36	19.8%
41-50 years old	29	16%
51 years and above	10	5.5%
Total = 181		

As mentioned in section 4.12, the target respondents for the study were General Managers, CEOs, Operations or Production Managers, or Supply Chain Managers. As Table 5.1 shows, the highest number of responses (n = 121) were provided by Operations/Production Managers, representing 67% of respondents. Responses from General Managers (n=27) accounted for 15% and Supply Chain Managers (n=22) 12%. Eleven CEOs responded (representing 6%).

As far as the experience of the respondents was concerned, it can be seen that the majority of the respondents (47 in number) have an experience ranging from 1 to 5 years (amounting to 27% of the sample) followed by 46 with an experience ranging from 6 to 10 years (26%) and 45 having experience ranging from 11 to 15 years (24%). These three groups of respondents put together represented the bulk of the respondents (138, 77%). The remaining 23% of the respondents belonged to the groups with experiences ranging from 16 to 20 years, 21 to 25 years and 26 years and above. It is thus significant to note that a wide spectrum of experienced respondents responded to the questionnaire.

In regard to industry sector, 30.3% (55 respondents out of 181) belonged to the chemicals, rubber, plastics, non-metallic products sector while 21.5% (n=39) belonged to the metals and metal products sector and 15.4% (28) belonged to the food and beverage industry sector. The remaining 32.6% of the respondents belonged to different industry sectors with 9.3% (n=17) belonging to primary sector (that is agriculture, mining and the like), 8.8% (n=16) belonging to the electrical, electronic and optical products sector, 6% (n=11) belonging to the wood, cork and paper industry sector and 5.5% (n=10) belonging to the machinery, equipment and furniture industry sector. The remaining respondents (2.7%) belonged to other industries namely textiles, wearing apparel and leather (1.1%), pharmaceutical products and preparations (0.5%) and printing and media (1.1%). The overall inference that can be made is that lean and agile production was found to be prevalent over a wide range of industries.

Another important component of the demography is the age of the company in which the respondents worked. The majority of the respondents, 45 (24.8%), were from firms the age of which lay between 11 years and 20 years. The respondents from those firms provide an indication of the ability of those firms to sustain economically, environmentally and socially. This argument is supported further by another 23.7% of the respondents (43 out of 181) who were working in firms the age of which lies between 21 and 30 years. 19.8% of the respondents were from firms with an age of over 31 years but less than 41 years, and 16% of the respondents were from firms with an age of over 41 years but less than 51 years. Overall, it can be seen the data obtained from the respondents shows that 84.3% of the respondents belonged to firms the age of which exceeded 11 years. This is a good indication of the economic sustainability of the firms. Only 18 (9.9%) of respondents were from firms with age falling in the range 1 to 10 years.

5.4 Descriptive analysis of the variables

Descriptive analysis of the variables was carried out using SPSS and is presented in table 5.2. It can be seen that all the variables satisfy the criteria concerning standard deviation, skewness and kurtosis indicating the data are distributed evenly around the normal and that the data collected for this research is normal. This is an important pre-condition to conduct structural equation modelling. The graphic representation of the four quantities measure has been provided for each one of the constructs in Appendix 3.

Table 5.2, Descriptive statistics of the main constructs. All observations within the limits set for this research.

Construct	Item code	Mean		Standard deviation (≤±2)		Skewness (≤±2)		Kurtosis (≤±3)	
		min	**max**	**min**	**max**	**min**	**max**	**min**	**max**
Lean production	LP1-LP11	2.6796	3.9503	1.02216	1.33804	-1.023	0.250	-1.055	0.839
Agile production	AP1-AP10	2.9448	3.8508	1.03724	1.19303	-0.728	-0.093	-0.700	-0.013
Supply chain collaboration	SCC1-SCC7	5.0442	5.8508	1.40034	1.62442	-1.544	-0.692	-0.207	2.291
Economic sustainability performance	ECON1-ECON8	3.1934	4.0663	1.07291	1.21392	-1.170	-0.274	-0.922	0.828
Environmental sustainability performance	ENVI1-ENVI6	3.4586	3.8564	1.24211	1.37771	-0.845	-0.383	-1.046	-0.450
Social sustainability performance	SOC1-SOC6	3.6796	4.0994	1.07033	1.21977	-1.162	-0.607	-0.551	0.716

After checking the distribution of the collected data and the normality of that data the next section deals with the reliability.

5.5 Reliability

As explained in chapter 4, reliability indicates extent of a research instrument is free from random error (Pallant, 2020), and one measure that provides an indication of reliability is internal consistency. SPSS provides the facility to measure the internal consistency using Cronbach's alpha, item-to-item correlation and item-to-total correlation (Pallant, 2020; Robinson et al. 1991). These measurements were discussed in detail in chapter 4. In line with those explanations, the measurements and the limits of those measurements were set and were based on prior research outcomes. Table 5.3 provides the Cronbach's alphas, inter item correlations and item to total correlations.

Table 5.3 Reliability analysis before deleting items

No.	Construct	Item code	Alpha (≥0.7)	Inter-Item Correlation (≥0.3)		Item-Total Correlation (≥0.5)		Remarks
				min	max	min	max	
1	Lean production	LP1-LP11	0.829	0.197	0.543	0381	0.559	There were some items that caused concern namely LP3, LP4, LP9. Further tests were carried out to improve inter-item correlation and item-total correlation.
2	Agile production	AP1-AP10	0.9	0.288	0.599	0.49	0.73	Two correlations namely AP1-AP9 and AP1-AP10 were causing concern. However, retained to see how these items performed in other tests. Under observation.
3	Supply chain collaboration	SCC1-SCC7	0.902	0.447	0.792	0.621	0.785	Accepted
4	Economic sustainability performance	EconSP1-EconSP8	0.891	0.332	0.734	0.497	0.759	Accepted
5	Environmental sustainability performance	EnviSP1-EnviSP6	0.935	0.600	0.830	0.737	0.831	Accepted
6	Social sustainability performance	SocSP1-SocSP6	0.936	0.824	0.593	0.755	0.858	Accepted

It can be seen from table 5.3 that with regard to some items measuring two constructs namely lean production and agile production there were possible concerns. However, deleting those items still did not entirely satisfy the minimum conditions. Considering the fact that the item to item and item to total correlations were near the threshold values set for this research and taking into account the fact that the items measuring lean production satisfied the condition set for Cronbach's alpha, no other items were deleted. A similar situation was observed with some items measuring the construct agile production. Taking into view the arguments presented for retaining the items causing concern with regard to measuring the construct lean production and applying those to the measurement of the construct agile production no items that were used to measure agile production were deleted. Thus the final set of items used for this research were arrived at after testing the internal consistency measures and are provided in table 5.4. At this stage the reliability of the research instrument and the data were considered to be valid with some items identified as items to be kept under observation during other tests that followed.

Table 5.4, Reliability analysis after deleting items that caused concern

No.	Construct	Item code	Alpha (≥0.7)	Inter-Item Correlation (≥0.3)		Item-Total Correlation (≥0.5)		Remarks
				min	max	min	max	
1	Lean production	LP1, LP2, LP5-LP8, LP10, LP11	0.813	0.252	0.543	0.480	0.587	Items LP3, LP4 and LP9 were deleted. Still there were items causing concern namely LP1-LP8; LP6-LP10; LP7-LP10. However, no more items were deleted at this stage. The relationships causing possible concern were still and kept under observation
2	Agile production	AP1-AP10	0.9	0.288	0.599	0.49	0.73	Two correlations namely AP1-AP9 and AP1-AP10 are causing possible concerns. However, retained to see how these items perform in other tests. Under observation
3	Supply chain collaboration	SCC1-SCC7	0.902	0.447	0.792	0.621	0.785	Accepted
4	Economic sustainability performance	EconSP1-EconSP8	0.891	0.332	0.734	0.497	0.759	Accepted
5	Environmental sustainability performance	EnviSP1-EnviSP6	0.935	0.600	0.830	0.737	0.831	Accepted
6	Social sustainability performance	SocSP1-SocSP6	0.936	0.824	0.593	0.755	0.858	Accepted

After measuring the reliability of the research instrument and data, the next test conducted was the validity test, conducted in line with the description given in chapter 4.

5.6 Validity

Validity measurements involved measuring content validity, convergent validity, discriminant validity and construct validity. This is in line with the arguments of Saunders et al. (2023), Creswell and Creswell (2022), Pallant (2020), Hair et al. (2006), Zikmund (2003) and Robinson et al. (1991).

Content validity: Creswell and Creswell (2022) suggest that content validity could be checked to improve questions, format, and scales. As recommended by Saunders et al. (2023) it was checked with experts in this field, prior literature and other researchers. The content pertaining to all items were found to be acceptable.

Convergent validity: Convergent validity was checked using internal consistency measures namely inter-item and item to total correlation. This is in line with the recommendations of Hair et al. (2006), Zikmund

(2003) and Robinson et al. (1991). Internal consistency measures used were Cronbach's alpha (>0.7), inter item correlation (>0.3) and item to total correlation (>0.5) (Robinson et al. 1991). Cohen (1988) suggests that inter item correlation equal to:

- 0.10 to 0.29 is considered as small correlation: both positive and negative correlation),
- 0.30 to 0.49 is considered medium correlation, and
- 0.50 to 1.00 is considered as large correlation.

All measures except a few were found to be acceptable (table 5.4). The items causing concern were retained because the correlation values were found to be closer to the acceptable values. Hence at this stage the researcher decided to retain those items and kept them under observation. Their performance was monitored in other tests that were conducted and based on the results either those items were retained or deleted.

Discriminant validity: The test used at this stage was the inter-item correlation. It is recommended in the literature that discriminant validity is said to be established if the inter-item correlation is within 0.9 (Holmes – Smith et al. 2006) as large correlations exceeding 0.9 are considered to cause concern with regard to discriminant validity. However, a more detailed test was conducted later namely average variance extracted to verify the achievement of discriminant validity under structural equation modelling section.

Construct validity: Construct validity is said to be established if the convergent and discriminant validity are found to be achieved (Holmes-Smith et al. 2006; Zikmund, 2003). At this stage it can be seen that both convergent and discriminant validity are achieved and it was concluded that construct validity was achieved.

The next step taken was to conduct the evaluation of the measurement model.

5.7 Evaluating the measurement model

Janssens et al. (2008) argue that SEM has two steps namely the confirmatory factor analysis (CFA) and the path analysis. CFA deals with testing of a measurement model with latent constructs while path analysis deals with estimation of structural relationships between latent constructs. Sections 5.8 that follows deals with the CFA.

5.8 Confirmatory factor analysis (CFA)

CFA is an analytical process by which it is possible to test a hypothesis which indicate that certain variables correctly measure a certain factor (Janssens et al. 2008). This in turn is expected to reveal the degree to which the different assumed variables truly measure a certain factor. The confirmatory model is depicted in figure 5.1.

Figure 5.1 The main model taken up for analysis

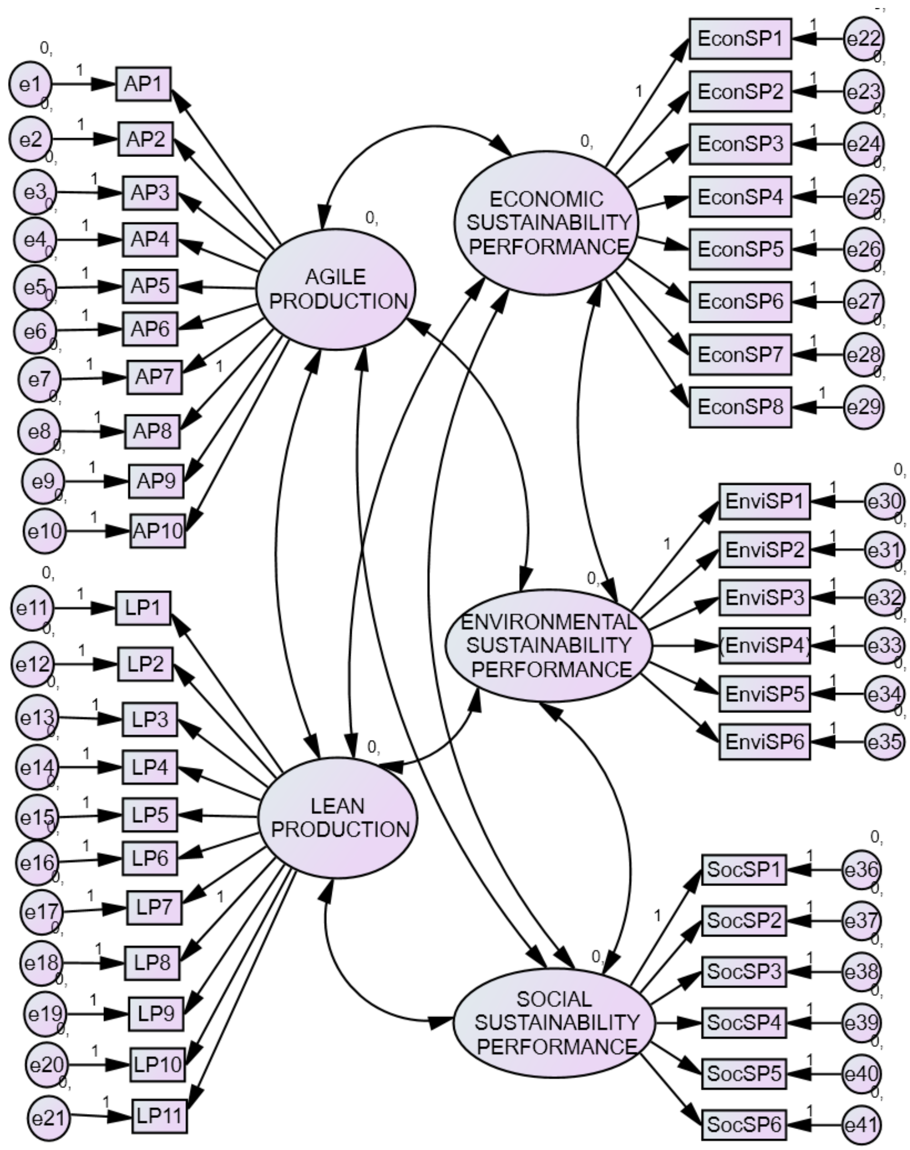


Figure 5.1 shows the 41 observed variables used to measure five latent constructs. Table 5.5 provides details of the latent constructs and the factors used to measure them. The evaluation of the measurement model led the researcher to ensure that the observed variables used are adequate enough to measure the exogenous and endogenous variables. Thus the initial model depicted in figure 5.1 is used to conduct the evaluation of the measurement model. The number of tests conducted in CFA include testing the construct reliability and validity. These aspects are discussed next.

Table 5.5 List of constructs

Latent construct	Item code	Measurement items
Lean production*	LP1	Our key suppliers deliver to our plant on Just-in-time basis
	LP 2	We adopt a formal supplier certification programme
	LP 3	We take active steps to reduce the suppliers' number in each category
	LP 4	Our key suppliers manage our inventory
	LP 5	Our customer gives us the performance feedback on quality and delivery
	LP 6	Our production is pulled by the finished goods shipment
	LP 7	Our products are classified into groups with similar processing requirements
	LP 8	Our equipment is grouped for producing the continuous flow of families of products
	LP 9	We work to reduce setup times
	LP 10	Our employees working in the shop floor lead the product and process improvement efforts
	LP 11	We give a portion of every day to planned equipment maintenance activities
Agile production*	AP1	We have decentralized decision making
	AP 2	We have cross functional teams
	AP 3	We use flexible production technology
	AP 4	We have leadership in the use of current technology
	AP 5	We have technology awareness
	AP 6	We have flexible and multi-skilled employees
	AP 7	We provide continuous training and development
	AP 8	We adopt culture of change
	AP 9	We force on customer driven innovation
	AP 10	We response to changing market requirements
Economic sustainable performance**	EconSP1	Increased company market share
	EconSP2	Enhanced company image
	EconSP3	Improved the company's marketplace position
	EconSP4	Increased company profitability
	EconSP5	Increased amount of the goods delivered on time
	EconSP6	Decreased inventory levels
	EconSP7	Decreased scrap rate
	EconSP8	Increased product quality
Environmental sustainable performance**	Envi1SP1	Air emissions reduction
	EnviSP2	Liquid waste reduction
	EnviSP3	Solid waste reduction
	EnviSP4	Decreased consumption for hazardous, harmful and toxic materials
	EnviSP5	Reduced environmental accidents number
	EnviSP6	Improved enterprise's environmental situation
Social sustainable performance**	SocSP1	Improved relationship with the community and stakeholders
	SocSP2	Improved work safety
	SocSP3	Improved work environment
	SocSP4	Improved living quality of surrounding community
	SocSP5	Improved workforce satisfaction
	SocSP6	Improved health and wellbeing
*		Exogenous constructs
**		Endogenous construct

The latent constructs that are under investigation are lean production, agile production, supply chain collaboration, economic sustainability performance, environmental sustainability performance and social sustainability performance. The CFA was analysed using AMOS. CFA involves testing the sample correlation, construct reliability, standardized residual covariance, model fit and drawing the factorized model which are discussed next. This is in line with the recommendations of Schreiber et al (2006).

5.8.1 Sample correlations

Measuring sample correlations provides the level of correlation between the latent constructs. According Holmes-Smith et al. (2006) correlations between any two items should not exceed 0.8. From table 5.6 it can be seen that the sample correlations between any two item does not exceed 0.8 indicating that this test has confirmed that all correlational value are within limits. This also indicates that there is no multicollinearity.

Table 5.6. Sample correlations

	LP11	LP10	LP9	LP1	LP2	LP3	LP4	LP5	LP6	LP7	LP8	AP10	AP9	Econ SP8	SocS P6	SocS P5	SocS P4	SocS P3	SocS P2	SocS P1	EnviS P6	EnviS P5	EnviS P4	EnviS P3	EnviS P2	EnviS P1	Econ SP7	Econ SP6	Econ SP5	Econ SP4
LP11	1.0																													
LP10	0.4	1.0																												
LP9	0.4	0.4	1.0																											
LP1	0.3	0.3	0.1	1.0																										
LP2	0.3	0.3	0.3	0.4	1.0																									
LP3	0.3	0.4	0.4	0.3	0.3	1.0																								
LP4	0.3	0.2	0.2	0.3	0.2	0.3	1.0																							
LP5	0.4	0.5	0.2	0.3	0.3	0.2	0.2	1.0																						
LP6	0.3	0.3	0.2	0.3	0.3	0.3	0.2	0.3	1.0																					
LP7	0.3	0.3	0.3	0.4	0.5	0.2	0.2	0.4	0.3	1.0																				
LP8	0.4	0.3	0.3	0.3	0.3	0.2	0.3	0.5	0.4	0.5	1.0																			
AP10	0.4	0.4	0.3	0.3	0.5	0.2	0.2	0.4	0.3	0.4	0.4	1.0																		
AP9	0.4	0.3	0.3	0.2	0.3	0.3	0.0	0.4	0.3	0.3	0.3	0.6	1.0																	
EconSP8	0.4	0.5	0.3	0.3	0.3	0.3	0.2	0.4	0.2	0.3	0.4	0.4	0.3	1.0																
SocSP6	0.5	0.4	0.3	0.2	0.3	0.4	0.1	0.4	0.2	0.2	0.3	0.5	0.5	0.5	1.0															
SocSP5	0.5	0.4	0.3	0.2	0.3	0.3	0.1	0.4	0.2	0.2	0.3	0.6	0.5	0.5	0.8	1.0														
SocSP4	0.5	0.4	0.3	0.2	0.4	0.2	0.2	0.4	0.3	0.3	0.4	0.5	0.4	0.5	0.7	0.7	1.0													
SocSP3	0.4	0.4	0.3	0.2	0.3	0.2	0.1	0.4	0.2	0.2	0.3	0.5	0.5	0.6	0.7	0.8	0.7	1.0												
SocSP2	0.4	0.4	0.3	0.2	0.3	0.3	0.1	0.4	0.2	0.2	0.3	0.5	0.5	0.6	0.7	0.7	0.6	0.8	1.0											
SocSP1	0.5	0.4	0.3	0.2	0.3	0.3	0.1	0.4	0.3	0.2	0.3	0.5	0.5	0.5	0.7	0.7	0.6	0.7	0.7	1.0										
EnviSP6	0.4	0.4	0.4	0.2	0.3	0.2	0.2	0.3	0.2	0.2	0.3	0.5	0.4	0.5	0.6	0.5	0.5	0.5	0.6	0.5	1.0									
EnviSP5	0.4	0.4	0.4	0.2	0.2	0.2	0.1	0.4	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.5	0.4	0.5	0.6	0.5	0.8	1.0								
EnviSP4	0.3	0.3	0.3	0.1	0.2	0.2	0.1	0.3	0.2	0.2	0.3	0.4	0.3	0.5	0.5	0.5	0.4	0.5	0.5	0.5	0.7	0.8	1.0							
EnviSP3	0.4	0.4	0.3	0.2	0.2	0.2	0.1	0.3	0.2	0.2	0.3	0.4	0.3	0.5	0.5	0.4	0.3	0.4	0.5	0.4	0.7	0.7	0.7	1.0						
EnviSP2	0.3	0.3	0.3	0.1	0.2	0.2	0.1	0.3	0.2	0.1	0.2	0.4	0.3	0.4	0.5	0.5	0.4	0.4	0.5	0.4	0.7	0.7	0.7	0.8	1.0					
EnviSP1	0.3	0.3	0.2	0.2	0.3	0.2	0.1	0.3	0.2	0.2	0.2	0.4	0.3	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.6	0.6	0.6	0.7	0.7	1.0				
EconSP7	0.4	0.3	0.3	0.2	0.1	0.2	0.1	0.4	0.2	0.1	0.2	0.3	0.2	0.5	0.4	0.3	0.3	0.3	0.5	0.4	0.4	0.5	0.4	0.5	0.4	0.3	1.0			
EconSP6	0.3	0.3	0.3	0.2	0.1	0.2	0.1	0.4	0.2	0.1	0.2	0.3	0.3	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.3	0.4	0.5	1.0		
EconSP5	0.3	0.4	0.2	0.3	0.3	0.2	0.1	0.4	0.3	0.3	0.3	0.4	0.3	0.6	0.5	0.5	0.4	0.5	0.5	0.5	0.4	0.5	0.4	0.4	0.3	0.4	0.4	0.4	1.0	
EconSP4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.5	0.4	0.3	0.4	0.5	0.4	0.6	1.0

5.8.2 Construct reliability

This test is conducted to check the extent of variance that is accounted for by the latent construct in an observed variable that is used to measure the construct. The method used is the squared multiple correlation (SMC) (Johari et al. 2011). Acceptable values suggested by researchers is ≥0.3. AMOS was used to compute SMC. Table 5.7 shows the AMOS report related to SMC concerning 41 items covering the two exogenous and three endogenous constructs.

Table 5.7, SMC of the CFA model (initial model in figure 5.1)

AP1	.247
AP2	.379
AP3	.368
AP4	.412
AP5	.545
AP6	.572
AP7	.602
AP8	.603
AP9	.515
AP10	.552
EconSP1	.623
EconSP2	.660
EconSP3	.699
EconSP4	.606
EconSP5	.495
EconSP6	.247
EconSP7	.284
EconSP8	.556

LP1	.285
LP2	.343
LP3	.242
LP4	.139
LP5	.419
LP6	.246
LP7	.340
LP8	.381
LP9	.235
LP10	.400
LP11	.424

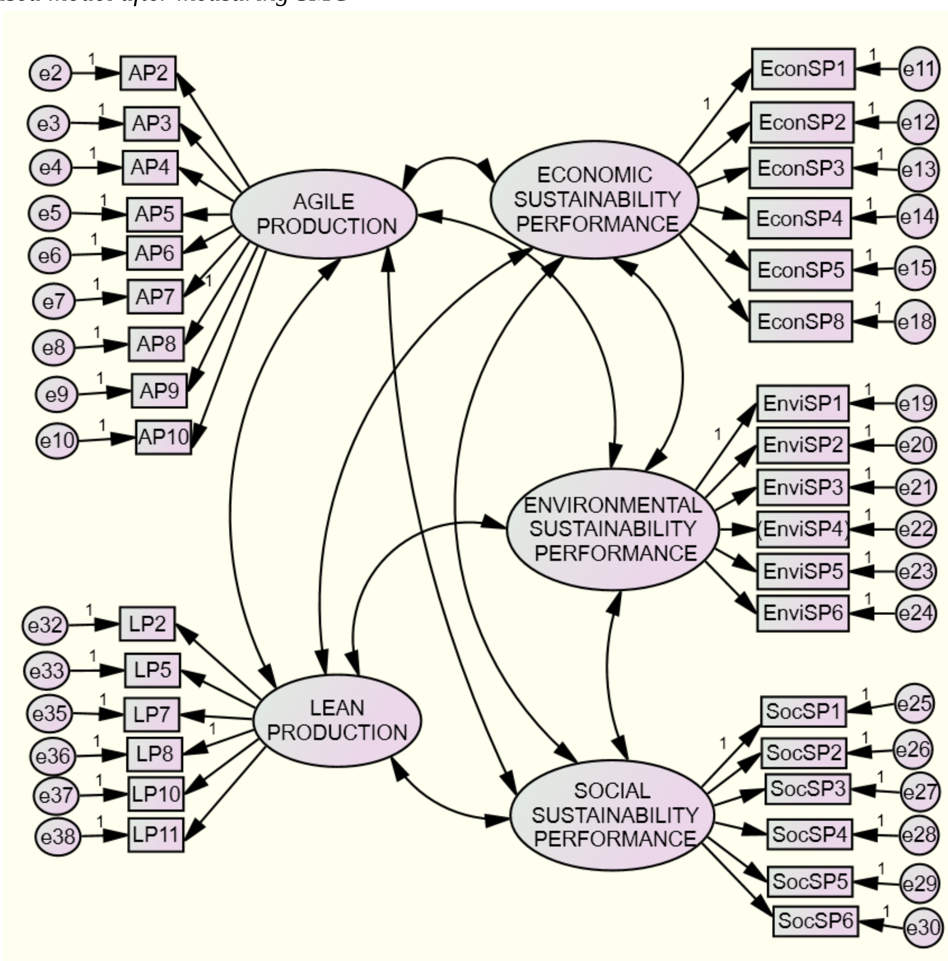
SocSP1	.647
SocSP2	.692
SocSP3	.745
SocSP4	.624
SocSP5	.795
SocSP6	.780
EnviSP1	.567
EnviSP2	.702
EnviSP3	.684
EnviSP4	.748
EnviSP5	.785
EnviSP6	.750

The items causing concern whose squared multiple correlations were less than 0.3 were LP9 (0.235), LP1 (0.285), LP3 (0.242), LP4 (0.139), LP6 (0.246), EconSP7 (0.284), EconSP6 (0.247) and AP1 (0.247). Those items were deleted and the SMC was measured again. The list of items retained is provided in table 5.8 and the CFA factorised model revised correspondingly is given figure 5.2.

Table 5.8, Revised SMC values

AP2	0.379	LP2	0.343	SocSP1	.647
AP3	0.368	LP5	0.419	SocSP2	.692
AP4	0.412	LP7	0.340	SocSP3	.745
AP5	0.545	LP8	0.381	SocSP4	.624
AP6	0.572	LP10	0.400	SocSP5	.795
AP7	0.602	LP11	0.424	SocSP6	.780
AP8	0.603	EconSP1	0.623	EnviSP1	.567
AP9	0.515	EconSP2	0.660	EnviSP2	.702
AP10	0.552	EconSP3	0.699	EnviSP3	.684
		EconSP4	0.606	EnviSP4	.748
		EconSP5	0.495	EnviSP5	.785
		EconSP8	0.529	EnviSP6	.750

Figure 5.2 Factorised model after measuring SMC



5.8.3 Standardised residual covariance

The next test conducted was the standard residual covariance between two items. The factorized model provides the optimum number of items needed measure the latent variables. Covariance between two items of indicators provides an understanding of the extent to which two items measuring a construct share the variance. This test provides the ratio of the residual covariance to the estimate of the standard error (Joreskog and Sorbom, 1984). Wong and Dean (2005) suggest a value of ±2 as acceptable and values outside this value should be investigated. However, Abderrahman et al. (2012) suggest ±2.58 as a more accurate value that is acceptable. Thus, in this research ±2.58 was set as the acceptable value for standardized covariance measurement. Using AMOS, the standardized residual covariances were measured, and as presented in table 5.9 all were acceptable.

Table 5.9, Standardised residual covariance of the structural model

	LP11	LP10	LP2	LP5	LP7	LP8	AP10	AP9	Econ SP8	SocS P6	SocS P5	SocS P4	SocS P3	SocS P2	SocS P1	Envi SP6	Envi SP5	Envi SP4	Envi SP3	Envi SP2	Envi SP1	Econ SP5	Econ SP4	Econ SP3	Econ SP2	Econ SP1	AP2	AP3	AP4	AP5	AP6	AP7	AP8
LP11	0.0																																
LP10	-0.1	0.0																															
LP2	-0.5	-0.4	0.0																														
LP5	-0.4	0.7	-0.6	0.0																													
LP7	-0.4	-0.9	1.7	-0.1	0.0																												
LP8	-0.2	-0.6	-0.4	0.4	2.3	0.0																											
AP10	0.3	0.4	1.5	0.4	0.5	-0.2	0.0																										
AP9	-0.1	-0.2	-0.1	0.1	-1.0	-0.9	0.4	0.0																									
EconSP8	0.6	1.8	-0.2	0.9	0.0	0.7	0.5	-0.3	0.0																								
SocSP6	1.1	0.8	-0.9	-0.1	-1.3	-1.3	-0.1	-0.4	0.4	0.0																							
SocSP5	1.0	0.6	0.0	-0.2	-1.8	-1.0	0.4	0.2	0.2	0.4	0.0																						
SocSP4	1.4	0.7	0.8	0.6	-0.3	0.2	0.4	-0.4	1.0	0.1	0.2	0.0																					
SocSP3	0.3	0.4	-0.1	-0.1	-1.2	-0.8	-0.1	0.2	0.7	-0.2	-0.1	0.4	0.0																				
SocSP2	0.9	0.9	-0.2	0.6	-1.1	-0.7	-0.3	-0.1	1.4	-0.1	-0.7	-0.7	0.8	0.0																			
SocSP1	1.7	1.0	0.3	0.8	-1.4	-0.6	0.5	0.7	0.3	-0.4	0.1	-0.5	-0.3	0.6	0.0																		
EnviSP6	1.2	1.0	0.1	0.1	-0.7	-0.2	1.2	0.3	0.9	1.2	0.3	0.2	0.3	1.1	0.4	0.0																	
EnviSP5	1.1	1.1	-0.8	0.8	-0.8	-0.4	0.7	0.1	1.0	0.7	-0.4	-0.8	0.1	1.1	0.0	0.7	0.0																
EnviSP4	0.1	0.5	-0.7	0.1	-0.5	-0.3	0.7	-0.3	1.3	0.1	-0.6	-1.0	-0.1	0.5	0.0	-0.1	0.5	0.0															
EnviSP3	1.0	0.9	-0.1	0.0	-1.0	-0.4	0.1	-1.0	1.1	-0.1	-0.7	-1.3	-0.8	0.0	-0.1	-0.6	-0.5	0.0	0.0														
EnviSP2	0.0	0.4	-1.0	-0.4	-1.6	-1.5	0.4	-0.7	0.4	-0.2	-0.6	-0.9	-0.5	0.4	-0.1	-0.3	-0.6	-0.2	1.1	0.0													
EnviSP1	-0.2	0.2	0.2	0.6	-1.0	-0.9	0.9	-0.6	1.7	0.3	-0.1	-0.5	-0.5	0.8	0.1	-0.4	-0.8	-0.5	1.0	1.2	0.0												
EconSP5	-0.6	1.5	0.1	0.5	0.0	-0.4	0.6	-0.6	0.9	0.5	0.1	-0.3	0.0	0.7	0.8	0.3	0.7	-0.6	-0.1	-0.7	0.9	0.0											
EconSP4	0.0	-0.3	0.2	-0.6	-0.6	0.6	0.4	-0.3	0.7	-0.2	-0.3	0.3	-0.7	0.1	0.6	-0.5	-0.1	0.1	-0.3	-1.1	-0.2	0.4	0.0										
EconSP3	0.4	-0.4	-0.5	-0.1	-0.7	-0.1	-0.2	-0.7	-0.8	-0.5	-0.4	0.4	-0.8	0.1	0.7	-0.5	-0.5	-0.8	-0.4	-0.5	0.4	0.1	0.2	0.0									
EconSP2	-0.2	0.3	-0.1	1.0	-1.0	-0.3	0.8	0.2	-0.1	-0.2	0.1	0.4	-0.4	1.4	1.1	0.9	0.3	0.2	-0.3	0.6	1.3	-0.5	-0.9	0.2	0.0								
EconSP1	0.4	-1.3	0.7	-0.3	-0.7	0.1	0.6	-0.2	-0.8	-1.0	-0.8	0.0	-0.9	0.0	0.3	-0.4	-0.6	-0.3	-0.1	-0.3	0.3	-0.8	0.3	0.5	0.5	0.0							
AP2	1.2	0.4	0.5	-0.5	-0.6	-1.6	0.5	-0.7	0.1	-0.2	0.8	0.3	0.3	0.5	1.1	1.6	1.4	0.6	1.3	1.2	0.1	0.9	0.4	0.5	0.5	0.0	0.0						
AP3	1.2	0.9	1.2	0.2	0.4	-1.1	-0.7	-0.2	0.6	-0.6	0.2	0.0	-0.6	-0.1	-0.7	0.0	0.0	-0.3	-1.1	-1.1	-1.5	-0.2	0.2	-1.0	0.8	0.4	0.3	0.0					
AP4	-0.4	0.1	0.9	0.3	0.1	-0.1	0.3	0.2	0.6	-1.0	-0.5	-0.1	-0.9	-0.7	-0.4	0.6	0.5	0.6	-0.3	-0.6	-0.3	0.3	0.3	-1.6	0.1	-0.8	-0.7	1.1	0.0				
AP5	1.2	0.2	0.1	-0.4	0.0	0.6	-0.6	-0.2	0.4	0.4	0.3	0.0	-0.9	-0.8	-0.1	-0.5	-0.4	-0.9	-1.2	-1.6	-1.8	-0.3	0.1	-1.2	-0.7	-0.7	-0.3	0.9	1.5	0.0			
AP6	0.6	0.8	-0.6	-0.3	-2.1	-1.0	-0.4	-0.3	0.8	-0.1	0.2	0.6	-0.4	-0.7	-0.6	0.4	-0.1	-1.0	-0.9	-0.6	-1.3	-0.2	0.2	-0.6	-0.5	-0.7	1.0	0.3	-0.4	-0.1	0.0		
AP7	1.4	1.3	0.6	-0.5	-1.1	-1.1	0.0	0.0	0.9	1.0	0.8	0.2	-0.1	-0.3	0.1	0.6	0.8	0.2	0.4	0.3	0.4	1.0	0.3	0.4	-0.4	-0.5	-0.2	-1.0	-0.8	-0.1	0.6	0.0	
AP8	0.3	-0.3	-0.1	-0.5	-1.2	-0.3	-0.1	0.7	0.2	-0.2	0.1	0.4	-0.5	-0.1	0.8	0.4	-0.2	0.5	0.1	-0.7	-0.7	-0.2	1.0	0.3	0.2	0.8	-0.5	-0.1	-0.1	-0.3	0.2	0.1	0.0

5.8.4 Model Fit Summary

The foregoing tests have shown that CFA has provided the optimum number of items that are needed to conduct the structural tests. Prior to proceeding with the structural test, the fitness of the model to the data was tested using a range of model fit tests. Commonly reported tests are shown in table 5.10.

Table 5.10, Commonly Reported Test Statistics used to evaluate Model Fit

Test Statistics	Abbreviation	Critical Value	Interpretation
Chi-squared Tests			
Chi-squared goodness of fit test.	CMIN (χ2)	Chi-squared= n.s.	Good fit to the justified model.
Normal chi-squared test.	CMIN/df	(Chi-squared/df) ≤ 3	Good fit to the justified model.
Test Statistics Using Independence Matrix			
Goodness or fit index.	GFI	0.9 < GFI < 1	Good fit to the justified model.
Adjusted goodness of fit index.	AGFI	0.9 < AGFI < 1	Good fit to the justified model.
Standardized root mean squared residual.	SRMR	0 < SRMR < 0.05	Good model fit.
Normed fit Index	NFI	0.9<NFI<1.0	Percent improvement over null model.
Tucker-Lewis Index	TLI	0.9<TLI<1.0	Percent improvement over null model.
Comparative fit Index	CFI	0.9<CFI<1.0	Percent improvement over null model.
Incremental fit Index	IFI	0.9<IFI<1.0	Percent improvement over null model.
Root mean square error of approximation	RMSEA	0 < RMSEA < 0.08	Good model fit.
Root mean square residual	RMR	Smaller the better	0 indicates perfect fit
Standard RMR	SRMR	≤ 0.8	Good model fit

Source: Kline, 1998; Arbuckle and Wothke, 1999; Byrne, 2001; Schreiber et al. 2006

Model fitness is a measure that is used as a standard practice by researchers who employ CFA in management research. Model fitness explains the degree to which a covariance model fits the sample data and usually explained through indices including Goodness Fit Index, Normed Fit Index, Comparative Fit Inces, Root mean square error of approximation and Tucker-Lewis Index (Schermelleh-Engel et al. 2003). However, literature shows that well laid out rules or instructions are not available to determine what the minimum acceptable values are that inform the researchers of adequate fit. Also there is no consensus amongst researches on the number of fitness indices that need to be reported by researchers. However, evaluating the model fit is an important step followed by researchers in specifying the final model and it is seen that researchers report as many indices as possible (Schermelleh-Engel et al.2003). AMOS generates a number indices some of which are reported in the table. Acceptable values of the indices are provided in tables 5.10 above.

Table 5.11, Model fitness to data

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	.072	.787	.754	.680
Saturated model	.000	1.000		
Independence model	.592	.138	.084	.130

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.824	.808	.920	.912	.919
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

RMSEA

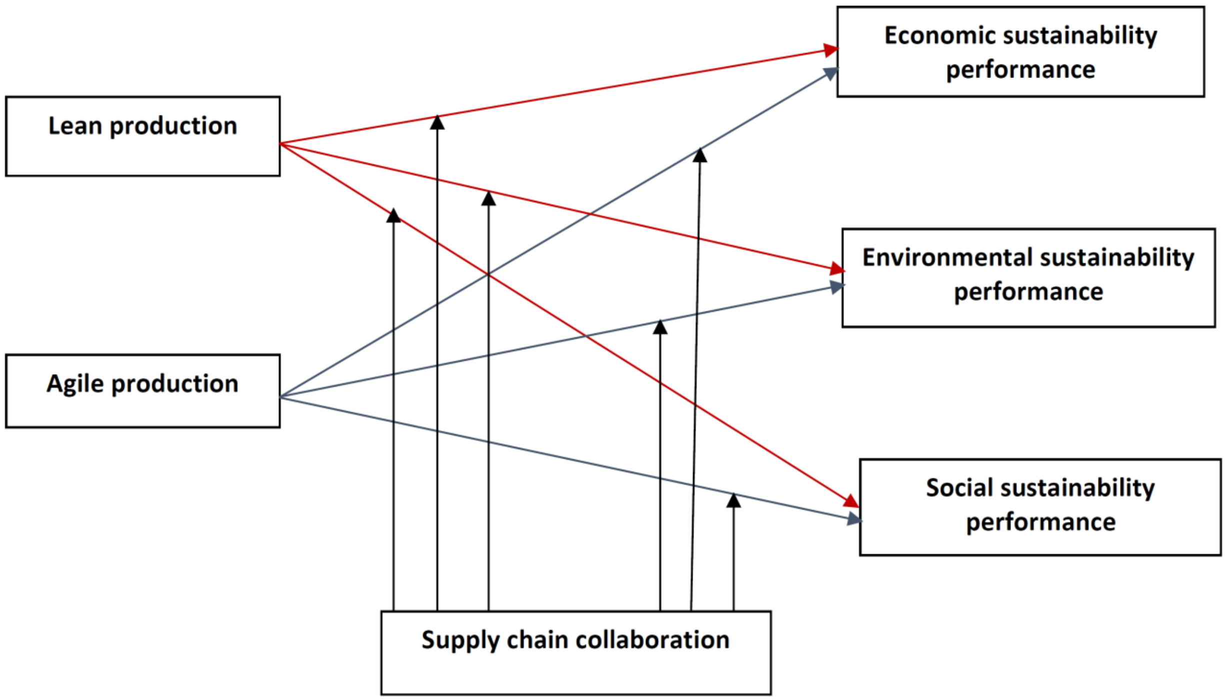
Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.062	.054	.069	.005
Independence model	.208	.203	.214	.000

It can be seen from the table 5.11 above that IFI, TLI, CFI, RMSEA, LO 90 and HI 90 all meet the minimum requirements. For instance, the generally recommended value of IFI, TLI and CFI in the literature is ≥0.9 and that of RMSEA, LO 90, HI 90 and PCLOSE is ≤0.08. These values have been achieved at the CFA stage which indicates that the model fits the data. Thus the next stage was to proceed to the structural modelling.

5.9 Research model – structural analysis

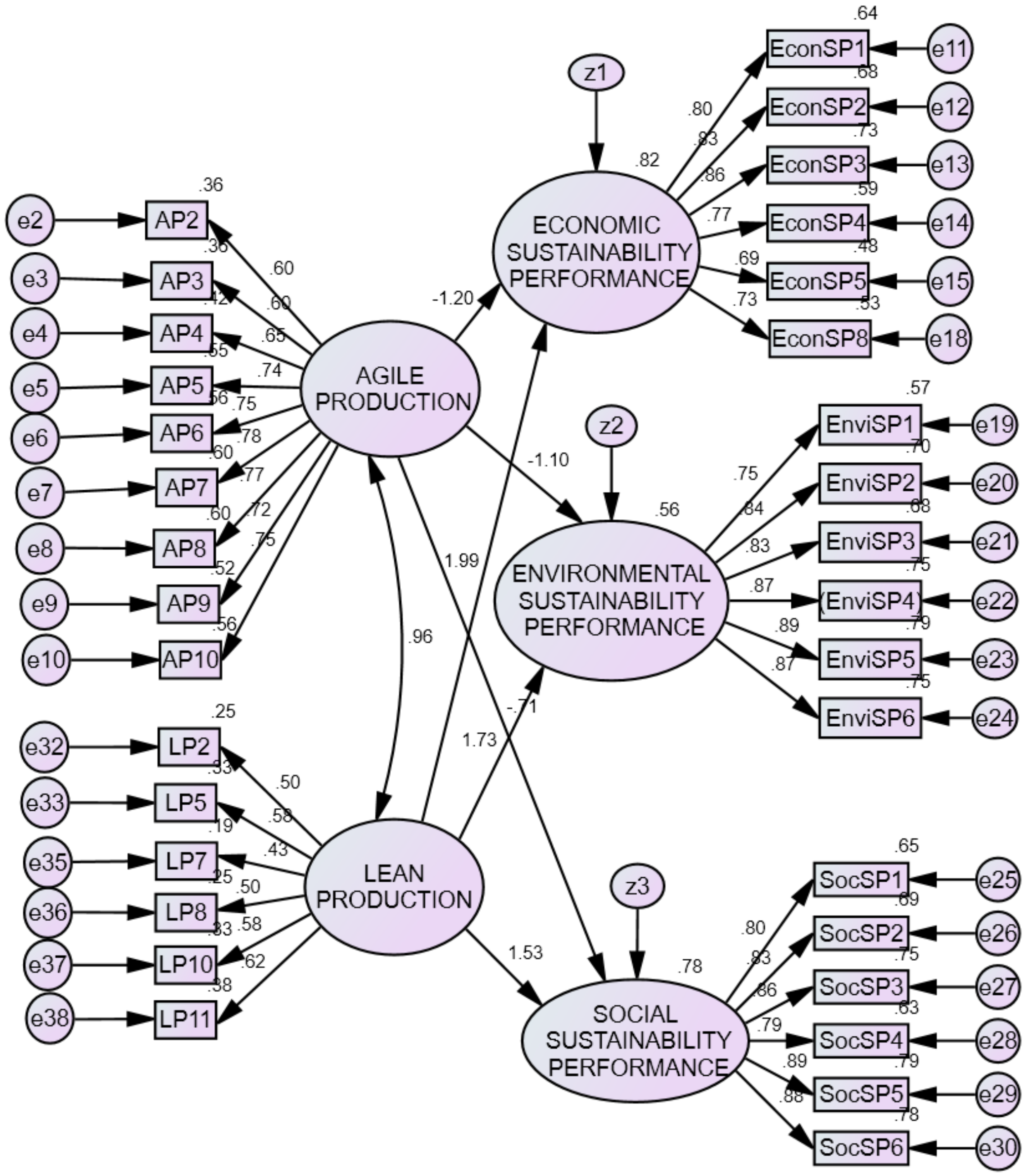
The initial model that was developed for this research is provided below

Figure 5.3, Research model



The model with lean and agile as the independent variables is provided in figure 5.4. To begin with the concepts of lean and agile production was analysed for their influence on sustainability factors namely economic, environmental and social sustainability performance. The step taken was to test the SMC of the model using AMOS. According to Arbuckle (2021) SMC is synonymous to R squared statistic used in multiple regression analysis and provides information to the researcher about the percentage of variance accounted for in the endogenous variables by the exogenous variable. For instance, in figure 5.4 the SMC for Economic Sustainability Performance is found to be 0.82 which indicates that 82% of the variance in Economic Sustainability Performance is accounted for by the exogenous variables Lean and Agile Production.

Figure 5.4 SMC of the endogenous variables of the structural model



The SMC for all the endogenous variables is provided in table 5.12

Table 5.12 SMC of endogenous variables

	SMC
SOCIAL_ SUSTAINABILITY_ PERFORMANCE	0.777
ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	0.556
ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	0.818

It can be seen that the lean production as an exogenous construct explains the extent the variance it accounts for in the endogenous constructs as follows:

- 77.7 percent of variance in social sustainability performance is accounted for by the independent variables.
- 55.6 percent of variance in environmental sustainability performance is accounted for by the independent variables.
- 81.8 percent of variance in economic sustainability performance is accounted for by independent variables.

Further to testing the variance accounted for by the exogenous variables lean and agile production, the next test conducted was the theoretical identification of a model. Identifying a model theoretically implies that the model has a unique solution possible for it and every one of its parameters. Three tests are suggested in the literature to suggest model identification namely checking whether model is recursive or not, the presence of multicollinearity and the number of parameters identified in the model is adequate, more than required or adequate (Abramson et al. 2005). The recursiveness was tested using AMOS, and the findings in table 5.13 shows that the model is recursive.

Table 5.13 Test of recursiveness of the model

Notes for Group (Group number 1)
The model is recursive.
Sample size = 181

The test of multicollinearity was conducted using the sample correlations which shows that all inter-item correlations are within the specified limit of 0.8. Thus it can be seen that multicollinearity is not present.

As far as the number of parameters in the model were concerned, it is reported in the literature that in model that is acceptable the number of parameters should not exceed the number of data points. The data points are calculated by the following equation (Ullman and Bentler, 2013):

The number of data points = $[p(p+1)/2]$ where p = the number of observed variables in the model = 30. Thus the number of data points in the model = [33(33+1)/2] =561.

The number of data points and the number of parameters are related to identify a model and a model is said to be identified if the number of data points exceed the number of parameters. A data point in the model indicates the variances and covariances of the observed variable (Byrne, 2009). Byrne (2009) explains that the core parameters in a structural equation model include the regression coefficients and the variances as well as the covariances of the independent variable that are analysed in a covariance structure. Thus the number of parameters in the model in figure 5.4 is calculated as follows:

Variances (regression coefficients) + Number of observed variables +Covariances = [(33+6) + 33 + 1] = 73. If one compares the number of data points (561) with the number of parameters (73), it can be seen that the number of data points exceed the number of parameters which indicates that the model is identified and hence fit for conducting the structural model analysis.

SEM introduces three different types of identified models namely over identified, under identified and just-identified models. Overidentified models are those wherein the number of data points are higher than the number parameters that can be estimated. In an overidentified model positive degrees of freedom (df) results which enable the researcher to allow for rejection of the model leading the researcher to use the model for scientific purposes. A degree of freedom is computed by AMOS using the formula df = (the number of distinct sample moments minus the number of distinct parameters that have to be estimated) (Arbuckle, 2009). According to Arbuckle (2009) the number of distinct sample moments includes variances and covariances. While using SEM the researcher aims to specify the model by testing it for the criteria applicable to an overidentified model (Byrne, 2009).

Underidentified models are those wherein the number of parameters are greater than the number of data points. In underidentified models it is not possible to attain a determinate solution of parameter estimation as the model does not contain sufficient information from the input data and implies that there are infinite solutions that are possible (Byrne, 2009). In just-identified models the data points and the structural parameters are in one-to-one correspondence with each other which means that the number of data points and the number parameters that can be estimated are equal. However, the just-identified models are not useful for scientific use as the number of degrees of freedom is zero and there is no chance for the model to be rejected even if the model is able to produce unique solutions for all parameters (Byrne, 2009).

From the discussions above it can be seen that the model identified for SEM in this research is an over-identified model and that the number of parameters is less than the number of data points. The next step taken was testing the model fit to the data, which is essential to be tested to proceed to the path analysis.

5.10 Model fit of the overidentified model

As mentioned in section 5.8.4, model fit was tested using AMOS to evaluate the overidentified model. The evaluation involves the following steps (Byrne, 2001, 2006; Arbuckle 1999, 2005; Holmes-Smith, 2000; Bollen and Long, 1993; Browne and Cudeck, 1993; MacCallum, 1990; Steiger, 1990; Mulaik et al. 1989):

- Assessing the measure of parsimony
- Comparing the identified model with baseline model
- Testing the goodness fit and associated measures
- Testing the minimum sample discrepancy function
- Testing the minimum population discrepancy function

The abovementioned tests are discussed in the following sections.

5.10.1. Assessing the measure of parsimony

Finding the most parsimonious summary of the interrelationship amongst the constructs in a model is an important aim in conducting SEM (Weston and Gore, 2006). However, it is necessary to acknowledge the fact that parsimonious models could lead to problems in goodness fit of the model (Preacher et al. 2008). Yet taking into account the arguments of Mulaik et al. (1989) who say that researchers should achieve a parsimonious model with high goodness fit, parsimony of the identified model was tested. The main parameter tested was the number of degrees of freedom which was compared with the number of parameters in the model. According to Weston and Gore (2006) a model is said to be parsimonious if the number degrees of freedom is greater than the number of parameters. The AMOS report which provides the number of parameters and the degrees of freedom with regard to the model in figure 5.4 is given in table 5.14.

Table 5.14 Measure of parsimony

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	73	859.483	488	.000	1.761
Saturated model	561	.000	0		
Independence model	33	4640.527	528	.000	8.789

From table 5.14 it can be seen that the number of degrees of freedom (488) far exceeds the number of parameters (73), thus it can be concluded that the model is parsimonious. However, in order to accept that the model is parsimonious it was necessary to check the model fit. AMOS produces the goodness fit report which is provided in table 5.15.

Table 5.15 Goodness fit of the identified model

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	.073	.777	.743	.675
Saturated model	.000	1.000		
Independence model	.592	.138	.084	.130

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.815	.800	.911	.902	.910
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.065	.058	.072	.000
Independence model	.208	.203	.214	.000

From table 5.15 and section 5.8.4 it can be seen that the indices IFI, TLI and CFI are greater than 0.9 a condition which indicates that the goodness fit is achieved. In addition, it can be seen that the RMSEA is found to be less than 0.08 which is also indicative of the goodness fit of the model. Another index that is found to be close to the acceptable levels is the Standardised Root Mean Squared Residual (SRMR) value. Researchers argue that acceptable range of SRMR values found the literature is 0 and 0.08 (Hu and Bentler, 1999). For the current model the SRMR indices reported by AMOS for the default model was found to be 0.0535. Thus it can be concluded that the model fits to the data and the meets the goodness fit requirement.

5.10.2. Comparing the identified model with baseline model

AMOS provides reports that compare the indices default model to two other models namely the saturated and independence models. Baseline comparisons of the hypothesized model are done in AMOS using indices for instance GFI, IFI, TLI and CFI. At one end of the continuum of the indices is the uncorrelated variables or independence model. The independence model is the one which corresponds to completely unrelated variables. According to the literature indices compared using the independence models will have degrees of freedom that is equal to the difference between the number of data points and the variances that are estimated (Ullman and Bentler, 2013). At the other end of the continuum concerning the indices is the saturated (full or perfect) model with zero degrees of freedom. In fact, Ullman and Bentler (2013) posit that fit indices used in baseline comparisons utilize a comparative fit method and place the estimated model (default model) at a position that lies somewhere along the continuum with zero indicating a bad fit and one indicating a perfect fit.

AMOS reports on the fitness indices when compared with the standard model fit continuum provided in figure 5.4, show that the IFI (0.911), TLI (0.902), CFI (0.91), RMSEA (0.065) and SRMR (0.0535) readings are better than the acceptable values. Thus it can be said that the baseline comparisons show that the model is fit and could be subjected to path analysis further.

5.10.3. Testing the goodness fit and associated measures

From the previous section it can be seen that the model fit readings reported by AMOS are superior to the acceptable levels. Five measures have been found to meet the minimum requirements which are IFI (should be ≥0.9 and was observed to be 0.911), TLI (should be ≥0.9 and was observed to be 0.902), CFI (should be ≥0.9 and was observed to be 0.91), RMSEA (should be ≤0.08 but was observed to be 0.065) and SRMR (should be ≤0.08 but was observed to be 0.0535). Other measures like CMIN/DF (p-value should be ≥ 0.05 to accept the null hypotheses), GFI (should be ≥0.9 but was observed to be 0.777), NFI (should be ≥0.9 but was observed to be 0.815) and RFI (should be ≥0.9 but was observed to be 0.8) were not found to satisfy the minimum values recommended in the literature. Yet considering the fact that five of the indices that are popular amongst researchers have met the requirements and the fact that there is no consensus amongst researchers on how many indices should be measured and reported in research (van Laar and Braeken, 2022), the researcher concluded that the model is found to fit the data and is not miss specified.

5.10.4. Testing the minimum sample discrepancy function

CMIN/DF is the statistic that provides information about the sample discrepancy function commonly used by researchers and is reported by AMOS with CMIN indicating minimum discrepancy and DF indicating degrees of freedom. CMIN/DF is also denoted as (λ^2/df) where λ^2 = CMIN and 'df' indicates the degrees of freedom (Byrne, 2009). According to Arbuckle (2005) when (λ^2/df) approaches 1 then the model is said to be correct for the sample size chosen by the researchers although the extent of deviation from 1 is not agreed upon by researchers. For instance, Byrne (2006) argues that (λ^2/df) values approaching up to 3 are acceptable. Another important limitation of using (λ^2/df) is the fact that (λ^2) is very sensitive to sample size and is dependent on it and hence Long and Perkins (2003) do not recommend using (λ^2/df) as a statistic to measure the sample discrepancy function. As far as this research is concerned the (λ^2/df) statistic was found to be 1.761 which is close to 1 and is also less than 3, the figure suggested by Byrne (2006). This result can be assumed to indicate that the research outcomes meet the minimum sample discrepancy function requirements. However, it is necessary to take into account the fact that some researchers do not agree on (λ^2) as a realistic standard that can be used for measuring the minimum sample discrepancy function (e.g., Fabrigar et al. 1999; Millis et al. 1999). In that situation the researcher relied upon other measures that could be used reliably to measure the minimum sample discrepancy function for instance the one recommended by Joreskog and Sorbom (1989) who suggest that in place of (λ^2) statistic it is possible to use other goodness fit statistic to indicate minimum sample discrepancy function. Thus using table 5.10 which shows that many goodness fit indices are achieved in this research, it was concluded by the researcher that the minimum sample discrepancy function requirements have been met. This implies that the sample size used in this research satisfies the minimum requirements of statistical analysis.

5.10.5. Testing the minimum population discrepancy function

Minimum population discrepancy function is used by researchers to check whether the model fits well in the population that is under study rather than the sample. Some researchers (e.g. Kaplan, 2000) argue that it may be more meaningful to understand the approximate fit of the model to a population as well as the discrepancy that could creep in than to a sample of that population (e.g. (λ^2/df)). Root Mean Square Error of Approximation (RMSEA) is a measure found in the literature that could support measuring the fitting of the model to a population and it helps in finding out the discrepancy that could be generated because of the approximation (Steiger, 1990). RMSEA is considered to be a fairly strong measurement that is used by researchers to test the model fit (e.g., Jackson et al. 2009; Taylor, 2008). Widely used figure of merit that is considered acceptable by researchers is in the range of 0.05-0.08 (Browne and Cudeck, 1993). According to Browne and Cudeck (1993) values of RMSEA $\leq$ 0.05 is considered to be good fit, values in the range of 0.05-0.08 as adequate fit and those in the range of 0.08-0.1 as mediocre fit and >0.1 as a value that should not be accepted.

While many researchers suggest the use of RMSEA some have cautioned against the use of RMSEA because of its susceptibility to the confidence interval used in determining the sample size as well as the model complexity (Byrne, 2001). Despite this limitation, RMSEA is still considered to be a robust measure by many researchers in comparison to any other measure (e.g., Jackson et al. 2009; Taylor, 2008). Thus in this research RMSEA was used to measure the minimum population discrepancy function and was measured using AMOS. The report from AMOS shows (table 5.15) that RMSEA value was measured as 0.065 and hence it was concluded by the researcher that the model fits into the population and the discrepancy caused by approximate fitting of the model using the root mean square error approximation is minimum.

The foregoing analyses clearly points out that the identified model is acceptable and there is no need to re-specify it. Thus the model was considered to be ready for further analysis and the model is ready to be subjected to path analysis. These are discussed next.

5.11 Path analysis

Path analysis provides the procedure for the researcher to determine the cause and effect relationship between the exogenous and endogenous variables and interpret the various numbers including the regression weights, the R squared value and the statistical significance of the relationships. According to Janssens et al., (2008) path analysis is the step that enables a researcher to estimate the structural relationships between the latent variables. Such an estimation was carried out using AMOS which generated the path coefficients. Path coefficients are accepted if only those structural relationships are found to be statistically significant which is indicated by the p-value of significance. Table 5.16 provides the estimate of the regression weights (path coefficients) of the various paths in the identified model.

Table 5.16 Regression weights of the identified model

			Estimate	S.E.	C.R.	P	Label
ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	<---	AGILE_ PRODUCTION	-1.263	.723	-1.748	.081	par_29
ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	<---	AGILE_ PRODUCTION	-1.241	.699	-1.777	.076	par_30
SOCIAL_ SUSTAINABILITY_ PERFORMANCE	<---	AGILE_ PRODUCTION	-.745	.585	-1.274	.203	par_31
ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	<---	LEAN_PRODUCTION	3.154	1.152	2.737	.006	par_32
ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	<---	LEAN_PRODUCTION	2.940	1.116	2.633	.008	par_33
SOCIAL_ SUSTAINABILITY_ PERFORMANCE	<---	LEAN_PRODUCTION	2.442	.938	2.603	.009	par_34

Table 5.16 shows the statistical significance of the paths that are significant. To statistically accept a relationship between two variables, the p-value of significance is examined. A relationship between two variables is said to be statistically significant and acceptable when the p-value of significance is found to be lower than the cut-off value of 0.05. Thus from table 5.16 it can be seen that the relationships

LEAN_PRODUCTION → ECONOMIC_ SUSTAINABILITY_ PERFORMANCE (p-value=0.006), LEAN_PRODUCTION → ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE (p-value=0.008) and LEAN_PRODUCTION → SOCIAL_ SUSTAINABILITY_ PERFORMANCE (p-value=0.009) are statistically significant. However, the relationships AGILE_PRODUCTION → ECONOMIC_ SUSTAINABILITY_ PERFORMANCE (p-value=0.081), AGILE_ PRODUCTION → ENVIRONMENTAL_SUSTAINABILITY_PERFORMANCE (p-value=0.076) and AGILE_ PRODUCTION → SOCIAL_ SUSTAINABILITY_ PERFORMANCE (p-value=0.203) were not found to be statistically significant.

Using table 5.16 above it was possible to compare the effect of each exogenous construct on the endogenous variable (Hair et al. 2006). The report generated by AMOS related to standardized regression weights (table 5.17) below enabled the researcher to infer whether the hypotheses can be accepted or rejected.

Table 5.17 Standardised regression weights of the structural model

			Estimate
ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	<---	LEAN_PRODUCTION	1.985
ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	<---	LEAN_PRODUCTION	1.733
SOCIAL_ SUSTAINABILITY_ PERFORMANCE	<---	LEAN_PRODUCTION	1.534

The results show that lean production has a direct and positive impact on all the three endogenous variables namely economic sustainability performance, environmental sustainability performance and social sustainability performance. Agile production does not affect the endogenous variables at all. This implies that lean and agile may not function together if applied on the production lines as standards. At this stage it is important to restate the main aim of this research. The main aim was to study the moderating effect of supply chain collaboration of the relationship between lean and agile production respectively and manufacturing sustainability performance. If the moderation effect of supply chain collaboration on the relationship between lean and agile production and manufacturing sustainability performance has to be tested it can be seen from the results above that the moderation effect of supply chain collaboration on the relationship between lean production and manufacturing sustainability performance can only be tested. The moderation effect of supply chain collaboration on the relationship between agile production and manufacturing sustainability performance will not be tested as the relationship between lean and agile production and manufacturing sustainability performance is not significant. In such a situation the researcher decided to test the relationship between lean and agile production and manufacturing sustainability performance by respecifying the structural model in figure 5.4 as shown in figures 5.5 and 5.6.

Figure 5.5 SEM with Lean Production as the predictor

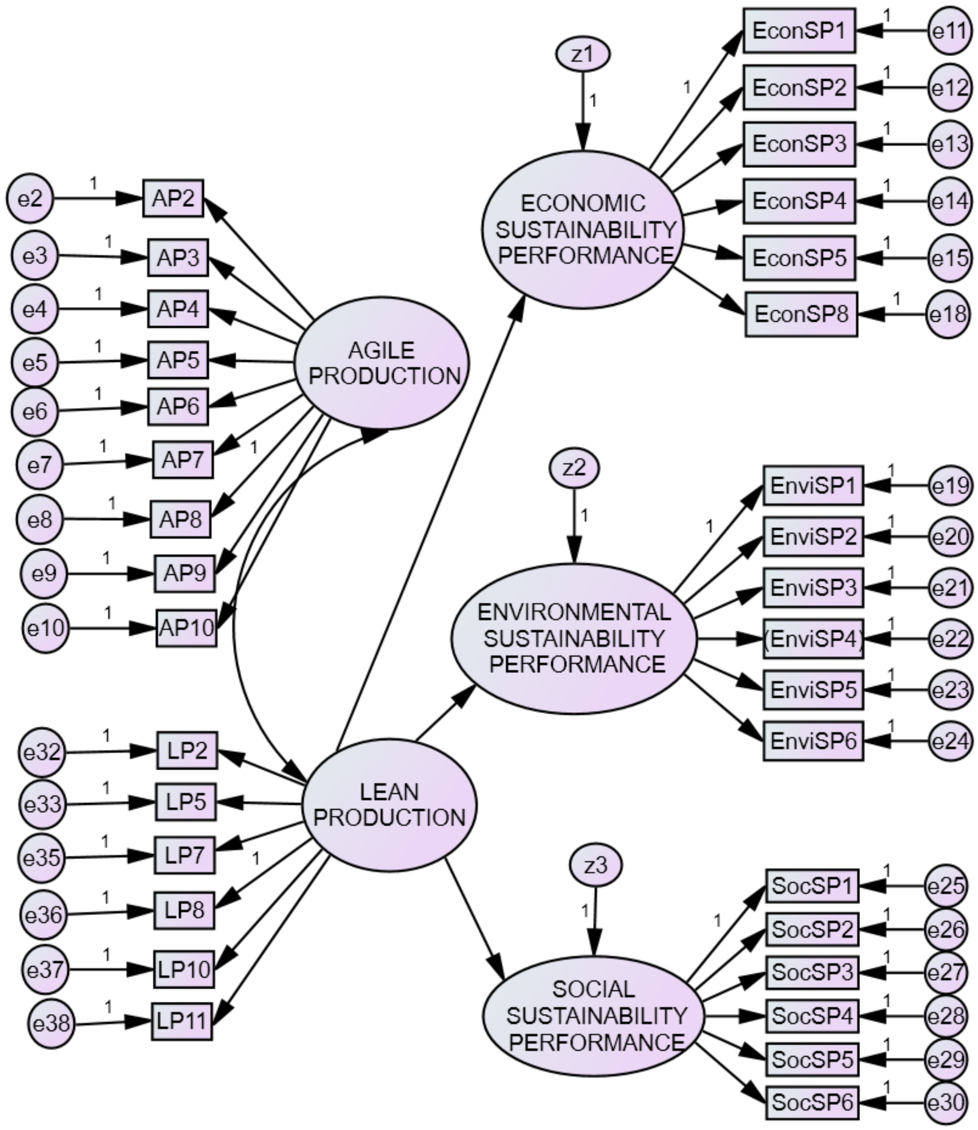
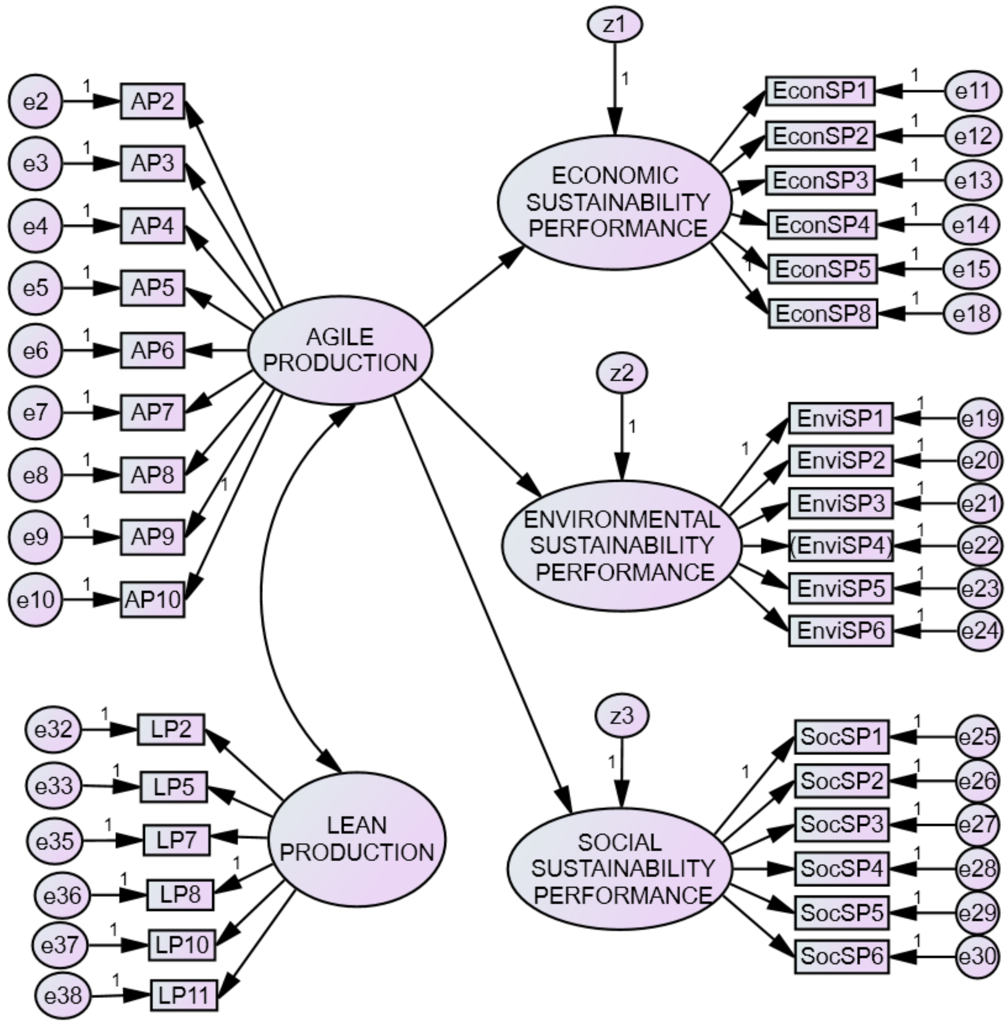


Figure 5.6 SEM with Agile Production as the predictor



The models differ as follows. The model in figure 5.6 shows that the direct relationship between agile production and the three sustainability performance factors has been removed as the relationship between agile production and the three sustainability performance factors was found to be statistically insignificant (table 5.16). However only the direct relationship between agile production and the three sustainability factors has been deleted but as a variable agile production was still retained as a covariant of lean production. This configuration followed directly from the results of the analysis of the composite model in figure 5.4 which simply showed that all the three relationships between agile production and the sustainability performance factors were statistically insignificant. However, the researcher also wanted to test the other configuration in figure 5.6 in which the relationships between lean production and the sustainability performance factors were removed and just retained lean production as a covariant to agile production. Here it can be seen that the model in figure 5.6 is converse to the model in figure 5.5. This configuration in figure 5.6 is a derivative of the main research model and was essential to test this configuration as respecifying the main research model need to be consistent in regard to operationalizing the two exogenous variables. Lack of consistency or just testing the model in figure 5.4 would have simply produced results that would not have provided knowledge about the impact of agile production on the three sustainable performance factors as an independent factor or covariant. An investigation into the two configurations is expected to produce results that completely cover the influence of the two predictors, independent of each other and provide new knowledge on how those predictors influence the sustainability performance aspects of a company. Thus the following sections analyse the two models in figures 5.5 and 5.6.

5.12 Analysis of the Lean Production model as the predictor

In figure 5.5 it can be seen that the structural model not only consists of lean production as the predictor but also agile production which has been added as the covariant. This implies that the original research model given in figure 5.4 has been now split into two models with each one of the split models indicating that the relationship between agile production or lean production and sustainability factors will be investigated with either of the two production factors acting as the covariant. Thus in figure 5.5 while lean production is shown as the predictor, agile production has been added to the predictor as the associating variable and the opposite is true in the figure 5.6. AMOS report on the path coefficients generated for the model in figure 5.5 is provided in table 5.18.

5.12.1 Path coefficients

Table 5.18 Path coefficients of the SEM in figure 5.5

			Estimate	S.E.	C.R.	P	Label
ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	<---	LEAN_PRODUCTION	1.114	.186	5.980	***	par_29
SOCIAL_ SUSTAINABILITY_ PERFORMANCE	<---	LEAN_PRODUCTION	1.291	.193	6.680	***	par_30
ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	<---	LEAN_PRODUCTION	1.280	.189	6.762	***	par_31
Note: *** indicates that the regression weight is significantly different from zero at the 0.001 level (two-tailed).							

From table 5.18 it can be seen that the relationships LEAN_PRODUCTION → ECONOMIC_ SUSTAINABILITY_PERFORMANCE (p-value < 0.001), LEAN_PRODUCTION → ENVIRONMENTAL_SUSTAINABILITY_PERFORMANCE (p-value< 0.001) and

LEAN_PRODUCTION → SOCIAL_SUSTAINABILITY_PERFORMANCE (p-value< 0.001) are statistically significant. The results produced by AMOS gives an opportunity to interpret the relationship between the independent and dependent variables in various ways. Prior to that it is necessary to assess and account for the variance of the dependent variables as a function of the independent variable using the quantity namely SMC between the independent and dependent variables. SMC of a variable indicates the proportion of the variance of that variable that is accounted for by its predictors (Arbuckle, 2019). Thus the SMC of the endogenous variables is provided in table 5.19.

5.12.2 Testing squared multiple correlation (SMC) of sustainability performance variables

Table 5.19 Squared multiple correlation of the lean production model

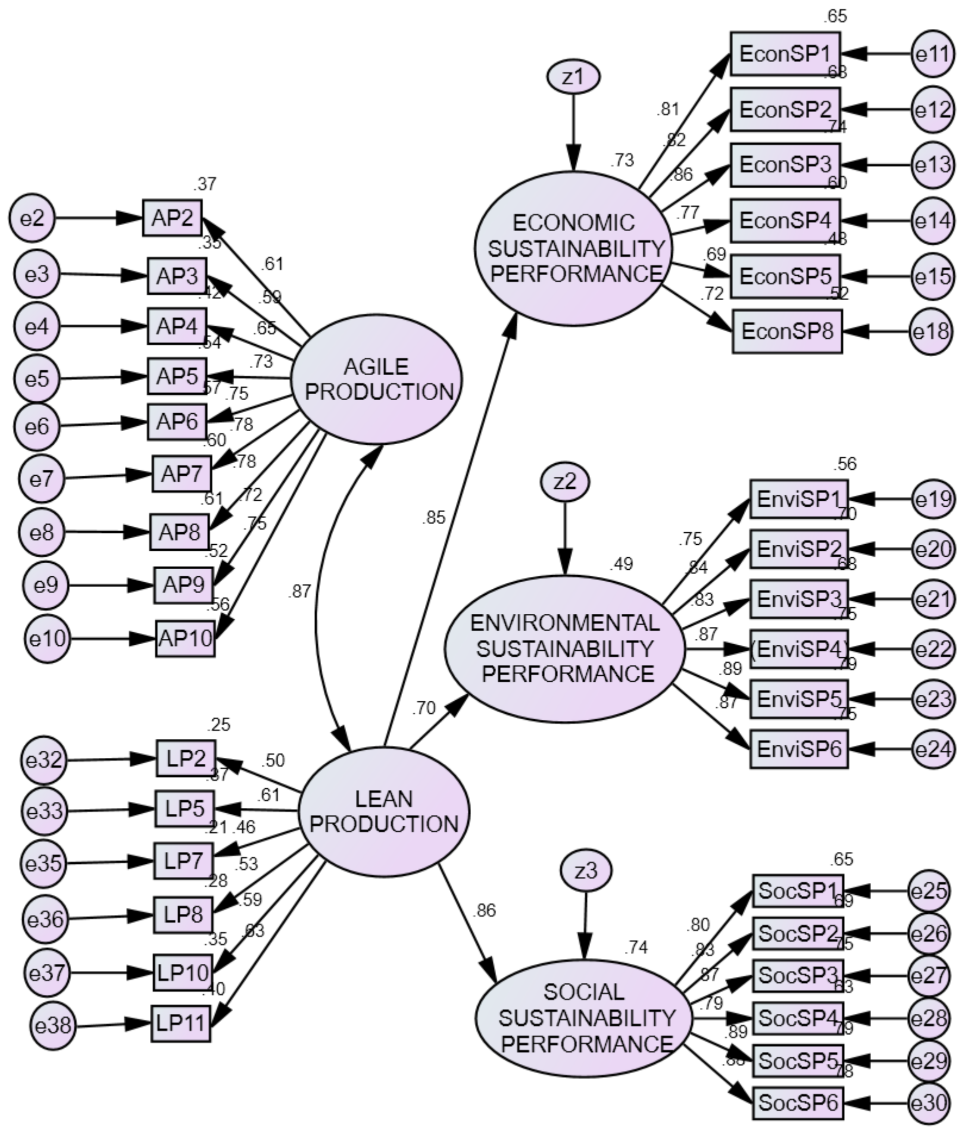
	Estimate
SOCIAL_ SUSTAINABILITY_ PERFORMANCE	.744
ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	.491
ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	.725

From table 5.19 the following inferences can be derived.

- 74.4% of variance in social sustainability performance is accounted for by lean production.
- 49.1% of variance in environmental sustainability performance is accounted for by lean production.
- 72.5% of variance in economic sustainability performance is accounted for by lean production.

The above results clearly indicate that lean production as an independent variable is having significant influence on all the three sustainability performance factors. This can be interpreted in a way that companies adopting only lean production are likely to influence significantly the three sustainability performance factors. After analysing the SMC, the next step involved the examination of the standardized regression weights of the significant paths found in table 5.18 which was necessary as this examination will lead to the testing of the hypotheses. Standardized regression weights reported by AMOS enabled the researcher to compare the relative effect of the independent construct on the dependent variable (Hair et al. 2006). Figure 5.7 provides the details of the standardized regression conducted on the model in figure 5.5.

Figure 5.7 Standardised regression coefficient measurement



The AMOS report on standardized regression coefficients is provided in table 5.20.

5.12.3 Standardized regression weights of the significant paths predicted by lean production

Table 5.20 AMOS report on standardized regression coefficients

			Estimate
ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	<---	LEAN_PRODUCTION	.701
SOCIAL_ SUSTAINABILITY_ PERFORMANCE	<---	LEAN_PRODUCTION	.862
ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	<---	LEAN_PRODUCTION	.852

The estimates of regression need to be understood in terms of the weights for instance against the classification by Kline (1998). According to Kline beta weights in the standardized output generated by AMOS with absolute values of 0.1, 0.3 and 0.5 can be classified as having small, moderate and large effects respectively of the exogenous construct on the endogenous construct. Thus from table 5.20 above it can be seen that LEAN_PRODUCTION as an exogenous variable is having a large effect on the three endogenous variables. These results indicate that hypothesis 1, Hypotheses 2 and Hypothesis 3 are all supported.

5.12.4 Association of lean production with agile production

An important aspect that needs attention in this research is the covariance that occurs between the predictor which is lean production and the associate variable agile production. In the initial model it was portrayed that both lean and agile production variables influence the sustainability performance variables but the results in table 5.16 show that agile production is not statistically significantly influencing the sustainability performance variables. The implication explained was that in a firm both lean and agile production variables may not operate at any point of time together on the sustainability performance variables. This further implies that in manufacturing units where lean methodology is already implemented, agile production is unlikely to be significant. This is perhaps possible because agile methodology in the literature is argued to have evolved from lean (Jin-Hai et al, 2003; Sharp et al, 1999; Booth 1996) and where lean production is already implemented, there is perhaps no need for adding agile methodology. Thus, the researcher found a scope to delete the direct relationship between agile production and the three sustainability performance variables from the research model which left lean production as the predictor but made agile production as a covariant to lean production. The AMOS result of the covariance is provided in table 5.21.

Table 5.21 Covariance between Lean Production and Agile Production

			Estimate	S.E.	C.R.	P	Label
AGILE_ PRODUCTION	<-->	LEAN_PRODUCTION	.511	.093	5.496	***	par_32

The relationship between lean production and agile production is shown to be statistically significant with a p-value found to be significant at the 0.001 level (table 5.21). Furthermore, the association between lean production and agile production is found to be one of large correlation (table 5.22) (coefficient of regression 0.866).

Table 5.22 Correlation between lean production and agile production

	Estimate
AGILE_ PRODUCTION <--> LEAN_PRODUCTION	.866

The interpretation is that even though lean production is dominant, there can be certain aspects of agile that could be brought into play when lean production acts as the predictor of the three sustainability performance variables. For instance, the table 5.23 below shows possible standards of lean production and agile production that can supplement each other. This table was generated based on the items provided in the research instrument used for this research. The linking of the lean production and agile production concepts emerge from a subjective view and experience of the researcher on a production line gained over several years.

Table 5.23 Matching of lean production and agile standards to indicate their supplementing operation between each other.

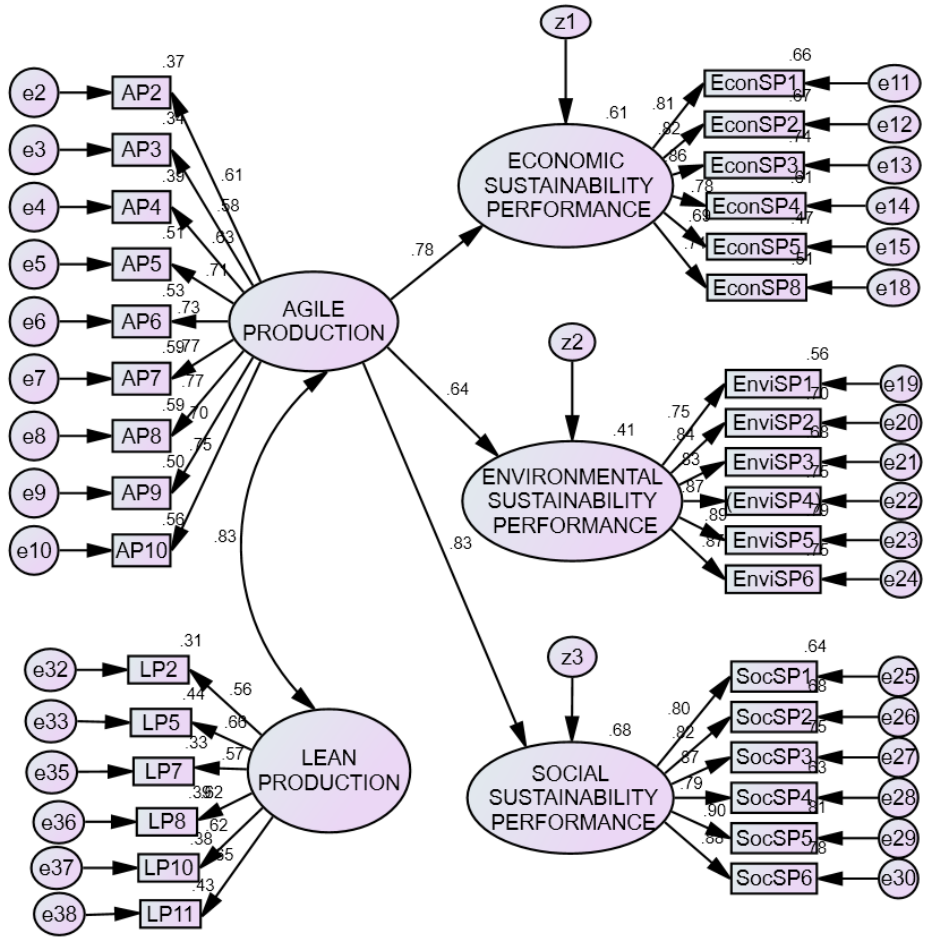
Lean production	Agile production
Our customer gives us feedback on quality and delivery performance	Customer driven innovation, Responsiveness to changing market requirements
Our employees working on the shop floor lead product and process improvement efforts	Cross functional teams, Technology awareness, Providing continuous training and development, Adoption of a culture of change

The supplementary function of the agile production on lean production and hence the three sustainability performance variables are supported by the literature (Vanichchinchai, 2022). For instance, literature shows that lean production standards are quite useful to standardize internal operations whereas agile production standards can be useful for external operation. If one takes the example of a lean production standard namely "our employees working on the shop floor lead product and process improvement efforts", this standard can be supplemented and facilitated by agile standards namely "cross functional teams", "technology awareness", "providing continuous training and development" and "adoption of a culture of change". It is also seen that agile production enhances the three sustainability performance variables. Similarly, with regard to the lean standard namely "Our customer gives us feedback on quality and delivery performance" it can be seen that agile standards namely "Customer driven innovation" and "Responsiveness to changing market requirements" supplement and facilitate the lean standard to enhance the sustainability performance. This result indicates that manufacturing firms that have implemented lean methodology can also employ agile methodology to some extent to enhance the sustainability performance of the firm. This is a new finding. After understanding the usefulness of agile production as a covariant of lean production, the next step taken was to ascertain whether agile production had any influence on the three sustainability performance variables. This was thought necessary because when the initial model was split into two, examining only the influence of lean production on the sustainability performance variables left out the possibility of agile production acting as a predictor. In such a case knowledge about the possible influence of agile production on the sustainable performance variables would be concealed. Although agile production was not found to be statistically significantly influencing the sustainability performance variables as a predictor, AMOS provided an opportunity to test the influence of agile production on the sustainable performance factors by removing the lean production as a variable from the initial composite model. Thus the model provided in figure 5.6 was tested in similar lines as testing lean production's influence on the sustainability performance variables.

5.13 Analysis of the Agile Production model as the predictor

Figure 5.8 gives the AMOS generated model of agile production as a predictor.

Figure 5.8 Agile production as predictor of sustainability performance variables



Following the same steps as the ones used in analysing the lean production as the predictor the report from AMOS is discussed next.

5.13.1. Path coefficients

Table 5.24 Path coefficients of the model in figure 5.8.

			Estimate	S.E.	C.R.	P	Label
ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	<---	AGILE_PRODUCTION	.762	.095	8.043	***	par_29
ENVIRONMENTAL_SUSTAINABILITY _ PERFORMANCE	<---	AGILE_PRODUCTION	.828	.114	7.282	***	par_30
SOCIAL_ SUSTAINABILITY_ PERFORMANCE	<---	AGILE_PRODUCTION	1.010	.107	9.431	***	par_31

From table 5.24 it can be seen that all the three paths linking agile production on the one side and the three sustainable performance variables on the other side are found to be statistically significant with the p-value observed to be significant at the 0.001 level.

5.13.2 Testing squared multiple correlation (SMC) of sustainability performance variables

Table 5.25 SMC of the sustainable performance variables

	Estimate
SOCIAL_ SUSTAINABILITY_ PERFORMANCE	.685
ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	.406
ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	.608

From table 5.25 the following inferences can be made.

- 68.5% of variance in social sustainability performance is accounted for by agile production.
- 40.6% of variance in environmental sustainability performance is accounted for by agile production.
- 60.8% of variance in economic sustainability performance is accounted for by agile production.

Thus it can be seen from the statistically analysed results that firms that implement only agile methodology can significantly influence the three sustainability performance variables.

5.13.3. Standardized regression weights of the significant paths predicted by agile production

Table 5.26 provides the details of the standardized regression conducted on the model in figure 5.6.

Table 5.26 Standardised regression weights of the paths predicted by agile production

			Estimate
ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	<---	AGILE_PRODUCTION	.779
ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	<---	AGILE_PRODUCTION	.637
SOCIAL_ SUSTAINABILITY_ PERFORMANCE	<---	AGILE_PRODUCTION	.827

From table 5.26 above it can be seen that AGILE_PRODUCTION as an exogenous variable is having a large effect on the three endogenous variables as all the regression weights are seen to be higher than 0.5. Thus it can be concluded that the hypothesis H6 which states "Agile production practices is positively related to social sustainability performance" is supported.

After testing the hypotheses related to both lean production and agile production, the next step taken was to analyse the possible role of lean production as an associate of agile production in line with the analysis conducted for lean production (section 5.12). This is discussed next.

5.13.4. Association of agile production with lean production

Arguing in similar lines as the ones in section 5.12 concerning the lean production, the AMOS report on the covariance between agile production and lean production was examined. From table 5.27 can be seen that the covariance between agile production and lean production is statistically significant with p-value found to be statistically significant at the 0.001 level.

Table 5.27 Association between the agile production and lean production variables

			Estimate	S.E.	C.R.	P	Label
LEAN_PRODUCTION	<-->	AGILE_PRODUCTION	.487	.083	5.839	***	par_32

Further to testing the covariance between the agile production and lean production, the correlation between the two variables was examined and it was found that there is a large correlation between the two variables (0.833) (table 5.28)

Table 5.28 Correlation between the agile production and lean production variables

			Estimate
LEAN_PRODUCTION	<-->	AGILE_PRODUCTION	.833

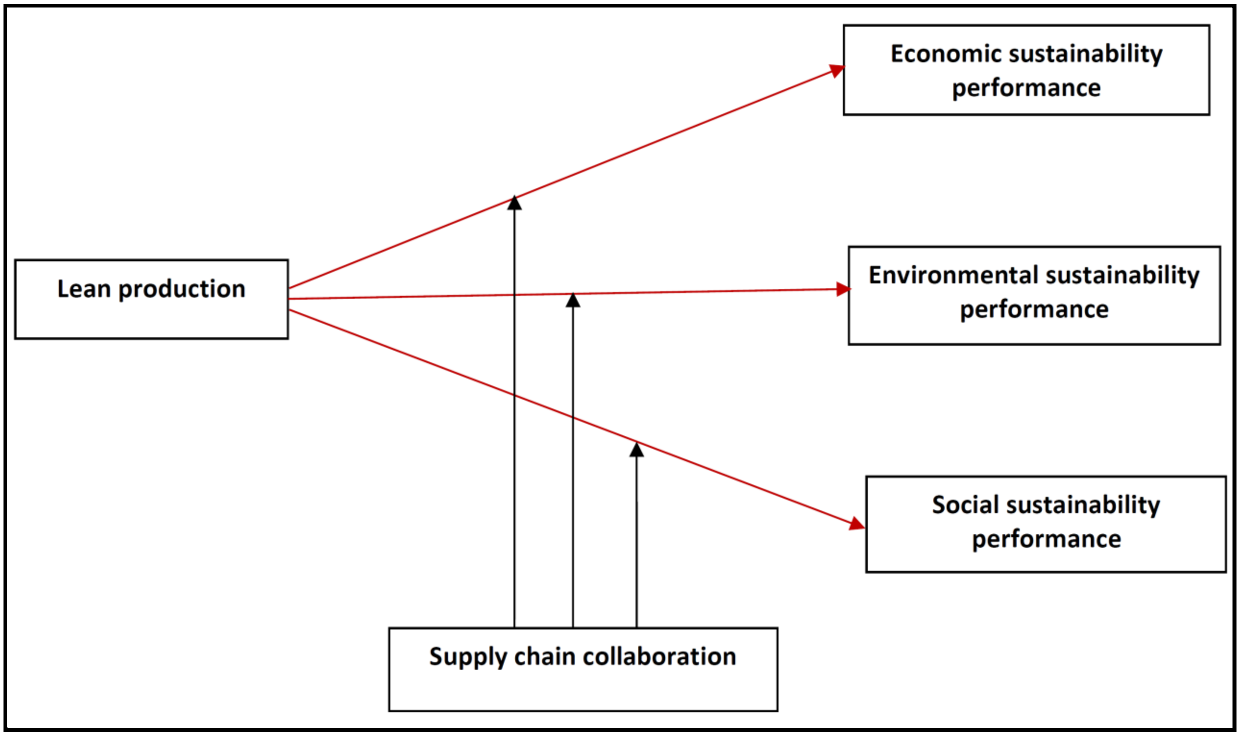
As far as the demonstration of the practical examples of the association between agile production and lean production, it can be seen that the examples in table 5.23 can be used here. Examples provided in section 5.12.4 for lean are also applicable here. The inference that emerges is that a firm that has implemented agile production method can also add certain standards related to lean production methodology on the production lines to enhance the sustainability performance of those firms.

The foregoing discussions have provided insight into the relationships between lean production and agile production on the one hand and sustainability performance factors on the other. Three models have been tested. The first model (figure 5.4) which encompasses two independent variables namely lean production and agile production yielded results which showed that agile as a predictor was not found to be statistically significant of all the three sustainability performance factors. The second model (figure 5.5) demonstrated that lean production as a lone predictor has a significant influence on the three sustainability performance factors and agile production supports as a covariant to enhance that influence. In the third model (figure 5.6) agile production as a lone predictor has a significant influence on the three sustainability performance factors and lean production supports as a covariant to enhance that influence. The hypotheses H1 to H3 were supported in the first model, the hypotheses H1 to H3 were supported in the second model and the hypotheses H4 to H6 were supported in the third model. In addition to the above, two other relationships namely (AGILE_PRODUCTION <--> LEAN_PRODUCTION) and (LEAN_PRODUCTION <--> AGILE_PRODUCTION) were found to be statistically significant which provided new knowledge into the relationship between the exogenous variables lean production and agile production. From this summary it can be seen that the main aim of testing the moderating effect of the supply chain collaboration (figure 5.4) can now be achieved by testing the moderating effect of supply chain collaboration on second and third models (figures 5.5 and 5.6). The moderation effect is discussed next in the following sections.

5.14 Moderation by supply chain collaboration on the relationship between lean production and sustainability performance

Figure 5.9 provides the moderation effect of supply chain on the second model (figure 5.5).

Figure 5.9 Moderation of supply chain collaboration on the relationship between lean production and sustainability performance



The moderation equation is derived from the regression equation. The regression equation that defines the relationship between lean production and each one of the three sustainability performance variables are given in equations 5.1, 5.2 and 5.3.

- Economic sustainability performance = k0 + b1 (Lean production) + e1 → (5.1)
- Environmental sustainability performance = k1 + b2 (Lean production) + e2 → (5.2)
- Social sustainability performance = k2 + b3 (Lean production) + e3 → (5.3)

Where 'k' represents the constant, 'b' represents the regression coefficient and 'e' represents the error component. The figures for these items were obtained from the regression report produced by SPSS.

The moderation effect of supply chain collaboration on each one of these equations are provided in equations 5.4, 5.5 and 5.6.

- Economic sustainability performance = k3 + b4 (Lean production) + b5 (Supply chain collaboration) + b6 (Lean production * Supply chain collaboration) +e4 → (5.4)
- Environmental sustainability performance = k4 + b7 (Lean production) + b8 (Supply chain collaboration) + b9 (Lean production * Supply chain collaboration) +e5 → (5.5)
- Social sustainability performance = k5 + b10 (Lean production) + b11 (Supply chain collaboration) + b12 (Lean production * Supply chain collaboration) +e6 → (5.6)

When the regression is performed, the product factor namely (Lean production * Supply chain collaboration) if found to be statistically significant (p-value $\leq$0.05) along with either or both of other two constructs (p-value $\leq$ 0.05) then it is construed that supply chain collaboration moderates the relationship. For instance, when equation 5.4 regressed and in the regression report if the p-value of significance is found to be $\leq$ 0.05 for the three factors namely Lean production, Supply chain collaboration and (Lean production * Supply chain collaboration) then it can be concluded that supply chain collaboration moderates the relationship (Lean production → Economic sustainability performance). Also, if the product factor in equation 5.4 namely (Lean production * Supply chain collaboration) and either of the two constructs namely Lean production or Supply chain collaboration are found to have statistically significant relationship with the dependent variable (p-value $\leq$0.05) then also it can be concluded that supply chain collaboration moderates the relationship (Lean production → Economic sustainability performance). Additionally, it must be noted that even if the product term is found to have a statistically significant relationship with the dependent variable but the other two variables do not have a statistically significant relationship with the dependent variable then it can be concluded that moderation does not occur. Thus in this research the equations 5.4, 5.5 and 5.6 were regressed using SPSS version 21. The following coding was assigned to the variables.

Table 5.29 Coding of variables used in regression of moderator supply chain collaboration

#	Construct	Code used in SPSS
1.	Mean of Lean Production	MAENLP
2.	Mean of Economic Sustainability performance	MEANECONALL
3.	Mean of Environmental Sustainability performance	MEANENVIALL
4.	Mean of Social Sustainability performance	MEANSCOALL
5.	Supply Chain Collaboration item 1	SCC1
6.	Supply Chain Collaboration item 2	SCC2
7.	Supply Chain Collaboration item 3	SCC3
8.	Supply Chain Collaboration item 4	SCC4
9.	Supply Chain Collaboration item 5	SCC5
10.	Supply Chain Collaboration item 6	SCC6
11.	Supply Chain Collaboration item 7	SCC7
12.	(Lean production * Supply chain collaboration)	MULTIMEANLPSCC
13.	(Lean production * Supply chain collaboration item SCC1)	MULTIMEANLPSCC1
14.	(Lean production * Supply chain collaboration item SCC2)	MULTIMEANLPSCC2
15.	(Lean production * Supply chain collaboration item SCC3)	MULTIMEANLPSCC3
16.	(Lean production * Supply chain collaboration item SCC4)	MULTIMEANLPSCC4
17.	(Lean production * Supply chain collaboration item SCC5)	MULTIMEANLPSCC5
18.	(Lean production * Supply chain collaboration item SCC6)	MULTIMEANLPSCC6
19.	(Lean production * Supply chain collaboration item SCC7)	MULTIMEANLPSCC7

It must be noted here that new variables have been created in SPSS with regard to Lean Production items and each one of the sustainability performance factors by taking the mean of the items measuring those constructs. However, with regard to the Supply Chain Collaboration, each individual item measuring the construct was used to check for its moderation. This arrangement provided a deeper insight into the moderation of the construct Supply Chain Collaboration at the item level.

5.14.1. Moderation of equation 5.4

Economic sustainability performance = k3 + b4 (Lean production) + b5 (Supply chain collaboration) + b6 (Lean production * Supply chain collaboration) +e4 → (5.4)

Equation 5.4 can be rewritten in terms of all the seven items of SCC namely SCC1 to SCC3 as follows:

MEANECONALL = k(31) + (b41)(MEANLP) + (b51)(SCC1)
+b(61)(MULTIMEANLPSCC1) + (e41) → (5.4.1)

MEANECONALL = k(32) + b(42)(MEANLP) + (b52)(SCC2)
+ (b62)(MULTIMEANLPSCC2) + (e42) → (5.4.2)

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$$\text{MEANECONALL} = k(37) + b(47)(\text{MEANLP}) + (b57)(\text{SCC7}) + (b67)(\text{MULTIMEANLPSCC7}) + (e47) \rightarrow (5.4.7)$$

Regression performed produced the following results. The main table generated by SPSS that shows whether moderation of the relationship between the independent and dependent variables by supply chain collaboration occurs is provided below (table 5.30).

Table 5.30 Regression result of equation 5.4.1 related to SCC1.

Coefficients[a]						
Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	2.037	.343		5.946	.000
	MAENLP	.156	.093	.173	1.672	.096
	We are in close contact with our customers (SCC1)	-.028	.087	-.046	-.322	.748
	MULTIMEANLPSCC1	.062	.023	.480	2.629	.009
a. Dependent Variable: MEANECONALL						

From table 5.30 it can be seen that the relationship between the variable MULTIMEANLPSCC1 and MEANECONALL is statistically significant (p-value = 0.009 which is < 0.05). However, the relationships (MEANLP → MEANECONALL) and (SCC1 → MEANECONALL) were not found to be statistically significant (p-value 0.096 and 0.748 respectively). This shows that SCC1 does not moderate the relationship MEANLP→MEAN because when the product term MULTIMEANLPSCC1 is introduced in the regression process the other two constructs namely MEANLP and SCC1 did not have a statistically significant relationship with MEANECONALL. A similar exercise was conducted with regard to all the variables SCC2 to SSC7 with regard to equations (5.4.2 to 5.4.7) and it was found that only two items namely SCC2 and SCC6 were found to moderate the relationship between MEANLP and MEANECONALL. This is tabulated in tables 5.31 and 5.32.

Table 5.31 Regression result of equation 5.4.2 related to SCC2

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.450	.340		7.206	.000
	MAENLP	.238	.097	.264	2.446	.015
	Our customers are actively involved in our product design process (SCC2)	-.121	.095	-.223	-1.275	.204
	MULTIMEANLPSCC2	.057	.027	.451	2.135	.034
a. Dependent Variable: MEANECONALL						

Table 5.32 Regression result of equation 5.4.2 related to SCC6

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.029	.348		5.832	.000
	MAENLP	.190	.094	.211	2.022	.045
	We maintain close communications with our suppliers about quality and design (SCC6)	-.003	.087	-.005	-.035	.972
	MULTIMEANLPSCC6	.050	.023	.410	2.151	.033
a. Dependent Variable: MEANECONALL						

It can be seen from tables 5.31 and 5.32 above although the moderators SCC2 and SCC6 did not have a statistically significant relationship with MEANECONALL (p-value 0.204 and 0.972 respectively) yet moderation can be said to occur. The reason is that the other relationships namely (MEANLP → MEANECONALL) (in tables 5.31 and 5.32), (MULTIMEANLPSCC2 → MEANECONALL) and (MULTIMEANLPSCC6 → MEANECONALL) were found to have statistically significant relationships (p-value 0.015, 0.045, 0.034 and 0.033 respectively). From these results of regression it can be seen that the relationship between Lean Production and Economic Sustainability Performance is moderated by Supply Chain Collaboration. In addition, it can be seen that the regression coefficients of the construct MULTIMEANLPSCC2 in tables 5.31 and 5.32 was measured as 0.057 and 0.05 respectively which are positive. Thus it can be concluded that hypothesis H7 which states "Supply chain collaboration moderates the impacts of Lean production practices on economic sustainability performance" is supported. In real terms it means that the supply chain collaboration namely "customers are actively involved in our product design process" and "We maintain close communications with our suppliers about quality and design" enable the firms to achieve economic sustainability when the production line adopts lean methodology. For example, Shekarian et al., (2022) argue that nowadays, companies that use sustainable practices have been found to have significant competitive and economic advantage in comparison to those that do not adopt such practices. This has led to many companies to adopt methods by which sustainability concepts are applied in their supply chain design. Lean production actually suggests this. For instance, SCC2 states that "We maintain close communications with our suppliers about quality and design". If this lean production standard is used by companies then those companies would be able to review their existing supply chain collaboration and modify such a collaboration with newer designs to derive competitive advantages (economic sustainability performance). This way companies implementing lean production can influence the economic sustainability performance directly with a better supply chain collaboration design. Such a finding is not usually found in the literature (Shekarian et al., 2022). This is a new finding.

5.14.2. Moderation of equation 5.5

Environmental sustainability performance = k4 + b7 (Lean production) + b8 (Supply chain collaboration) + b9 (Lean production * Supply chain collaboration) + e5 → (5.5)

This equation can be rewritten as:

MEANENVIALL = k4 + b7 (MEANLP) + b8 (SCC) + b9 (MULTIMEANLPSCC) + e51

Taking into account all the 7 items (SCC1-SCC7) used for measuring the Supply Chain Collaboration equation 5.5 can be expanded into 7 equations as follows:

MEANENVIALL = k(41) + (b71)(MEANLP) + (b81)(SCC1)
+ b(91)(MULTIMEANLPSCC1) + (e51) → (5.5.1)

MEANENVIALL = k(42) + b(72)(MEANLP) + (b82)(SCC2)
+ (b92)(MULTIMEANLPSCC2) + (e52) → (5.5.2)

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MEANENVIALL = k(47) + b(71)(MEANLP) + (b87)(SCC7)
+ (b97)(MULTIMEANLPSCC7) + (e57) → (5.5.7)

Regression results showed that none of the three variables namely MEANLP, (SCC1-SCC7) and the product term MULTIMEANLPSCC7 had statistically significant relationship with MEANENVIALL. Thus it was concluded that hypothesis H8 which states that "Supply chain collaboration moderates the impacts of Lean production practices on environmental sustainability performance" is not supported. This implies that none of the seven items used to measure supply chain collaboration were found to moderate the relationship between Lean Production and Environmental Sustainability Performance. However, this result is contradicting the widely accepted view that the relationship between lean production and environmental sustainability performance is affected by supply chain collaboration (e.g. Piercy and Rich, 2015). One reason that could have resulted in this situation could be that supply chains are very complex and sustainability issues including environmental sustainability could be very difficult to be tackled alone (Schwalbach, 2022). Schwalbach (2022) adds that supply chain collaboration requires the right partners who have the right technology. To some extent this aspect could be true which must have resulted in the situation wherein the hypothesis has been rejected.

5.14.3. Moderation of equation 5.6

Social sustainability performance = k5 + b10 (Lean production) + b11 (Supply chain collaboration) + b12 (Lean production * Supply chain collaboration) +e6 → (5.6)

This equation can be rewritten as:

MEANSOCALL = k5 + b10(MEANLP) + b11(SCC) + b12(MULTIMEANLPSCC) + e6

Taking into account all the 7 items (SCC1-SCC7) used for measuring the Supply Chain Collaboration equation 5.6 can be expanded into 7 equations as follows:

MEANSOCALL = k(51) + (b101)(MEANLP) + (b111)(SCC1)
+ b(121)(MULTIMEANLPSCC1) + (e61) → (5.6.1)

MEANSOCALL = k(52) + b(102)(MEANLP) + (b112)(SCC2)
+ (b122)(MULTIMEANLPSCC2) + (e62) → (5.6.2)

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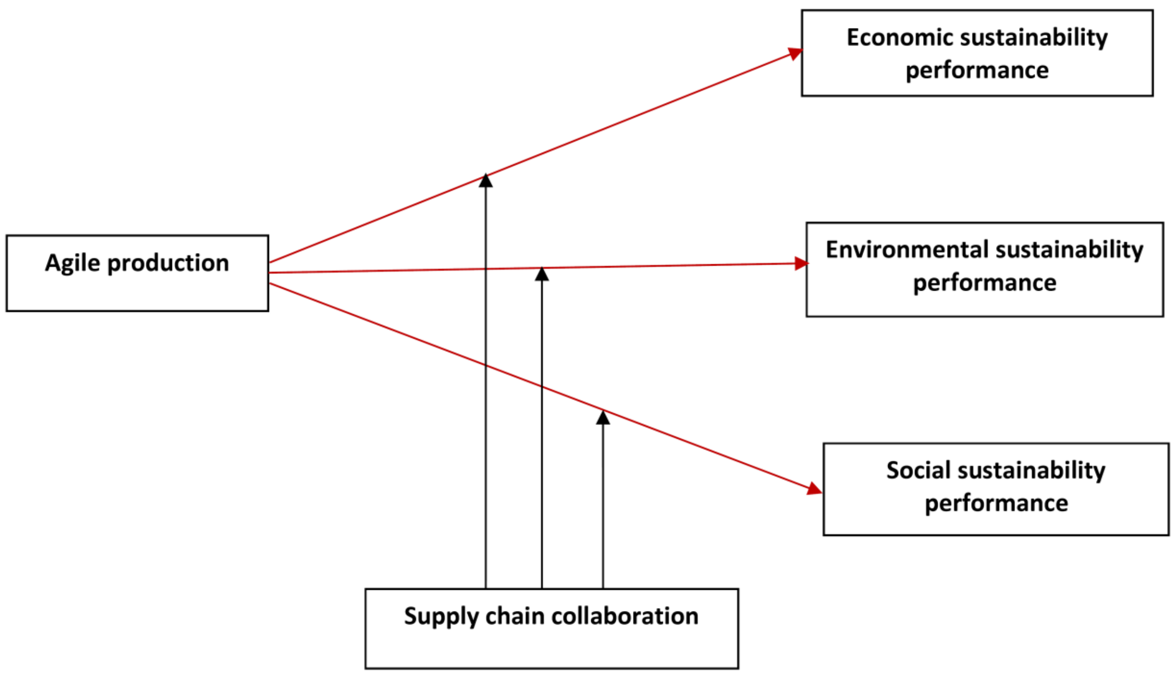
MEANSOCALL = k(57) + b(107)(MEANLP) + (b117)(SCC7)
+ (b127)(MULTIMEANLPSCC7) + (e67) → (5.6.7)

Regression results showed that none of the three variables namely MEANLP, (SCC1-SCC7) and the product term MULTIMEANLPSCC7 had statistically significant relationship with MEANSOCALL. Thus, it was concluded that hypothesis H9 which states that "Supply chain collaboration moderates the impacts of Lean production practices on social sustainability performance" is not supported. The reason for this result could be explained in a similar manner as has been explained in the previous section.

5.15 Moderation by supply chain collaboration on the relationship between agile production and sustainability performance

Figure 5.10 provides the moderation effect of supply chain on the second model (figure 5.6).

Figure 5.10 Moderation of supply chain collaboration on the relationship between agile production and sustainability performance



As explained section 5.14 the regression equation that defines the relationship between agile production and each one of the three sustainability performance variables can be written as in equations 5.7, 5.8 and 5.9.

Economic sustainability performance = k6 + b13 (Agile production) + e7 → (5.7)

Environmental sustainability performance = k7 + b14 (Agile production) + e8 → (5.8)

Social sustainability performance = k8 + b15 (Agile production) + e9 → (5.9)

The moderation by supply chain collaboration requires definition of the product factors using the agile production and supply chain collaboration terms. As described in section 5.14 earlier, a similar process was followed to test the moderation effect of supply chain collaboration on the relationship between agile production and sustainability performance factors. To begin with the relevant factors were coded (table 5.33). The following coding was assigned to the variables.

Table 5.33 Coding of variables used in regression to test the moderation effect of supply chain collaboration on the relationship (MAENAP→Sustainability performance factors)

#	Construct	Code used in SPSS
1.	Mean of Agile Production	MAENAP
2.	Mean of Economic Sustainability performance	MEANECONALL
3.	Mean of Environmental Sustainability performance	MEANENVIALL
4.	Mean of Social Sustainability performance	MEANSCOALL
5.	Supply Chain Collaboration item 1	SCC1
6.	Supply Chain Collaboration item 2	SCC2
7.	Supply Chain Collaboration item 3	SCC3
8.	Supply Chain Collaboration item 4	SCC4
9.	Supply Chain Collaboration item 5	SCC5
10.	Supply Chain Collaboration item 6	SCC6
11.	Supply Chain Collaboration item 7	SCC7
12.	(Agile production * Supply chain collaboration)	MULTIMEANAPSCC
13.	(Agile production * Supply chain collaboration item SCC1)	MULTIMEANAPSCC1
14.	(Agile production * Supply chain collaboration item SCC2)	MULTIMEANAPSCC2
15.	(Agile production * Supply chain collaboration item SCC3)	MULTIMEANAPSCC3
16.	(Agile production * Supply chain collaboration item SCC4)	MULTIMEANAPSCC4
17.	(Agile production * Supply chain collaboration item SCC5)	MULTIMEANAPSCC5
18.	(Agile production * Supply chain collaboration item SCC6)	MULTIMEANAPSCC6
19.	(Agile production * Supply chain collaboration item SCC7)	MULTIMEANAPSCC7

The moderation effect of supply chain collaboration on each one of these equations are provided in equations 5.7, 5.8 and 5.9.

- Economic sustainability performance = k9 + b16 (Agile production) + b17 (Supply chain collaboration) + b18 (Agile production * Supply chain collaboration) +e9 → (5.10)
- Environmental sustainability performance = k10 + b19 (Agile production) + b20 (Supply chain collaboration) + b21 (Agile production * Supply chain collaboration) +e10 → (5.11)
- Social sustainability performance = k11 + b22 (Agile production) + b23 (Supply chain collaboration) + b24 (Agile production * Supply chain collaboration) +e11 → (5.12)

5.15.1. Moderation of equation 5.7

The moderation equation is provided in equation 5.10 which is

Economic sustainability performance = k9 + b16 (Agile production) + b17 (Supply chain collaboration) + b18 (Agile production * Supply chain collaboration) +e9 → (5.10).

This can be rewritten based on table 5.33 as

MEANECONALL = k9 + b16 (MEANAP) + b17 (SCC) + b18 (MEANAP * SCC) +e9.

Taking into account all the 7 items (SCC1-SCC7) used for measuring the Supply Chain Collaboration equation 5.10 can be expanded into 7 equations as follows:

MEANSOCALL = k(91) + (b161)(MEANAP) + (b171)(SCC1)
+ b(181)(MULTIMEANAPSCC1) + (e91) → (5.10.1)
MEANSOCALL = k(92) + b(162)(MEANAP) + (b172)(SCC2)
+ (b182)(MULTIMEANAPSCC2) + (e92) → (5.10.2)
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MEANSOCALL = k(97) + (b167)(MEANAP) + (b177)(SCC7)
+ (b187)(MULTIMEANAPSCC7) + (e97) → (5.10.7)

Regression performed produced the following results. The main table generated by SPSS that shows whether moderation of the relationship between the independent and dependent variables by supply chain collaboration occurs is provided below (table 5.34).

Table 5.34 Regression result of equation 5.10.4 related to SCC4

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.358	.487		-.735	.463
	MEANAP	1.009	.150	.941	6.717	.000
	We work as a partner with our customers (SCC4)	.408	.101	.717	4.037	.000
	MULTIMEANAPSCC4	-.087	.029	-.748	-2.979	.003
a. Dependent Variable: MEANECONALL						

From table 5.34 it can be seen that the relationship between the variable MULTIMEANAPSCC4 and MEANECONALL is statistically significant (p-value = 0.003 which is < 0.05). Similarly, the relationships (MEANAP → MEANECONALL) and (SCC4 → MEANECONALL) were found to be statistically significant (p-value 0 and 0 respectively). This shows that SCC4 moderates the relationship MEANAP→MEAN because when the product term MULTIMEANLPSCC4 is introduced in the regression process the other two constructs namely MEANAP and SCC4 yielded a statistically significant relationship with MEANECONALL. In fact all other supply chain collaborating items namely (SCC2, SCC3, SCC5, SCC6 and SCC7) were found to moderate the relationship MEANAP → MEANECONALL except SCC1. It is further seen that the regression coefficient of the relationship (MULTIMEANAPSCC4 →

MEANECONALL) (-0.087) is negative as also the other relationships. Thus, it was concluded that hypothesis H10 which states that “Supply chain collaboration moderates the impacts of Agile production practices on economic sustainability performance” is supported. The significance of this finding is that the relationship (MULTIMEANAPSCC4 → MEANECONALL) is moderated by supply chain collaboration (SCC4). This is demonstrated by the following tables 5.35 and 5.36 generated by SPSS:

Table 5.35 Testing the sign of moderation caused by SCC4

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.694	.196		13.760	.000
	We work as a partner with our customers (SCC4)	-.141	.067	-.247	-2.111	.036
	MULTIMEANAPSCC4	.091	.014	.785	6.713	.000
a. Dependent Variable: MEANECONALL						

From the table 5.35 above it can be seen that both SCC4 and the multiplication component MULTIMEANAPSCC4 are found to be statistically significantly related to the economic sustainability performance factor MULTIECONALL (p-value ≤ 0.05). However, the regression coefficient of SCC4 is negative (-0.141) while that of the multiplication factor MULTIMEANAPSCC4 is positive (0.091). Before concluding that it is SCC4 which has contributed to the negative moderation of the relationship between MEANAP and MULTIMEANAPSCC4, another test was conducted using SPSS. The report from SPSS is provided in table 5.36 below.

Table 5.36 Testing the sign of moderation caused by MEANAP

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.414	.220		6.436	.000
	MULTIMEANAPSCC4	.024	.010	.209	2.431	.016
	MEANAP	.519	.092	.484	5.627	.000
a. Dependent Variable: MEANECONALL						

From table 5.36 above it can be seen that both MEANAP and the multiplication component MULTIMEANAPSCC4 were found to be statistically significantly related to the economic sustainability performance factor MULTIECONALL (p-value ≤ 0.05). It was also found that the regression coefficient of SCC4 is negative (-0.141) (see table 5.35) while that of the multiplication factor MULTIMEANAPSCC4 is positive (0.024). A comparison of the two tables 5.35 and 5.36 shows that it is the factor SCC4 that has contributed to the negative moderation as the regression coefficient of SCC4 is found to be negative. When this component is regressed along with agile production (MEANAP) and the multiplication factor MULTIMEANAPSCC4 together (table 5.34), then the results generated by SPSS shows that the regression coefficient of the multiplication factor MULTIMEANAPSCC4 is negative (-.087) although the regression coefficient of the two other factors namely SCC4 and MEANAP were found to be positive (1.009 and 0.408 respectively). From the above discussions it can be concluded that the negative moderation of the relationship (MEANAP → MULTIMEANAPSCC4) was only caused by the moderating variable SCC4. Similar explanations could be offered with regard to the remaining moderator variables namely SCC2, SCC3, SCC5, SCC6 and SCC7 which were found to moderate the relationship between MEANAP → MULTIMEANAPSCC4 negatively.

That is to say that the supply chain collaboration component (SCC4) "We work as a partner with our customers" is moderating the relationship between agile production and economic sustainability performance as a whole. An example of this could be that when a company that has adopted agile production method (e.g. Customer driven innovation) works towards achieving economic sustainability performance (e.g. Improved the company's marketplace position) then supply chain collaboration needs to ensure that the company works as a partner with its customers. A practical example of this explained by Moreno-Miranda (2022) who argues that there is a necessity for coordination between partners and traders in the social, economic and environmental areas with supply chain links (e.g. agile production). Moreno-Miranda (2022) explains that there is a need to expand research in regard to the relationship between coordination and sustainability which implies research outcomes of this research fills this requirement. For instance, a study of the relationship between the cross functional team (an agile component) and improved company's marketplace position (an economic sustainability performance component) could produce knowledge about the moderation effect of supply chain component namely working as a partner with customers.

5.15.2. Moderation of equation 5.8

The moderation equation is provided in equation 5.11 which is

Environmental sustainability performance = k10 + b19 (Agile production) + b20 (Supply chain collaboration) + b21 (Agile production * Supply chain collaboration) +e10 → (5.11).

This can be rewritten based on table 5.33 as

MEANENVIALL = k10 + b19 (MEANAP) + b20 (SCC)
+ b21 (MEANAP * SCC) +e10.

Taking into account all the 7 items (SCC1-SCC7) used for measuring the Supply Chain Collaboration equation 5.10 can be expanded into 7 equations as follows:

This can be rewritten based on table 5.33 as

MEANENVIALL = k10 + b19 (MEANAP) + b20 (SCC) + b21 (MEANAP * SCC) +e10.

Taking into account all the 7 items (SCC1-SCC7) used for measuring the Supply Chain Collaboration equation 5.10 can be expanded into 7 equations as follows:

MEANENVIALL = k(101) + (b191)(MEANAP) + (b201)(SCC1)
+ b(211)(MULTIMEANAPSCC1) + (e101) → (5.11.1)

MEANENVIALL = k(102) + b(192)(MEANAP) + (b202)(SCC2)
+ (b212)(MULTIMEANAPSCC2) + (e102) → (5.11.2)

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MEANENVIALL = k(107) + b(197)(MEANAP) + (b207)(SCC7)
+ (b217)(MULTIMEANAPSCC7) + (e107) → (5.11.7)

Regression performed produced the following results. The tables 5.37 and 5.38 generated by SPSS that show whether moderation of the relationship between the independent and dependent variables by supply chain collaboration occurs are provided below.

Table 5.37 Regression result of equation 5.11.2 related to SCC2

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.202	.710		-.285	.776
	MEANAP	1.097	.224	.781	4.886	.000
	Our customers are actively involved in our product design process (SCC2)	.348	.154	.491	2.264	.025
	MULTIMEANAPSCC2	-.094	.045	-.631	-2.096	.038

a. Dependent Variable: MEANENVIALL

Table 5.38 Regression result of equation 5.11.4 related to SCC4

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.689	.738		-.934	.352
	MEANAP	1.089	.227	.775	4.786	.000
	We work as a partner with our customers (SCC4)	.469	.153	.628	3.060	.003
	MULTIMEANAPSCC4	-.102	.044	-.667	-2.299	.023
a. Dependent Variable: MEANENVIALL						

Tables 5.37 and 5.38 show that the supply chain collaboration variables SCC2 and SCC4 as the ones that have a moderating effect on the relationship between agile production and environmental sustainability performance. The remaining variables namely SCC1, SCC3, SCC5, SCC6 and SCC7 were not found to moderate the relationship between agile production and environmental sustainability performance. Further, from tables 5.37 and 5.38 it can be seen that the relationships between the variables MULTIMEANAPSCC2 and MULTIMEANAPSCC4 on the one hand and MEANENVIALL on the other is statistically significant (p-values = 0.038 and 0.023 respectively which are < 0.05). Similarly, the relationships (MEANAP → MEANENVIALL), (SCC4 → MEANENVIALL) and (SCC4 → MEANENVIALL) were found to be statistically significant (p-values 0, 0, 0.038 and 0.023 respectively). This shows that SCC2 and SCC4 moderate the relationship MEANAP→MEANENVIALL because when the product term MULTIMEANLPSCC4 is introduced in the regression process the other three variables namely MEANAP, SCC2 and SCC4 yielded a statistically significant relationship with MEANECONALL. However, the moderation by SCC2 and SCC4 appears to be negative (regression coefficients -0.094 and -0.102 respectively). This could be demonstrated in the same way as has described under section 5.14 above. Thus it can be concluded that the hypothesis H11 which states that "Supply chain collaboration moderates the impacts of Agile production practices on environmental sustainability performance" is supported. This result implies that the relationship between agile production and the environmental sustainability performance is moderated by supply chain collaboration inversely. That is to say when supply chain collaboration is improved then the relationship between agile production and the environmental sustainability performance delivers a lower environmental sustainability performance.

The above results provide insight into probable cause due to which the contradictory results have been found in this research. While there could be reasons why supply chain collaboration as a moderator introduced an inverse relationship between agile production and environmental sustainability performance, one important reason that stands out is the one suggested by Schwalbach (2022). As has been mentioned earlier in section 5.14, it can be seen that supply chains are very complex and sustainability issues including environmental sustainability could be very difficult to be tackled alone. Thus while there is support for the finding that H11 is supported in the literature, it is also possible to recognize that there is a need to understand how supply chain collaboration as a variable can play a major role in regard to both the lean and agile methodologies. This inference could be arrived at based on the results achieved in this research which shows that the:

- lean production does not lead to environmental and social sustainability performance while supply chain collaboration moderates the relationship between lean production and economic sustainability performance positively (section 5.14.1).
- that agile production influences environmental sustainability performance negatively while supply chain collaboration is introduced as a moderator of that relationship (see above).

5.15.3. Moderation of equation 5.9

The moderation equation is provided in equation 5.12 which is

Social sustainability performance = k11 + b22 (Agile production) + b23 (Supply chain collaboration) + b24 (Agile production * Supply chain collaboration) +e11 → (5.12)

This can be rewritten based on table 5.33 as

MEANSOCALL = k11 + b22 (MEANAP) + b23 (SCC)
+ b24 (MEANAP * SCC) +e11.

Taking into account all the 7 items (SCC1-SCC7) used for measuring the Supply Chain Collaboration equation 5.11 can be expanded into 7 equations as follows:

MEANSOCALL = k(111) + (b221)(MEANAP) + (b231)(SCC1)
+ b(241)(MULTIMEANAPSCC1) + (e121) → (5.12.1)

MEANSOCALL = k(112) + (b222)(MEANAP) + (b232)(SCC2)
+ (b242)(MULTIMEANAPSCC2) + (e122) → (5.12.2)

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MEANENVIALL = k(117) + b(227)(MEANAP) + (b237)(SCC7)
+ (b247)(MULTIMEANAPSCC7) + (e127) → (5.12.7)

Regression performed produced the following results. An example of the table 5.39 generated by SPSS that shows whether moderation of the relationship between the independent and dependent variables by supply chain collaboration occurs is provided below.

Table 5.39 Regression result of equation 5.12.2 related to SCC2

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.215	.520		-.413	.680
	MEANAP	1.194	.165	.949	7.253	.000
	Our customers are actively involved in our product design process (SCC2)	.233	.113	.368	2.071	.040
	MULTIMEANAPSCC2	-.069	.033	-.516	-2.097	.037
a. Dependent Variable: MEANSOCALL						

Table 5.39 shows that the supply chain collaboration variable SCC2 has a moderating effect on the relationship between agile production and social sustainability performance. Similar results were found with regard to the other supply chain collaboration variables namely SCC3, SCC4 and SCC5. However, SCC1, SCC6 and SCC7 were not found to moderate the relationship between agile production and social sustainability performance. Further, from table--- it can be seen that the relationship between the variable MULTIMEANAPSCC2 and MEANSOCALL is statistically significant (p-values = 0.037 which is < 0.05). Similarly, the relationships (MEANAP → MEANSOCALL) and (SCC2 → MEANENVIALL) were found to be statistically significant (p-values 0 and 0.04 respectively which are < 0.05). This shows that SCC2 moderates the relationship MEANAP→MEANENVIALL because when the product term MULTIMEANAPSCC2 is introduced in the regression process the other two variables namely MEANAP and SCC2 yielded a statistically significant relationship with MEANECONALL. However, the moderation by SCC2 appears to be negative (regression coefficients -0.069). This could be demonstrated in the same way as has described under section 5.15.1 above. Thus it can be concluded that the hypothesis H12 which states that "Supply chain collaboration moderates the impacts of Agile production practices on social sustainability performance" is supported.

This result implies that the relationship between agile production and the social sustainability performance is moderated by supply chain collaboration inversely. That is to say when supply chain collaboration is improved then the relationship between agile production and the social sustainability performance delivers a lower social sustainability performance. One of the reasons could be that in the multiplication factor namely MULTIMEANAPSCC2 either of the variables namely MEANAP or SCC2 could have contributed to the negative moderation. For instance, if supply chain factor is complex then the firms would not be in a position to achieve sustainability performance (Schwalbach, 2022) and lead to a negative sign before the multiplication term. On the other hand, if agility methodology is not well understood for instance no involvement of stakeholders and customers, then also the sustainability performance might not be achieved (El-Khalil and Mezher, 2020) in which case there would be a negative sign before multiplication component. Thus it can be seen that the results of this research has provided new knowledge with regard to the nature of moderation effect of the supply chain collaboration on the relationship between agility production and social sustainability performance. Finally, the unidimensionality and the average variance extracted results are provided next.

5.16 Unidimensionality (Lean model in figure 5.5)

This test is conducted to check whether a model has a set of variables which have only one underlying dimension in common (Janssens et al., 2008). According to Janssens et al., AMOS provides the report on unidimensionality using three different quantities namely p-value of significance (should be ≤ 0.05), the critical ratio (CR) (should be $> \pm 1.96$) and the estimated standardized regression output of the observed variables (should be >0.5).

Table 5.40 Regression Weights: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
AP6	<---	AGILE_ PRODUCTION	.845	.079	10.745	***	par_1
AP5	<---	AGILE_ PRODUCTION	.903	.087	10.349	***	par_2
AP4	<---	AGILE_ PRODUCTION	.774	.087	8.920	***	par_3
AP3	<---	AGILE_ PRODUCTION	.695	.086	8.093	***	par_4
AP2	<---	AGILE_ PRODUCTION	.728	.088	8.323	***	par_5
EconSP1	<---	ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	1.000				
EconSP2	<---	ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	.939	.074	12.661	***	par_6
EconSP3	<---	ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	1.044	.077	13.482	***	par_7
EconSP4	<---	ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	.971	.084	11.534	***	par_8
EconSP5	<---	ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	.777	.079	9.845	***	par_9
EnviSP1	<---	ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	1.000				
EnviSP2	<---	ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	1.093	.092	11.903	***	par_10
EnviSP3	<---	ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	1.015	.087	11.704	***	par_11
EnviSP4	<---	ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	1.167	.097	12.020	***	par_12
EnviSP5	<---	ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	1.115	.091	12.198	***	par_13
EnviSP6	<---	ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	1.054	.088	11.970	***	par_14
SocSP1	<---	SOCIAL_ SUSTAINABILITY_ PERFORMANCE	1.000				
SocSP2	<---	SOCIAL_ SUSTAINABILITY_ PERFORMANCE	.923	.071	12.997	***	par_15
SocSP3	<---	SOCIAL_ SUSTAINABILITY_ PERFORMANCE	1.010	.074	13.670	***	par_16
SocSP4	<---	SOCIAL_ SUSTAINABILITY_ PERFORMANCE	.983	.081	12.089	***	par_17
SocSP5	<---	SOCIAL_ SUSTAINABILITY_ PERFORMANCE	1.125	.078	14.334	***	par_18
SocSP6	<---	SOCIAL_ SUSTAINABILITY_ PERFORMANCE	1.118	.080	14.025	***	par_19
AP7	<---	AGILE_ PRODUCTION	1.004	.090	11.181	***	par_20
AP8	<---	AGILE_ PRODUCTION	1.000				
EconSP8	<---	ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	.803	.078	10.366	***	par_21
AP9	<---	AGILE_ PRODUCTION	.911	.088	10.307	***	par_22
AP10	<---	AGILE_ PRODUCTION	.852	.080	10.686	***	par_23
LP5	<---	LEAN_PRODUCTION	1.027	.164	6.246	***	par_24
LP2	<---	LEAN_PRODUCTION	1.026	.188	5.450	***	par_25
LP7	<---	LEAN_PRODUCTION	.732	.141	5.206	***	par_26
LP8	<---	LEAN_PRODUCTION	1.000				
LP10	<---	LEAN_PRODUCTION	.988	.162	6.088	***	par_27
LP11	<---	LEAN_PRODUCTION	1.094	.172	6.346	***	par_28

From table 5.40 it can be seen that all the three conditions have been met indicating the model in figure 5.5 is unidimensional.

5.17 Unidimensionality (Agile model in figure 5.6)

Table 5.41 Regression Weights: (Group number 1 - Default model) (Agile model))

			Estimate	S.E.	C.R.	P	Label
EconSP1	<---	ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	1.269	.124	10.263	***	par_1
EconSP2	<---	ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	1.179	.112	10.484	***	par_2
EconSP3	<---	ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	1.318	.122	10.817	***	par_3
EnviSP1	<---	ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	1.000				
EnviSP2	<---	ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	1.097	.092	11.881	***	par_4
EnviSP3	<---	ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	1.017	.087	11.658	***	par_5
EnviSP4	<---	ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	1.171	.098	11.979	***	par_6
EnviSP5	<---	ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	1.117	.092	12.133	***	par_7
EnviSP6	<---	ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	1.056	.089	11.909	***	par_8
SocSP1	<---	SOCIAL_ SUSTAINABILITY_ PERFORMANCE	1.000				
SocSP2	<---	SOCIAL_ SUSTAINABILITY_ PERFORMANCE	.919	.072	12.750	***	par_9
SocSP3	<---	SOCIAL_ SUSTAINABILITY_ PERFORMANCE	1.014	.075	13.564	***	par_10
SocSP4	<---	SOCIAL_ SUSTAINABILITY_ PERFORMANCE	.986	.082	11.999	***	par_11
SocSP5	<---	SOCIAL_ SUSTAINABILITY_ PERFORMANCE	1.138	.079	14.367	***	par_12
SocSP6	<---	SOCIAL_ SUSTAINABILITY_ PERFORMANCE	1.126	.081	13.964	***	par_13
EconSP4	<---	ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	1.232	.122	10.088	***	par_14
LP5	<---	LEAN_PRODUCTION	.957	.135	7.112	***	par_15
LP7	<---	LEAN_PRODUCTION	.782	.119	6.580	***	par_16
LP8	<---	LEAN_PRODUCTION	1.000				
LP10	<---	LEAN_PRODUCTION	.885	.135	6.579	***	par_17
LP11	<---	LEAN_PRODUCTION	.969	.141	6.870	***	par_18
LP2	<---	LEAN_PRODUCTION	.978	.159	6.153	***	par_19
EconSP5	<---	ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	.975	.109	8.952	***	par_20
EconSP8	<---	ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	1.000				
AP10	<---	AGILE_PRODUCTION	1.000				
AP9	<---	AGILE_PRODUCTION	1.045	.108	9.657	***	par_21
AP8	<---	AGILE_PRODUCTION	1.156	.109	10.575	***	par_22
AP7	<---	AGILE_PRODUCTION	1.173	.110	10.631	***	par_23
AP6	<---	AGILE_PRODUCTION	.965	.097	9.978	***	par_24
AP5	<---	AGILE_PRODUCTION	1.033	.107	9.691	***	par_25
AP4	<---	AGILE_PRODUCTION	.883	.104	8.461	***	par_26
AP3	<---	AGILE_PRODUCTION	.800	.103	7.747	***	par_27
AP2	<---	AGILE_PRODUCTION	.859	.104	8.244	***	par_28

From table 5.41 it can be seen that all the three conditions have been met indicating the model in figure 5.6 is unidimensional.

5.18 Average variance extracted (AVE)

This test provides an estimate of the discriminant validity of the CFA model in figure 5.1. The steps involved in determining the AVE as follows (Jassens et al., 2008):

5.18.1. Correlate the latent variables: AMOS report provided in table 5.42 below.

Table 5.42 Implied Correlations

	LEAN_PRODUCTION	ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	SOCIAL_ SUSTAINABILITY_ PERFORMANCE	ENVIRONMENTAL_ SUSTAINABILITY_ PERFORMANCE	AGILE_ PRODUCTION
LEAN_PRODUCTION	1.000				
ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	.719	1.000			
SOCIAL_ SUSTAINABILITY_ PERFORMANCE	.678	.800	1.000		
ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	.563	.665	.667	1.000	
AGILE_ PRODUCTION	.802	.702	.773	.557	1.000

5.18.2. Compute the square of the correlations: AMOS report provided in table 5.43 below.

Table 5.43 Square of implied correlations

	LEAN_PRODUCTION	ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	SOCIAL_ SUSTAINABILITY_ PERFORMANCE	ENVIRONMENTAL_ SUSTAINABILITY_ PERFORMANCE	AGILE_ PRODUCTION
LEAN_PRODUCTION	1.000				
ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	0.517	1.000			
SOCIAL_ SUSTAINABILITY_ PERFORMANCE	0.46	0.64	1.000		
ENVIRONMENTAL_SUSTAINABILITY_ PERFORMANCE	0.317	0.442	0.445	1.000	
AGILE_ PRODUCTION	0.643	0.493	0.598	0.31	1.000

5.18.3. Computation of the average of the standard regression weights of items measuring each latent variable:

Table 5.44 Standardized Regression Weights: (Group number 1 - Default model)

	Estimate	**[Σ (ITEMS)] ÷ (Total number of items measuring a construct)**
LP2	.557	(LP2+LP5+LP7+LP8+LP10+LP11)/6 =0.6155
LP5	.664	
LP7	.578	
LP8	.630	
LP10	.617	
LP11	.647	
AP2	.606	(AP2+AP3+AP4+AP5+AP6+AP7+ AP8+AP9+AP10)/9 = 0.707
AP3	.593	
AP4	.645	
AP5	.738	
AP6	.752	
AP7	.776	
AP8	.779	
AP9	.724	
AP10	.750	

	Estimate	**[Σ (ITEMS)] ÷ (Total number of items measuring a construct)**
EconSP1	.802	(EconSP1+ EconSP2+ EconSP3+ EconSP4+ EconSP5+ EconSP8)/6 =0.779
EconSP2	.827	
EconSP3	.856	
EconSP4	.770	
EconSP5	.692	
EconSP8	.727	
EnviSP1	.753	(EnviSP1+ EnviSP2+ EnviSP3+ EnviSP4+ EnviSP5+ EnviSP6)/6 = 0.839167
EnviSP2	.838	
EnviSP3	.826	
EnviSP4	.865	
EnviSP5	.886	
EnviSP6	.867	
SocSP1	.804	(SocSP1+ SocSP2+ SocSP3+ SocSP4+ SocSP5+ SocSP6)/6 = 0.844
SocSP2	.832	
SocSP3	.863	
SocSP4	.790	
SocSP5	.892	
SocSP6	.883	

5.18.4. Tabulating the AVE:

Table 5.45 AVE tabulation

	LEAN_PRODUCTION	AGILE_ PRODUCTION	SOCIAL_ SUSTAINABILITY_ PERFORMANCE	ENVIRONMENTAL_ SUSTAINABILITY_ PERFORMANCE	ECONOMIC_ SUSTAINABILITY _ PERFORMANCE
LEAN_PRODUCTION	**0.6155**				
AGILE_ PRODUCTION	0.517	**0.707**			
SOCIAL_ SUSTAINABILITY_ PERFORMANCE	0.46	0.64	**0.844**		
ENVIRONMENTAL_SUSTAINABILITY _ PERFORMANCE	0.317	0.442	0.445	**0.839167**	
ECONOMIC_ SUSTAINABILITY_ PERFORMANCE	0.643	0.493	0.598	0.31	**0.779**

AVE is determined by comparing the average of the standard regression weight computed for each one of the constructs as given in table 5.44 with the SMC of the various latent constructs given in table 5.45. In table 5.45 above the bold figures are extracted from table 5.44. The other figures come from table 5.43. According to Janssens et al., (2008) the figures in bold should be >0.5 and none of the other figures in a particular column or row concerning the bold figures should exceed the bold figure to conclude that AVE test is valid. For instance, the figure of 0.6155 is the average of the standardised regression weights of the items measuring LEAN_PRODUCTION. The other figures under this column with heading LEAN_PRODUCTION should all be less than 0.6155. However, one figure pertaining to the relationship LEAN_PRODUCTION - ECONOMIC_ SUSTAINABILITY_ PERFORMANCE that is 0.643 is found to be higher than 0.6155. But the difference between 0.6155 and 0.643 is too close to call for an error and hence verification with the sample correlations (table 5.6) was done. Sample correlations showed that all the correlations are less than the acceptable figure of ≤0.9. Thus taking into consideration the sample correlations as well as the difference between the two figures being so close it was concluded that the results of this research for the latent construct LEAN_PRODUCTION satisfies the condition stipulated to be met has been met. Similar arguments can be extended to the other variables and it can be concluded that the AVE for all latent variable has been met.

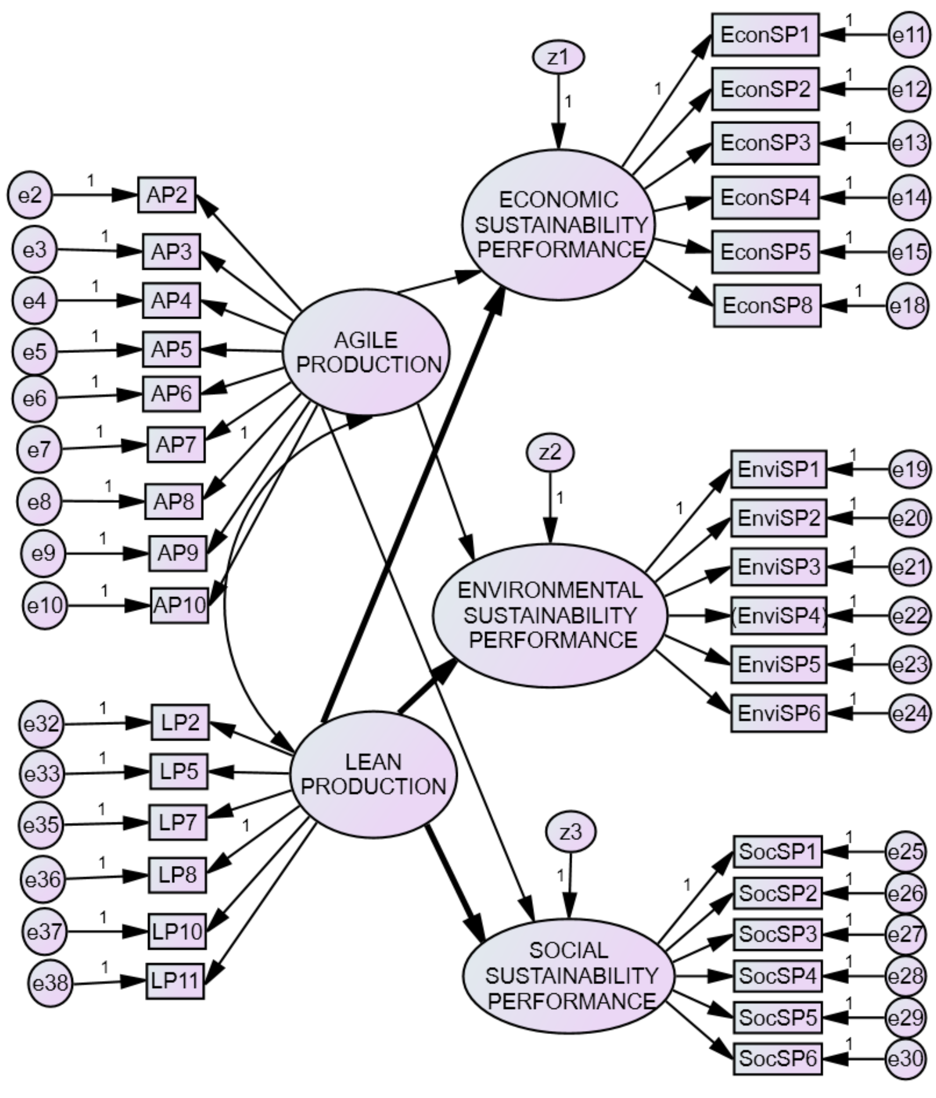
At this stage it was concluded that all the statistical tests that needed to be conducted to test the hypotheses have been completed. This led the researcher to reach a conclusion on the final models. These models are provided next.

5.19 Final models

5.19.1 Model A:

The model in figure 5.11 is the one which is the outcome of the analysis of the model in figure 5.3. This model is the research model (figure 5.4). The resultant model shows that three relationships namely (AGILE PRODUCTION→ECONOMIC SUSTAINABILITY PERFORMANCE), (AGILE PRODUCTION→ENVIRONMENTAL SUSTAINABILITY PERFORMANCE) and (AGILE PRODUCTION→SOCIAL SUSTAINABILITY PERFORMANCE) were found to be statistically insignificant.

Figure 5.11Finally tested research model

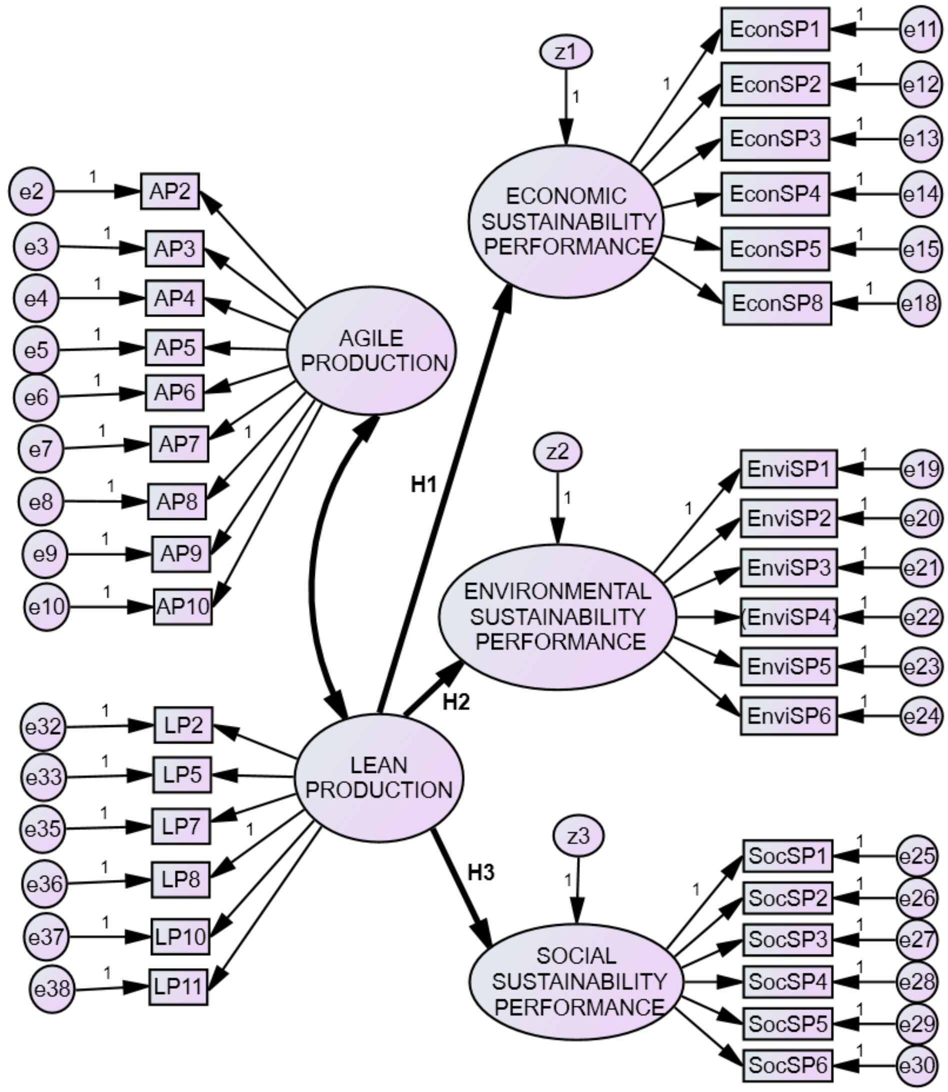


The line in bold indicate that statistically significant relationships exist between the independent and dependent variables. The thin lines indicate statistically insignificant relationships between the independent and dependent variables. However, this model could not be sustained and reasons for not sustaining this model have been provided in section 5.11. Thus the model was split into two (figures 5.5 and 5.6). The finally tested models pertaining to those two figures have been provided next in models B and C.

5.19.2 Model B Lean Production as the exogenous variable:

The model in figure 5.12 is the one which is the outcome of the analysis of the model in figure 5.5. The line in bold indicate that statistically significant relationships exist between the independent and dependent variables. This model shows that all the three relationships namely (LEAN PRODUCTION→ECONOMIC SUSTAINABILITY PERFORMANCE), (LEAN PRODUCTION→ENVIRONMENTAL SUSTAINABILITY PERFORMANCE) and (LEAN PRODUCTION→SOCIAL SUSTAINABILITY PERFORMANCE) have been found to be statistically significant. Thus the three hypotheses namely H1, H2 and H3 have been found to be supported. Additionally, it shows that the association between the LEAN PRODUCTION and AGILE PRODUCTION is also statistically significant.

Figure 5.12 Statistically significant paths of Model B

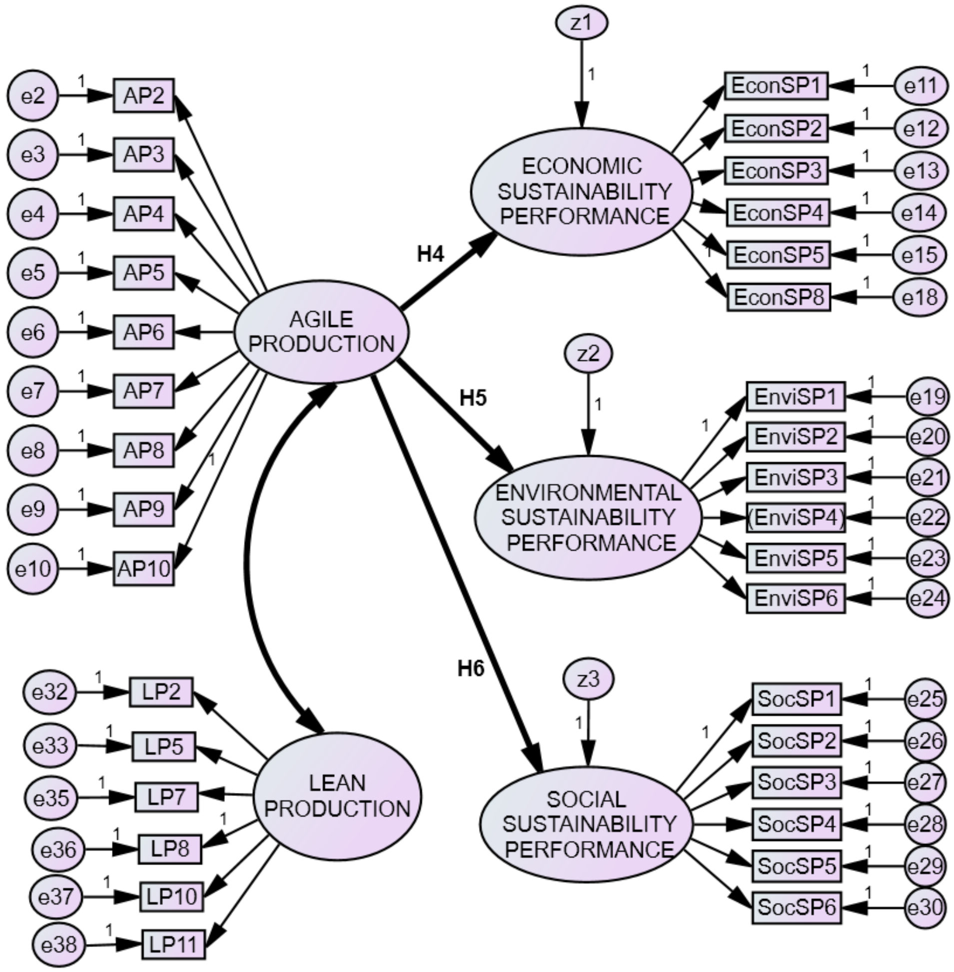


5.19.3 Model C Agile Production as the exogenous variable:

The model in figure 5.13 is the one which is the outcome of the analysis of the model in figure 5.6. The line in bold indicate that statistically significant relationships exist between the independent and dependent variables. This model shows that all the three relationships namely (AGILE PRODUCTION→ECONOMIC SUSTAINABILITY PERFORMANCE), (AGILE PRODUCTION→ENVIRONMENTAL SUSTAINABILITY PERFORMANCE) and (AGILE PRODUCTION→SOCIAL SUSTAINABILITY PERFORMANCE) have been found to be statistically significant. Thus the three hypotheses namely H4, H5 and H6 have been found to be supported.

Additionally, it shows that the association between the LEAN PRODUCTION and AGILE PRODUCTION is also statistically significant.

Figure 5.13 Statistically significant paths of Model C



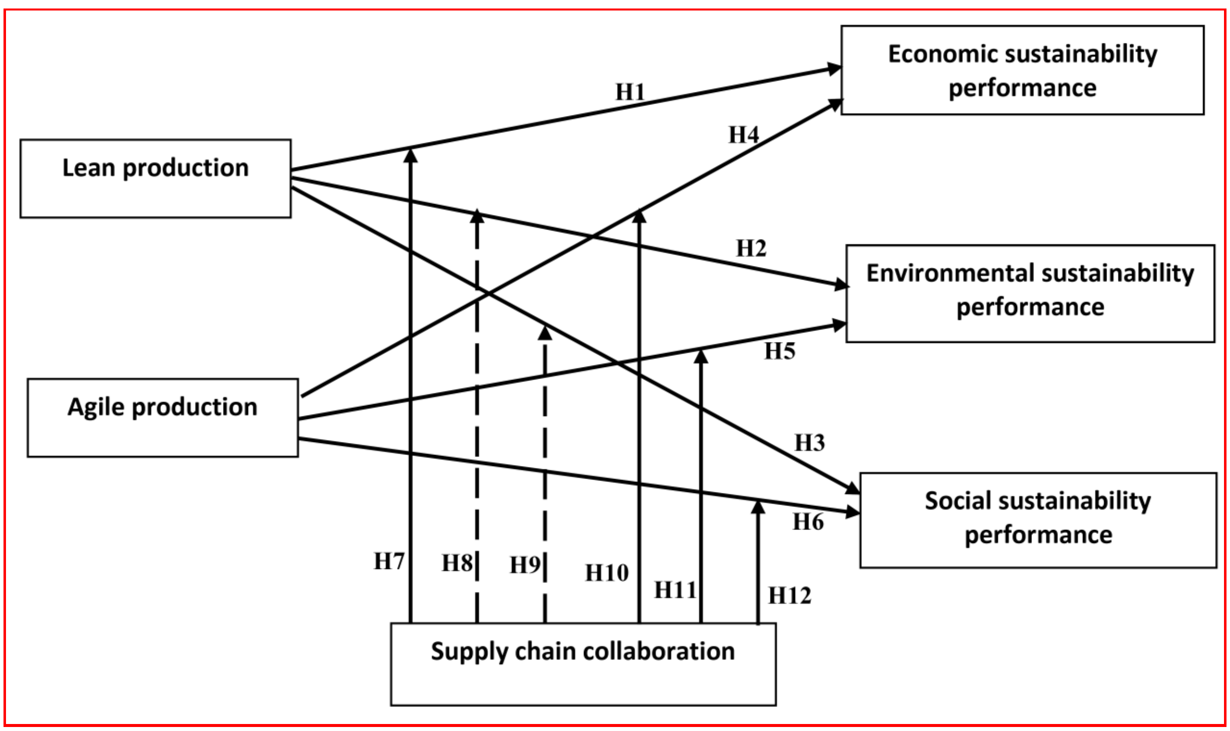
5.19.4 Model D (Moderation by supply chain collaboration):

This is the final model that depicts the status of the tests conducted on moderators. The line in bold indicate that statistically significant relationships exist between the independent and dependent variables. The broken lines indicate statistically insignificant relationships between the independent and dependent variables. This figures shows that out of the 6 moderating paths only 4 have been found to be statistically significant. The remaining two were not. Thus the hypotheses H7, H10, H11 and H12 were supported and hypotheses H8 and H9 were not found to be supported.

Table 5.46: Summary of hypotheses testing results

No.	Path	Type of hypothesised relationship	Results
H1	LP → EconSP	Direct (+)	Supported
H2	LP → EnviSP	Direct (+)	Supported
H3	LP → SocSP	Direct (+)	Supported
H4	AP → EconSP	Direct (+)	Supported
H5	AP → EnviSP	Direct (+)	Supported
H6	AP → SocSP	Direct (+)	Supported
H7	SSC X LP → EconSP	Interaction	Supported (+)
H8	SSC X LP → EnviSP	Interaction	Rejected
H9	SSC X LP → SocSP	Interaction	Rejected
H10	SSC X AP → EconSP	Interaction	Supported (-)
H11	SSC X AP → EnviSP	Interaction	Supported (-)
H12	SSC X AP → SocSP	Interaction	Supported (-)

Figure 5.14 Statistically significant paths of moderators



5.20 Conclusion

This chapter has analysed three different relationships namely the direct relationship between lean production and sustainability performance, agile production and sustainability performance and moderation of the above two relationships by supply chain collaboration. Results led to the conclusion that lean production and agile production are positively related to sustainability performance factors while supply chain collaboration moderates only some relationships. The relationships moderated by supply chain collaboration are: lean production and economic sustainability performance, agile production and economic sustainability performance, agile production and environmental sustainability performance and agile production and social sustainability performance. The results further found that the nature of moderation is negative in all relationships determined by agile production while the lone relationship determined by lean production is moderated positively. Furthermore, the results revealed that it is possible to conclude that there is an association between the lean production and agile production. It was also possible to conclude that lean production and agile production do not operate together in a single model as determinants and when such a situation occurs, it is the lean production that is found to determine the sustainability performance factors, not the agile production. Chapter 6 that follows discusses the findings.

Chapter 6: Discussion

6.1 Introduction

This chapter discusses the findings derived through the data analysis in chapter 5. The research findings have been evaluated using other findings reported by researchers in the literature relevant to this research. The evaluation of the findings is used to answer the research questions. This chapter thus sets the basis for identifying the contribution this research makes to the body of knowledge related to the core issue of the relationship between lean production, agile production, sustainability factors and supply chain collaboration. The model developed in chapter 3 was tested using the data collected for this research. The model was tested using SEM. AMOS results have led the researcher to conclude on the validity of the various relationships posited in the research model. Each of these relationships is discussed next with regard to the various findings.

6.2 Lean and agile production as independent variables

An important aspect that was considered in this research was to test a composite model having both lean and agile production factors as independent variables. The results showed that only lean production had significant but positive relationship with the three sustainability factors. Agile lacked any significant relationship with the three sustainability performance factors.

The findings pointed out that in a firm if both lean and agile production are implemented, then it is lean production that becomes dominant and important to ensure that sustainability performance is achieved. However, it must be noted that there was a significant association that existed in the covariant relationship between lean and agile production. This implies that agile as an associate could support in the influence exerted by lean production on the sustainability performance factors. This gave rise to two decisions that were taken by the researcher. One was to respecify the model in figure 5.3. The respecification resulted in two models (figures 5.5 and 5.6). The second decision was to test the moderation effect of supply chain collaboration with the respecified models (figures 5.9 and 5.10). When the model was respecified as in figures 5.5 and 5.6, then a new situation emerged wherein lean production was considered as independent variable in one model with agile production as a covariant, agile production was considered as an independent variable in another model with lean production as a covariant (figures 5.5 and 5.6). The results of the analysis pertaining to four models namely the ones in figures 5.5 and 5.6 and other two concerning moderation (figures 5.9 and 5.10). The following sections discuss each of those models.

6.3 Relationship between lean production and sustainability performance with agile production as a covariant

In this section the results of the data analysed concerning the model in figure 5.5 are discussed. The results showed that lean production as an independent variable has a direct and positive relationship with the three sustainability performance factors in association with agile production. It was seen from the results in section 5.12 that agile as an associate variable has the potential to influence the relationship between lean production and the three sustainability performance variables in different ways. These aspects are discussed in the following sections taking each one of the relationships namely (lean production → economic sustainability performance), (lean production → environmental sustainability performance) and (lean production → social sustainability performance) individually. Section 6.4 discusses the covariance between lean production and agile production.

6.3.1 Lean production and economic sustainability performance

The study predicted a positive relationship between lean production and economic sustainability performance (H1). The research results support to this prediction (regression estimate 0.852). This implies that if the level of lean production changes in the positive direction, then economic sustainability changes in the positive direction. That is to say that a one unit change in the positive or negative direction of the construct lean production, then there will be a change by 0.852 unit in the positive or negative direction respectively in the construct economic sustainability performance. Similar results have been reported in the literature by other researchers. For instance, Nath and Agrawal, (2020) who empirically investigated lean management and economic sustainability performance, using data of 311 practitioners working in Indian factories, found that lean management has positive and direct effect on economic sustainability performance. Similarly, the two investigations by Dey et al. (2020) and Rupasinghe and Wijethilake (2021) based on SMEs in UK and Sri Lanka, respectively, revealed that lean production directly and positively affects economic sustainability performance. Likewise, Jum'a et al. (2022) collected data from 392 managers from different manufacturing firms in Jordan and argued that there is a direct positive relationship between lean practice as an independent variable and the three sustainability performance factors namely economic, environmental and social. These contributions imply that a manufacturing unit that has adopted lean production methods will be able to drive economic sustainability performance of that firm. Explained by Siegel et al. (2019) who argued that it is the capacity of a company to achieve its financial objectives in the short and long terms using such practices as lean production.

6.3.2 Lean production and environmental sustainability performance

In addition to its impact on economic sustainability performance, the study predicted a positive effect of lean production on environmental sustainability performance (H2). The research results support this hypothesis and lean production has a large influence (regression coefficient of 0.701) on environmental sustainability performance. This implies that a one unit change in the construct lean production in the positive direction will result in a 0.701 unit change in the construct environmental sustainability performance. This is in line with the results reported by Rupasinghe and Wijethilake (2021) who found, using data from 106 SMEs in Sri Lanka, that lean production directly affects all the three different sustainability performance factors. Likewise, Jum'a et al. (2022) argued that there is a direct positive relationship between lean practice as an independent variable and the three sustainability performance factors namely economic, environmental and social. This result is also supported by other researchers including Nath and Agrawal, (2020).

However, this result contradicts some of the researchers who found that lean manufacturing adoption may cause a negative effect on environmental sustainability performance. For instance, Sartal et al. (2018) investigated the lean principles in the context of manufacturing firms in Spain and tested whether those lean principles are ecofriendly. They found that while lean principles of Jidoka and Respect for People (RfP) had a positive influence on environmental sustainability performance, another lean principle JIT was found to have a major trade-off with the green goals. Similarly, Rodrigues and Kumar (2019), who conducted an exploratory case study-based research in three companies to identify the key synergies and misalignments between lean production and green in the global distribution networks context, found that in several cases simultaneous implementation of lean production and green practices can have positive or negative impact depending on the proposed initiative. For example, if a company want to increase service levels to enhance quality of products by having chilled vehicles, this might cause higher CO2 emissions. One explanation for the existence of this divergent situation is that if lean production aims at greater levels of productivity and efficiency that may not be consistent with environmental sustainability performance (Dieste and Panizzolo, 2018).

6.3.3 lean production and social sustainability performance

The study also posited that the implementation of lean production positively influences social sustainability performance (H3). The results suggest that the relationship between the lean production and social sustainability performance is positive and lean production has a large influence (regression coefficient of

0.862) on social sustainability performance. This implies that a one unit change in the construct lean production in the positive direction will result in a 0.862 unit change in the construct social sustainability performance. This is in line with results reported by Jum'a et al. (2022), Rupasinghe and Wijethilake (2021) and Nath and Agrawal., (2020) who found that lean production has direct and positive influence on the three sustainability performance factors namely economic, environmental and social. More specifically, Uhrin et al., (2017), using data from a sample of first tier suppliers in automotive industry in Spain, found that there is a positive relationship between the level of implementation of lean production and the level of workforce development. Furthermore, Bonavia and Garcia (2011), collecting data from 76 ceramic tile companies in Spain, found that the implementation of lean production was associated with higher levels of training and employment security, the latter an important element of social sustainability from the employee perspective.

However, insignificant relationships between lean production and social sustainability performance have been reported in literature contradicting the findings of this research. For instance, while conducting research on multisector manufacturing industries in Malaysia, Xiang and Nor (2021) found that the lean factors namely manufacturing planning and control practices, human resources practices and supplier relationship practices were not statistically significantly related to social sustainability performance. Furthermore, Resta et al., (2016) found a negative relationship between lean practices and social sustainability practices in five industry sectors of investigation.

6.4 Association of agile production with lean production as an independent variable

Table 5.21 shows that the covariance between lean production and agile production is statistically significant. This implies that any variation in agile production is expected to bring in a change in lean production and hence in the three relationships that is between lean production on the one hand and the three sustainability performance factors on the other. This tabulated in table 6.1.

Table 6.1, Lean production as an independent variable but agile as a covariant (figure 5.5)

	Economic sustainability performance	Environmental sustainability performance	Social sustainability performance	Association between the independent variable and agile as covariant
Lean production	0.852	0.701	0.862	0.866

From table 6.1 it can be seen that when lean or agile production as a covariant changes by one unit it introduces a change of 0.866 units in either in the positive or negative direction depending the direction of change. This is a large change. How this impacts the three relationships between lean production on the one hand and the three sustainability performance factors on the other has been clearly discussed in sections 6.3.1, 6.3.2 and 6.3.3. Thus it can be inferred that in firms where lean production is dominant, including agile production practices enhances the influence of lean production on the three sustainability performance variables. This is an important finding not found in the relevant literature in the context of Saudi Arabia. After discussing the findings of the analysis concerning figure 5.5 the next section discusses the findings related to figure 5.6.

6.5 Relationship between agile production and sustainability performance with lean production as a covariant

In this section the results of the data analysed concerning the model in figure 5.6 are discussed. The results showed that agile production as an independent variable has a direct and positive relationship with the three sustainability performance factors in association with lean production. It was seen from the results in section 5.13 that lean as an associate variable has the potential to influence the relationship between agile production and the three sustainability performance variables in different ways. These aspects are discussed in the following sections taking each one of the relationships namely (agile production → economic sustainability performance), (agile production → environmental sustainability performance) and (agile production → social sustainability performance) individually. After that, the covariance between lean production and agile production is discussesed in section 6.6.

6.5.1 Agile production and economic sustainability performance

The study expected a positive relationship between agile production and economic sustainability performance (H4). The results produced by AMOS provided strong evidence to support this expectation and agile production has a large influence (regression coefficient of 0.779) on economic sustainability performance. This implies that a one unit change in the construct agile production in the positive direction will result in a 0.779 unit change in the construct economic sustainability performance. This is in line with the results reported by El-Khalil and Mezher (2020) who found, using data of 212 managers from 152 automotive manufacturing firms in the US, that lean production has direct and positive influence on the three sustainability performance factors namely economic, environmental and social. Most specifically, Nabass and Abdallah (2019) demonstrated that agile production positively and directly affected business/economic performance. This result is also supported by other researchers including Nath and Agrawal, (2020) and Geyi et al., (2020). Although there are other results that have shown negative relationship (e.g. Ojha, 2008) or no relationship (e.g. Shin et al., 2015, Ojha, 2008) between agile production and economic sustainability performance, the outcome of this research has shown a large correlation between agile production and economic sustainability performance.

6.5.2 Agile production and environmental sustainability performance

In addition to its impact on economic sustainability performance, the study predicted a positive effect of agile production on environmental sustainability performance (H5). Results of this research support this hypothesis and agile production has a large influence and agile production has a large influence (regression coefficient of 0.637) on environmental sustainability performance. This implies that a one unit change in the construct agile production in the positive direction will result in a 0.637 unit change in the construct environmental sustainability performance. This is in line with the results reported by Geyi et al., (2020) who found, using data of 311 participants from a variety of manufacturing firms in the UK, that agile production has direct and positive influence on the three sustainability performance factors namely economic, environmental and social. This result is also supported by other researchers including Nath and Agrawal, (2020) and El-Khalil and Mezher (2020). However, Sikabbwele et al., (2021) argue that there could be negative relationship between agile and sustainability goals including environmental sustainability goals in firms that stress customization leading to the manufacturing processes producing more industrial waste. There are also occasional studies that have found neither negative nor positive relationship between agile and environmental sustainability performance. For instance, Claver-Cortés et al., (2007) did not find significant link between agility and environmental sustainability a finding that is similar to the one reported by Carmona-Moreno et al., (2004).

6.5.3 Agile production and social sustainability performance

The study also posited that the implementation of agile production positively influences social sustainability performance (H6). Results of this research support this hypothesis and agile production has a large influence (regression coefficient of 0.827) (table 6.14) on social sustainability performance. This implies that a one unit change in the construct agile production in the positive direction will result in a 0.827 unit change in the construct social sustainability performance. This result is in line with the findings of Nath and Agrawal, (2020) who empirically investigated the relationship between agile production and sustainability performance in manufacturing industry sector in India. Similar arguments are also provided by Geyi et al., (2019) and El Khalil and Mezher (2020) confirming that the findings of this research align with the findings which showed that there is positive relationship between agile production and social sustainability performance. It must also be mentioned here that there is a scarcity of publications that have addressed the relationship between agile production and social sustainability performance.

6.6 Association of lean production with agile production as an independent variable

Table 5.27 shows that the covariance between lean production and agile production is statistically significant. This implies that any variation in lean production is expected to bring in a change in agile production and hence in the three relationships that is between lean production on the one hand and the three sustainability performance factors on the other. This tabulated in table 6.2.

Table 6.2, Agile production as an independent variable but lean production as a covariant (figure 5.6)

	Economic sustainability performance	Environmental sustainability performance	Social sustainability performance	Association between the independent variable and lean as covariant
Agile production	0.779	0.637	0.827	0.833

From table 6.2 it can be seen that when agile or lean production as a covariant changes by one unit it introduces a change of 0.833 units in either in the positive or negative direction depending the direction of change. This is a large change. How this impacts the three relationships between agile production on the one hand and the three sustainability performance factors on the other has been clearly discussed in sections 6.5.1, 6.5.2 and 6.5.3. Thus it can be inferred that in firms where agile production is dominant, including lean production practices enhances the influence of agile production on the three sustainability performance variables. This is an important finding not found in the relevant literature in the context of Saudi Arabia.

6.7 Comparison of the influence of lean and agile production on sustainability performance factors

The discussions in the previous sections have analysed three different configurations of the relationships between lean and agile production on the one hand and the three sustainability performance factors on the other. The main theoretical model in figure 5.3 yielded only partial results with the relationship between agile production and the three sustainability performance factors not finding statistical significance. Further investigations into the causes revealed that it is worthwhile to respecify the model in figure 5.3 with one independent variable (either lean or agile production) influencing the three sustainability performance factors. This respecification resulted in models in figures 5.5 and 5.6. The analysis of the respecified models brought out significant results that contribute to the body of knowledge of lean production, agility production and sustainability literature. However, a comparison of the performance of the two models was thought of to determine the differences between the two models in figures 5.5 and 5.6 what inferences could be drawn from the comparison. Thus, a comparative table (table 6.3) was prepared. The results are discussed next.

Table 6.3, Comparative performance of the models in figures 5.5 and 5.6

Sustainability performance factor	Impact of lean	Regression weight (lean)	Impact of agile	Regression weight (agile)	Comparison of sustainability parameter performance
Economic sustainability performance	Positive	0.852	Positive	0.779	Lean's influence is greater than agile.
Environmental sustainability performance	Positive	0.701	Positive	0.637	Lean's influence is greater than agile.
Social sustainability performance	Positive	0.862	Positive	0.827	Lean's influence is greater than agile.

From table 6.3 it can be seen that influence of lean production on economic and environmental and social sustainability performance is greater than agile production. This is an important finding the reason being hardly any knowledge is available in the extant literature that provides an idea about the influence of lean and agile production on the three sustainability performance factors in one research concerning manufacturing sector. This knowledge provides a clear idea to the managers in the various firms on where to focus and achieve sustainability. This finding is useful in a situation where a firm is focusing on achieving sustainability performance in regard to all the three factors as research that has addressed all the three sustainability factors in one research project is hardly found in the literature. Most of the researchers have either focused on a single sustainability performance factor for instance economic (Kalyar et al. 2019) or environmental (Yang et al. 2011) or sometimes a couple of sustainability factors (Anastasov et al., 2019) and not all the three in one research. For instance, García-Alcaraz et al., (2021) argue that all research outcomes found in the literature analyze sustainability as a generic concept and most papers have only dealt with environmental sustainability ignoring social and economic sustainability. In fact, a comparison of this nature has enabled an evaluation of the relationship between lean production and agile production in regard to their influence on the three sustainability factors which is rarely found in the literature. Such an evaluation can help practitioners and researchers to understand the importance of the dominance of a particular production process and the relationship between to production processes in helping a firm attain sustainability. For instance, Varela et al., (2019) evaluated the relationship between lean manufacturing and industry 4.0 to explain how firms can achieve sustainability. Thus the findings of this research provide knowledge to managers on how to deal with all the three sustainability factors in any firm which has implemented lean production or agile production or both and the extent to which the two process impact sustainability.

6.8 Correlation between sustainability factors

An analysis was made about the correlation between the three sustainability factors in order to understand on which of the three sustainability factors firm owners should focus. From table 6.4 it can be seen that the correlation between the three factors is positive and large.

Table 6.4, Correlation amongst sustainability factors based on figure 5.1

Correlation between	Value
Economic sustainability performance and environmental sustainability performance	0.665
Economic sustainability performance and social sustainability performance	0.8
Environmental sustainability performance and social sustainability performance	0.667

However, an examination of the table 6.4 shows that no single factor can dominate the achievement of sustainability in a manufacturing firm. According the managers and above, it is always a combination of sustainability factors that need to be considered as there is a clear statistically significant correlation between the three sustainability factors. Thus if one firm wants to focus on economic sustainability, that firm cannot ignore its correlation with social or environmental sustainability. This implies that the firm needs to achieve sustainability in all the three sustainability factors at the same time. Further, it can be seen that the impact of such a correlation is more on the economic-social sustainability relationship than the other two. That is to say that environmental sustainability has more or less equal correlation with either economic sustainability or social sustainability implying that when focus is on environmental sustainability then there should be equal consideration on achieving economic and social sustainability. However, when the focus is on social sustainability then the focus on economic sustainability should be higher than that of environmental sustainability. This is a unique finding. In the literature it can be seen that firms that implement lean production or agile production focus more on one of the sustainability factors and not a pair. For instance, Venugopal and Saleeshya (2019) argue that where firms implement lean production, it appears that those firms give weightage to economic aspects while where firms implement agile production, there it appears that firms give weightage to social sustainability. In comparison to these arguments it can be seen that the outcome of this research shows that there is a need to weigh the correlation between any sustainability factors but not in isolation, an aspect that is widely seen in practice. For instance, Anastasov et al., (2019) argue that environmental and economical sustainability need to be linked to enhance sustainability by citing many real time examples. Anastasov et al., (2019) explain that one of the important aspects in production is the chosen level environmental safety which need to be ensured by an appropriate distribution of sufficient material, financial and human resources in lean production. In firms that emit carbon and polluting the environment, there is a need to have economic sustainability to reduce and control the carbon emission without which environmental sustainability can be guaranteed. In this situation it is clear that environmental and economic sustainability are in play at the same instant. Similar examples can be found in the literature which clearly point out the need to consider a pair of sustainability factors while dealing with long term achievement of sustainability in organisations regardless of whether the firm has implemented lean production or agile production. Such a finding is not commonly reported in the literature.

6. 9 Moderation of the lean production and agile production and sustainability factors

The main aim of this research was to test the moderation of the relationship between lean production and agile production on the one side and sustainability factors by supply chain collaboration. The two models in figures 5.5 and 5.6 were respecified for moderation by supply chain collaboration. The resulting diagrams are provided in figures 5.9 and 5.10. The results of the moderation by supply chain collaboration are discussed step by step beginning with (lean production-economic sustainability performance) relationship.

6.9.1 Moderation of supply chain collaboration on the relationship between lean production and economic sustainability performance

The study predicted that supply chain collaboration moderates the impact of lean production practices on economic sustainability performance (H7). The findings provide support to this prediction and show that moderation of supply chain collaboration contributes to the relationship in the positive direction. That is, when the moderation is high, then the strength of the relationship between lean production and economic sustainability performance could be high. Similarly, when the moderation is low, the strength of the relationship between lean production and economic sustainability performance could be low. Also, it is seen that the relationship between lean production and economic sustainability performance is moderated by only SCC2 “Our customers are actively involved in our product design process” and SCC6 “We keep close communications with our suppliers about quality and design” while the remaining variables do not moderate the relationship.

The importance of the findings emanates from the fact that supply chain collaboration integration can take place only with regard to certain aspects of supply chain and enable the implementation of sustainability performance concepts in firms. Where other aspects of supply chain collaboration are not interacting with the implementation of sustainability performance concepts in firms such a phenomenon could happen in case there are barriers to the integration of supply chain collaboration in the relationship between lean production and economic sustainability performance.

6.9.2 Moderation of supply chain collaboration on the relationship between lean production and environmental sustainability performance

The study predicted that supply chain collaboration moderates the impact of lean production practices on environmental sustainability performance (H8). The findings provide no support to this prediction and show that the relationship namely lean production and environmental sustainability performance is not moderated by supply chain collaboration on either the customer or supplier side. However, statistical analysis shows that supply chain collaboration from the customer side namely SCC2 “Our customers are actively involved in our product design process” acts as a determinant of environmental sustainability performance alongside lean production. This implies that supply chain factors from the customer side could directly influence environmental sustainability performance ignoring the firm’s lean production system.

However, lean production focuses on maintaining close and long relationships with suppliers with high information transparency level to achieve cost reduction and quality improvement (Lamming, 1993). There is strong evidence that close supplier relationships also enhance environmental sustainability performance (Klassen, 2001). Sharing information to reduce the bullwhip effect in firms, has been observed to reduce overproduction, inventory holding, and transportation, reducing environmental impacts (Kainuma and Tawara, 2006). Therefore, this result contradicts the widely accepted view that supply chain collaboration can influence the relationship between lean production and environmental sustainability performance. One explanation for this result might be that supply chains are very complex and sustainability issues could be very difficult to be tackled alone (Schwalbach, 2022) Another reason could be that supply chain collaboration needs the right partners with the right technology (Schwalbach, 2022).

6.9.3 Moderation of supply chain collaboration on the relationship between lean production and social sustainability performance

The study predicted that supply chain collaboration moderates the impact of lean production practices on social sustainability performance (H9). The findings provide no support to this prediction and show that the relationship namely lean production and social sustainability performance is not moderated by supply chain collaboration on either the customer or supplier side. There appears to be factors that are inhibiting the integration of supply chain collaboration which needs further investigation.

6.9.4 Moderation of supply chain collaboration on the relationship between agile production and economic sustainability performance

The study predicted that supply chain collaboration moderates the impact of agile production practices on economic sustainability performance (H10). The findings provide support to this prediction and show that moderation of supply chain collaboration contributes to the relationship in the negative direction. That is, when the moderation is high, then the strength of the relationship between agile production and economic sustainability performance could be low. Similarly, when the moderation is low, the strength of the relationship between agile production and economic sustainability performance could be high. Also, it is seen that the relationship between agile production and economic sustainability performance is moderated by only SCC4 “We work as a partner with our customers” while the remaining variables do not moderate the relationship.

6.9.5 Moderation of supply chain collaboration on the relationship between agile production and environmental sustainability performance

The study predicted that supply chain collaboration moderates the impact of agile production practices on environmental sustainability performance (H11). The findings provide support to this prediction and show that moderation of supply chain collaboration contributes to the relationship in the negative direction. That is, when the moderation is high, then the strength of the relationship between agile production and environmental sustainability performance could be low. Similarly, when the moderation is low, the strength of the relationship between agile production and environmental sustainability performance could be high. Also, it is seen that the relationship between agile production and environmental sustainability performance is moderated by only SCC2 “Our customers are actively involved in our product design process” and SCC4 “We work as a partner with our customers” while the remaining variables do not moderate the relationship. That is to say when supply chain collaboration is improved then the relationship between agile production and the environmental sustainability performance delivers a lower environmental sustainability performance. While there could be reasons why supply chain collaboration as a moderator introduced an inverse relationship between agile production and environmental sustainability performance, one important explanation has been provided by Schwalbach (2022). It can be seen that supply chains are very complex and sustainability issues could be very difficult to be tackled alone. It is also there is a need to understand how supply chain collaboration as a variable can play a major role in regard to agile methodology.

6.9.6 Moderation of supply chain collaboration on the relationship between agile production and social sustainability performance

The study predicted that supply chain collaboration moderates the impact of agile production practices on social sustainability performance (H12). The findings provide support to this prediction and show that moderation of supply chain collaboration contributes to the relationship in the negative direction. That is, when the moderation is high, then the strength of the relationship between agile production and social sustainability performance could be low. Similarly, when the moderation is low, the strength of the relationship between agile production and social sustainability performance could be high. Also, it seen that the relationship between agile production and social sustainability performance is moderated by only SCC2 "Our customers are actively involved in our product design process", SCC3 "Our customers involve us in their quality improvement efforts", SCC4 "We work as a partner with our customers" and SCC5 "We maintain cooperative relationships with suppliers' while the remaining variables do not moderate the relationship. The result implies that supply chain collaboration as a moderator introduced an inverse relationship between agile production and social sustainability performance. That is when supply chain collaboration is enhanced then the relationship between agile production and the social sustainability performance delivers a lower social sustainability performance.

6.10 Review of the study's research questions

The present study posed three research questions, as follows:

Research Question 1 (RQ1): What is the nature of the relationship between lean production and the three sustainability dimensions in the presence of agile production?

Research Question 2 (RQ2): What is the nature of the relationship between agile production and the three sustainability dimensions in the presence of lean production?

Research Question 3 (RQ3): What role does supply chain collaboration play in facilitating the relationship between:

(a) Lean production and sustainability dimensions, and

(b) Agile production and sustainability dimensions

All three questions have been addressed as evidenced by the conceptual model specified in Chapter 3, followed by the data collected and the analyses undertaken and presented in Chapter 5. Each question is briefly reviewed next.

Research Question 1 (RQ1): What is the nature of the relationship between lean production and the three sustainability dimensions in the presence of agile production?

From the results of the SEM it can be seen that lean production acts as an independent variable and has a direct and positive influence on the three sustainability dimensions in the presence of agile production as an independent variable. Sections 6.3.1, 6.3.2 and 6.3.3 provided the evaluation of this result.

An important finding is that agile production did not have statistically significant relationship with the three sustainability performance factors in the presence of lean production as another independent variable in the same model. Similar findings have not been reported in the literature as majority of the studies have neither used lean production and agile production in a conceptual model nor have they used all the three sustainability performance factors in one single study. These findings also led to the re-specification of the model as in figures 5.5 and 5.6. Re-specification involved testing the influence of lean production and agile production as independent variables in separate models with agile production acting as a covariant in the model where lean production is conceptualized as an independent variable and the reverse where lean production was conceptualized as a covariant in the model wherein agile production was considered as the independent variable. After re-specifying the model, it was found that lean production was found to influence the three sustainability performance factors with positive association with the construct agile production. This implies that there could be an indirect effect of agile production on the sustainability performance factors by acting as a covariant to lean production an aspect that could be found in practice. Thus it can be concluded that RQ1 has been answered.

Research Question 2 (RQ2): What is the nature of the relationship between agile production and the three sustainability dimensions in the presence of lean production?

The results of the analysis of the data (section 6.2) clearly showed that agile production does not influence sustainability performance factors when it is conceptualized to be an independent variable along with lean production in a single conceptual model. This finding is new as there is hardly any evidence in the literature which shows that researchers have contemplated using both lean production and agile production as independent variables and conceptualized them as influencing the three sustainability factors in a single study. The nearest comparison one could find in the literature is that lean production or agile production is conceptualized as influencing one sustainability performance factor independently without combining the two in one single study.

However, the results of this research shows that using both lean production and agile production with equal weightage in one study yielded a result that showed that when lean production is found in operation in influencing the sustainability performance factors, the operation of agile production was found to be insignificant although an association between lean production and agile production was found to exist that was statistically significant. As noted above, this led to the re-specification of the model into two different. In the first conceptualization (figure 5.5) lean production was made the dominant independent variable and agile production was conceived as an associate variable to lean production, as covariant. In the second conceptualization (figure 5.6) agile production was made the dominant independent variable and lean production was conceived as an associate variable to agile production as covariant.

The results of the anslyses of the two re-specified models clearly showed that both the conceptualisations produced statistically significant results with lean production influencing the three sustainability performance factors positively as an independent variable but in association with agile production and agile production influencing the three sustainability perfomance factors positively as an independent variable but in association with lean production. Thus the answer to the research question is that agile production does not influence the three sustainability performance factors directly when agile production is conceived to operate in combination with lean production. However, in the re-specified models both lean production and agile production were found to influence the three sustainability performance factors directly and positively with either of the two independent variables acting as an associate to each other. Thus it can be concluded that research question RQ2 has been answered.

Research Question 3a (RQ3a): What role does supply chain collaboration play in facilitating the relationship between:

(a) Lean production and sustainability dimensions

With regard to interventions in the relationship between lean production and sustainability dimensions, it can be seen that supply chain collaboration as a factor has the potential to act as an intervention. This was established in sections 6.9.1, 6.9.2 and 6.9.3, where it was noted that the only relationship that is affected by the supply chain collaboration construct is the relationship between lean production and economic sustainability performance. The supply chain collaboration factor is acting as a moderator. It must also be mentioned here that the supply chain collaboration construct concerned with both customer and supplier side effects the relationship between lean production and economic sustainability performance. This is a unique finding. This implies that the supply chain collaboration can support a firm in its effort to maintain economic sustainability performance and there is a need to involve both the customers and suppliers in this effort. Involving supply chain collaboration appears to be advantageous to the firms that have implemented lean production and those firms can now control the influence of supply chain collaboration to achieve a controlled level of economic sustainability performance.

It was also found that that supply chain collaboration as a construct does not intervene in the relationship between lean production and the other two sustainability dimensions namely environmental and social sustainability performance dimensions. Thus it can be concluded that RA3 (a) has been answered.

Research Question 3b (RQ3b): What role does supply chain collaboration play in facilitating the relationship between:

(b) Agile production and sustainability dimensions

With regard to interventions in the relationship between agile production and sustainability dimensions, it can be seen that supply chain collaboration as a factor has the potential to act as an intervention. From 6.9.4, 6.9.5 and 6.9.6, it can be seen that all the three relationships are affected by the supply chain collaboration construct namely the relationship between agile production on the one hand and economic, environmental and social sustainability performance on the other. The supply chain collaboration factor is acting as a moderator contributing to all the three relationships in the negative direction. It must also be mentioned here that the supply chain collaboration construct concerned with customer side effects the relationship between agile production on the one hand and economic, environmental and social sustainability performance on the other. However, with regard to the supplier side it can be seen from section 6.9.6 that the only relationship that was found to get affected by the supply chain collaboration construct was the one between agile production and social sustainability performance. Thus it can be concluded that RA3 (b) has been answered.

6.11 Chapter summary

The foregoing discussions have attempted to provide a comprehensive understanding of the various findings of this research. The main inferences that can be made are that there is a relationship between the lean and agile production constructs as independent variables but not in composite model, rather in two models (figures 5.5 and 5.6). It is seen that both lean and agile production constructs can determine sustainability performance dimensions individually as a single construct as an independent variable and vice versa. Finally, it is seen that supply chain collaboration contributes to influencing the relationship between lean and agile production and sustainability performance as a moderator, but not uniformly - it is only acting as a moderator partially. The final chapter that flows clarifies the contribution that the study makes to the extant knowledge and puts forward suggested directions for future research.

Chapter 7: Conclusion

7.1 Introduction

This chapter provides the conclusions derived from the research. Based on the interpretations given in the previous chapter, this chapter provides the contributions the study has made to the body of knowledge concerning the sustainability performance of firms that adopt lean production and agile production. The chapter sets out how this research has contributed to theory, practice and policy making. Finally, the limitations of the research and recommendations for future research are discussed.

The main aim of this research was to examine the direct relationship between lean production and agile production on the one hand and sustainability performance on the other, with supply chain collaboration as an intervention in that relationship, in the context of manufacturing firms.

It can be concluded that all the four objectives stated in section 1.3 have been achieved. A new conceptual framework was developed (figure 3.1) for this research and has been tested which shows that a relationship between lean production and agile production on the one hand and economic, environmental and social sustainability performance on the other exists (chapter 5). Next the interrelationship between lean production and agile production has been examined and it is shown that there is a positive covariance between the two (sections 6.4 and 6.6; tables 6.1 and 6.2). Section 6.9 showed how supply chain collaboration acts as a moderator and intervenes in the relationship between lean production and agile production on the one hand and the sustainability performance factors on the other.

The research established a statistically valid relationship between lean production and agile production on the one hand and sustainability performance on the other, with supply chain collaboration as an intervention in that relationship. Both lean production and agile production were found to influence the sustainability performance factors positively (sections 6.3 and 6.5). However, it must be noted here that when both the constructs lean production and agile production were implemented as independent variables in a single conceptual model, it is seen from section 6.2 that it is only the lean production that was found to influence the three sustainability performance factors positively and agile production was not found to influence the three sustainability performance factors. This is a new finding. However, when the conceptual model was respecified as in figures 5.5 and 5.6, it was seen that both lean production and agile production were found to influence the three sustainability performance factors positively. It was also found that both lean production and agile production as independent variables act as covariants (sections 6.3 and 6.5). This is a new finding.

This research examined which of the two independent factors had higher impact on sustainability performance (section 6.7). It was found that that influence of lean production on economic and environmental and social sustainability performance is greater than agile production. Furthermore, the examination of the correlation amongst the sustainability performance factors showed that they have a large correlation. This is also a new finding.

Additionally, it was found that when supply chain collaboration was introduced in the relationship between lean production and agile production on the one hand and sustainability performance on the other as a moderator, it was seen that the results obtained were mixed in nature. The examination of this aspect was discussed in section 6.9. While the relationship between lean production on the one hand and economic performance on the other is moderated by supply chain collaboration positively, the other two relationships between lean production on the one hand and environmental performance and social performance on the other are not moderated by supply chain collaboration. However, with regard to agile production, all the three relationships between agile production and the three sustainability performance dimensions were moderated by supply chain collaboration negatively. Thus, it can be concluded that the stated aim for this research has been achieved.

7.2 Contribution to knowledge – theoretical contributions

This research has contributed to the body of knowledge concerning lean production, agile production, sustainability performance factors and supply chain collaboration in the context of manufacturing industries in several important ways. The main contributions to knowledge are as follows:

Firstly, the central issue of this research was to examine whether lean production and agile production can co-exist and enable manufacturing units to achieve sustainable performance while supply chain collaboration acts as an intervention. Researchers argue that given the nature of flexibility associated with agile production and cost efficiency associated with lean, there is a need to address both lean and agile production in a single research study instead of considering them as individual silos (Gunasekaran et al. 2008; Narasimhan et al. 2006; Naylor et al. 1999). However, it is seen that researchers have divergent views on whether lean production and agile production can co-exist to achieve sustainability performance with some arguing for it (Ding et al. 2023; Kant et al. 2016; Galankashi and Helmi, 2016) and others casting doubts on it (Qamar et al. 2020; Hallgren and Olhager, 2009; Goldsby et al. 2006). For instance, Gunasekaran et. al. (2002) found in their study of aerospace industry that lean strategy should be applied to well established products whereas new products may require agile strategy. In both instances, literature shows that there is no conclusive evidence to rely upon which indicates whether or not lean production and agile production can co-exist and if so how (Krishnamurthy and Yauch, 2007). Krishnamurthy and Yauch (2007) classified the existence of lean production and agile production into three categories. They are that lean production and agile production cannot co-exist, lean production and agile production can co-exist supporting each other and lean production is a precursor to agile production. However, this research provides conclusive evidence and shows that when lean production and agile production are positioned to co-exist in a manufacturing unit, it is lean production that is having significant influence on the three sustainability performance factors and not agile production. This is a new contribution to knowledge.

Secondly, when lean production and agile production co-exist, it is found that agile production acts as a covariate to lean production and thus supporting lean production to have a better influence on sustainability performance. This is a new contribution to the existing knowledge. This contradicts the findings of other researchers who argue that lean production acts as a precursor (Flumerfelt et. al. 2012; Narasimhan et al. 2006) to agile production whereas it was found in this research that agile acts as an associate of lean production which directly influences the three sustainability performance factors. In fact, Narasimhan et al. (2006) argued that lean production acts as an antecedent to agile production which was contradicted by Inman et al. (2011) who argued that lean production cannot be an antecedent to agile production but mutually supportive to each other or they cannot co-exist. Thus, the findings of this research indicate that when lean production is dominant in a manufacturing unit, agile production acts as a covariate or associate of lean production, a concept not explicitly indicated in the extant literature. Here lean strategy acts as the dominant strategy with agile supporting it in the development of new products and their production. Thus, the new knowledge discovered in this research has the potential to support manufacturers in practice, and also fills the gap in the literature where it was found that researchers have called for investigating the combined performance of the two methods as current research efforts are restricted to investigating either of the two methods by considering them as individual silos (Knol et al. 2018; Johansson and Osterman, 2017; Pinho and Mendes, 2017; Tarafdar and Qrunfleh, 2017; Tortorella and Fettermann, 2017).

Thirdly, the research delved into the respecified models that were extensions of the original model. Two models emerged. One where lean production was the only independent variable and the other where agile production was the only independent variable. In both cases it was posited that each one of the independent variables was influencing the three sustainability performance factors. Additionally, in the case where lean production was the independent variable, it was posited that agile production will act as the associate of lean production or its covariate. Similarly, in the case where agile production was posited as the independent variable, lean production was visualised as the associate or covariate of agile production. These configurations are new contributions to the knowledge - in the prior literature no previous research was observed to have been conducted to this effect (Chen et al. 2020). Furthermore, even where individual sustainability performance factors are investigated as influenced by either lean production or agile production as independent variables, results produced by other researchers are inconclusive or inconsistent (Awad et al., 2022; León and Calvo-Amodio, 2017). This research has filled these two gaps. This is a new contribution to knowledge as using the discoveries of this research it is possible for the manufacturing firms to predict the relationship between lean production (with agile production as covariate) or agile production (with lean production as covariate) on the one hand and the three sustainability performance factors on the other. The importance of this knowledge resides in the fact that manufacturers can now decisively identify the factors concerning lean production and agile production and link them to the three sustainability performance factors through individual and independent relationships, and seek to optimize their efforts to achieve sustainable performance using lean and agile production strategies.

The findings of this research fulfill the recommendations of various researchers who have argued that the current knowledge available in the literature is inadequate to understand how lean production or agile production influence the three sustainability performance factors. This research has addressed the arguments of Enache et al. (2023) who argued that use of optimum tools to reduce losses and increase profits is not well studied in lean literature. In addition, researchers including Pearce et al. (2021), Melin and Barth (2018) and Satolo et al. (2017) argued that current knowledge with regard to the relationship between lean production on the one hand and environmental and social sustainability performance is insufficient. The findings of this research fill this gap and contribute to knowledge. In a similar vein it can be argued that in regard to the agile production literature researchers including Hartinia and Ciptomulyono (2015) and Acar et al. (2015) have argued that current knowledge prevailing in the literature is not complete with regard to the understanding of the relationship between agile production and sustainability. This research fills this gap and adds to the body of knowledge concerning lean production, agile production and sustainability performance.

Further, an important aspect that draws attention of the researchers is the interaction between the sustainability performance factors that needs to be understood when the three sustainability performance factors are implemented at the same time in manufacturing units that use lean production or agile production or both. Researchers have highlighted that the implementation and operational aspects of the three sustainability factors are complex and difficult to understand when the three sustainability factors are operating in conjunction with each other (Aydoğan and Kara, 2023). There are conflicting results reported in the literature regarding the nature of the interaction between the three sustainability performance factors and the relationship amongst them. For instance, Younis et al. (2017) found inconsistent results with regard to the interaction between the three sustainability performance factors in their research on the relationship between financial performance and the three sustainability performance factors while studying the sustainable development of Asian economies. Similarly, Lai and Wong (2012) found a positive relationship between environmental management and operational performance in green economy while Schoenherr and Talluri (2012) found a positive relationship between sustainable environmental practices and plant efficiency. Hallegate et al. (2011) argued that economic and social improvements tend to go hand in hand indicating a positive relationship while Cole et al. (1997) posited that there exists a relationship between economic growth and environmental decline indicating a negative relationship. Thus, the above examples indicate that while it is possible to agree that both lean production and agile production can positively influence the three sustainability performance factors, however whether such an influence will remove any correlation between the three factors or impact the correlation amongst them. This research found that the influence of lean production or agile production on the three sustainability performance factors can influence the correlation between the three factors. This was evident from the results of this research which showed the positive correlation amongst the three sustainability performance factors can be affected by the strength of the independent variables. This finding is new knowledge as prior research has not tested the relationship between lean production or agile production and the correlation between the sustainability performance factor. This also implies that the three sustainability performance factors are interdependent and the performance of one factor should not be favoured over the other.

Another important contribution to knowledge is the finding that resulted based on the comparison of the influence of lean production and agile production on the three sustainability performance factors. It was found from this research that lean production is having a greater influence on economic, environmental and social sustainability performance factors when compared to agile production. This knowledge can help manufacturers to focus more on the lean production when the three sustainability performance factors are to be achieved. However, it is seen that some results found in the extant literature could not point towards this situation. For instance, the results produced by Venugopal and Saleeshya (2019) shows that where firms implement lean production, it appears that those firms give weightage to economic aspects while firms implementing agile production, it appears that firms give weightage to social sustainability.

After discussing the contribution to the body of knowledge concerning lean production, agile production and sustainability performance, the next discussion focuses on supply chain collaboration that has been introduced as an intervention in the relationship between lean production and agile production on the one hand and the sustainability performance on the other. Introduction of supply chain collaboration in the relationship between lean production and agile production and the sustainability performance in the two distinct models respecified in this research has revealed new knowledge in operationalizing the intervention as a moderator.

A number of contributions to the body of knowledge concerning the concept of supply chain collaboration flow from this research. Foremost, it was found that supply chain collaboration as a moderator impacts only specific relationships. Taking into account the two configurations found in figures 5.5 and 5.6 it can be seen that supply chain collaboration affects the following relationships in various ways as a moderator.

With regard to figure 5.5 the following findings were derived.

1. Supply chain collaboration moderates the impact of lean production practices on economic sustainability performance with regard to both customer side and supplier side and acts as an enabler.
2. Supply chain collaboration does not moderate the impact of lean production practices on environmental sustainability performance either on the customer side or supplier side and could act as an inhibitor.
3. Supply chain collaboration does not moderate the impact of lean production practices on social sustainability performance either on the customer side or supplier side and could act as an inhibitor or be irrelevant to the relationship.

While literature shows (e.g. Riofiandi et al. 2022; Rocio et al. 2019; Feng et al. 2018) that supply chain collaboration influences sustainability performance in lean production environments at the same time Vaishnavi and Suresh (2020) claim that with regard to applications of leagile model in manufacturing and service industries, the quantum of research produced is low and more research is needed to understand the applicability of leagile concept. This gap in the literature has been filled by this research. Another important aspect is that this research has conceived a new concept namely the triangles or triads that is lean production-economic sustainability performance-supply chain collaboration, lean production-environmental sustainability performance-supply chain collaboration and lean production-social sustainability performance-supply chain collaboration. Conceiving such triads provides clarity to the managers in the manufacturing units to classify the supply chain collaboration on both the customer and supplier side and control the lean production and supplier chain collaboration to achieve sustainability performance. Although two out of the three triads have been found to fail in the analysis, yet the triad namely lean production-economic sustainability performance-supply chain collaboration provides a way for the manufacturing units to control the economic sustainability performance using supply chain collaboration in regard to both the customer side and supplier side. This knowledge is new and is not found in extant literature. However, this is an anomalous situation that needs to be investigated further. The lack of significant moderation by supply chain collaboration from both the customer and supplier side of collaboration can be a major challenge to the manufacturing units in implementing complete sustainable performance in regard to all the three factors.

With regard to figure 5.6 the following findings were derived.

4. Supply chain collaboration moderates the impact of agile production practices on economic sustainability performance from the customer side only and acts as a moderator in negative direction. This is a new finding and provides an opportunity for managers in the manufacturing unit to deal with inhibitors in a way that those inhibitors do not affect the supply chain collaboration in achieving economic sustainability (section 6.9.4).
5. Supply chain collaboration moderates the impact of agile production practices on environmental sustainability performance in regard to the customer side of supply chain collaboration only but in the negative direction. This implies that supply chain collaboration could hinder the influence of agile production on the environmental sustainability performance in manufacturing units. This is an anomalous situation.
6. Supply chain collaboration moderates the impact of agile production practices on social sustainability performance but in a negative direction in regard to both the customer and supplier side. This implies that supply chain collaboration could hinder the implementation of social sustainability performance in manufacturing units. This is an anomalous situation as it will be a major bottle neck for manufacturing units which will be expecting an enabling function from the supply chain collaboration from both the customer side and supplier side. Thus, there is a challenge that needs to be recognized by the manufacturing units while implementing the social sustainability performance.

Taking into consideration the arguments of Vaishnavi and Suresh (2020) and based on the earlier discussions provided above, it can be argued that the triads agile production-economic sustainability performance-supply chain collaboration, agile production-environment sustainability performance-supply chain collaboration and agile production-social sustainability performance-supply chain collaboration can be conceived to provide way for manufacturers to maneuver the supply chain collaboration as a construct. Such maneuvering could enable the manufacturing units to find ways to overcome the hindering nature of the triads and make them as enablers. However, the current results do not support the wider knowledge available in the literature that argues that supply chain collaboration is a major enabler of implementation of sustainability performance in industries that have adopted agile strategy (Zhu and Wu, 2022; Vanichchinchai, 2019; Yusuf et al. 2020). The findings of this study thus contradict the existing literature. Deeper investigations may be necessary to understand this anomalous situation.

In summary, this research has conclusively established that both lean production and agile production directly and positively influence each one of the sustainability performance factors in one model through empirical testing. The research also has established through this empirical study that both lean production and agile production act as covariates with agile production acting as a covariate to lean production when lean production is dominant and lean acting as a covariate to agile production when agile production is dominant. In addition, supply chain collaboration was found to act inconsistently as a moderator with regard to the relationship between lean production and sustainability performance on the one hand and agile production and sustainability performance on the other. After understanding the various contributions to knowledge this research makes the next discussion provides a view of the theoretical contributions made by this research.

At the outset it can be seen that more than one theory was required to explain the various relationships that have been posited in the conceptual model given in figure 3.1. They include the RBV (resource based view), lean theory, stakeholder theory, theory of sustainable development, the theory of transaction cost economics (TCE) and the dynamic capability theory. That multiple theories play a role in establishing and testing the various relationships in the conceptual model in figure 3.1 was demonstrated in chapters 3, 5 and 6. Fundamentally, the outcomes of this research have shown that they significantly add value to the concept of sustainability in manufacturing industries by providing original insights into the phenomenon of sustainability performance determined by lean production and agile production.

7.3 Contribution to practice

Managers in factories are always under enormous pressure from stakeholders and regulatory authorities (e.g. customers and governments) to consume resources and control waste generation in a sustainable manner due to concerns on global warming and social issues (Iranmanesh et al. 2018; Zailani et al. 2015). Thus, pressure is being built on the firms to be economically, environmentally and socially responsible. Managing this issues is a challenging and complex task. This research provides a number of practical implications that can help managers in manufacturing units to better understand and manage sustainability performance of firms.

Firstly, this study provides clear guidance to the practitioners about implementing lean production or agile production or both to achieve sustainable performance. It indicates that in a firm if both lean production and agile production are implemented, then it is lean production that becomes dominant and important to ensure that sustainability performance is achieved while agile production only acts as a covariate or associate of lean production. Thus, managers in manufacturing units who are currently implementing the lean production and agile production together or who are thinking of adopting and implementing sustainability performance may wish to apply lean strategy to well established products and agile strategy to new products (Gunasekaran et al. 2002). Here lean strategy acts as the dominant strategy with agile supporting it in the development of new products and their production. Managers should understand that agile production does not influence economic, environmental, and social sustainability performance factors directly when agile production is conceived to operate in combination with lean production. However, in the re-specified models both lean production and agile production influence the three sustainability performance factors directly and positively with either of the two independent variables acting as an associate to each other.

Secondly, lean production in this research has identified six important factors as influencing economic, environmental and social sustainability performance positively. Thus, managers should consider and invest in activities, practices and policies that promote the engendering of this six factors including supplier certification, customer feedback, standardistaion, cellular manufacturing, continuous improvement and total productive maintenance (TPM). For example, managers may wish to implement TPM in manufacturing units to reduce accidents and increase employee safety, which is concerned with social sustainability performance.

Thirdly, agile production in this research has identified nine important factors as influencing economic, environmental and social sustainability performance positively. Thus, managers need to actively engage in leveraging these factors in manufacturing units' process and activates. That includes cross functional teams, flexible production technology, technology leadership, technology awareness, flexible employees, training and development, culture of change, customer driven innovation and responsiveness to changing market. In practical terms, for instance, cross functional teams have a major role to play in determining and reducing waste (Ferreira and Nobre, 2022). In factories which involve multi-functional teams, agile production needs to have unification and synchronization of teams from multi-functions to produce value. This example shows that reducing waste improves environmental sustainability. As a practical example, in sectors like electronics, firms are likely to need to be flexible if they want operate competitively in the market. Fast changes taking place in certain sectors will also need professionals specialized in those sectors, for example where rapdly changing customer demands may require development of new products to meet the changing demand. While developing new products new skillset may be required. Multiskilled employees and multidisciplinary teams may be needed to adapt to the changing needs of the market (Conforto et al., 2014). This example shows that flexibility drives social sustainability performance by way of meeting customers demand through recruitment of multiskilled employees or training and developing current employees.

Fourthly, based on the comparison of the influence of lean production and agile production on the three sustainability performance factors, it was found in this research that lean production is having a greater influence compared to agile production. Therefore, managers should focus more on the lean production when the three sustainability performance factors are to be achieved in their firms.

Fifthly، the study found that involving supply chain collaboration concept appears to be advantageous to the firms that have implemented lean production and those firms can control the influence of supply chain collaboration to achieve a controlled level of economic sustainability performance. In order to support a firm in its effort to maintain economic sustainability performance, managers need to actively engage in leveraging supply chain collaboration dimensions involving both the customers and suppliers. Managers need to work towards establishing active involvement of customers in their product design process, and close communications with suppliers about quality and design. These two collaborative factors were found to influence the relationship between lean production and economic sustainability performance positively in this research.

Finally, the study showed that supply chain collaboration moderates the relationship between agile production and economic, environmental and social sustainability performance in the negative direction. Therefore, managers should be conscious of seeking to adopt and establish a balanced emphasis on supply chain collaboration strategy whilst implementing agile production practices to achieved sustainability performance. As extra emphasis on implementing collaborative activities can extremely effect firms' sustainability performance in agile production environment in the negative way.

7.4 Contribution to policy making

In the face of contradictory expert opinions, managers in manufacturing units can have difficulty in developing strategies to implement sustainability performance in their units (for example Gholami et al. 2021 oppose utility of sustainable performance while Machado et al. 2020 argue in favour sustainable performance). Such contradictory opinions and lack of awareness about the importance and usefulness of implementation of sustainable performance could potentially discourage managers of manufacturing units from forming policies related to implementation of sustainability performance mechanisms in their units. However, the outcome of this research that posits lean production or agile production independently and simultaneously directly and positively influence the three sustainability performance factors, should encourage every manager to look at the implementation of sustainability performance positively. That is to say that evidence is now brought out through this research that manufacturers can unambiguously adopt lean production as the dominant construct with agile production as covariate or agile production as the dominant construct and lean as the covariate and use those constructs to implement sustainability performance in those units. Thus, as policy makers, managers in manufacturing units, and the representative of manufacturers' associated industry and professional bodies should develop policies to guide the adoption of lean production or agile production as dominant enabling constructs as the first step to implement sustainability performance.

The second step should be to develop policies to implement all the three sustainability performance factors in the unit. The evidence from this research clearly indicates that all the three sustainability performance factors could be simultaneously implemented. Thirdly as policy makers, both managers and the representative of manufacturers' associated industry and professional bodies should ensure that awareness about the need to implement sustainability performance with the stakeholders so that their support could be solicited in dealing with the various challenges that act as barriers to the implementation of sustainability performance constructs. Fourthly, it is necessary for the managers to encourage a policy to collaborate with both customer side and supplier side while implementing sustainability performance. Fifthly as a matter of policy, managers and their advisors located in their associated industry and professional bodies, must have a holistic understanding of the usefulness of adopting lean production or agile production or both in their units with supply chain collaboration as the moderator of the relationship between lean production or agile production on the one side and sustainability performance on the other. Finally, managers must generate policies on using either lean production or agile production as the dominant construct that could drive the sustainability performance constructs and use either agile production or lean production respectively as the associate of lean production or agile production respectively. Thus, the policy developed by the managers must use either lean production or agile production as the dominant construct, not both. It can therefore be concluded that this research has significantly contributed to policy making by managers in the medium and large manufacturing sectors. After describing the various contributions, this chapter proceeds next to determine the limitations of this research.

7.5 Limitations of research

This research, while making strong contributions to the body of knowledge, theory, practice and policy making concerning sustainability, lean production, agile production and supply chain collaboration in manufacturing units, also has certain limitations. Foremost amongst the limitations is the lack of significant relationship between agile production and the three sustainability performance factors. While there are arguments found in the literature that lean production and agile production can co-exist and function simultaneously in any model, at the same time in this research it is clear that such a claim is not supported. As regards the implementation of sustainability performance in manufacturing units, it is clear from the outcome of this research that only lean production matters and not agile production. There is a need to investigate this further. One reason for this could be the specific territory of Saudi Arabia that was chosen for this research that has strong influence on the manufacturing units and where flexibility may not be perceived as much of a priority as efficiency and cost control for manufacturing units due to what are sometimes observed to be strict government rules and regulation. Secondly, it can be seen that supply chain collaboration was not found to be significantly moderating the relationships between lean production and agile production on the one hand and environmental and social sustainability on the other in specific cases. The reason for this is not clear. Further investigations into this in any other territory could reveal the reason for this. Thirdly, it can be seen that this research did not involve any mediators between lean production and agile production on the one hand the three sustainability performance factors on the other which could have brought out different results. Finally, with regard to the moderator, it was seen that it can also act as a determinant of some sustainability performance factor. This is a deviation from the assumption that supply chain collaboration can only moderate the relationship between lean production and agile production on the one hand and the sustainability performance factor on the other. Further investigations are needed to understand this phenomenon. Further to determining the limitations of this research the next section provides recommendations for future research.

7.6 Recommendation for future research

The findings of this research offer a fertile grounding for researchers to conduct future research. Firstly, there is a need for future researchers to investigate the reasons for agile production not finding significant relationship with the three sustainability performance factors when tested as a construct co-existing with lean production. Qualitative research (e.g. interviews) with practitioners may provide the insights needed. One way to broaden the investigation could be to include mediating variables between both lean production and agile production on the one hand and the three sustainability performance factors on the other. For instance, researchers might examine such factors as 'transformational capabilities' suggested by Mohaghegh et al. (2023) as the mediator. Similarly, Erwin (2021) suggests that introduction of information sharing and advance manufacturing technology as factors that could be introduced as mediators between agile production and sustainability performance.

Secondly, this research was based on quantitative research method. Future research could investigate the various relationships posited in figure 3.1 using a qualitative research method to understand how lean production and agile production could affect the three sustainability performance factors as well as the moderating function of supply chain collaboration. In addition, it would be interesting for further research to build on this study's results by separately examining, again at a more detailed richer level through qualitative research, the customer side and supplier side of SSC, and their independent moderating impact on the relationship between lean production and agile production on the one hand and sustainability performance on the other.

Thirdly, the conceptual model was tested using a sample from medium/large manufacturing firms operating in Saudi Arabia. Further research can reproduce the study in different geographical contexts including other countries and in the service industry sector. Moreover, although this study has suggested that the successful implementation of sustainability performance could be influenced by the firm's size that firms are more likely to generate stronger environmental and social impacts, future study can adopt these research insights to investigate the barriers and enablers of adopting sustainability performance in small-sized firms.

Finally, this research used cross-sectional method to collect data. This data is collected just once over a period of time. The longitudinal studies that collect data more than once, over several weeks or months (Sekaran and Bougie, 2019) can be used for future study to identify more possible causal relationships among lean production, agile production, supply chain collaboration and sustainability manufacturing performance.

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Appendices

Appendix 1 – Survey questionnaire

Dear Sir or Madam

As part of a PhD research study in operations management, we are studying the concepts of lean and agile production, supply chain collaboration, and manufacturing sustainability. The latter is a relatively new field that requires in depth investigation. The purpose of the study is to examine the influence of supply chain collaboration in manufacturing companies on the relationship between lean and agile production and sustainable performance including its economic, environmental and social aspects. This relationship has received little attention and it is therefore important to refine our understanding of the linkages, not least to help guide practitioners in their efforts to adopt suitable lean and agile practices and to help enhance the sustainability outcomes of manufacturing companies.

Your candid and thoughtful responses to the questions comprising this survey will be crucial in providing the necessary information to complete this research. It is not expected that completion will take more than 15 to 20 minutes of your time. Your response and any comments will be treated with strictest confidentiality and will be used solely for the purpose of this research.

If you choose to take part and have any have questions you would like to ask about your participation before doing so, please contact us directly: abdullal.alsahly@brunel.ac.uk in the first instance, or david.gallear@brunel.ac.uk (supervisor).

Please follow this link to the survey questionnaire:
https://qfreeaccountssjc1.az1.qualtrics.com/jfe/form/SV_eR6M8F6wUtQbc6G

Thank you very much for your time and considered opinion.

Kind regards

Abdullah Mohammed Alsahly, PhD Researcher, Brunel University London

Please confirm the following:

• I have read the Participant Information Sheet included with this questionnaire
• I am over the age of 18
• I understand that no personal identifying data is collected in this study, therefore I know that once I have submitted my answers I am unable to withdraw my data from the study
• I agree that my data can be anonymized, stored and used in future research in line with Brunel University's data retention policies
• I agree to take part in this study
I confirm (press here to answer)

Section A

Respondent information:

Please answer all of the following questions, including adding your actual job title (or inserting the most suitable closest job title from those listed in brackets); and your number of years' experience in that/or similar equivalent role.

1 **Job title** ……………………………….. (e.g. General Manager, CEO, Operations/Production Manager, Supply Chain Manager)

2 **Number of years' experience** ……………………………………

Organization information:

Please answer all of the following questions about your manufacturing company:

3 **Industry sector -** Please choose the sector (one only) from the list that most closely describes the nature of your business:

a. Primary sector (agriculture, mining, etc.) [ ]
b. Chemicals, rubber, plastics, non-metallic products [ ]
c. Textiles, wearing apparel and leather [ ]
d. Wood, cork and paper [ ]
e. Metals and metal products [ ]
f. Machinery, equipment, furniture [ ]
g. Pharmaceutical products and preparations [ ]
h. Food and beverages [ ]
i. Electrical, electronic and optical products [ ]
j. Printing and media [ ]

4 **Number of employees:**………………………………

5 **Age of the company:**………………………………………………

Section B

Lean production practices	*1= no implementation*	*2= little implementation*	*3= some implementation*	*4= extensive implementation*	*5= complete implementation*

	Please indicate the extent of implementation of each of the following practices in your plant:	**1**	**2**	**3**	**4**	**5**
1.	Our key suppliers deliver to our plant on a Just-in-time (JIT) basis					
2.	We adopt a formal supplier certification programme					
3.	We take active steps to reduce the number of suppliers in each component/service category					
4.	Our key suppliers have an active role in managing our inventory					
5.	Our customer gives us feedback on quality and delivery performance					
6.	We use a ‘pull’ production system					
7.	Products are classified into groups with similar processing requirements					
8.	Our equipment is grouped for producing the continuous flow of families of products					
9.	We are working to lower setup times in our plant					
10.	Our employees working on the shop floor lead product and process improvement efforts					
11.	We give a portion of every day to planned equipment maintenance activities					

Section C

Agile production Practices	*1= no implementation*	*2= little implementation*	*3= some implementation*	*4= extensive implementation*	*5= complete implementation*

	Please indicate the extent of implementation of each of the following practices in your plant	**1**	**2**	**3**	**4**	**5**
12.	Decentralized decision making					
13.	Cross functional teams					
14.	Use of flexible production technology					
15.	Leadership in the use of current technology					
16.	Technology awareness					
17.	Flexible and multi-skilled employees					
18.	Providing continuous training and development					
19.	Adoption of a culture of change					
20.	Customer driven innovation					
21.	Responsiveness to changing market requirements					

Section D

Supply chain collaboration	*1= strongly disagree*	*2= disagree*	*3= somewhat disagree*	*4=* neither agree nor disagree	*5= somewhat agree*	*6= agree*	*7= strongly agree*

	Please indicate the extent to which you perceive that your plant practices each of the following:	**1**	**2**	**3**	**4**	**5**	**6**	**7**
22.	We are in close contact with our customers							
23.	Our customers are actively involved in our product design process							
24.	Our customers involve us in their quality improvement efforts							
25.	We work as a partner with our customers							
26.	We maintain cooperative relationships with suppliers							
27.	We maintain close communications with our suppliers about quality and design							
28.	We strive to build long-term relationships with our suppliers							

Section E

Economic sustainable performance	*1= not at all*	2= *a little bit*	3= *to some degree*	4= *relatively significant*	5= *significant*

	Please indicate the extent to which you perceive that your plant has achieved each of the following during the past year	1	2	3	4	5
29.	Increased company market share					
30.	Enhanced company image					
31.	Improved the company's marketplace position					
32.	Increased company profitability					
33.	Increased amount of the goods delivered on time					
34.	Decreased inventory levels					
35.	Decreased scrap rate					
36.	Increased product quality					

Section F

Environmental sustainable performance	*1= not at all*	2= *a little bit*	3= *to some degree*	4= *relatively significant*	5= *significant*

	Please indicate the extent to which you perceive that your plant has achieved each of the following during the past year	1	2	3	4	5
37.	Reduction of harmful emissions to the air					
38.	Reduction of liquid waste					
39.	Reduction of solid waste					
40.	Decrease in consumption for hazardous, harmful and toxic materials					
41.	Decrease in frequency for environmental accidents					
42.	Improvement in an enterprise's environmental situation					

Section G

Social sustainable performance	*1= not at all*	**2**= *a little bit*	**3**= *to some degree*	**4**= *relatively significant*	**5**= *significant*

Please indicate the extent to which you perceive that your plant has achieved each of the following during the past year		**1**	**2**	**3**	**4**	**5**
43.	Improved relationship with the community and stakeholders					
44.	Improved work safety					
45.	Improved work environment					
46	Improved living quality of surrounding community					
47	Improved workforce satisfaction					
48	Improved health and wellbeing					

Thank you for taking the time to complete this survey. Your answers will be treated strictly confidentially.

Appendix 2 – Research Ethics Approval

College of Business, Arts and Social Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

10 December 2021

LETTER OF APPROVAL

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 10/12/2021 AND 30/11/2022

Applicant (s): Mr Abdullah Alsahly

Project Title: The Impact of Lean and Agile Production on Manufacturing Sustainability Performance: the Moderation Effect of Supply Chain Collaboration

Reference: 33525-LR-Nov/2021- 35105-1

Dear Mr Abdullah Alsahly

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- Recruitment by email – You must ensure that the collection of email addresses of those you wish to contact is lawful. Do not send mass recruitment emails by entering multiple email addresses in the 'To' field of your email message. You should email each person individually. If you have to send emails to multiple recipients you must use the 'Bcc' function i.e. enter the recipients' addresses in the 'Bcc' field of your email message.
- Data Storage - You store your data on the Brunel Network server
- **Approval is given for remote (online/telephone) research activity only. Face-to-face activity and/or travel will require approval by way of an amendment.**
- **The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.**
- In addition to the above, please ensure that you monitor and adhere to all up-to-date local and national Government health advice for the duration of your project.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor David Gallear

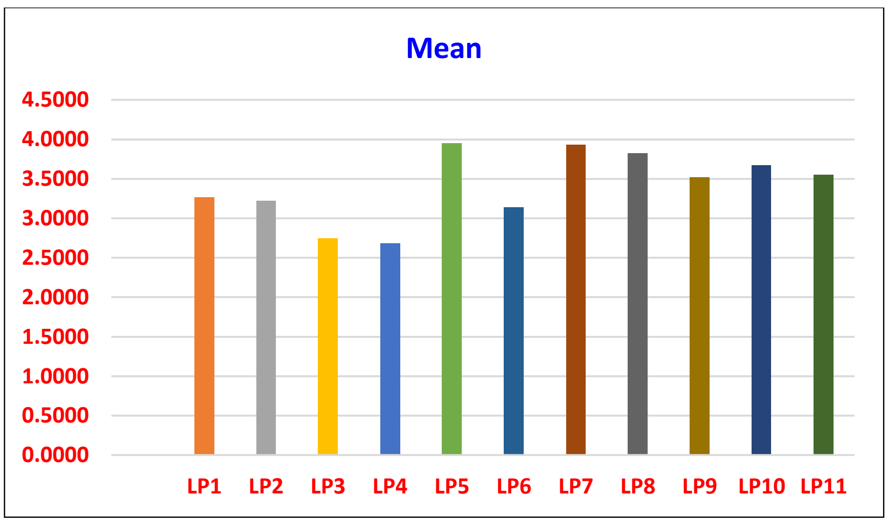
Chair of the College of Business, Arts and Social Sciences Research Ethics Committee

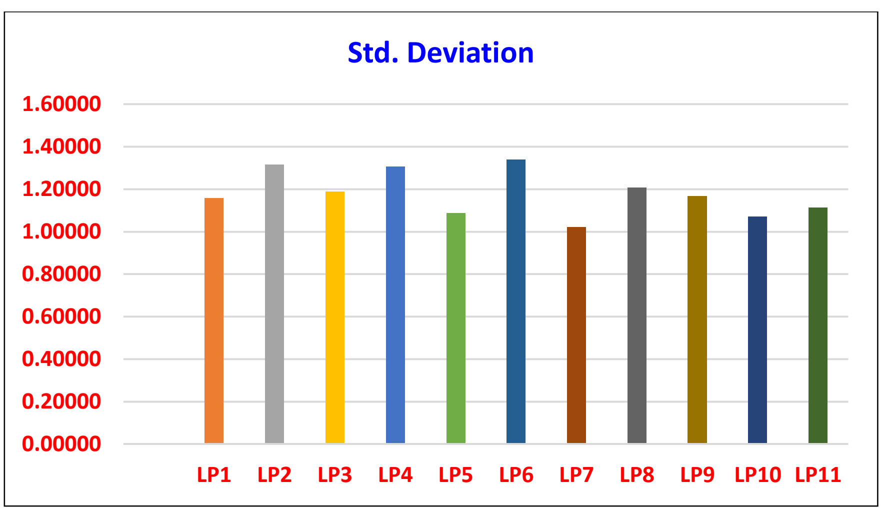
Page 1 of 2

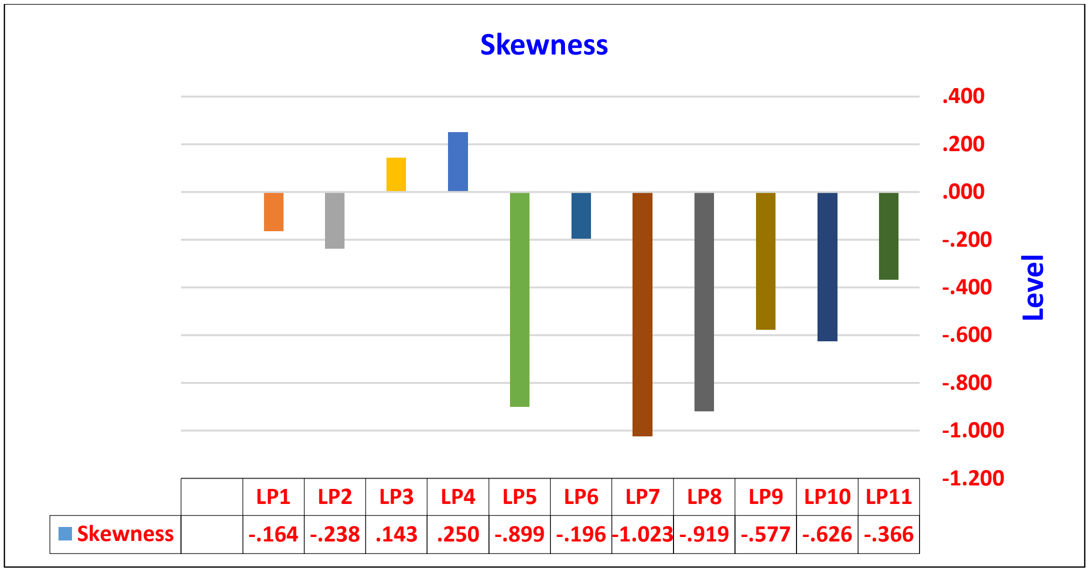
Appendix 3 – Data Presentation and Visualisation

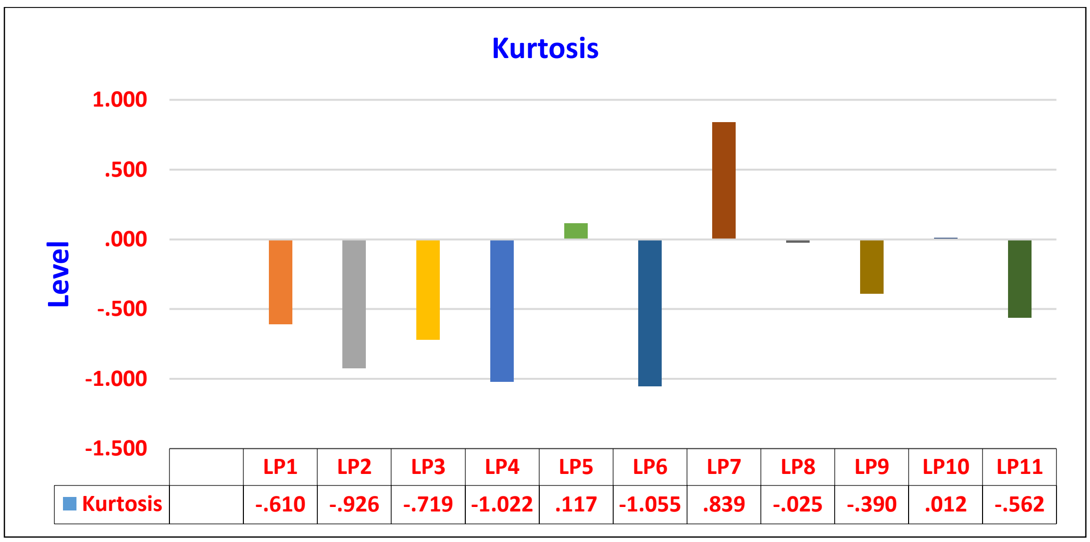
The data presented here concerns four important descriptive quantities namely mean, standard deviation, skewness and kurtosis of the six constructs investigated in this research, that is lean production, agile production, supply chain collaboration, economic sustainability performance, environmental sustainability performance and social sustainability performance. These have been discussed under section 5.4. Here only the graphic representation of the four quantities measure has been provided for each one of the constructs.

Lean production

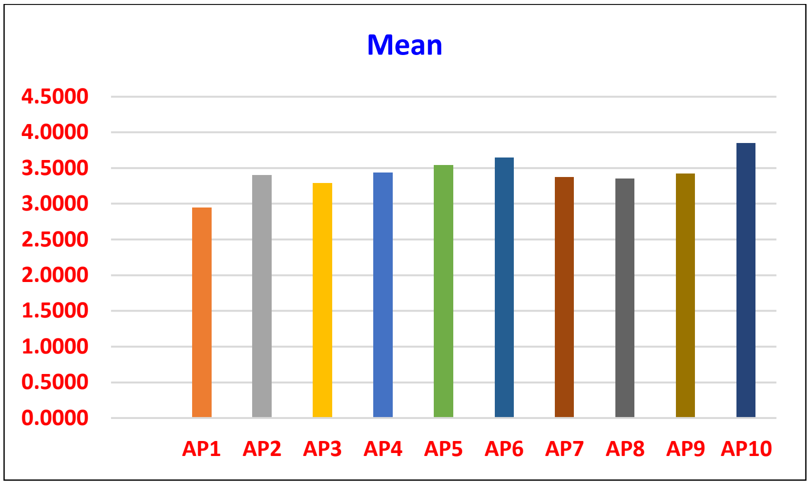


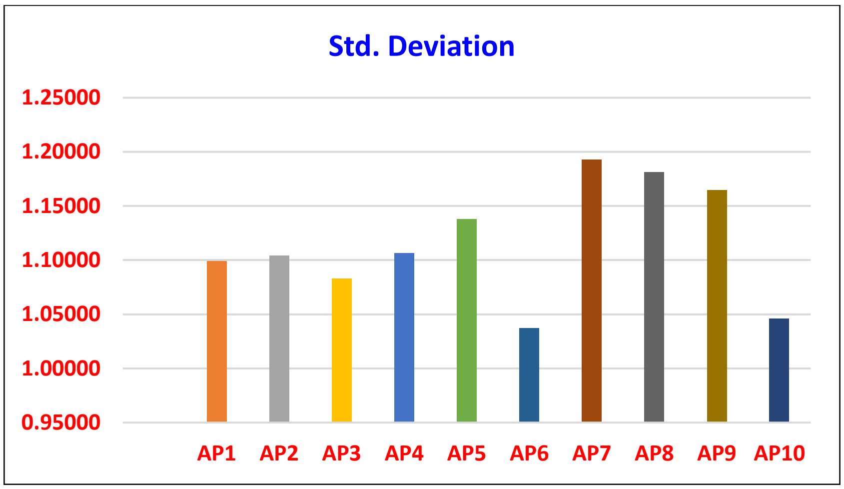


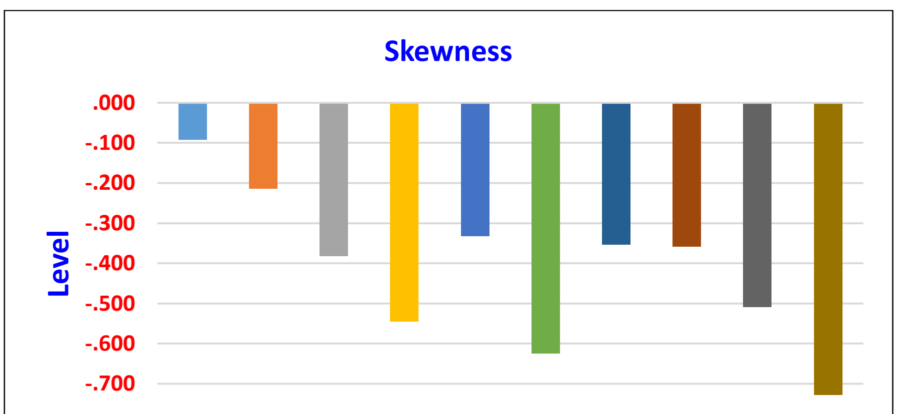

Skewness
.400
.200
.000
-.200
-.400
-.600
-.800
-1.000
-1.200
Level
LP1 LP2 LP3 LP4 LP5 LP6 LP7 LP8 LP9 LP10 LP11
Skewness -.164 -.238 .143 .250 -.899 -.196 -1.023 -.919 -.577 -.626 -.366


Kurtosis
1.000
.500
.000
-.500
-1.000
-1.500
Level
LP1 LP2 LP3 LP4 LP5 LP6 LP7 LP8 LP9 LP10 LP11
Kurtosis -.610 -.926 -.719 -1.022 .117 -1.055 .839 -.025 -.390 .012 -.562

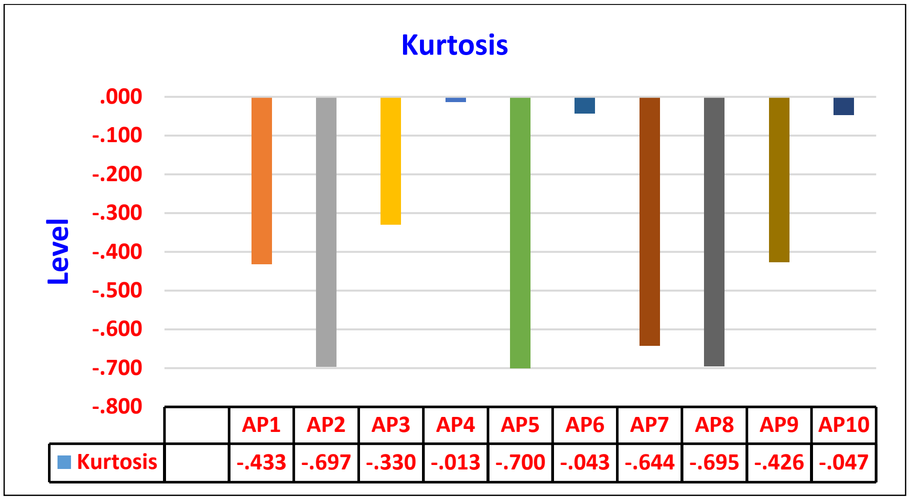
Agile production



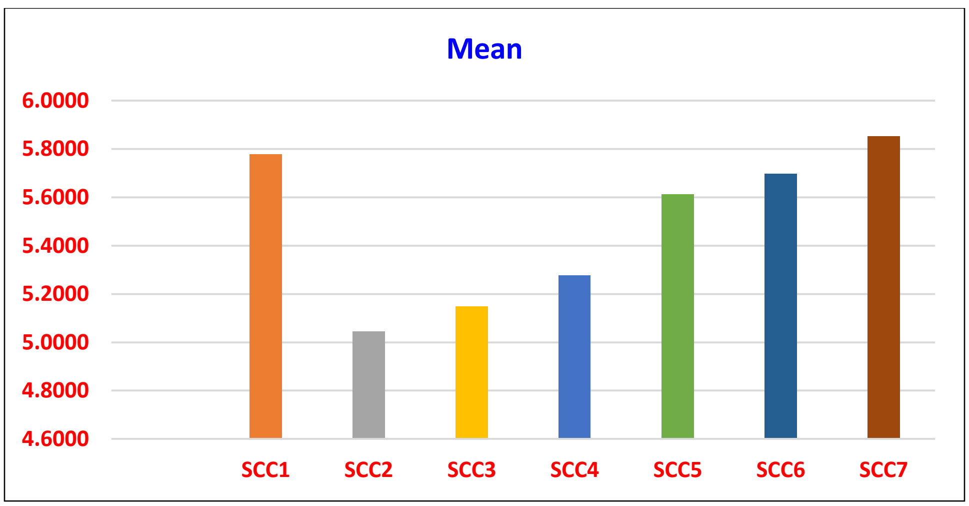


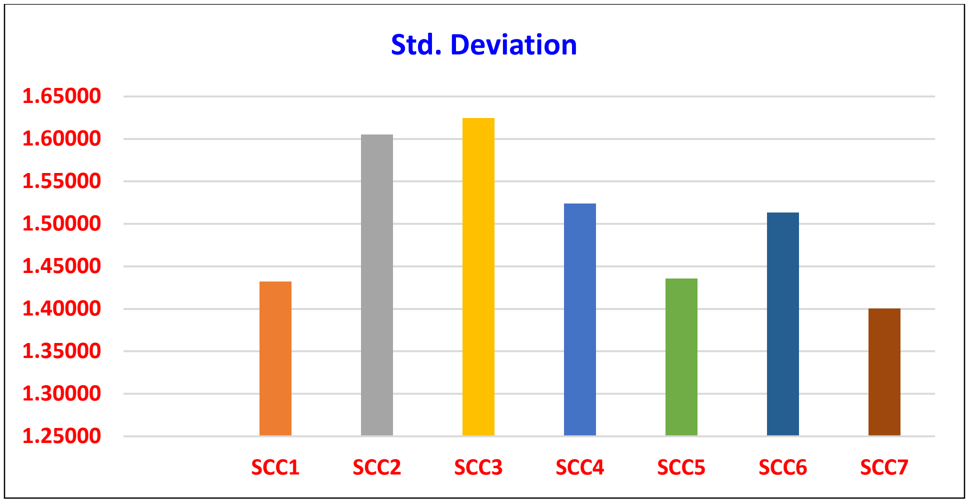


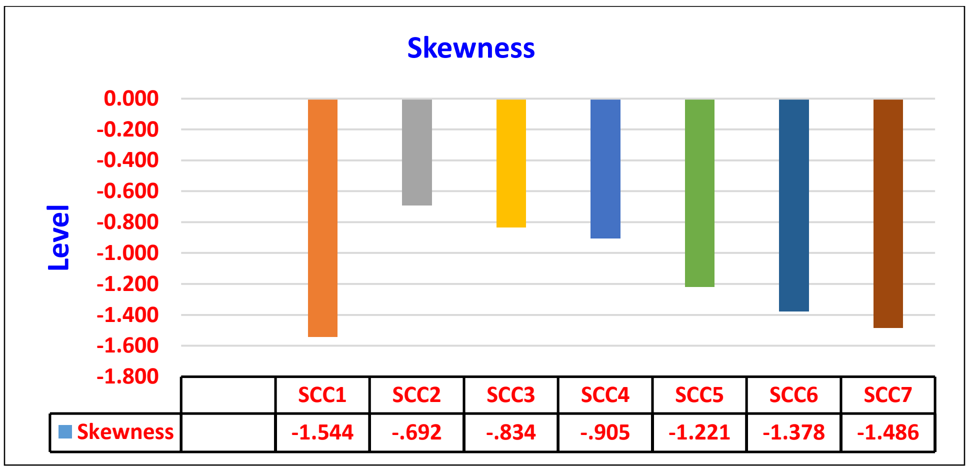
	AP1	AP2	AP3	AP4	AP5	AP6	AP7	AP8	AP9	AP10
Series1	-.093	-.214	-.381	-.545	-.332	-.624	-.353	-.357	-.508	-.728



Supply chain collaboration




Std. Deviation
1.65000
1.60000
1.55000
1.50000
1.45000
1.40000
1.35000
1.30000
1.25000
SCC1
SCC2
SCC3
SCC4
SCC5
SCC6
SCC7


Skewness
Level
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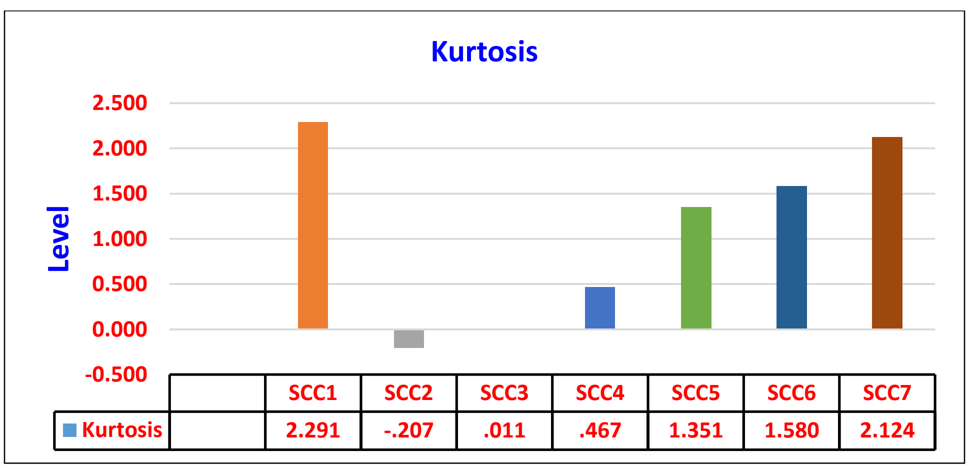
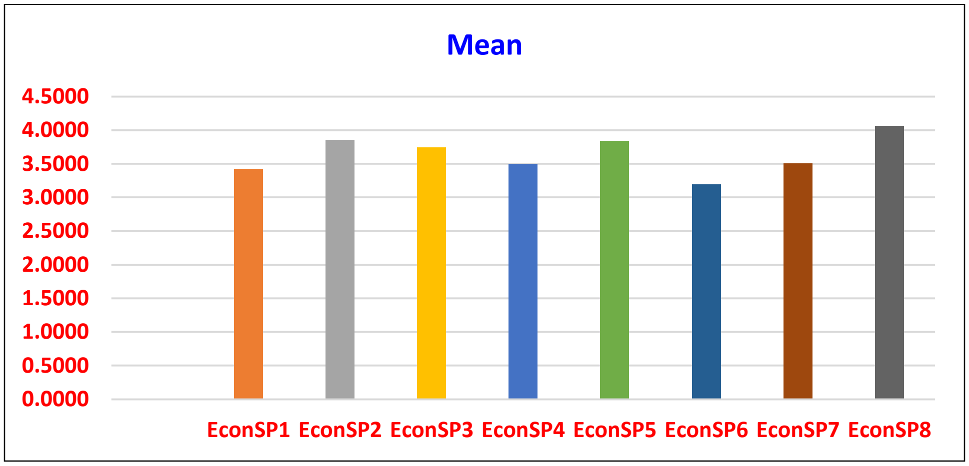
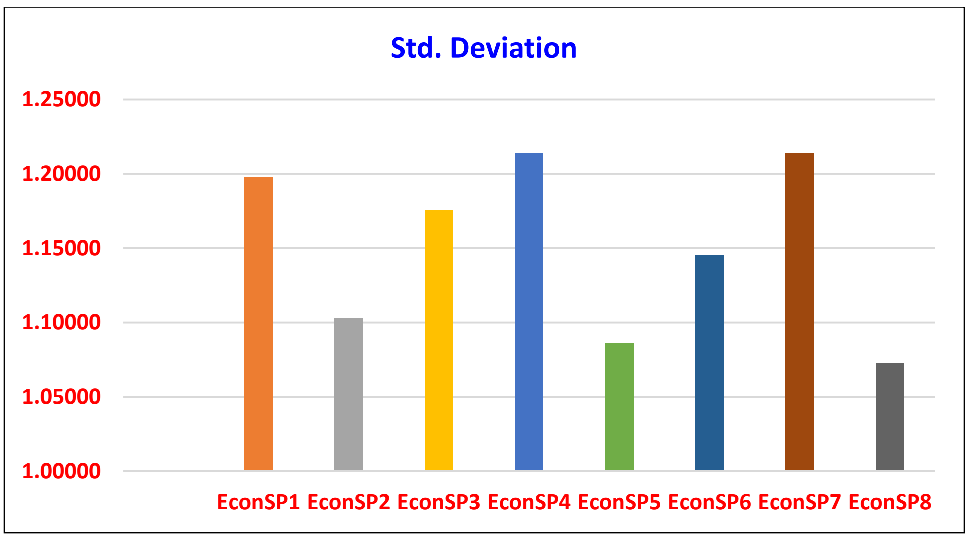
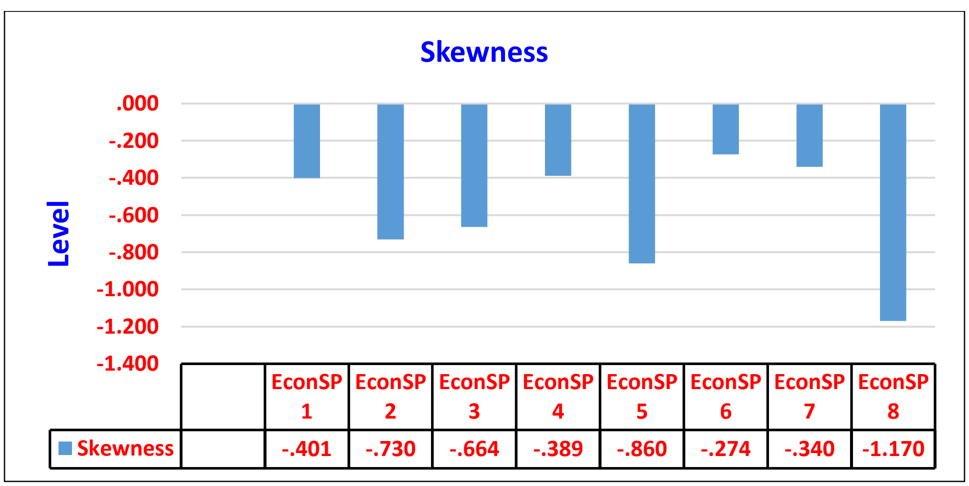
-0.200
-0.400
-0.600
-0.800
-1.000
-1.200
-1.400
-1.600
-1.800
SCC1 SCC2 SCC3 SCC4 SCC5 SCC6 SCC7
Skewness -1.544 -.692 -.834 -.905 -1.221 -1.378 -1.486

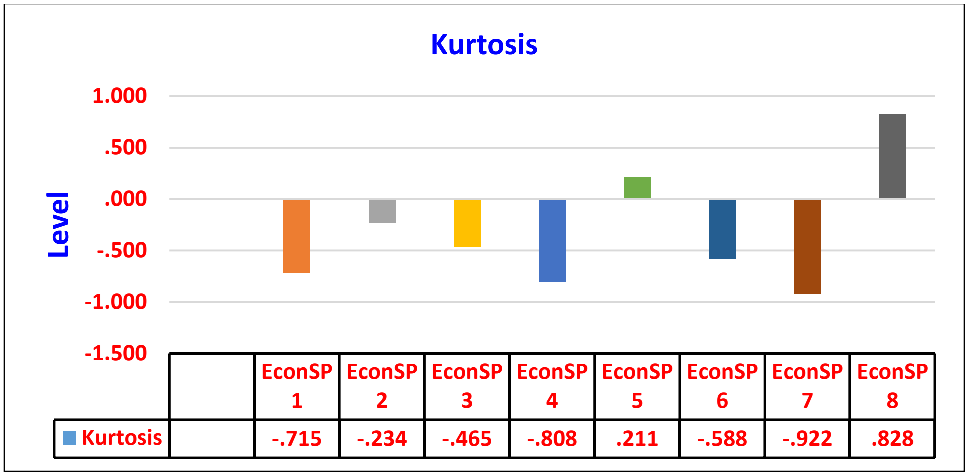

Kurtosis
Level
2.500
2.000
1.500
1.000
0.500
0.000
-0.500
SCC1 SCC2 SCC3 SCC4 SCC5 SCC6 SCC7
Kurtosis 2.291 -.207 .011 .467 1.351 1.580 2.124

Economic sustainability performance









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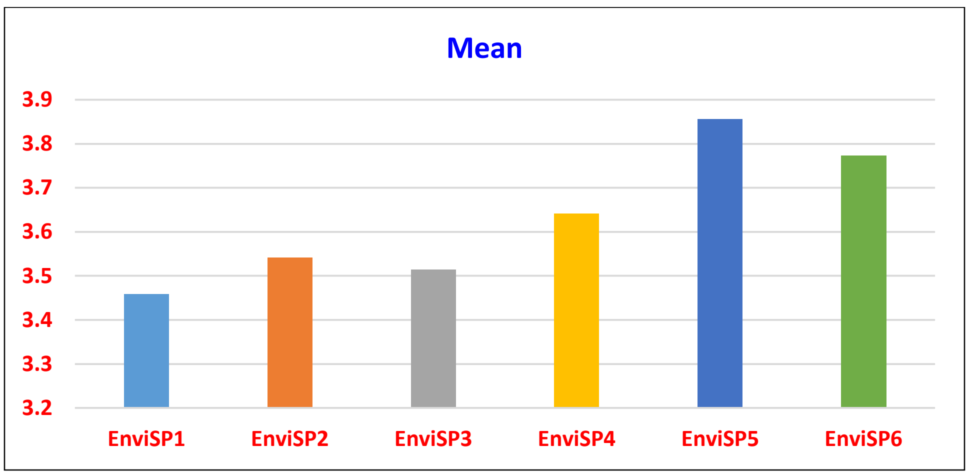
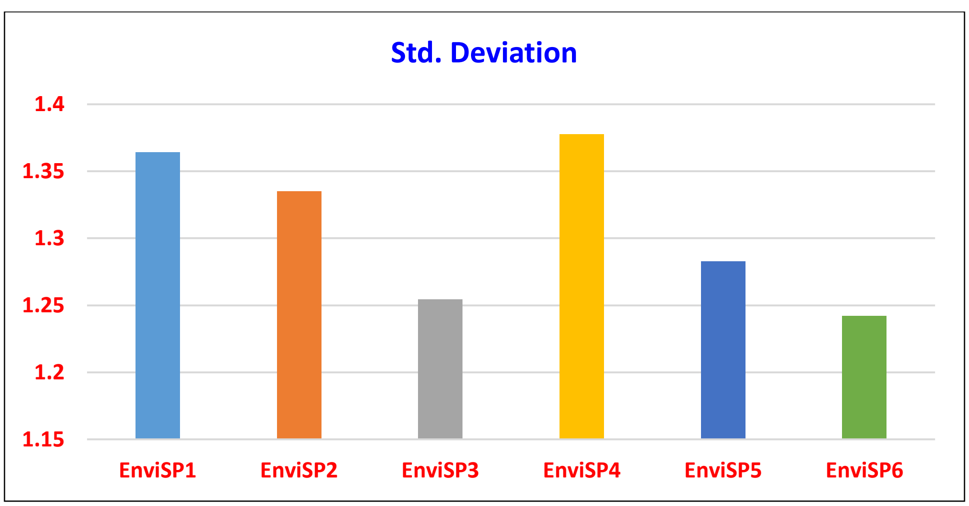
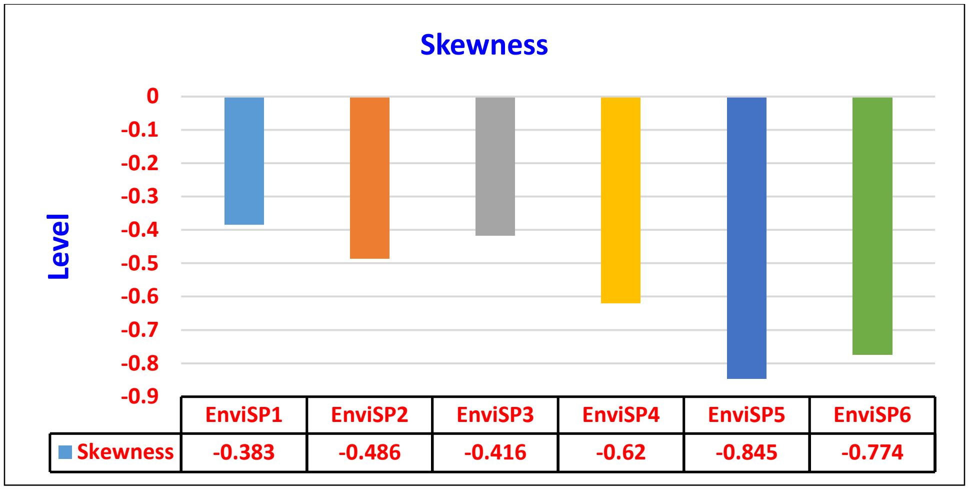
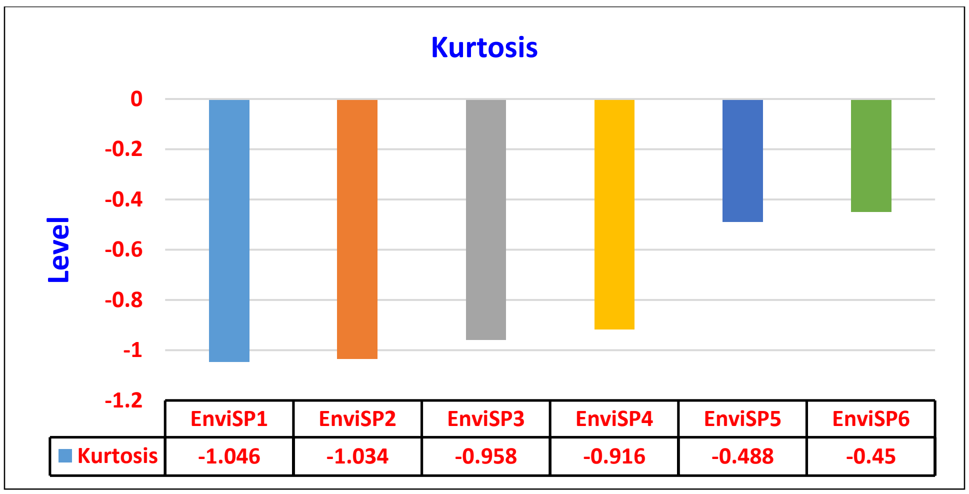
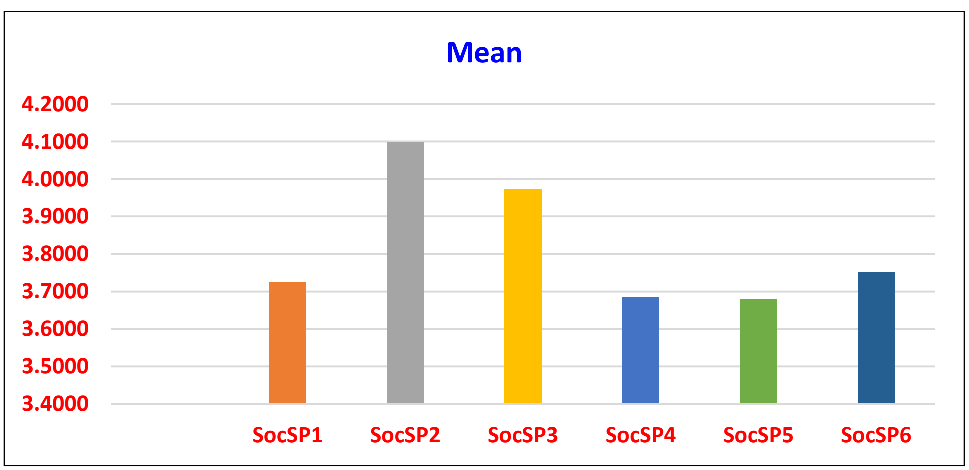


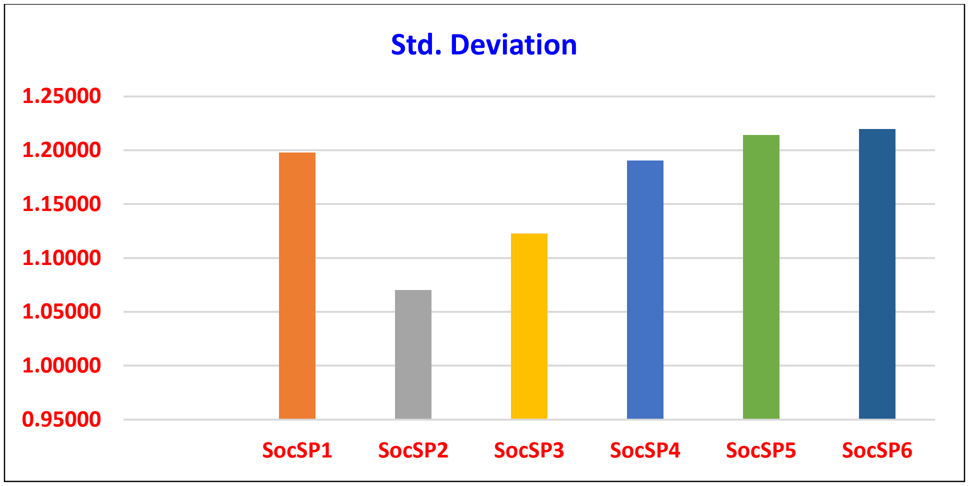






Social sustainability performance

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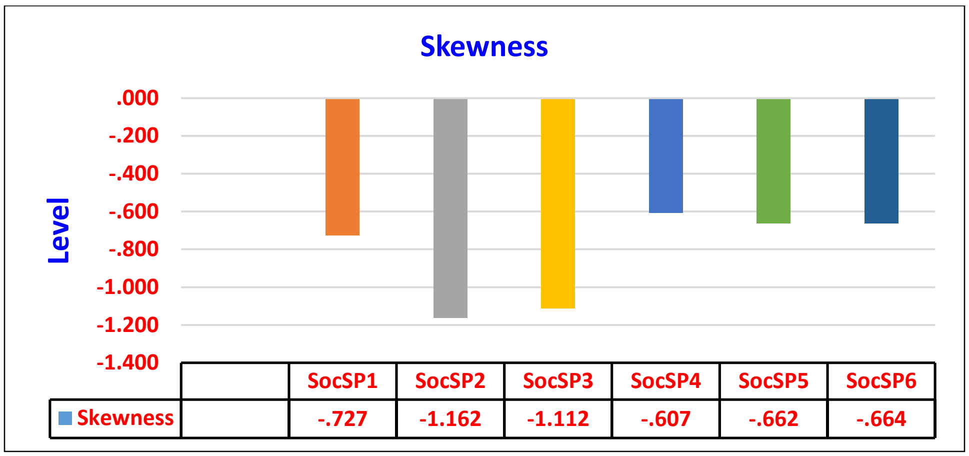
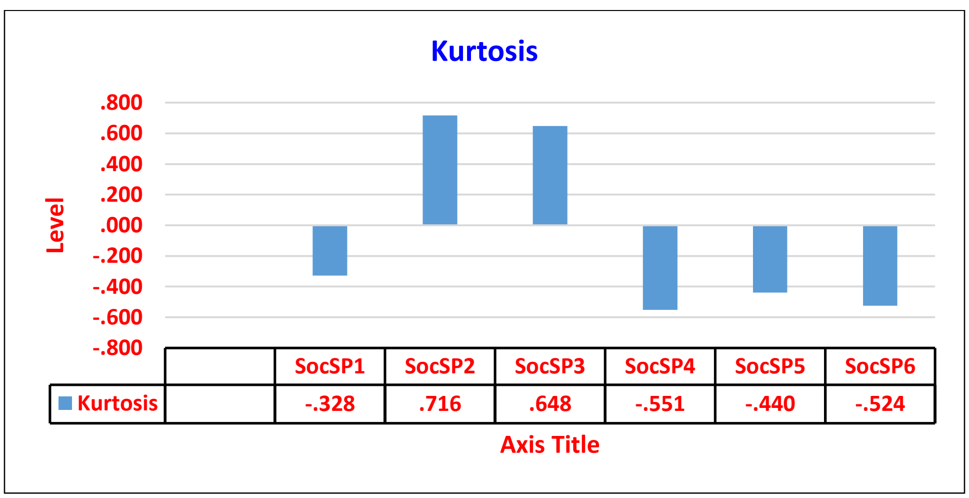
1.20000
1.15000
1.10000
1.05000
1.00000
0.95000
SocSP1
SocSP2
SocSP3
SocSP4
SocSP5
SocSP6


Skewness
Level
.000
-.200
-.400
-.600
-.800
-1.000
-1.200
-1.400
SocSP1 SocSP2 SocSP3 SocSP4 SocSP5 SocSP6
Skewness -.727 -1.162 -1.112 -.607 -.662 -.664


Kurtosis
Level
.800
.600
.400
.200
.000
-.200
-.400
-.600
-.800
SocSP1 SocSP2 SocSP3 SocSP4 SocSP5 SocSP6
Kurtosis -.328 .716 .648 -.551 -.440 -.524
Axis Title

Appendix A5.2

SPSS report related to the negative sign associated with the multiplication term (Agile*SCC)-Customer

Table A5.2-1

Relationship	Regression coefficient (B)	p-value of significance	Moderation factor	Finding
AP → Economic sustainability performance	1.061	0.000	Agile*SCC4	(Agile*SCC4) moderates in the negative direction
SCC4→Economic sustainability performance	0.373	0.006		
Agile*SCC4	-0.077	0.046		

Regression of economic sustainability performance using SCC4 and (Agile*SCC4)
Table A5.2-2

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	MULTIMEANAPSCC4, We work as a partner with our customers (SCC4)[b]	.	Enter
a. Dependent Variable: MEANECONALL			
b. All requested variables entered.			

Table A5.2-3

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.588[a]	.346	.338	.70613
a. Predictors: (Constant), MULTIMEANAPSCC4, We work as a partner with our customers (SCC4)				

Table A5.2-4

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	46.859	2	23.430	46.988	.000[b]
	Residual	88.755	178	.499		
	Total	135.614	180			
a. Dependent Variable: MEANECONALL						
b. Predictors: (Constant), MULTIMEANAPSCC4, We work as a partner with our customers (SCC4)						

Table A5.2-5

Coefficients[a]						
Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	2.694	.196		13.760	.000
	We work as a partner with our customers (SCC4)	-.141	.067	-.247	-2.111	.036
	MULTIMEANAPSCC4	.091	.014	.785	6.713	.000
a. Dependent Variable: MEANECONALL						

Regression of economic sustainability performance using MEANAP and (Agile*SCC4)
Table A5.2-6

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	MEANAP, MULTIMEANAPSCC4[b]	.	Enter
a. Dependent Variable: MEANECONALL			
b. All requested variables entered.			

Table A5.2-7

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.656[a]	.430	.424	.65872
a. Predictors: (Constant), MEANAP, MULTIMEANAPSCC4				

Table A5.2-8

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	58.378	2	29.189	67.269	.000[b]
	Residual	77.237	178	.434		
	Total	135.614	180			
a. Dependent Variable: MEANECONALL						
b. Predictors: (Constant), MEANAP, MULTIMEANAPSCC4						

Table A5.2-9

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.414	.220		6.436	.000
	MULTIMEANAPSCC4	.024	.010	.209	2.431	.016
	MEANAP	.519	.092	.484	5.627	.000
a. Dependent Variable: MEANECONALL						

Table A5.2-10

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	MEANAP, We work as a partner with our customers (SCC4)[b]	.	Enter
a. Dependent Variable: MEANECONALL			
b. All requested variables entered.			

Table A5.2-11

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.673[a]	.452	.446	.64595
a. Predictors: (Constant), MEANAP, We work as a partner with our customers (SCC4)				

Table A5.2-12

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	61.343	2	30.671	73.508	.000[b]
	Residual	74.272	178	.417		
	Total	135.614	180			
a. Dependent Variable: MEANECONALL						
b. Predictors: (Constant), MEANAP, We work as a partner with our customers (SCC4)						

Table A5.2-13

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.927	.231		4.008	.000
	We work as a partner with our customers (SCC4)	.124	.034	.217	3.640	.000
	MEANAP	.602	.064	.562	9.411	.000
a. Dependent Variable: MEANECONALL						

Comparing the three coefficient tables 4, 8 and 12 it can be seen that the negative associated with SCC4 (-0.141) in table 4 contributes to the negative sign associated with the product term (Agile*SCC4) which is MULTIMEANAPSCC4.

Table A5.2-14

Relationship	Regression coefficient (B)	p-value of significance	Moderation factor	Finding
AP → Environmental sustainability performance	1.093	0.000	Agile*SCC2	Agile*SCC2 moderates in the negative direction
SCC2→Environmental sustainability performance	0.359	0.02		
Agile*SCC2	-0.093	0.039		

Table A5.2-15

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Our customers are actively involved in our product design process (SCC2), MEANAP[b]	.	Enter
a. Dependent Variable: MEANENVIALL			
b. All requested variables entered.			

Table A5.2-16

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.507[a]	.257	.248	.98626
a. Predictors: (Constant), Our customers are actively involved in our product design process (SCC2), MEANAP				

Table A5.2-17

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	59.819	2	29.909	30.749	.000[b]
	Residual	173.142	178	.973		
	Total	232.961	180			
a. Dependent Variable: MEANENVIALL						
b. Predictors: (Constant), Our customers are actively involved in our product design process (SCC2), MEANAP						

Table A5.2-18

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.108	.340		3.258	.001
	MEANAP	.674	.099	.479	6.800	.000
	Our customers are actively involved in our product design process (SCC2)	.043	.050	.061	.862	.390
a. Dependent Variable: MEANENVIALL						

Table A5.2-19

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	MULTIMEANAPSCC2, Our customers are actively involved in our product design process (SCC2)[b]	.	Enter
a. Dependent Variable: MEANENVIALL			
b. All requested variables entered.			

Table A5.2-20

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.421[a]	.177	.168	1.03786
a. Predictors: (Constant), MULTIMEANAPSCC2, Our customers are actively involved in our product design process (SCC2)				

Table A5.2-21

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	41.226	2	20.613	19.136	.000[b]
	Residual	191.735	178	1.077		
	Total	232.961	180			
a. Dependent Variable: MEANENVIALL						
b. Predictors: (Constant), MULTIMEANAPSCC2, Our customers are actively involved in our product design process (SCC2)						

Table A5.2-22

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.048	.263		11.584	.000
	Our customers are actively involved in our product design process (SCC2)	-.249	.099	-.352	-2.516	.013
	MULTIMEANAPSCC2	.103	.021	.691	4.949	.000
a. Dependent Variable: MEANENVIALL						

Table A5.2-23

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	MEANAP, MULTIMEANAPSCC2[b]	.	Enter
a. Dependent Variable: MEANENVIALL			
b. All requested variables entered.			

Table A5.2-24

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.504[a]	.254	.245	.98825
a. Predictors: (Constant), MEANAP, MULTIMEANAPSCC2				

Table A5.2-25

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	59.118	2	29.559	30.266	.000[b]
	Residual	173.843	178	.977		
	Total	232.961	180			
a. Dependent Variable: MEANENVIALL						
b. Predictors: (Constant), MEANAP, MULTIMEANAPSCC2						

Table A5.2-26

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.222	.333		3.666	.000
	MULTIMEANAPSCC2	.002	.015	.014	.147	.883
	MEANAP	.693	.138	.493	5.030	.000
a. Dependent Variable: MEANENVIALL						

Table A5.2-27

Relationship	Regression coefficient (B)	p-value of significance	Moderation factor	Finding
AP → Environmental sustainability performance	1.078	0.000	Agile*SCC4	Agile*SCC4 moderates in the negative direction
SCC4→Environmental sustainability performance	0.443	0.004		
Agile*SCC4	-0.096	0.032		

Table A5.2-28

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.605	.281		9.258	.000
	We work as a partner with our customers (SCC4)	-.123	.096	-.165	-1.291	.198
	MULTIMEANAPSCC4	.091	.020	.595	4.642	.000
a. Dependent Variable: MEANENVIALL						

Table A5.2-29

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.346	.327		4.118	.000
	MEANAP	.526	.137	.375	3.837	.000
	MULTIMEANAPSCC4	.026	.015	.171	1.756	.081
a. Dependent Variable: MEANENVIALL						

Table A5.2-30

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.813	.347		2.343	.020
	We work as a partner with our customers (SCC4)	.136	.051	.182	2.671	.008
	MEANAP	.613	.096	.436	6.391	.000
a. Dependent Variable: MEANENVIALL						

Table A5.2-31

Relationship	Regression coefficient (B)	p-value of significance	Moderation factor	Finding
AP → Social sustainability performance	1.194	0.000	Agile*SCC2	Agile*SCC2 moderates in the negative direction
SCC2→Social sustainability performance	0.233	0.04		
Agile*SCC2	-0.069	0.037		

Table A5.2-32

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.740	.244		3.035	.003
	MEANAP	.923	.101	.733	9.160	.000
	MULTIMEANAPSCC2	-.004	.011	-.033	-.417	.677
a. Dependent Variable: MEANSOCALL						

Table A5.2-33

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.746	.249		2.992	.003
	MEANAP	.883	.073	.702	12.161	.000
	Our customers are actively involved in our product design process (SCC2)	.010	.037	.015	.266	.791
a. Dependent Variable: MEANSOCALL						

Table A5.2-34

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.322	.206		16.107	.000
	Our customers are actively involved in our product design process (SCC2)	-.417	.078	-.656	-5.367	.000
	MULTIMEANAPSCC2	.146	.016	1.090	8.915	.000
a. Dependent Variable: MEANSOCALL						

Table A5.2-35

Relationship	Regression coefficient (B)	p-value of significance	Moderation factor	Finding
AP → Social sustainability performance	1.19	0.000	Agile*SCC3	Agile*SCC3 moderates in the negative direction
SCC3→Social sustainability performance	0.271	0.015		
Agile*SCC3	-0.073	0.029		

Table A5.2-36

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.790	.242		3.265	.001
	MULTIMEANAPSCC3	.004	.011	.028	.350	.727
	MEANAP	.865	.100	.688	8.678	.000
a. Dependent Variable: MEANSOCALL						

Table A5.2-37

Coefficients[a]						
Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3.156	.205		15.414	.000
	MULTIMEANAPSCC3	.142	.016	1.051	8.840	.000
	Our customers involve us in their quality improvement efforts (SCC3)	-.370	.075	-.589	-4.959	.000
a. Dependent Variable: MEANSOCALL						

Table A5.2-38

Coefficients[a]						
Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.668	.251		2.664	.008
	Our customers involve us in their quality improvement efforts (SCC3)	.040	.036	.063	1.106	.270
	MEANAP	.861	.072	.684	12.010	.000
a. Dependent Variable: MEANSOCALL						

Table A5.2-39

Relationship	Regression coefficient (B)	p-value of significance	Moderation factor	Finding
AP → Social sustainability performance	1.18	0.000	Agile*SCC4	Agile*SCC4 moderates in the negative direction
SCC4→Social sustainability performance	0.362	0.001		
Agile*SCC4	-0.078	0.017		

Table A5.2-40

Coefficients[a]						
Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.457	.253		1.805	.073
	MEANAP	.817	.070	.649	11.664	.000
	We work as a partner with our customers (SCC4)	.107	.037	.161	2.888	.004
a. Dependent Variable: MEANSOCALL						

Table A5.2-41

Coefficients[a]						
Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	2.879	.219		13.161	.000
	We work as a partner with our customers (SCC4)	-.280	.074	-.419	-3.768	.000
	MULTIMEANAPSCC4	.131	.015	.958	8.610	.000
a. Dependent Variable: MEANSOCALL						

Table A5.2-42

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.879	.239		3.679	.000
	MULTIMEANAPSCC4	.021	.011	.153	1.920	.057
	MEANAP	.746	.100	.593	7.444	.000
a. Dependent Variable: MEANSOCALL						

SPSS report related to the negative sign associated with the multiplication term (Agile*SCC)-Supplier

Table A5.2-43

Relationship	Regression coefficient (B)	p-value of significance	Moderation factor	Finding
AP → Social sustainability performance	0.359	0.002	Agile*SCC5	Agile*SCC5 moderates in the negative direction
SCC5→Social sustainability performance	1.242	0.000		
Agile*SCC5	-0.082	0.015		

Table A5.2-44

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.852	.239		3.566	.000
	MEANAP	.762	.107	.606	7.149	.000
	MULTIMEANAPSCC5	.018	.012	.131	1.543	.125
a. Dependent Variable: MEANSOCALL						

Table A5.2-45

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.815	.242		11.632	.000
	MULTIMEANAPSCC5	.128	.014	.918	9.105	.000
	We maintain cooperative relationships with suppliers (SCC5)	-.269	.072	-.380	-3.766	.000
a. Dependent Variable: MEANSOCALL						

Table A5.2-46

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.419	.268		1.567	.119
	MEANAP	.828	.070	.658	11.839	.000
	We maintain cooperative relationships with suppliers (SCC5)	.101	.039	.142	2.553	.012
a. Dependent Variable: MEANSOCALL						