ANALYSIS OF SUPPLY CHAIN AND CIRCULAR ECONOMY

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQURIMENTS FOR THE AWARD OF THE DEGREE OF

MASTER OF TECHNOLOGY
IN
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DECLARATION

I declare that the work presented in this thesis titled "**ANALYSIS OF SUPPLY CHAIN AND CIRCULAR ECONOMY**", submitted to the Department of Mechanical Engineering, is an authentic record of my own work carried out under the supervision of Assistant Professor Dr. Saurabh Agrawal, Department of Mechanical Engineering, Delhi Technological University, Delhi.

This report does not, to the best of my knowledge, contain part of my work which has been submitted for the award of any other degree either of the university or any other university without proper citation.

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CERTIFICATE

This is to certify that report entitled" **ANALYSIS OF SUPPLY CHAIN AND CIRCULAR ECONOMY**" by Sachin Jaisar (2K17/PIE/12) in the requirement of partial fulfilment for the award of the degree of **Master of Technology(MTECH)** in **Production Engineering** at **Delhi Technological University.** This work was completed under my supervision and guidance. He has completed his work with utmost sincerity and diligence. The work embodied in this project has not been submitted for the award of any other degree to the best of my knowledge.

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ABSTRACT

Supply chain performance is a need that every industry looks forward to, but the responsibility towards the nature and resources also compel to see the importance of circular economy critical factors on the performance of the supply chain. To identify the critical factors, strong literature review was done and related to these factors; questionnaire was made and sent to the employees of different sectors. After collecting the survey data, Partial Least Square Path Modeling technique was used to check the relationship between these factors and performance of supply chain on applying them all. This technique comes under the category of data analysis. After running Consistent PLS algorithm in Smart PLS software 3.2.8, significance of the relationship amongst different factors was measured. The impact of the factors on supply chain performance was showed by t-statistics. This report is an effective effort to demonstrate this relation and also tells the stability of the purposed model. For future reference, new method like K-nearest neighbor could be used in accordance to this technique so the necessity of building model again and again is not required and the significance of the new factor can be predicted on the basis of its closeness to its neighbor.

KEYWORDS:- Circular economy, supply chain management, PLSPM, AVE

CHAPTER 1: INTRODUCTION

In this chapter a brief discussion on supply chain management, Indian sectors overview and flow of study is described. Increasing demand for influence oriented in organization can be accommodated by different techniques of Supply Chain Management (SCM). The sincere working on circular economy critical measures can enhance organization effectiveness up to some extent but this improvement comes with a cost of few adjustments. Mostly successful organizations works in a continuous learning mode so today organizations must become continuous learners. The challenge of increasing competition, globalization, technological innovation, and growth through expansion is the need of the hour. Diversification of the business model is required which consists of successful implementation of supply chain strategies.

1.1 Supply Chain Orientation

The basic definition of this term is an integration of need and fulfilling this need. The supply chain management concept has come into picture from practices in management like Just in Time, Total Quality Management and Logistics. The main strategy is applied either on how to decrease inventory for improving the performance of the system, decrease operation costs or on how to increase throughput. Supply chain refers to the web that connects all the entities in some predetermined sequence so that final efficiency of the chain could increase. Earlier supply chain considered only the service providers but now customer is also taken under this chain.

Supply chain is the movement of funds, products and information in both directions. Value generated in supply chain is final product price pitched to customer and the work put in completing the customer requirement. Supply chain value is correlated to the profitability of the supply chain. Success of this term is when the whole chain is profited and not a single entity is benefited.

The following concept of the supply chain contains several points (Houlihan, 1985):

1. The supply chain is recognized as the need to fulfill the consumer need.
2. Across organizational boundaries the supply chain extends itself.
3. The first and foremost objective of the supply chain is to fulfill the need of consumer such that an appropriate balance could be generated between assets and costs.

1.1.1 Importance of Integration in SCM

Before the introduction of supply chain management, integration was focused on the internal processes within a company. Melnyk and Wassweiler (1992) identified four types in the regular business context:

Functional integration deals with the integration within functional bodies such as manufacturing, marketing or logistics.

Organizational integration deals with the extent of coordination between the different areas of the firm, such as between manufacturing and marketing divisions.

Strategic integration deals with the extent to which the processes of implementing, evaluating, formulating, and revising strategic objectives between functional areas are integrated.

Inter-organizational (channel) integration deals with external organizations linkages.

1.1.2 Different stages of supply chain generation

Generally, a supply chain consists of three different phases:

Strategy or design- In this stage, the firm strategies how to start the supply chain and what its blueprint should looks like. It is a very long term plan which also becomes the basis of the supply chain. This phase decide which location and what capacities of facilities should be chosen, what products to be made and stored at different location, which mode of transportation should be preferred, and what information systems should be used.

Supply chain strategies are too expensive to reverse hence uncertainty should be considered while strategizing.

P**lanning-** This stage comes into picture with a demand forecast of coming year. Relatively shorter term is used as compared to the design phase. Different perceptions are explored here, such as which market need should be fulfilled first and from which location and what policies related to inventory should be considered. This phase consider demand uncertainty, exchange rates and competition over the time horizon.

Operations- This is a very small term plan which could be reviewed weekly or daily. This phase comprises of different decisions taken in the favor of allocation of orders, checking due dates of the order, availability of stocks at a warehouse, set delivery schedule etc.
The best thing about this phase is that it has much less uncertainty.

1.1.3 Supply Chain Performance Measurement

In order to manage a system efficiently its performance should be measured. Beamon (1998) noted that to improve the performance of the supply chain design, certain analysis of the measures are required. A new measurement system is required as old systems are not precisely working with the current needs which are out of organizational boundaries.

Lambert and Pohlen (2001) mentioned, why it is necessary to have brand new measures in SCM:
1. A big lack in finding performance of supply chain.
2. Take a supply chain perspective and go beyond internal metrics.
3. The need to determine the interrelationship between supply chain performance and corporate.

Gradually the focus of supply chain management is turning into supplying materials sustainably from supplying at minimum cost. It is of big concern that environmentally sustainable products are offered in an integrated supply chain not only deliver at best quality, best prices, and at best possible variety. Thus the integrated supply chain should make sure that in all phases of the supply chain the production processes are clean and green and the materials are environment

friendly (Corbett & Kleindorfer, 2003). The key drivers here are the customers especially if they want to know how the products are made and what impact it would keep on environmental. Having proper knowledge and a vision could communicate this effort to their customers, partners and the public.

1.2 Different industries in Indian

Manufacturing sector has emerged as one of the lofty growth sectors in India. Its growth is can say exponentially increasing but an estimate could be made out of it; from the current 16% to 25% of GDP by 2025. Encouraging steps has been taken by both the industrialist and the government to enhance this growth rate so that employment can be generated with the same rate of increasing population. This sector is predicted to create up to 90 million jobs by 2025.

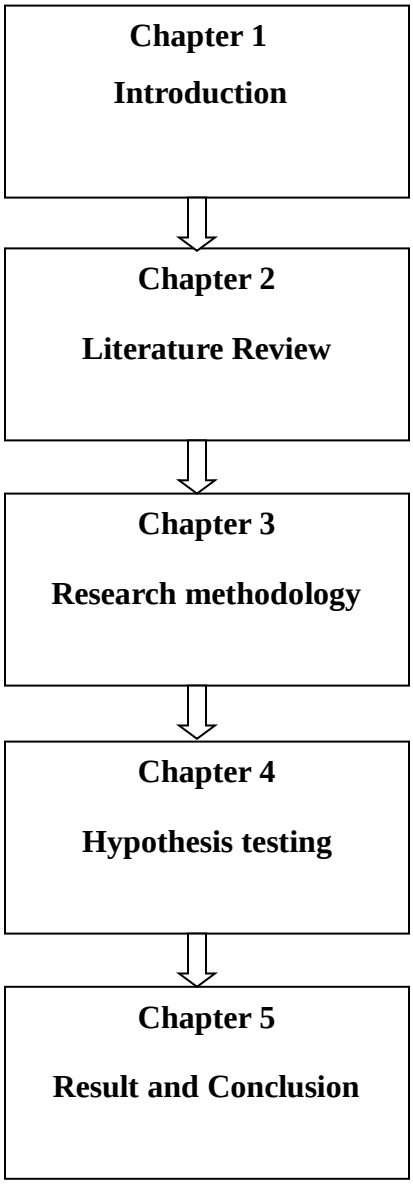
Figure 1 Manufacturing sector comparison

Investment from different countries are been approached by the government regularly so that they could set up their manufacturing business here in India and new job opportunity could increase. There are numerous social platforms; especially those allied to crowd-funding that support manufacturers find customers, who wants to actually invest in their products.

Figure 2 Indian Service Sector

In order to depict the sectors scenario in India, it features work and generate consultancy. A constant and steady wave of employment is there in Indians which results in betterment of the economy but with the changing circumstances that are very uncertain to predict, India still needs a better strategy to tackle effectively. When the talk is about which is the highly growing sector of India, service sector is the name which make its existence in the top 1% list. Lots of modifications have been obtained in this industry from unorganized to organize section. For further more innovation updated technology is used in order to knock the unused prospect buyers with the support of diverse marketing and promotional strategies. Indian telecom sector has gone through a major course of transformation through numerous strategy reforms and regulations. With the introduction of new entrants this sector is becoming more competitive day-by-day.

1.3 Organization of thesis



CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The required aim of this work is to explore circular economy factors affecting supply chain effectiveness. To examine, a literature review has been done on different aspects of circular economy. In this context, a literature survey was conducted during the work being reported in this thesis. The findings of this survey were used to gather information about the key driver and barrier factors while implementing structural equation modeling. The findings of this study suggest many factors which help to achieve effectiveness related to supply chain. The criticality of effectiveness is also discussed in this section which is revealed through literature review. The findings of this study suggest many factors which help to achieve effectiveness within supply chain, factors like product service system, stake holders, economy, technology and management, forecasting and environment. The literature review begins with an overview of the studies in circular economy.

2.2 Review related to circular economy

The origin of circular economy was found in different schools of thought (Ghisellini et.al., 2014). Introduction to CE was first picked up by an environmental economist Pearce & Turner (1990) who observed the shift to circular economic system from traditional linear economy system. According to the authors, two economic functions are associated with environment: life support system and price related to it. Roots of Circular economy can be found in ecology of the industry which works with the environment by flow of energy, material and information. In simple words, circular economy is rethinking growth for long term prosperity with some advances and adjustments. McDonough and Braungart (2000) mentioned that at creating an industrial system i.e. uplifting by intention circular economy represents a theoretical concept; recently, seeing it as a mechanism that can be used to create competitive advantage, business

have become more aware about such concept. They also seek to address apply these practices in a supply chain framework from environmental, policy, market, and societal points of view.

Khosla (2008) stated that the awareness of strategies that are inclined towards sustainable techniques are not only amongst national progress but also includes environmental and social values. India face resource constraints like natural, physical and financial that makes adaptation of circular economy doubly difficult. Ghosh (2016) mentioned that the world's increasingly population requires everything in abundance which is a threat for both resources and economy. Circular economy concept serves the necessity of a change of game. The researcher also recognized that circular economy for up-building countries like India includes the sectors like informal one in decision taking and providing a habitual place in the on-going chain.

According to Lazarevic and Valve (2016), varieties of scientific disciplines are involved with in circular economy roots, such as ecological economics and math behind environment, which conclude its involvement with a variety of concepts. If considered as a whole, CE is no different from other terms such as Bio and Green Sustainable techniques which are vital to be used in social and economy (D'Amato et al., 2017). Sachan (2017) said that as far as Indian manufacturing companies are concerned, with growing time they are also exponentially increasing which will for sure generate large waste. That is why this approach is the presently best suited practise.

Tan and Kannan (1998) mentioned that how a single entity can be formed by suppliers in the linear transformation and enhance overall performance in SCM. Many firms have confirmed the sustainable goodness of SCM efficiency. In Europe, a big percentage of around 85% are in the race of redesigning their processes and 3% are done with this crucial step (The Economist Intelligence Unit, 1996).

Lummus Vokurka, and Alber (1998) stated that the importance of supply chain is increasing as the change in organization is not steady, increased market competition, and it's direct effect on company's goodwill. Christopher (1992) suggested that the globalization of industry, customer service explosion, organizational integration and time compression has played a noticeable effect

on supply chain. The researcher also said that logistics management could be replaced with a thorough business philosophy. Burgess (1998) mentioned that to get upper hand in the market, some reliability is been offered by SCM with better customer service, lead times, and supply chain synergy.

Dora, Bhatia and Gallear (2017) identified numerous notations like ‘closed loop ’, ‘sustainable’, ‘reverse’, ‘green’ and circular’. Researchers use them interchangeably even though there is an ambiguity among these terms (Govindan et.al, 2015). Need is that how to show they are related and how they are distinguished from each other (Pan et.al, 2015).

Genovese et al. (2017) purposed that by emphasizing the idea of converting products so that a positive relationship could exist between economic growth and systems of ecology, circular economy pushes the frontiers of environmental sustainability. Therefore, circular economy terminology not only deals minimizing the environmental sake usage of products, but it also concerns the product over and over again use strategy which leads to the formation of self-sustaining production systems.

Table 1 Classification of indicators currently relevant to circular economy

Indicator type	Examples
Material flow	Domestic material input, net additions to stock, domestic processed output, physical trade balance, total domestic output, total material requirement
Organisational behaviour	Remanufacturing, eco-innovation, per capita statistics, use of recycled raw materials
Societal behaviour	Municipal waste recycle, sharing, environmental/resource taxation, waste generated per capita
Economy performance	Recycling industry, green jobs, waste generation/GDP, resource productivity,

	'transformation of the economy'
Environmental	Air pollution, agriculture, biodiversity, energy, fisheries, climate change, land and soils, waste, water, transport

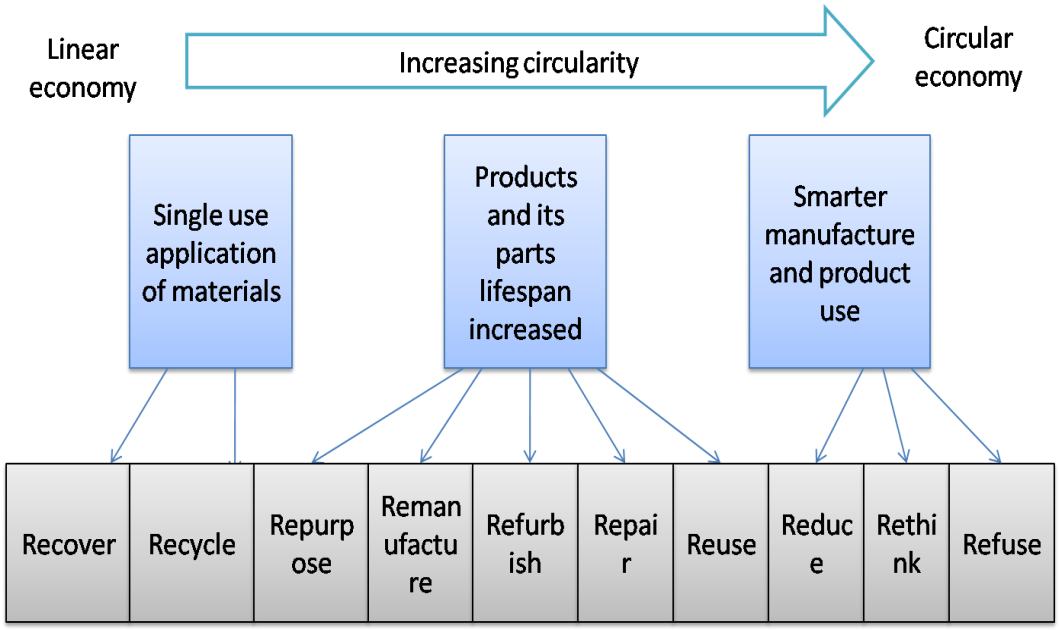


Figure 3 Modified transformation from linear to circular economy adopted from Potting et al., 2017

2.3 Theoretical Framework of the Variables under Study

2.3.1 Manufacturing System

According to Yang et al. (2018), Manufacturing models are assigned the capability to enhance and trigger closed supply chain which is also referred as circularity. Providing the product on renting rather than selling produces an effective implication on the supply chain regularity. Linder and Williander (2015) stated that different manufacturing models that are been used in the

corporation shows high level of negative effect which is only the repercussion increased capital words.

Two models suggested are result-directed and use-directed which are taken into account for the flow of supply chain been better than before. At a constant time, inspection and research of the models plays an important role in developing value in the supply chain.

2.3.2 Environmental Performance

According to Acquaye et al. (2018), due to inherent multi-criteria nature of the problem and standardized methodologies environmental performance of a supply chain is a challenging task. For continuous improvement, performance measurement for supply chain sustainability is very important. All the present issues imply that for sustainable supply chains, performance measurement models concentrates only on direct impacts, and thus do not take the supply chain in a more holistic view. Challenges that comes with issues of creating reliable sustainable supply chain performance measurement approaches consists different factors that must be taken into account to characterize the performance driven by data (Afful-Dadzie, Afful-Dadzie, & Turkson, 2016) and the study on reporting green supply chain management initiatives implementation rather than outcomes (Zhu, Sarkis, & Lai, 2008).

Based on an industrial lifecycle thinking approach for calculating and manipulating carbon footprint of industrial- level supply chains an environmental sustainability performance model is used. The researcher also determined that for India, China and South Africa, there is a strong linear correlation existing between the total cumulative carbon footprint and time. This remark was introduced on the basis of previous 20 years long data. In SCM, the idea of Green SCM makes use of circular strategy, while additionally working with aspects of sustainable environment and optimization of resource in order to address emerging degradation of environmental (Sheu, Chou, & Hu, 2005). In order to make entire supply chain process extra sustainable it also considers the recycling of goods (Ying & Li-jun, 2012).

In this sense, a tremendous positive impact on environmental management can be exerted by Green SCM (Chakraborty, 2010). Teuteberg &Wittstruck, 2010 investigated the recent state of

research on sustainable supply chain management; in this field more than 30 unsolved issues are there which are of big environmental issues concern. Schrödl and Simkin (2014) integrate the Circular Economy model with SCOR (Supply Chain Operations Reference model) to establish a sustainable SCM model beyond Green SCM.

Yinga and Li-junb (2012) mention that introducing green in respect of supply chain management can reduce the resource consumption, maximize the resource utilization, and enhance its international image with the improvement of its operation performance so as to promote the compatibility between enterprises and society and environment, thus achieving sustainable development. Circular economy strives to reduce landfill, solid waste and emissions all the way through activities such as remanufacturing, reuse and/or recycling.

2.3.4 Technological Factors

Technology and management can be looked as a categorical variable which would comprise of few factors that completely describes it. These critical factor are very important to consider as it adds a new concept of looking at an essential which would change the way how supply chain is been seen. Slack and Lewis, (2002) mentioned that the management of tangible and intangible firm resource stocks related with firm performance objectives can be accomplished at the operations level by modifying the related resource flows through two broad operations strategy assessment areas: i) concern the rate of remanufacturing by the retailers, production and recycling rate of OEMs, (ii) logistics management and supply chain decisions which concern the stream of new and used products in the supply chain. To achieve and maintain a desired balance in the use of organisational resources firm strive to exploration and exploitation activities.

2.3.5 Economic Performance

Sharma, Rajan, Jose and Rao (2015) stated that the industry perception of its benchmarking and economic performance for an organisation is very essential for identifying the ‘best practices’ for an establishment in an industry. Thus it becomes critical to measure the various processes in circular economy in terms of economic performance. To meet market demand objectives and

efficiency, the output of the processes enabled by the supply chain must be compared with a set of standards. Improved economic and environmental performance can be achieved by greening various phases of supply chain.The greening of inbound function and production considerably lead to greening outbound, which results in better economic performance and competitiveness of the firm. In order to secure competitiveness and profitability, each individual company should strive for gaining economic benefits. It is an integrative approach from product design and business models selection to choice of materials and supply chain design.

2.4 Additional Drivers and Barriers of Circular Supply Chain

Table 2 Drivers of circular supply chain

Drivers	Reference
Good business opportunity, Collaborate with customers & Improve firm performance	Govindan, Soleimani and Kannan (2015)
Regulatory compliance, Green Business strategy, Requirement from customer & Gaining competitive advantage	Zhu & Geng (2013)

Table 3 Barriers of circular supply chain

Barriers	Reference
Institutional Challenges of SMEs ,Technological - Linear technologies are deeply rooted, Financial	Mathews & Tan (2011)
Lack of appropriate business model, Resistance from powerful stakeholders with	Govindan, Soleimani and Kannan (2015)

large interests in status quo, Collaborative business models & Regulatory challenges	
Lack of human resource capabilities	Sarkis et al., (2010)
Exchange of materials is limited by capacity of reverse logistics	Kok, Wurpel & Ten Wolde (2013).

2.5 Performance Indicators of Circular Economy

Kaplan and Norton (1995) mentioned that to show progress towards strategic objectives and to support overall strategy, organizations use indicators. Through annual financial reports, many indicators are available publicly but for more operational objectives indicators also provide internal support. Primarily indicators can be divided into financial goals such as working capital or return on investment and operational goals such as quality, lead time, stock turnover (Neely 2005). However, non-economic indicators are also well accepted in an organization such as social and environmental which are driven by transparency imperatives and accountability (Keeble, Topiol, and Berkeley 2003). These non-economic indicators are used to achieve a safety and health goals of environmental targets and zero accidents. Ahi and Searcy (2015) classified the issue of sustainable or green supply chain metrics using 13 dimensions of sustainable supply chain management classification which covered the following: Economic, Volunteer, Resilience, Long term, Environmental, Social, Relationship, Value, Efficiency, Stakeholder, Flow, Coordination and Performance. These types of indicators can be significant here given the scope of the CE whereby a network of firm aim to decrease overall environmental impacts, but are restricted to the supply chain scope.

Ghisellini, Cialani, and Ulgiati (2016) stated that performance measurement and indicators are well developed in the literature of sustainability but relatively there is very less research into indicators that support CE objectives. There is an ambiguous understanding of CE which correlates it with sustainability and closed loop design. Recent research on CE indicators focuses on the regional or national level and that too from a Chinese perspective.

Table 4 Indicators that requires implementation of circular economy.

Indicators	
Linear Flow Index (LFI)	A measure of the amount of virgin material that is been used in product and disposed at the end
Materials Circularity Index (MCI)	A measure of efficiency of the recourse based on the use of product and lifetime
Carbon footprint	Released greenhouse gases during production
Water footprint	Usage of water during production
Material scarcity	The scarcity and abundance of materials used
Material toxicity	Toxic materials present in a product
Supply chain risk	Risk related to the virgin material that continuing in the supply chain
Value	The possible value of products or constituent materials at the end of life

Circular economy depends upon the principles of 3Rs: Reduce, Reuse and Recycle. Jawahir, Bradley (2016) study was aimed at reducing natural resources, emissions, producing minimum pollutions, wastes and optimum production by utilizing the 3R. Model of circular economy also

consists of eco-design, repair, refurbishment, remanufacture, product sharing, reuse, waste prevention and waste recycling. In circular economy, resource scarcity is social prosperity, which depends on the supply of finite resource. For CE realization, it makes regenerative use of resources mandatory. Howard, Hopkinson and Miemczyk (2018) proposed the following high-level indicators.

Table 5 High level indicators and their measures.

Indicators	Measures
Regeneration and maintenance of biological material flow and stocks of natural capital.	These practices are combined to improve the quantity and quality of air, ground water, soils etc. Bio-nutrient's quality and quantity returned back into the biosphere.
Stocks of technical material depletion and total use	It is been taken into account for relative to global stocks, technical material flows the total quantities through the supply chain. Critical and at-risk materials are under specific attention.
Biological products and materials re-circulation of quantities	It is measure the re-circulated and cascaded quantity of material relative to the total stock of materials.
Quality of biological products and materials re-circulation	It monitors the circulation and recovery of material quality at all possible stages
Technical material's longevity in circulation	It focus on the difference between total

	potential and designed life of technical materials
Value of re-circulated materials	The circulation of materials not only consists reduced cost of inputs but also added value from remanufactured products.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter deals with the adopted methodology for prioritizing the critical factors that are essential part of the circular economy and are useful when special attention is given to them in the context of supply chain. The analysis include from conducting a literature review, finding the critical factors, making good questionnaire regarding them, putting that questionnaire to the employees of different sector related companies in a well structured survey form, applying partial least square path modeling technique on the information getting from the survey form and finally check each critical factor responsibly effecting the supply chain. The factors taken under consideration may differ due to the need of the work. The methodology will help future researchers to apply technique in the context of an amalgamation of circular economy and supply chain management.

3.2 Sample size

The sample size can be determined by two ways in PLS – PM models (Hair et al., 2014, p.23). First, the literature on PLS – SEM mentions the use of the statistical power analysis (Cohen, 1992) and second rule of thumb (Barclay et al., 1995) for determining the sample size. The current study has reflective indicators hence; the assumption that the sample size should be equal to ten times the number of formative indicators becomes illogical for this study. The sample size is determined by applying the rule of thumb, ten times the total no. of arrows pointing towards the construct, the sample size would be a minimum 50 respondents.

Other method to determined sample size is by considering R^2 level. For obtaining a statistical power of 80% while determining the sample size, significance level, the numbers of arrows that points towards a construct and minimum desired R^2 level are considered. Maximum arrows are study have are five, that point towards the dependent construct. The minimum desired R^2 level

would be 0.25 at 5% significance level. After considering this the sample size would be 70. Below given table determines the sample size Cohen's (1988).

3.2.1 Data collection

The literature review in this study calculates a total of six construct. These constructs are manufacturing system, economic performance, forecast, technological factor, environmental performance and supply chain performance. Manufacturing system was measured by 2 indicators. Similarly, economic performance, forecast, technological factor, environmental performance was measured by 8, 3, 3, 2 and 2 indicators respectively. Supply chain performance was measured by 2 indicators.

Demographic characteristics of respondents

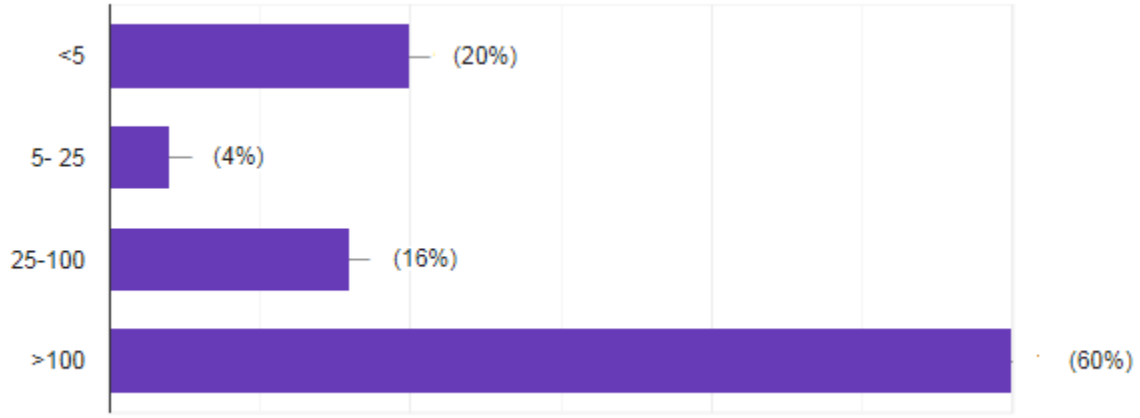


Fig 4 Annual turnover of the company in 2017-2018

60% of the companies had annual turnover of greater than 100 crores whereas others have a cumulative percent of 40% and was lying between 25 to 100 crores.

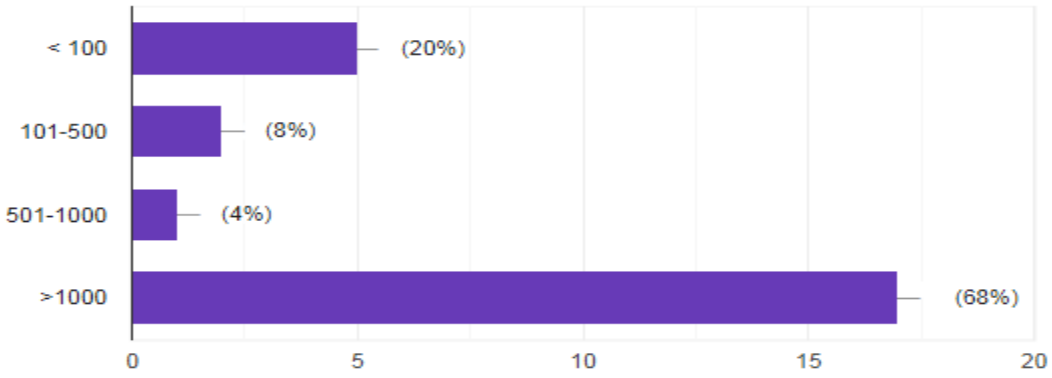


Figure 5 No. of employees in the company

68% of the companies considered for this survey have more than 1000 employees, 4% have between 501 to 1000, 8% have between 101 to 500 and 20% have less than 100.

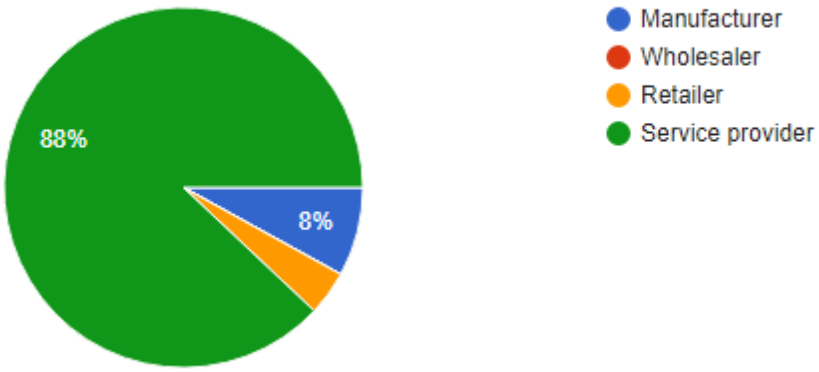


Figure 6 Total Percent of companies of different sectors

Main focus of the study will be on service provider as it consist maximum share of the pie chart drawn above but to make this study more diverse I have considered all the sectors and have given equal weightage to each one.

3.2.2 Scale

The current research study has taken all the constructs except supply chain performance as an exogenous construct. For the scale of variables different options were there to choose: such as semantic differential scale, binary scale or Likert scale. The scale which is most suitable for the

analysis is Likert scale because it makes a range which is permissible by the SmartPLS software. The data type that is used to measure the responses is metric data. This study has taken into consideration the construct of product service system as a mediator so as to reveal the relationship between forecasting and supply chain performance. All the data relating to mediator i.e. forecasting are also captured through Likert scale. The endogenous construct on which the final implication is made is supply chain performance because we are actually finding that what will be the result if we use circular economy critical factors on supply chain management context. The responses got from the survey are occupied by stating each value to a positive, negative or neutral measure where five- point Likert scale is used. In the Likert scale 1 represents highly disagreeing to the question and 5 represents highly agreeing to the question. For the purpose of capturing responses an ordinal scale is used from the target respondents. An important care is been taken to actually ensure the distance between the responses to be same. Therefore, every response marked between the two extreme responses is ensured to be equidistant.

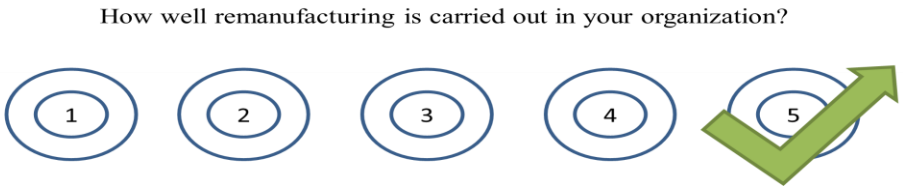


Figure 7 Likert scale

Above figure shows that the respondent is strongly agreed to the question which means that in his/her organization, remanufacturing of the products are very often carried out.

Table 6: Earlier data sources and sample size used:

Authors	**Data Source**	**Sample Size**	**Country**
Jha & Iyer	Questionnaire survey	112 respondents	India
Gan et al.	Questionnaire survey	179 respondents	China
Ling et al.	Questionnaire survey	27 interviews	China

	and interview		
Chan and Tam	Interviews and questionnaire survey	55 respondents	Hong Kong
Chua et al.	Questionnaire survey	20 respondents	Singapore
Arditi and Gunaydin	Questionnaire survey	137 respondents	USA
Mohsini and Davidson	Questionnaire survey	21 respondents	Canada

3.3 PLS-PM

It is a method for studying multivariate relations between observed and latent variables. In this research study, 'Consistent PLS algorithm' is used instead of 'PLS algorithm' as all the indicators are reflective in nature. In the option of different weighting schemes like centroid, factor and path; path weighting scheme is preferred. In Smart PLS 3.2.8, Consistent PLS algorithm maximum iteration 300 is used and stopping criteria is 10^{-7}. A non- parametric test is used as there is no assumption about the distribution of data. This non- parametric test is considered to test the significance of coefficients. The number of observation taken through the survey is 50 and for these 50 observations, 5000 bootstrap samples are used.

Each time the algorithm of bootstrapping is run it will take 5000 samples by randomly selecting and apply the PLS-SEM algorithm. Proper care taken in considering the no. of observation equal to the number of indicators indicated within the model.

After bootstrapping, it will generate values with respective to t-statistics and p value. Both these measures are taken to consider the significance of the variable. As two-tailed test is used with 95% significance so relative t is 1.96, any value greater than this statistics will be considered as significant and will be retained within the model else that latent construct will be vanished.

Confidence interval is also taken under consideration. For calculating the predictive relevance blind folding technique is taken into consideration.

3.3.1 Constructs of the study: Operational definitions

The operational definitions of the constructs is provided in this section i.e. manufacturing system, economic performance, forecast, technological factor, environmental performance and supply chain performance. PLSPM makes no distribution assumptions because bootstrapping is incorporated to determine the significance of parameter. The path coefficients are actually being sampled from a population of parameter value. Because of the distribution is unknown, bootstrapping is used to estimate the standard error. Here neither we assume multivariate normality nor univariate normality.

Considering a large sample size would definitely give a closer result to the actual result but as the data is been taken with the help of survey, it is very difficult to get the feedback of the survey by numerous persons. Instead to make it easier a sample size would also do the work. Just like regression, in PLSPM also we try to maximize the variance in predicted variables. Because PLSPM is a predictive approach hence it is a confirmatory approach.

Although complex models are not well entertained by the algorithm of PLSPM still it has the ability to deal with the complex models with the same intensity. Running complex models may introduce a lag in the total time required to execute it. Statements are generated according to the factors that are considered after doing the literature review. Now if the variable taken into account has some questions related to it, those questions should be answered either in binary format or using a likert or semantic differential scale.

PLSPM works on systematic variance and gives best results with the ratio type data. Data can be non-normal, skewed or kurtotic.

Manufacturing System

Manufacturing System models can enhance the supply chains circularity features. The result-oriented and use-oriented system business models are more appropriate because of the ownership of product for circular supply chain development. Circular value creation could be enabled by

timely research of the system models. In this construct the medium by which the product is given to consumers is considered. Three types of manufacturing business models are product-, use- and result-oriented.

Economic Performance

Economy of the organisation may vary according to the methods that are implemented within the organisation. It is taken as a very crucial parameter in designing the model as every firm is focussed on how much profit is been made out of new strategy performed. By having a chat with some of my college colleague who currently working in MNCs I got to know that companies are not at all interested in putting some effort on circular economy because first of all they need to change their strategy which were going on from years and then new they have to train there employee and hire some professionals for which actually cost money. So instead of putting so much emphasis on circular economy, company prefer to work with old skills. The output of the processes enabled by the supply chain must be compared with a set of standards to meet market demand objectives and efficiency. By greening various phases of supply chain improved economic and environmental performance can be achieved. Each individual company should strive for gaining economic benefits in order to secure competitiveness and profitability.

Environmental Performance

Today's need is to minimize the carbon emission which is increasing every second in our country. According to some generous blogs it is known that circular economy would help in reducing carbon footprint as well. This strategy not only is applicable to carbon footprint but also useful for remanufacturing purposes. Practices now a day's are all based upon those techniques which could help environment in recovering fast. For calculating and manipulating carbon footprint an environmental sustainability performance model is used of industrial- level supply chains. According to some famous researchers, total cumulative carbon footprint is increasing with time which a great reason to worry about. This statement was made on the basis of 20years old data analysis. Most important for a supply chain in the aspect of environment is to go for green supply chain rather than applying full circular economy. Green supply chain means it will

automatically assumes environment as an integral part of supply chain and also introduces sustainability.

Forecasting Factor

This is basically a technique that is used to predict the future. In this context forecast means how well few statements can make a variable look good and make performance of the both economy and supply chain feasible. This construct will be dealing with some questions which are to be presented in front of the big MNC employees and after collecting responses from them they will cumulatively make forecast construct.

Technological Factor

Technology and management includes reliable information and market issue as the critical part of its existence. Basically this construct name is very factor or categorical in nature as it does not imply anything precise but provides great insights when linked with forecasting techniques. New technology in the concern field is always appreciated as it allows the transition of new strategies to goal achieving methods. This transaction deals not only in hypothetical world but also in real life solving problems.

Supply Chain Performance

This construct can be termed as dependent construct as all other construct are accumulated to answer this very construct. Performance of supply chain can be evaluated by connecting the entire construct in such a manner that the model is valid and in a condition to have prediction relevance i.e. Q^2.

3.4 Measurement model

Measurement model also known as outer model is taken as reflective in nature as the construct itself speaks about these the indicators. Only after coming on the construct, these indicators or manifest variables are determined. Number of relationships are reduced to ensure structural model parsimony, and in order to start discriminant validity reduction of collinearity issues are

the most important reasons for using the reflective component model (Hair et al., 2014, pp.229-230). In reflective component intentionally the less outer loading indicators are kept. As the model building was very difficult, removing any indicator results into a wrong value of R^2 or lower AVE. So the model is made with much care so that the model should be stable and have good R^2 value.

3.4.1 Reliability

The measurement of reliability is taken as a crucial step by using the measure of composite reliability as it is far better than Cronbach's Alpha in measuring internal consistency reliability. Composite reliability has two advantages over Cronbach's Alpha: First is that it does not consider all the indicators of the construct are equal contributor which is a measure issue in Cronbach's Alpha. Secondly, by adding more and more indicators it does not increase the value of internal consistency reliability as does by Cronbach's Alpha. Cronbach's alpha pre considers that all indicators are equal reliable (i.e., outer loadings of all the indicators on the construct are equal). Henseler et. al. (2012), stated that threshold value of internal consistency reliability for confimative studies should be greater than or equal to 0.70 but according to Daskalakis & Mantas (2008) it will be better if this value reaches more than 0.80.

Indicator reliability is item's communality. It can be find out by squaring the outer loading. Indicator reliability also has a threshold value like every other reliability measure which is greater than 0.5 (Hair et al., 2014). This threshold value states that atleast 50% of the variation in the items(indicators) is explained by the construct itself which also means that the relation between the construct and the indicators are well managed and it also embedded theoretically meaning.

3.4.2 Convergent validity

A strongly recommended test to measure the convergent validity is the average variance extracted (AVE) (Naylor et al., 2012). AVE threshold value should be more than 0.50 to have a genuine convergent validity. The amount of correlation that the manifest variable of a reflective construct has on different measure on different construct is known as convergent validity. AVE

is used to measure convergent validity. AVE is also known as the construct's communality. It indicates variance of construct explained by its indicators.

3.4.3 Discriminant validity

Discriminant validity can be worked using Fornell-Lacker (1981) criterion which is a association between other latent variables and square root of AVE. Discriminant validity is a uniqueness measure of a construct which represents is differentiation from other constructs. Discriminant validity of scales uses a relationship by examination whether the construct square root of AVE is better than the inter-construct present in the model (Fornell & Larcker, 1981). A latent variable should explain better the variance of its own indicators than the variance of other latent variables.

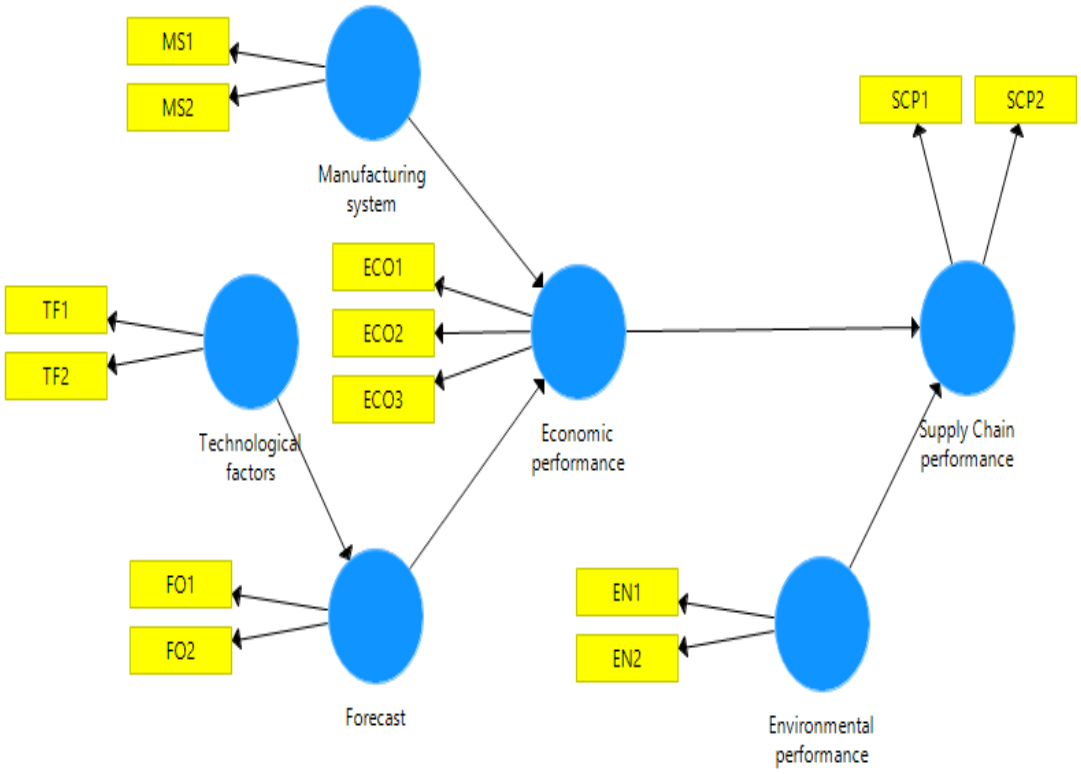


Figure 8 Measurement model of the constructs

3.5 Structural model

This research study has used the constructs of product service system, stakeholders, economy, forecasting, technology and management as the exogenous constructs. Further, this research study has taken supply chain performance as an endogenous construct. Therefore, types of stakeholders are theoretically expected to enhance the economy of the organization that improves endogenous latent variable supply chain management performance. This research study considers many different construct that would help the formation of a model that leads it to supply chain performance. In the present study the structural model does not conceptualizes the mediating effect of forecasting on the relationship between technology and management. This model only contains the constructs and not their respective manifest variables. This is because the structural model shares path coefficients which if taken alone then it behaves just like linear regression. Path coefficients are also know as beta which helps to calculate the relationship between independent and dependent variable.

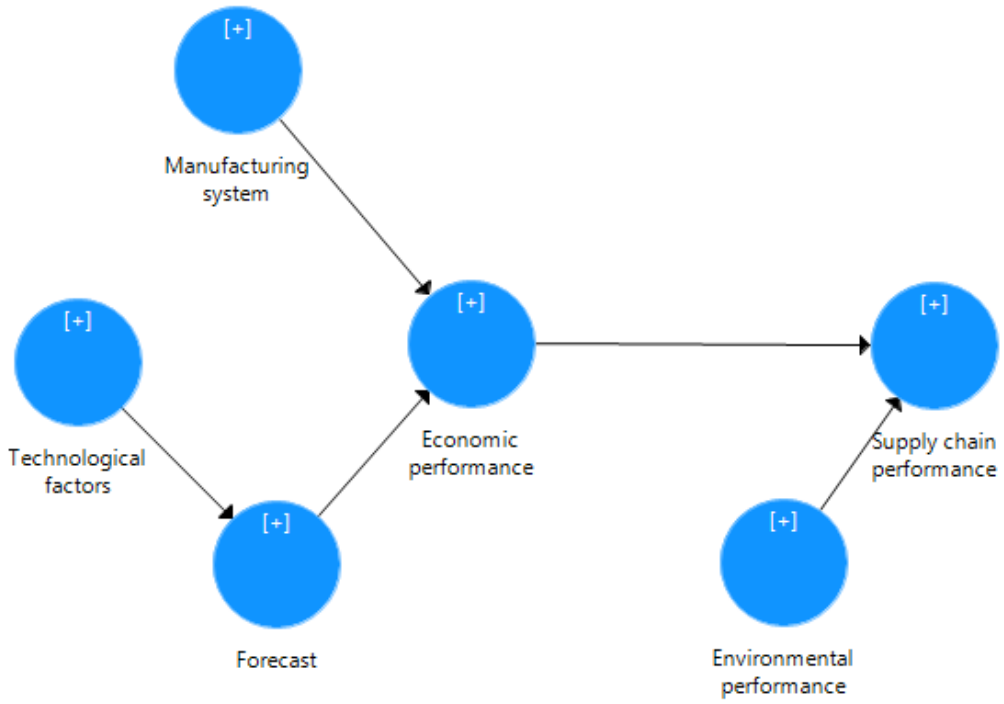


Figure 9 Structural model of the constructs

3.5.1 Predictive Relevance (Q^2)

When there is need of prediction purpose, PLS requires a measure of predictive capability. Blindfolding is the suggested approach that is applicable to only reflective endogenous variable. Firstly, applying blindfolding in the inner model for getting the prediction of endogenous variable and then from endogenous variable predicts its indicators.

For setting omission distance,12<D<3 (not necessarily). D should not be the multiple of number of observant then each with iteration it will omit a complete row. For each endogenous latent variable calculate the sum of square of prediction and sum of square of original (omitted) values.

$Q^2 > 0$ The model has predictive relevance.

$Q^2 < 0$ The model has a lack of predictive relevance.

CHAPTER 4: HYPOTHESIS DEVELOPMENT

4.1 Introduction

This chapter assesses the structural and measurement model study and also derives different insights out of the data. Structural Equation Modeling (SEM) is used as a data analysis technique to work on the path modeling. Within SEM there are basically two methods: first one is covariance based and other is variance based. CB-SEM is known as co variance based structural equation modeling. Estimation of coefficient of determination, determination of effect sizes of relationships, assessment of significance of relationship among constructs of the study, predictive relevance, and the inference of effect sizes of values of predictive relevance are detailed converse in this chapter. Hypothesis testing result are also carried out in this chapter. Finally this chapter defines PLSPM result in an appropriate manner.

4.2 Hypotheses development

In a stepwise procedure, the structural model analysis was performed. The relationship between dependent variable and independent variables was considered so as to test the hypotheses 1 to 5.

a) Direct effect of 'Manufacturing System' on 'Economic Performance' (Hypothesis 1).

b) Direct effect of 'Economic Performance' on 'Supply Chain Performance' (Hypothesis 2).

c) Direct effect of 'Technological factors' on 'Forecast' (Hypothesis 3).

d) Direct effect of 'Forecast' on 'Economic Performance' (Hypothesis 4).

e) Direct effect of 'Environment' on 'Supply Chain Performance' (Hypothesis 5).

As there is no mediating construct hence no complexity in the execution of the model is obtained. For analyzing these hypothesis structural model is taken into account so that it should be clear that whether it does affect the endogenous construct or it has no significance. For checking the significance of the hypotheses there t value and respective p values are considered. As the test that is used to signify whether hypotheses are significant, two-tailed test is used hence minimum value of t-value is 1.96 and p value is 0.05(considering significance level as 5%).

4.3 Measurement model assessment

Table 1 Reliability and Validity of constructs

Below table shows that all the variables and their indicators either endogenous or exogenous have significant reliability. Taking about AVE it is also significant and can be used without any problem. Composite reliability should be between 0.60 and 0.70 and is considered acceptable. Reflect on Cronbach's alpha as a conventional measure of internal consistency reliability.

Table 7 Reliability and validity of construct

Construct	Indicators	Outer loadings	Composite reliability	AVE
MS	MS1	0.830	0.713	0.559
	MS2	0.787		
TF	TF1	0.755	0.722	0.564
	TF2	0.748		
FO	FO1	0.962	0.783	0.611
	FO2	0.819		
ECO	ECO1	0.755	0.821	0.778
	ECO2	0.75		
	ECO3	0.896		
EN	EN1	0.783	0.723	0.566
	EN2	0.721		
SCP	SCP1	0.73	0.704	0.726
	SCP2	0.81		

Convergent validity is determined by AVE which should be higher than 0.50. To obtain the AVE values, squaring of each of the outer loading, getting the sum of the three squared outer loadings, and calculating the average value is done. Therefore, communality of a construct is equivalent to the AVE.

4.4 Structural model assessment

The most common measure for examining the structural model is coefficient of determination. This coefficient is a gauge of the accuracy of model's prediction and is designed as the squared correlation between a definite endogenous (dependent) construct's actual and predicted values. The coefficient of determination for exogenous variables is 0 as they don’t have any preceedor to

it so none is present for explaining its variance. Above table shows that all the measures are above threshold which means, it is good to retain all the used indicators.

Table 8 R square values of the dependent variable

	R Square	R Square Adjusted
ECO	0.337	0.335
FO	0.296	0.294
SCP	0.473	0.460

Discriminant validity is the degree to which a construct is extremely distinct from all other constructs which means that each construct is unique in itself. Two measures of discriminant validity have been offered. It represents the square root of the AVE values with the correlations of the latent variable. Specifically, a construct shares more variation with its related indicators than with other mentioned indicators of other construct.

Table 9: Fornell-Lacker criteria of all constructs

	ECO	EN	FO	PSS	SCP	TM
ECO	**0.760**					
EN	0.287	**0.753**				
FO	0.310	0.580	**0.781**			
MS	0.207	0.114	0.484	**0.747**		
SCP	0.173	0.472	0.237	0.387	**0.725**	
TF	0.289	0.382	0.482	0.411	0.073	**0.751**

4.5 Hypothesis testing

a) Direct effect of manufacturing system on economic performance

The direct effect of ‘manufacturing system’ on economic performance shares a path coefficient of 0.337. By the empirical t value of 2.3127, the significance of this path coefficient that shows the relationship between ‘manufacturing system’ and economic performance is significant. Hence it shows the positive relevance of both the construct and also tells that the hypothesis corresponding to respective construct is significant as they share a direct effect relationship.

b) Direct effect of economic performance on supply chain performance

The direct effect of ‘economic performance’ on supply chain performance shares a path coefficient of 0.321. By the empirical t value of 8.9672, the significance of this path coefficient that shows the relationship between ‘economic performance’ and supply chain performance is significant. Hence it shows the positive relevance of both the construct and also tells that the hypothesis corresponding to respective construct is significant as they share a direct effect relationship.

c) Direct effect of technological factors on forecast

The direct effect of ‘technology and management’ on forecast shares a path coefficient of 0.282. By the empirical t value of 5.471, the significance of this path coefficient that shows the relationship between ‘technology and management’ and forecast is significant. Hence it shows the positive relevance of both the construct and also tells that the hypothesis corresponding to respective construct is significant as they share a direct effect relationship.

d) Direct effect of forecast on economic performance

The direct effect of ‘forecast’ on economic performance shares a path coefficient of 0.276. By the empirical t value of 7.9473, the significance of this path coefficient that shows the relationship between ‘forecast’ and economic performance is significant. Hence it shows the positive relevance of both the construct and also tells that the hypothesis corresponding to respective construct is significant as they share a direct effect relationship.

e) Direct effect of environment on supply chain performance

The direct effect of ‘environment’ on supply chain performance shares a path coefficient of 0.173. By the empirical t value of 4.5633, the significance of this path coefficient that shows the relationship between ‘environment’ and supply chain performance is significant. Hence it shows the positive relevance of both the construct and also tells that the hypothesis corresponding to respective construct is significant as they share a direct effect relationship.

Table 10 Significance of relationship

Hypothesis	Relationship	Path coefficients	t-value	P-value	Result
H1	MS-ECO	0.337	3.46	0.012	**Accepted**
H2	ECO-SCP	0.321	2.54	0.014	**Accepted**
H3	TF-FO	0.282	2.16	0.016	**Accepted**
H4	FO-ECO	0.276	3.12	0.011	**Accepted**
H5	EN-SCP	0.173	3.02	0.010	**Accepted**

CHAPTER 5: RESULT AND CONCLUSION

5.1 Introduction

This chapter summarizes all the calculations and builds a relationship between what has happened earlier and what conclusion this study has come up with. Further, this study examines the effect of each construct on its latent endogenous construct and also tells whether to retain that construct in the model or not and the same is for indicators as well. A small glance of the actually data file is shared in this chapter with and without standardizing them. Measures such as reliability and validity as discussed in the previous chapter are also explained here in the context of circular economy factors in supply chain management. For examining the structural model, predictive relevance (Q^2) is used. Finally, the strongest and mildest relations between different constructs are evaluated on the basis of different measures calculated earlier.

5.2 Outer loading

It is the loading of the indicators to the respective constructs. From previous studies this insight could be made that an indicator must share higher values of outer loading with the construct because it helps in explaining the construct well and a strong bond is made between them. In this study, each construct is examined with its indicators to check the relationship. After running the consistent PLS algorithm, all the outer loading related to the indicators are shown in table below. Any outer loading that is less than 0.7 should be ignored in the further process.

According to the Table, economic performance has three indicators ECO1, ECO2, ECO3 and all these indicators share a good amount of relation with the construct economic performance. Among all the three indicators, ECO3 has the largest outer loading which states that it explains its existence in this construct much well than other twos. ECO3 has 0.896 outer loading and ECO1 and ECO2 have 0.755 and 0.75 outer loadings.

In respect of environment construct, it has only two indicators EN1 and EN2. Considering this construct, EN1 has a high value of outer loading as compared to the other same construct indicator. As both the indicators crossed the threshold of the outer loading both of them are retained. Similarly for forecast construct also, all the indicators are feasible to be used within the model. FO1 has an outer loading of 0.962 and FO22 has an outer loading of 0.819 which is a number for any indicator to achieve.

In respect of manufacturing system construct, it has only two indicators MS1 and MS2. Considering this construct, MS1 has a high value of outer loading as compared to the other same construct indicator. As both the indicators crossed the threshold of the outer loading both of them are retained. MS1 is 0.83 and MS2 is 0.787. Supply chain performance construct has two indicators SCP1 and SCP2 and both these indicators share a good relationship with the construct supply chain performance. Among these two indicators, SCP2 has the largest outer loading which tells that it explains its subsistence in this construct much well than other one. SCP1 has 0.73 outer loading and SCP2 has 0.81 outer loadings. In respect of technology and management construct, it has only two indicators TF1 and TF2. Considering this construct, TM2 has a high value of outer loading as compared to the other same construct indicator. As both the indicators crossed the threshold of the outer loading both of them are retained. TM1 is 0.755 and TM2 is 0.748.

5.2.1 Reliability and Validity

Economic performance construct have R^2=0.337 which is 33.7% variance explained by the indicator, composite reliability is 0.821, indicator reliability is 0.838 and average value extracted (AVE) is 0.57. Forecast construct have R^2=0.296 which is 29.6% variance explained by the indicator, indicator reliability is 0.73, composite reliability is 0.783 and average value extracted (AVE) is 0.611.

Supply chain performance construct have R^2=0.473 which is 47.3% variance explained by the indicator, composite reliability is 0.704, indicator reliability is 0.749 and Average variance extracted (AVE) is 0.526.

Structural model contains data related to predictive relevance and effect size of the constructs. This model is made by connecting different construct in sequence of their meaningful way. Following are the different measures for constructs:

Having manufacturing system as an independent variable and economic performance as the dependent one, its predictive relevance is 0.28. Considering forecast as an independent variable and economic performance as the dependent one, its predictive relevance is 0.29. Having technological factors and management as one exogenous variable and forecast as the endogenous, their predictive relevance is 0.28.

Considering economic performance as the independent construct and supply chain performance as dependent construct, their predictive relevance is 0.47 which is very high. Finally, environments construct as independent and supply chain performance as dependent construct, its predictive relevance is 0.34.

Conclusion

As a conclusion of all the measures discussed in chapter 5, all hypothesis are supported and significant. In India, mostly all sectors prefer the need of maintenance that should be done periodically of the products and depending on the working of sector, renting of the products must be preferred. This service system of the product is supported by our model too. Good product service system have influencing power on economic performance, hence a better service system should be opted. It is essential for the supply chain to have a prior knowledge of the market which is very critical for the profitability of the organization.

Capturing new market is also good for the firm. This knowledge is lead to forecasting techniques where this information is analyzed and meaning patterns are been taken out of it. Uncertainty in return product has been found as critical measure in the implementation of circular economy in the supply chain which makes forecasting difficult. Market research is a key parameter which should be taken into account before applying circular economy in the organization.

Forecasting with recent technologies and management does have positive influence on the economic performance of the firm. In case of share holders, all the considered share holder are significant which means no conclusion can be made out of it regarding which one should be chosen for the organization. But this insight can be made that significance of society as a share holder is highest amongst the other two. Share holder chosen does positively affect economic performance of the firm but as compared to other variable like product service system and forecast it is little less effective.

To enhance the economic performance, reusability of the products should be accepted; virtual customer service should also be maintained and good quality and warranty products are much promoted. If marketing is done enough of the eco-friendly products it actually generates attention from the customer as customers now a day are very conscious about the environment which positively affects the performance of the supply chain. Proper disposal of the product is also a way to be customer centric which strengthens supply chain performance. Shorter product life cycle depends on the product actually but according to this model, shorter product life cycle is responsible for the effectiveness of the supply chain.

In the model, economic performance has the highest significance value with supply chain performance and also has highest predictive relevance and effect size which means most effective parameter in the model that is responsible for the performance of supply chain is its economic performance. Hence, these circular economy factors do have a statistically significant potential to influence the performance of the supply chain.

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Appendix

Factors	Questionnaire	Factors hypothesis
Manufacturing System	Q1. To what extent maintenance of product is important in a supply chain? Q2. Does renting of a product is good for the company?	H_1: Product Service System positively effects economic performance
Economic Performance	Q1 Does introducing reusability can enhance a supply chain economy? Q2 Does having a good quality and warranty of products leads to a better supply chain economy? Q3 Does having a virtual customer servicing enhances supply chain economy?	H_2: Economic performance positively effects supply chain performance
Technological factors	Q1 Does market information has critical significance with the supply chain? Q2 Does capturing new market leads to a change in the supply chain strategy?	H_3: Technology and management positively effects forecast
Forecast	Q1 Does uncertainty in return products effects forecasting for new products in a supply chain? Q2 Does predicting on the basis of market research is enough for the supply chain betterment?	H_4: Forecasting directly effects economic performance of circular economy in supply chain
Environmental performance	Q1 Does making products environment friendly is responsible for the increase in attention from customer? Q2 Does proper disposal of the products is good for customer centric supply chain?	H_5: Environment directly effects supply chain performance
Performance of Supply chain	Q1 Does incorporating circular economy factors actually strengthens the supply chain efficiency? Q2 Does having a shorter product life cycle leads to a not so good supply chain?	