UNIVERSITY OF DERBY

C-LEAN, AN INTEGRATED APPROACH TO ACHIEVE CIRCULARITY IN MANUFACTURING OPERATIONS OF SMEs

Simon Peter Nadeem

Doctor of Philosophy 2019

ABSTRACT

Purpose – The concept of Circular Economy has gained momentum both because its emergence is timely and that it proposes the solution that makes businesses more responsible, considerate and ethical. While the concept is straightforward to understand, its practical implementation is challenging, especially for manufacturing SMEs. Its popularity and adoption, mainly at the macro level is at rise, however, that is not the case at the micro and meso level (SMEs). Without the participation of SMEs in adopting Circular Economy, its full spectrum cannot be realised, since SMEs contribution to national GDP is nearly 50% globally. Therefore this research focuses on developing an integrated framework to achieve circularity in manufacturing operations of SMEs by combining the principles of Circular Economy and Lean, as they both focus on waste elimination and value creation/ preservation. The proposed framework (C-LEAN) utilises Lean tools and methods mingled with Circular Economy principles to achieve circularity as well as efficiency and effectiveness in manufacturing operations, especially at SMEs level.

Design/ Methodology/ Approach – The framework's design/ development is inspired by existing frameworks proposed by scholars. While the framework might seem a reflection of DMAIC, it, however, differ in its core nature/ purpose as the former focuses on problem-solving existing in operations, while for the proposed framework an operation might be functioning fine but would require a change to deal with bigger picture issues, such as resource scarcity and environmental damage. The conceptual framework is verified through Delphi study, where experts (both the academic and the practitioners) have been engaged to analyse the construct and practicality of the conceptual development. The framework has been modified/ updated in light of Delphi study's results. Furthermore, the framework has been validated through a case study method with partial implementation, where its initial phases have been applied in two medium size manufacturing companies, to test its practical relevance.

Findings – It was realised that there is both a massive lack of awareness/ understanding about Circular Economy as well as skills/ knowledge to identify the potential and adopt Circular Economy in the manufacturing operations among SMEs. However, at the same time, the existence of a Circular Economy practice was observed in a company where the purpose was solely for economic benefit, without any knowledge or intent of participating in Circular Economy goals. The analysis of companies pointed to potential improvements, that will lead towards achieving circularity in those respective companies. At the same time, the framework

serves as a tool for the companies to continuously monitor and explore potential to improve their operations and achieve efficiency with effectiveness in a circular manner.

Research implication/ Limitation – This research's novelty lies in the fact that the convergence of Circular Economy and Lean has not been explored by scholars to its full extent and that no such framework has been developed earlier by combining the strengths of two concepts to benefit the management of manufacturing operations, especially at SMEs level.

A major limitation is the partial implementation of the framework with the projected scenario of the potential outputs. The full implementation of the framework was not realistic, as it requires time to see the observable outcomes as well as changes in processes and capital to acquire resources.

Practical implications – The proposed framework is of greater practical relevance as it is grounded in two concepts of Circular Economy and Lean, and benefits from the approach/ design of earlier developed frameworks. Moreover, an amalgamation of Circular Economy with Lean further affirms its relevance as Lean has been widely appraised and adopted among the manufacturing sector.

DEDICATION

Frist of all, to my Lord and Saviour Jesus Christ, I dedicate my work through the words of this hymn:

To God be the glory, great things He hath done,
So loved He the world that He gave us His Son,
Who yielded His life our redemption to win,
And opened the life-gate that all may go in.

Oh, come to the Father, through Jesus the Son,
And give Him the glory; great things He hath done.

Fanny Crosby (1875)

And to my parents (Chaman Nadeem and Parveen Nadeem), their life and example is always a shining light for me.

ACKNOWLEDGEMENT

With my utmost gratitude to the Lord God Almighty, I would like to thank my wife Esther, daughter Shulmiyat and son Timothy, as well as my parents and siblings for their prayers, encouragement and support on this voyage of doctoral studies.

I am extremely grateful to my supervisor, Professor Dr Jose Arturo Garza-Reyes, for his phenomenal guidance, mentorship, and role model. He not only led me through the process of this research but also honed me as a researcher to contribute for a bigger impact.

I would also like to thank my second supervisor, Dr Anthony I. Anosike, who has provided his support to strengthen this research and to blend teaching with research in an inspiring way for students.

The author is thankful to the participants of Delphi study and the management/staff of the respected companies for participating in this study and allowing the testing of the developed framework in their respective workplace.

Finally, my sincere gratitude to the management, staff and leadership of the University of Derby for making it possible for me to achieve my ambitions for doctoral studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PUBLICATIONS

Publications related to this research topic
Journal Papers

Garza-Reyes, J. A., Salomé Valls, A., Nadeem, S. P., Anosike, A., & Kumar, V. (2018) "A circularity measurement toolkit for manufacturing SMEs", *International Journal of Production Research*, p. In press.

Book Chapters

Nadeem, S. P., Garza-Reyes, J.A., Glanville, D., (2018), The Challenges of the Circular Economy. In: E. Conway and D. Byrne, ed., *Contemporary Issues in Accounting.* Palgrave Macmillan.

Conference Papers:

Nadeem, S.P., Garza-Reyes, J.A., Anosike, T., Kumar, V. (2019), "Coalescing the Lean and Circular Economy", *Proceedings of the International Conference on Industrial Engineering and Operations Management Bangkok, Thailand, March 5-7, 2019,*
[Awarded the "Best Track Paper Award" under the Circular Economy]

Nadeem, S.P., Garza-Reyes, J.A., Leung, S.C., Cherrafi, A., Anosike, T., Lim, M.K. (2017), "Lean manufacturing and environmental performance – exploring the impact and relationship", *IFIP International Conference on Advances in Production Management Systems (APMS 2017): Advances in Production Management Systems. The Path to Intelligent, Collaborative and Sustainable Manufacturing*, Hamburg, Germany, September 3-7, pp. 331-340, Springer

Nadeem, S.P., Garza-Reyes, J.A., Anosike, T., Kumar, V. (2017), "Spectrum of Circular Economy and its prospects in Logistics", *Proceedings of the 2017 Symposium on Industrial Engineering and Operations Management* (IEOM), Bristol, UK, July 24-25, pp. 440-451.
[Awarded the "Best Track Paper Award" under the Circular Economy and Computing category]

Nadeem, S.P., Lim, M.K., Garza-Reyes, J.A. & Anosike, A.I., 2017. "Research Streams in the Scope of Circular Economy". In *CE2S Conference, The Circular Economy: Transitioning to Sustainability*, Coventry, 2017.

Other publications, not directly related to this research

Journal Papers

Gólcher-Barguil, L.A., Nadeem, S.P., Garza-Reyes, J.A., "Measuring Operational Excellence: An Operational Excellence Profitability (OEP) Approach", *Production Planning and Control*. In press.

Journal papers under review

Choudhary, S., Kumar, A., Garza-Reyes, J.A., Kumar, V., Nadeem, S. P., Khan, S. A. R., "Mapping the effectiveness of hard dimensions of green supply chain management", currently in revision for publication in the Journal of *Resource Conservation and Recycling*.

Conference Papers:

Dieu Ho, T.H., Daniel, J., Nadeem, S.P., Garza-Reyes, J.A., Kumar, V. (2018), "Improving the Reliability of Warehouse Operations in the 3PL Industry: An Australian 3PL Case Study", *Proceedings of the 2018 International Conference of the Production and Operations Management Society (POMS), Kandy, Sri Lanka, December 14-16.*

Kumar, V., Sabri, S., Garza-Reyes, J.A., Nadeem, S.P., Kumari, A., Akkaranggoon, S. (2018), "The challenges of GSCM implementation in the UK manufacturing SMEs", *Proceedings of the 2018 International Conference of the Production and Operations Management Society (POMS), Kandy, Sri Lanka, December 14-16.*

Seifullina, A., Er, A., Nadeem, S.P., Garza-Reyes, J.A., Kumar, V. (2018), "A Lean Implementation Framework for the Mining Industry", *Proceedings of the 16th IFAC Symposium on Information Control Problems in Manufacturing*, Bergamo, Italy. June 11-13

Garza-Reyes, J.A., Tangkeow, S., Kumar, V., Nadeem S.P. (2018), "Lean manufacturing adoption in the transport and logistics sector of Thailand – An exploratory study", *Proceedings of the 8th International Conference on Industrial Engineering and Operations Management (IEOM)*, Bandung, Indonesia, 6-8 March.

Maldonado-Guzman, G., Garza-Reyes J.A., Pinzon-Castro, S.Y., Mejia-Trejo, J., Kumar, V., Nadeem S.P. (2018), "Innovation and growth in family-owned SMEs", *Proceedings of the 8th International Conference on Industrial Engineering and Operations Management (IEOM)*, Bandung, Indonesia, 6-8 March.
[*Awarded the "Best Track Paper Award" under the Entrepreneurship and Innovation category]*

Pratama, N.A., Kumar, V., Garza-Reyes, J.A., Kumari, A., Nadeem, S.P. (2018), "Investigating the benefits and challenges of the implementation of ISO 9001 and ISO 14001 in the aerospace industry", *Proceedings of the 8th International Conference on Industrial Engineering and Operations Management (IEOM*), Bandung, Indonesia, 6-8 March.

Nadeem, S. P., 2016. *Risk Pooling, A Technique to Manage Risk in Supply Chain Management.* Bishkek, Kyrgyz Russian Slavic University, pp. 86-93. [Published in Russian language]

Chapter 1 Introduction

Research is a voyage of discovery (Saunders and Lewis, 2018) to explore, discover and expand the boundaries of knowledge for effective and efficient realisation of ideas/ concepts. This research is focused on discovering the potential of merging two concepts of Circular Economy and Lean, to benefit from their synergetic properties.

This chapter aims to provide a brief overview and rationale for this research, overall aims and objectives for this research, and the structure of this research.

1.1 Research background

Development, growth and innovation have always been the endeavour of human beings (Nadeem et al., 2018), both to meet the basic necessities, as well as for comfort and leisure. With growing urbanisation, and population growth expected to reach around 9 billion by 2050 (Govindan and Hasanagic, 2018), production and consumption are at a higher pace causing resource depletion (Jowit, 2008; Zhu et al., 2010) and environmental damages (Lai et al., 2013). The expected demand for resources is expected to be tripled by 2050 (L. Kok et al., 2013; Reh, 2013). Businesses are producing products with a shorter product life cycle (Wang et al., 2013), pertaining to fast production and consumption pattern (Garza-Reyes et al., 2018). While the increased production itself may not be a major issue, the damage to the environment due to the waste created and resource depletion is of concern (Lai et al., 2013).

Concerns initially raised by Boulding (1966) were further elaborated by Pearce and Turner (1989) who emphasised that a non-environmentally friendly economic system, with no clue for recycling (Su et al., 2013a), cannot sustain the future. This has raised alarming concerns requiring urgent attention by scholars and practitioners as it directly impacts present and future generations (Nadeem et al., 2017a). Webster (2015) argues the current economic system is no more than a race for the remaining resources.

Initiatives, tools, and models have been and are being, developed to manage this phenomenon at hand, either directly or indirectly. One of the relatively recent developments with a direct focus on the given issue is Circular Economy (hereafter referred as CE) that has and is gaining momentum (Ghisellini et al., 2016; Govindan and Hasanagic, 2018; Kirchherr et al., 2017). Ellen MacArthur Foundation (2017c), one of the leading organisations to develop and promote this concept globally provides a comprehensive infographic in the form of a butterfly-shaped diagram (see Figure 1.1) to describe the concept and its principles, discussed in chapter 2.

'content removed for copyright reasons'

Figure 1.1 Circular Economy system diagram (source Ellen MacArthur Foundation, 2017c)

1.2 The rationale for this research

Effectiveness and efficiency are two elements that are often not achieved to their fuller extent (Mass, 2005; Mouzas, 2006), especially in the context of the manufacturing business. For decades, there has been growing research resulting in the emergence of new methodologies, concepts and tactics to optimise the business operations (e.g. Lean, BPR [business process reengineering], Six Sigma and Balance Scorecard). While the research and development increased the efficiency of business operations, it did not always achieve effectiveness in its full depth especially when seen from the concerns of CE perspective. Instead, it did come with the consequences such as environmental damage, resource depletion, and irresponsible disposal of the products at the end of their life cycle. This lead to what the businesses and world face today in terms of climate change, scarcity of resources, along with ocean and land polluted with disposal; causing harm to habitat and damage at an alarming level (Jowit, 2008; Winston, 2018).

This research is stimulated from this recently emerged and one of the most explored research areas of CE (Urbinati et al., 2017) and its application in manufacturing operations management, especially at SMEs (small and medium enterprises) level. CE claims to set a new contrasting pathway to the existing linear economic model (Webster, 2015) that leads to both the economic growth as well as addressing the challenges causing the ecological issues and resource scarcity faced today. SMEs represent a significant proportion in an economic setting with up to 50% contribution to national GDP (Oliveira et al., 2018), therefore adoption of CE is of greater relevance among SMEs. SMEs struggle to adopt CE due to lack of knowledge, skills, finances and resources (Dekoninck et al., 2016; Rizos et al., 2016).

One of the barriers for CE implementation is the need for new business models (Abreu and Ceglia, 2018) and implementation methods/ tools to enable the implementation (Ghisellini et al., 2016; Pieroni et al., 2019) or to adapt the existing business operations to become circular (Urbinati et al., 2017). Moreover businesses lack the knowledge and skills to enable the adoption of CE in their operations (Muranko et al., 2018; Rizos et al., 2015). This research gap is further emphasised by scholars highlighting the need for manufacturing companies to change their own business model (Parida et al., 2019) as they have a significant impact on ecology (Franco, 2017).

1.3 Aim and objectives of this research

The overall aim of this research is to explore the potential amalgamation of the two concepts of Lean and CE to benefit from each other's strengths and build on their synergetic properties to benefit the manufacturing sector, especially at SMEs level.

To achieve the above-mentioned aim, the following research objectives (RO) are defined for this research:

RO1 To understand the concept of Circular Economy, its scope and implications

RO2 To explore the synergies and divergences between Circular Economy and Lean

RO3 To amalgamate the strengths of the two concepts and develop an implementation framework for the manufacturing sector, especially at SMEs level

RO4 To verify the developed framework through experts' opinion

RO5 To validate the developed framework through implementation

1.4 Research structure

With the above aim and objectives, this research is structured in six stages (see Figure 1.2) containing 8 chapters. Stage 1 is for scoping the research; stage 2 is for literature review and exploring the synergies and divergences between CE and Lean; stage 3 defines the research methodology; stage 4 is for conceptual development of the framework; stage 5 is for verification and validation of the conceptually developed framework; and finally, stage 6 provides conclusions, limitations and future research directions of and from this research.

Chapter 1 provides a brief overview of this research with the background, the rationale for this research, its aim and objectives and the overall structure of the whole research.

Chapter 2 explores a review of literature on the concept of CE. It explores the academic published literature as well as other reliable online sources such as websites, reports and articles of well-known organisations engaged in the development and application of CE. The chapter provides information regarding the concept, its definition and principles, its adoption and barriers faced in its implementation and finally identifies a research gap to be considered for this research.

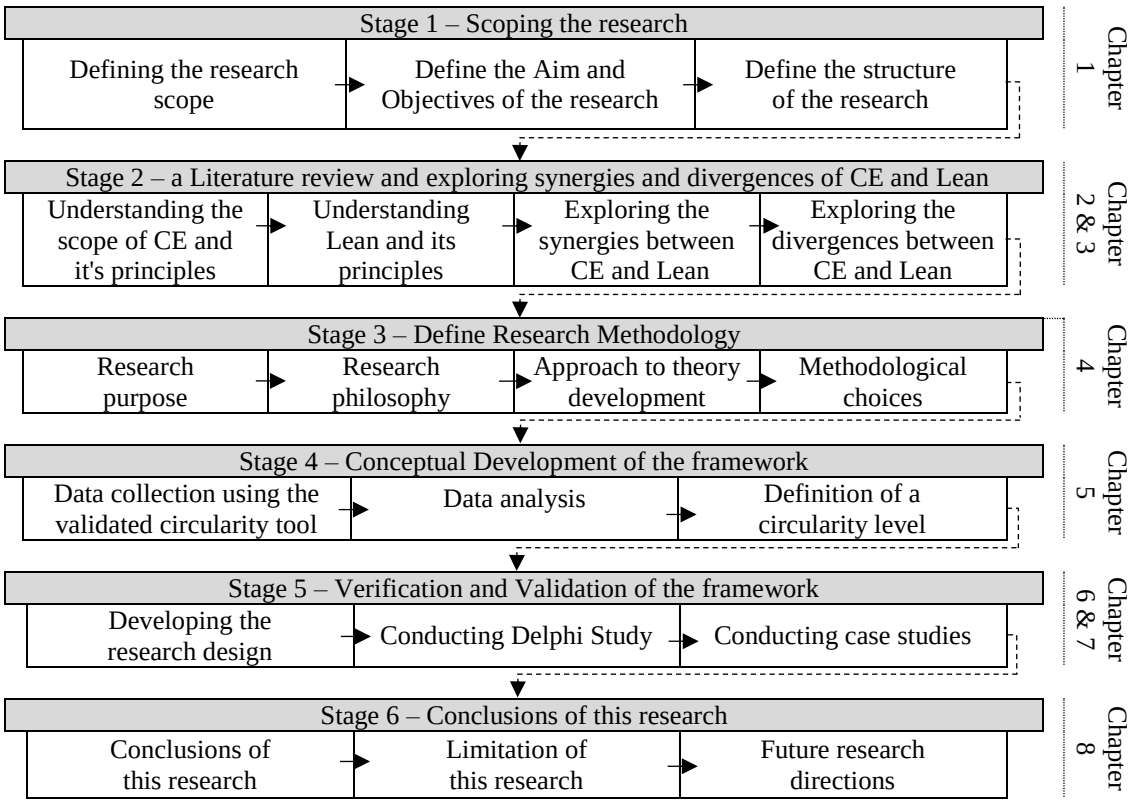


Figure 1.2 Structure of the research

Chapter 3 studies the concept of Lean and its principles. It further explores the common elements between CE and Lean and defines the interrelatedness of the two concepts. It affirms the potential of amalgamating the two concepts to benefit from their synergies.

Chapter 4 scopes the research methodology, utilising the research onion approach developed by Mark Saunders. The chapter provides an overview of the research purpose, its philosophy, the approach to theory development and methodological choices chosen for this research. It further defines the research strategy, time horizon, data collection and data analysis approach utilised in this research.

Chapter 5 develops the conceptual framework by combining the best of the two concepts of CE and Lean. An overview of how the proposed framework is developed is outlined prior to definitions of each phase and step of the proposed framework, with academic underpinning. The framework is called C-LEAN, with its meaning being '*Circular Lean*'.

Chapter 6 designs a verification mechanism to verify the conceptually developed framework. The approach of the Delphi study is utilised to seek experts' opinion and amendments are made in light of the constructive criticism, suggestion and feedback from the research participants.

Chapter 7 validates the verified framework through a case study approach. A partial implementation of the proposed verified framework in two manufacturing SMEs led to support the reliability and practical relevance of the developed framework.

Chapter 8 draws the conclusions from this research and provides the contribution of this research. It further provides limitations of this research and potential future research directions to be explored.

Chapter 2 Literature review (Circular Economy)

2.1 Introduction

The concept of CE is relatively new, receiving significant attention both by researchers and practitioners (Nadeem et al., 2018, 2017a; Reike et al., 2018). CE has great potential to benefit the current day challenges of resource scarcity and environmental damages through its closed-loop approach in contrast to the existing linear economic model (Ellen MacArthur Foundation, 2015a; Webster, 2015).

The aim of this chapter is to explore the academic literature in the era of CE to understand its scope, depth, and implementation among the manufacturing sector, especially at SMEs level.

With the above aim the objectives of this chapter are:

- To develop a sound understanding of CE, its principles and scope
- To understand the challenges/ barriers to CE implementation
- To identify the gap that can potentially be addressed through this research

To achieve the above aim and objectives, an online search was carried out utilising the keywords: *Circular Economy*, *Circularity*, and *Circle Economy*. Academic journal articles and research papers were accessed from following electronic database portals; Science Direct (www.sciencedirect.com), Emerald Insight (www.emeraldinsight.com), Inderscience (www.inderscience.com), Springer (www.springer.com), Taylor & Francis (www.tandfonline.com), IEEE Xplore (ieeexplore.ieee.org/Xplore/home.jsp), Google Scholar (scholar.google.co.uk) and from the resources available in library of the University of Derby. In addition, further research was carried out through websites of major organisations active in promotion and implementation of Circular Economy (e.g. Ellen MacArthur Foundation, Circle Economy, WRAP, European Commission, McKinsey&Company, Zero Waste Scotland). A further Google search also revealed news articles and other reports which provided further insight to develop a comprehensive understanding of the topic.

The above-mentioned resource repositories were considered sufficient to establish an understanding of the topic at hand and lay the foundation for the development of further research. The major criteria for exclusion and inclusion were that it had to be focused on exploring the scope of CE, expanding the understanding, and exploring limitations/ gaps for

further research. The research only included articles which had been published with direct focus, and within the purview of CE.

This chapter is organised in six sections to present the overall scope, aim, objectives and methodology for this chapter (see section 2.1), exploring the concept of CE (see section 2.2), the adaptation of CE at policy level (see section 2.3), barriers in implementation of CE (see section 2.4), identifying the gaps in current developed academic research (see section 2.5) and finally the conclusions (see section 2.6).

2.2 Circular Economy – concept and exploration

The concept of CE contrasts with the linear approach (see Figure 2.1) using *'roundput'* instead of *'throughput'*, where resources are used but not used up (Webster, 2015) through cyclical thinking (Homrich et al., 2018). The concept is approached from different perspectives and is believed to have its origin in the Eco-Industrial Development (EID) concept which suggests that both healthy economy and healthy environment can coexist (Geng and Doberstein, 2010; Ghisellini et al., 2016). Irrespective of the origins of CE, its emergence is out of necessity due to the alarming situation of the current economic system, where the resource consumption is 30% higher to what the earth can replenish (Jowit, 2008).

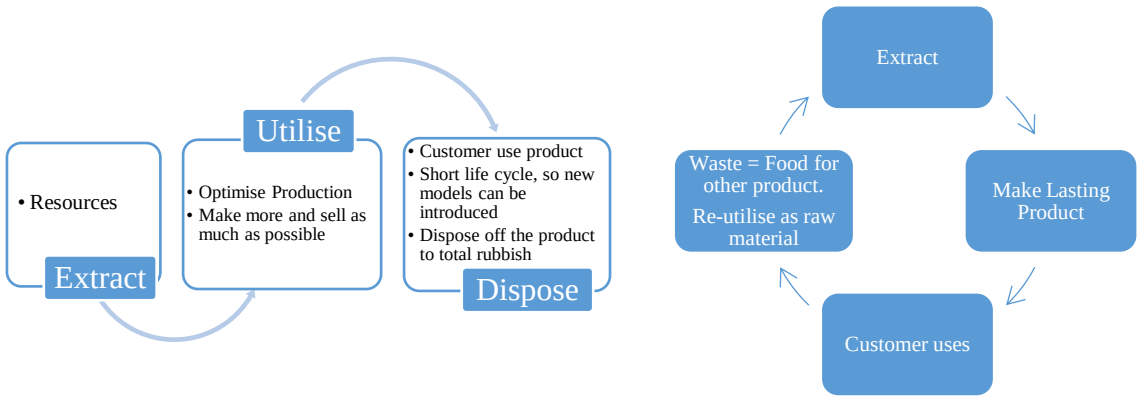


Figure 2.1 Linear vs Circular Economy

CE proposes decreased usage of virgin raw material and instead to reutilise the existing materials (Govindan and Hasanagic, 2018; L. Kok et al., 2013) through re-extraction from the product at the end of their life cycle. Moreover, the concept proposes utilising the product as a service to reduce immense dependence on natural resources (Ejik, 2015). Due to the growing awareness and knowledge about the increasing scarcity of resources, businesses are compelled

to rethink their business strategy and make it as Green, Lean, Sustainable, and Circular as possible to minimise their negative impact to the environment (Lai et al., 2013). This also opens the growth and expansion opportunities for businesses (Nadeem et al., 2018; Yuan et al., 2006).

2.2.1 Historical development

The concept has been the point of discussion and development over the last five decades (Nadeem et al., 2018, 2017a) however it is believed to have existed for a long time (Murray et al., 2017). Its origin cannot be traced back to any specific date (Millar et al., 2019) but has gained momentum since the late 1970s (Webster, 2015).

Professor Kenneth E. Boulding, a pioneer environmental economist, is believed to have conceived the embryonic idea of CE (Boulding, 1966; George et al., 2015; Ghisellini et al., 2016). Resource scarcity, increased extraction, escalating prices, and climate change are among the top reasons for the development of CE (Boulding, 1966; Gregson et al., 2015). If to look back further in history, Henry Ford's credo *"You must get the most out of the power, out of the material, and out of the time"*, can be named as the initiation of the momentum towards CE (Braungart and McDonough, 2002). Further developments occurred on the similar notion and the concept, ideas and practices emerged such as Just in Time [JIT] (Liker, 2004), Green Production and Logistics (McKinnon et al., 2010) and Lean Thinking (Goldsby and Martichenko, 2005).

While all of these concepts/ approaches benefited the business world, Jowit (2008) would argue this also led to an *'ecological credit crunch'*. Jowit in 2008 and Winston in 2018, both recognised the fast approaching critical prediction of future by 2030, whereby two planets will be needed to sustain life if no actions are taken (Jowit, 2008; Winston, 2018). In support of this, scholars have highlighted the fact that the economic system from the past 250 years is living on borrowed time (Lacy and Rutqvist, 2015).

Earlier mentioned and similar concepts/ models have mainly prioritised business optimisation in a linear manner, which is take – make – dispose (Ellen MacArthur Foundation, 2015b), also known as *"Cradle to Grave"* (Braungart and McDonough, 2002). The linear economy assumes large quantities of and easily accessible resources and energy, which is being idealistic in the face of resource scarcity faced in the present day (Webster, 2015). Concepts such as Green, Ecological, Environment-Friendly, Sustainability, Lean and Recycling, have provided

solutions but mostly in a reactive manner (Nadeem et al., 2018); whereas the current speedy depletion of resources demands for different rules of the game (Webster, 2015).

Circular Economy is a pro-active approach where there is no concept of waste because waste becomes food for another within the closed loop system (Ellen MacArthur Foundation, 2015b; Webster, 2015). The core idea is to re-utilise the resources for their residual value and doing so by closed loop economic system. Table 2.1 below presents the evolution of CE with a brief overview of key concepts that contributed to the emergence of CE.

Table 2.1 Evolution of Circular Economy

School of Thoughts	Key idea(s)	Developed by	References
Earth as a spaceship	Planet Earth with a closed loop system	Kenneth Boulding	(Boulding, 1966; Hu et al., 2011)
Regenerative Design	Regenerative design that could be applied to all systems	John T. Lyle	(Ellen MacArthur Foundation, 2015b)
Performance Economy	Closed loop approach: • Product Life extension • Long life goods • Reconditioning activities • Waste prevention Functional service economy - Sell services rather than products	Walter Stahel	(Walter R. Stahel, 2016; Webster, 2015)
Cradle to Cradle	All material is a nutrient of two categories: technical and biological. Nature's biological metabolism as a model for developing Technical Metabolism. Waste equals food.	Michael Braungart	(Braungart et al., 2007; Ellen MacArthur Foundation, 2015b; Webster, 2015)
Industrial Ecology	Focusing on connections between operators within the industrial ecosystem – aim for creating closed-loop processes. Science of sustainability	Robert A. Frosch and Nicholas E. Gallopoulos	(Graedel, 1996; Yuan et al., 2006)
Biomimicry	Innovation inspired by Nature Imitate nature's best ideas to solve human problems Nature as a model, measure and mentor	Jaine Benyus	(Ellen MacArthur Foundation, 2015b; Webster, 2015)
Blue Economy	Cascading – waste of one product becomes the input to create new cash flow. Substituting something with nothing. Creating prosperity with what you didn't know you already had.	Gunter Pauli	(Ellen MacArthur Foundation, 2015b; Webster, 2015)
Permaculture	Conscious design and maintenance of the agriculturally productive ecosystem, which has diversity, stability and resilience of the natural ecosystem.	Bill Mollison, David Holmgren	(Ellen MacArthur Foundation, 2015b; Webster, 2015)

Webster emphasises *'the boundaries of the circular economy are not defined, nor are they ever likely to be'* (Webster, 2015). While the emergence of CE is an answer to the problem of resource scarcity, new avenues and development will keep emerging to further fulfil the objectives of CE. Nadeem et al., (2018) further emphasises that just as the circular loops can be reiterative without any limit, thus the boundaries for CE are hard to be drawn.

With this brief overview of the origins of CE, it's best to define the concept to understand its breadth, scope and span.

2.2.2 Definitions of Circular Economy

Although the concept is relatively new, there is no lack of attempts in defining it and in this rigour, multiple attempts have blurred the actual meaning (Kirchherr et al., 2017), thus there is no universal agreed upon definition of the concept (Millar et al., 2019; Rizos et al., 2017). It is important to highlight that CE should not be confused with recycling as the later can be part of the former but does not represent the full breadth of CE (Nadeem et al., 2018). The concept of CE deals with resource recovery (Gregson et al., 2015; Li et al., 2013; Singh and Ordoñez, 2016) and resource efficiency (Hu et al., 2011; Schulte, 2013) by promoting the creation of industrial symbiosis remanufacturing, waste prevention and minimisation (Velis, 2015) within the closed loop system (Ellen MacArthur Foundation, 2015b; Webster, 2015).

To map out the overall scope and broad spectrum of CE, following five definitions are chosen as they provide a comprehensive understanding of the overall concept of CE:

> *"A circular economy is one that is waste-free and resilient by design. It is a new economic model that is ambitious as well as practical. Designing the economy in a way that is restorative of ecosystems, ambitious with its innovation, and impactful for society, is a bold challenge but one that is achievable when guided by the principles of the circular economy"*. (Circle Economy, 2016)
>
> *"In a circular economy profits, jobs and growth come not from extracting, moving, shaping, selling and dumping ever more resources, but from the work done and value created by handling resources with sufficient care that ecosystems and total natural resources actually expand, making it possible to meet human needs everywhere"*. (Greyson, 2015)
>
> *"The circular economy is one that is restorative and regenerative by design and*

aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles". (Ellen MacArthur Foundation, 2015a)

"The circular Economy refers to an industrial economy that is restorative by intention; aims to rely on renewable energy; minimises, tracks, and hopefully eliminates the use of toxic chemicals; and eradicates waste through careful design". (Webster, 2015)

Kirchherr, Reike and Hekkert (2017) study 114 definitions of CE and after analysing them proposes another comprehensive definition that covers its breadth in a good manner. They define CE as:

> *"An economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers."*

Overall, it would be correct to say that CE is a move to a wholly sustainable era where loopholes in an economic system are closed by introducing a new way to conduct the business. The demand for resilience in design and thinking in cascade is what makes CE standout as a unique and ideal solution to the present-day challenges of resource scarcity and environmental damages. CE takes a holistic approach by ensuring that the system design is mindful of the value of the resource and that the product is designed with perspective, whereby the manufacturer and other related supply chain members take responsibility for maximum utility, life cycle, and the end of life cycle management.

To understand how CE aims to realise the defined claim, an overview of its principles and its scope is necessary to explore.

2.2.3 Circular Economy principles

The concept of CE is developed on three core principles portrayed in Figure 2.2 and are discussed further.

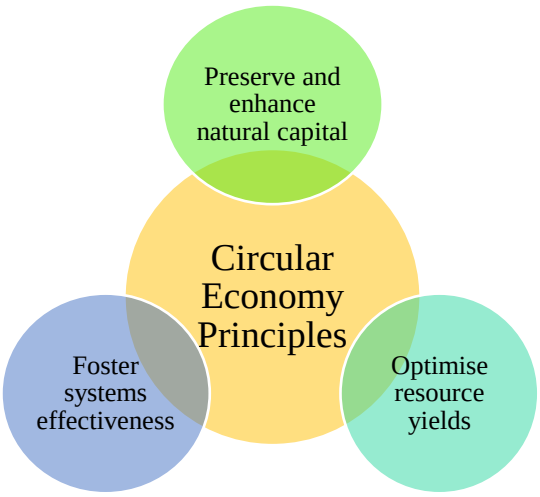


Figure 2.2 Principles of Circular Economy

Circularity requires and proposes a contrasting proactive approach of *'roundput'* instead of *'throughput'* (Webster, 2015) to replace the traditional linear system of take – make – dispose (Ellen MacArthur Foundation, 2015c). Natural resources are preserved through a closed-loop system, where an earlier extracted resource is re-utilised repeatedly to ensure that the resources are used but not used up (Webster, 2015). The distinctive feature of CE is that it gets to the root cause of the problem instead of managing it at surface level (Webster, 2015). This closed-loop system ensures resource recovery (Gregson et al., 2015; Li et al., 2013; Singh and Ordoñez, 2016), resource efficiency and effectiveness (Hu et al., 2011; Schulte, 2013), sustainable consumption and production, industrial symbiosis, urban metabolism, zero waste, eco-design, materials criticality, design for recycling, up-cycling/down-cycling and cascade models, remanufacturing, waste prevention and minimisation (Velis, 2015). These are key elements to incorporate at the very design stage of the product development and throughout its life cycle.

Another of the key principles to enable the adaptation of CE is to ensure the optimisation of resource utility (Geng and Doberstein, 2008) as well as the resource conservation by making maximum effort to minimise the use of virgin material (Wübbeke and Heroth, 2014) and to maximise the effort to re-utilise previously extracted resources (Singh and Ordoñez, 2016) by optimising their lifespan (Pialot et al., 2017) or virtualise the use of resources (Jabbour et al., 2017). In other words, the core principle of max-min policy for waste elimination and max-max policy of value optimisation (Nadeem et al., 2018, 2017a) must be incorporated into an economic system.

Another of the key principles to incorporate is systems thinking and foster systems effectiveness. It requires the participants of any economy to understand how different elements influence one another within a whole system (Romero and Noran, 2015) and not just focus on the company itself alone. Systems thinking is not an option but a requirement for sustainability (Murray et al., 2017). It requires businesses to regard themselves in the setting of overall supply chain and its impact while thinking in cascades (Elia et al., 2017; Kobza and Schuster, 2016; Murray et al., 2017). Natural environmental system (biomimicry) (Romero and Noran, 2015) has a lot to offer and to learn from, where the focus is on optimising the overall system and not the individual components alone (Webster, 2013). It is vital for the companies to engage in systems thinking where no functional divisions as well as companies, work in isolation or in subgroups but have common strategic goals to achieve in a responsible manner.

2.2.4 Architectural frameworks of Circular Economy

It is believed that CE truly envelops the triple bottom line (Andersen, 2007) by protecting the environment, guiding the society for the sustainable living pattern, providing a mechanism for sustainable economic growth, by minimising the utilisation of virgin material (Wübbeke and Heroth, 2014) and keeping the resources in the closed-loop system (Webster, 2015). Nadeem, et al., (2017) summarises the existence of CE for two goals/ strategies of *'max-min'* and *'max-max', where maximum effort is made to minimise/ eliminate waste and maximum effort is made to maximise the utility of a resource.* To achieve these goals, three major frameworks (discussed below) exist to further build on foundational values of CE.

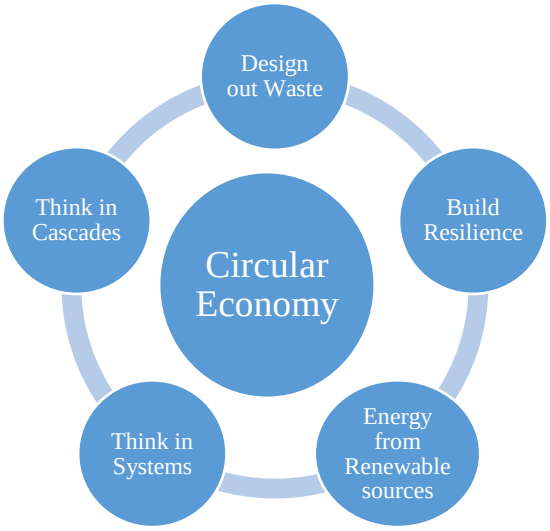


Figure 2.3 Framework of Circular Economy, illustrated by (Nadeem, et al., 2018) – adapted from (Webster, 2015)

Webster developed five major principles (Webster, 2015) which can serve to make CE a reality. Figure 2.3 portrays the 5 principle framework proposed by Webster (2015). This framework suggests five radical changes to the current economic system. At first, the focus is on Designing out any waste. It is noteworthy that the design stage is of ultimate importance as at this stage if the occurrence of waste is designed out, the rest will just follow. In other words, this stage suggests that design out any possibility that could lead to waste in both the product and resource life cycle. Second, it suggests building resilience through system perfection where a system restores itself in case of any negative occurrences (Webster, 2013). The third major element is to utilise energy from renewable resources. The fourth integral element is think in systems. Without thinking in systems, there would not be any motivation to adopt the other four principles. Any entity needs to understand that they are part of the big supply chain where they have a responsibility which is both individual as well as collective. Finally, the fifth major element of this framework is thinking in cascades, where waste from one level becomes food for another (Ellen MacArthur Foundation, 2017b).

Another framework which is a further development by Ellen MacArthur Foundation (2015a), provides six action areas to enable the move towards the CE. These actions are portrayed in Figure 2.4 below. Here the focus is similar to the earlier framework by Webster. The *regenerate* aspect of the framework promotes utilising renewable energy while developing a healthy eco-system where waste, if any, is discarded to the biosphere in a responsible manner. The second aspect, *share*, is something that has existed/practised for a long time, where resources and products are shared among businesses and consumers. The core idea is to maximise the utility of a product/ resource by sharing any unutilised value, as well as by re-utilising them. Another core principle of CE is *optimisation*. The emphasis is to optimise the life cycle of a product reducing waste in production. Extending optimisation, *loop* utilises the components of the product at the end of its life cycle, thus retaining residual value within the economic system by ensuring that the products are re-manufactured, refurbished and recycled almost infinitely. When the product/ resource comes to the end of its life, then both the biological and technical waste is separated and disposed off in a responsible manner. The fifth element *virtualise*, is to help reduce the usage of resources where possible, such as; energy usage reduction through online shopping instead of in-store shopping as well as minimalising paper usage through encouraging e-books. Finally, the sixth element here is to *exchange* old for new technology, through which the energy and resource utilisation is at an optimal level (e.g. using an electric car instead of other ones using fuel).

'content removed for copyright reasons'

Figure 2.4 ReSOLVE framework, source: Delivering the Circular Economy, A Toolkit for Policymakers (2015a)

Circle Economy (2016), an organisation based in the Netherlands, proposes a framework with 6 elements (see Figure 2.5 below) as the key principles for CE. This framework majorly resembles earlier frameworks as it also focused on cycling materials infinitely, derive energy from renewable or otherwise sustainable sources, creating value through resources, and building ecosystem. Its key distinguishing features are two elements of Health and Society. These two elements are of utmost importance as the ultimate outcome of all development is to ensure that humans live healthy lives and develop a cohesive society. This would not be a reality if human beings are out of resources and build piles of waste without any management.

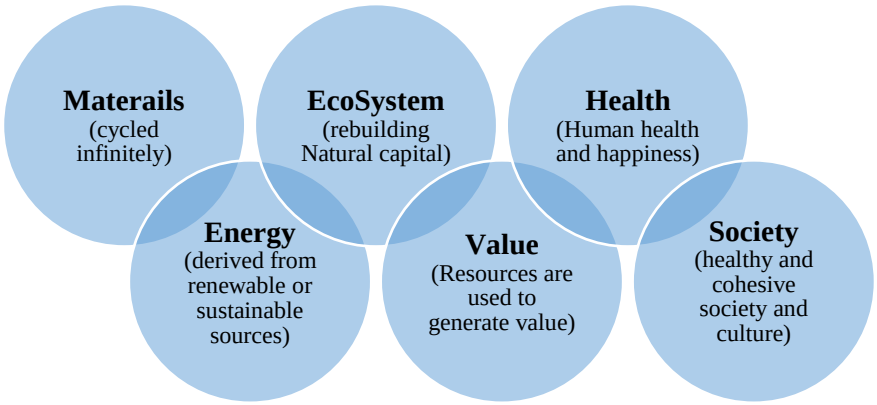


Figure 2.5: Six principles of CE (by Circle Economy) source: Nadeem et al., (2018)

These three frameworks have common/interlinked elements. Nadeem, *et al.*, (2017) developed the interlinkage of these three frameworks, as portrayed in Figure 2.6. These framework's basics are the same in which the players in any economic system work in collaboration with each other while not only thinking of themselves but also of future generations and the planet. The differing features of these frameworks are that Ellen MacArthur's framework and action steps are the means through which the principles defined by Webster are achieved. For example, sharing and virtualisation are not mentioned in Webster's framework but are an integral part of 'thinking in Systems'.

The distinguishing feature of Circle Economy framework is that it specifically highlights that the human activities must support the eco-system and health aspects. These are not directly highlighted in the other two frameworks; however, it would be an outcome of their utilisation.

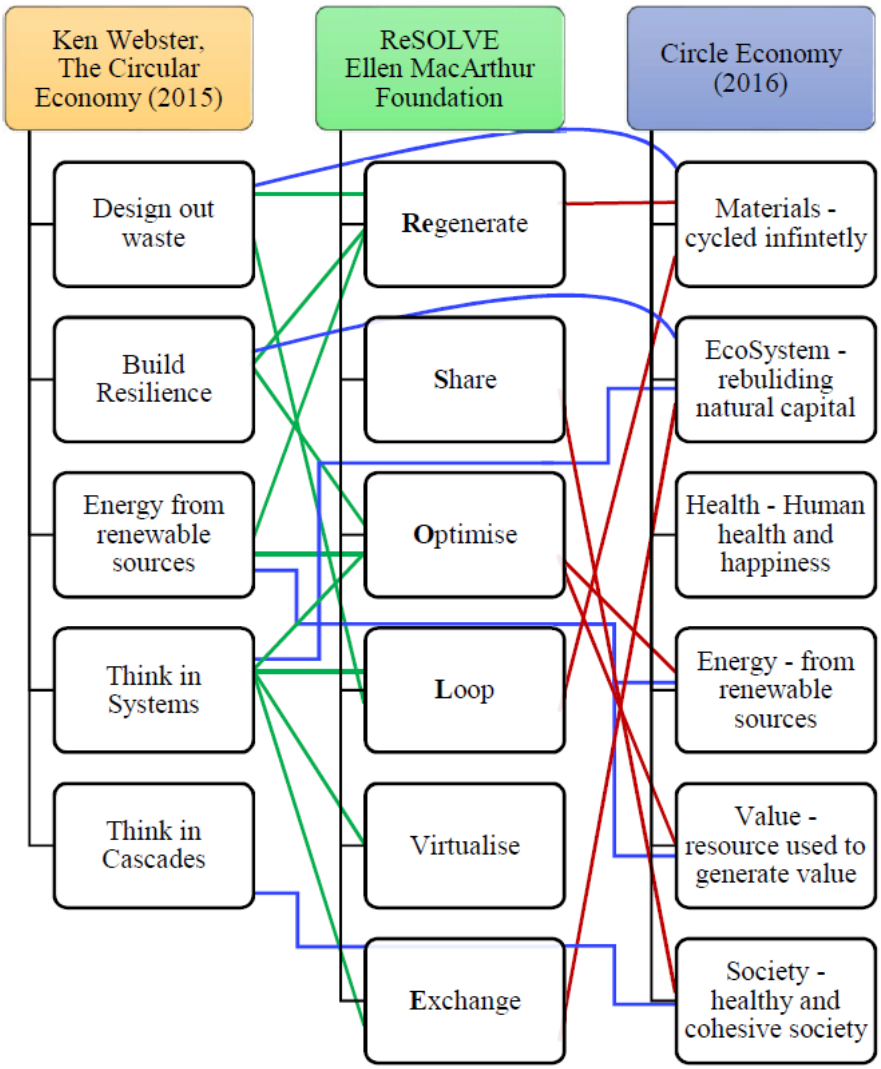


Figure 2.6 Interlinkage of three frameworks of CE (Source: Nadeem et al., 2017)

2.2.5 Building blocks of Circular Economy

The Ellen MacArthur Foundation further identifies four building blocks of CE and have also provided the case studies for each of the building blocks on their website (Ellen MacArthur Foundation, 2017c). These building blocks depicted in Figure 2.7, at their core demands that:

- Businesses need to develop core competencies in a circular design to reuse, recycle and cascade the product;
- New business models need to be developed to either transform/ vitalise or either completely new model to seize the new opportunity;
- New skills are necessary to recycle or dispose of the product;
- The market has to play a vital role by benefiting from policymakers, academics, leaders to make the favourable and enabling environment for CE to function.

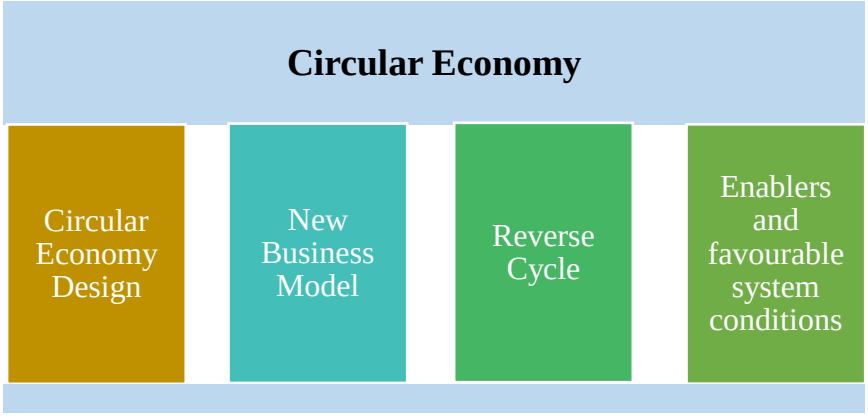


Figure 2.7 Building blocks of CE (adapted from Ellen MacArthur Foundation 2017c)

Since CE differs in its core nature being circular instead of linear, these four pillars are of vital importance. The design for CE demands new thought pattern and innovation subsequently requiring a different business model. For a new business model to be functional, new skill sets are needed. And last but not least, unless the market, its players, its contributors, policy makers, buyers do not join in circular practices, CE cannot become fully functional.

2.3 Policy adaptation of Circular Economy

CE is gaining growing popularity at present and some of the leading organisations like Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2015c), WRAP (The Waste and Resource Action Programme, 2016), Circle Economy (Circle Economy, 2016), McKinsey and Company (McKinsey&Company, 2014), Capital Institute (Capital Institute, 2017), Zero Waste Scotland (Zero Waste Scotland, 2016), ARC21 (arc21, 2017) are making significant contributions in the development and realisation of CE. Initiatives, such as CE100 (Ellen MacArthur Foundation, 2015a), have gathered collaboration from global giants such as Cisco, Google, H&M, Philips, Nike, Renault, Unilever, DHL, IKEA, and M&S.

Many countries have developed and/or are in the process of establishing national policies to adopt CE. Among these the early adapters are Germany in 1996 by enacting a law for closed cycle waste management and environmentally compatible waste disposal (Su et al., 2013a), China in 2006 by making CE as national policy under the 11th five year plan (Zhou et al., 2014), Japan in 2002 by developing legal framework to move towards recycling-based society (Ministry of Economy, 2004; Su et al., 2013a), Denmark with initiatives such as banning the construction of incineration plants with the goal that by 2022 to be recycling 50% of household waste (The Danish Government, 2013), Scotland with the waste reduction goal of 25% by 2025 (Zero Waste Scotland, 2016), Sweden aiming to increase recycling of paper-based packaging

material from current level of 65% to 85% by 2020 (Braw, 2014), Poland in 2013 by adopting the Act on Waste (European Commission, 2015), and Thailand by establishing an Industrial Estate authority (Winans et al., 2017).

These policies are a good starting point for the implementation of CE (Jiao and Boons, 2015). However, since the development of CE and its implementation is at the initial stages, there are challenges/barriers faced in its realisation (Kirchherr et al., 2018).

2.4 Challenges/ barriers to Circular Economy

As CE endeavours to ensure proper resource and waste management in a win-win manner (Homrich et al., 2018), there are numerous barriers to its adoption among a range of industries (Araujo Galvão et al., 2018; Bey et al., 2013). Ellen MacArthur Foundation (2015a) developed a toolkit to identify barriers to CE. This toolkit points to 15 types of barriers (see Table 2.2) categorised as Economic, Market Failure, Regulatory Failure and Social Factors.

Table 2.2 Barriers to CE and their categorisations by Ellen MacArthur Foundation

Category	Barrier
Economic	Not profitable for businesses even if other barriers are overcome
	Capital Intensive and/or uncertain payback times
	Technology not yet available at scale at a cost-effective level
Market Failure	Externalities (true costs) not fully reflected in market prices
	Insufficient public goods/ infrastructure provided by the market or the state
	Insufficient competition/ markets leading to the lower quantity and higher prices than is socially desirable
	Imperfect information, for example, asymmetric or high-cost information, that negatively affects market decisions
	Split incentives (agency problem) when two parties to a transaction have different goals and levels of information
	Transaction costs such as the cost of finding and bargaining with customers or suppliers
Regulatory Failure	Inadequately defined legal frameworks that govern areas such as the use of new technologies
	Poorly defined targets and objectives which provide either insufficient or skewed direction to the industry
	Implementation and enforcement failures leading to the effects of regulations being diluted or altered
	Unintended consequences of existing regulations that hamper circular practices
Social Factors	Capabilities and skills lacking either in-house or in the market at a reasonable cost
	Custom and habit: ingrained patterns of behaviour by consumers and businesses

The above barriers to CE and their categorisations developed by Ellen MacArthur Foundation (2015a) envelop the overall breadth of barriers to CE. In a similar manner, Geng and Doberstein (2010) highlight 3 barriers/ challenges to CE in the context of China. These barriers/ challenges are Policy, Technology, and Public Participation. It is important to emphasise that the distinctive acknowledgement of public participation is of utmost importance, as without it there would be no impact of all the other efforts.

Kirchherr *et al.*, (2018) studies the implementation of CE in the European Union context and recognises that there is limited implementation. In order to find actual barriers to the implementation of CE, Kirchherr *et al.*, (2018) conducted a survey with 208 respondents and interviews with 47 experts. Their findings are summarised in Table 2.3.

Table 2.3 Barrier to CE - identified by Kirchherr et al., 2018

Category	Barrier
Cultural	Lacking consumer interest and awareness
	Hesitant company culture
	Operating in a linear system
	Limited willingness to collaborate in the value chain
Market	Low virgin material prices
	High upfront investment costs
	Limited funding for circular business models
	Limited standardization
Regulatory	Obstructing laws and regulations
	Lack of global consensus
	Limited circular procurement
Technological	Limited circular design
	Too few large-scale demonstration projects
	Lack of data, e.g. on impacts
	Ability to deliver high quality remanufactured products

The findings from this study affirm the earlier discussed barriers and further points to a 'cultural' element that was not specifically highlighted by earlier scholars; however, it can be linked to the public participation aspect identified earlier. Another study by Govindan and Hasanagic (2018) identifies 39 barriers, of which 10 are related to the external environment and 29 are related to the internal environment. Govindan and Hasanagic (2018) categorise these barriers under 8 clusters, see Table 2.4.

Table 2.4 Clusters of barriers to CE identified by Govindan and Hasanagic (2018)

Clusters	**Descriptions**
Governmental	• Lack of standard systems for performance assessment, recycling policies that are ineffective to obtain high quality, • New laws that are passed with insufficient coordination and existing laws that do not support the circular economy.
Economic	• Financial and economic barriers related to the implementation of the circular economy in a supply chain.
Technological	• Technological limitations, • Managing uncertainty at the end of life phase for products, • Managing product quality through the life cycle of a product, • Design challenges to create or maintain durability, etc.
Knowledge and Skills	• Lack of reliable information, • Lack of public awareness, • Lack of skills, • Lack of consumer awareness of the value of refurbished products.
Management	• Lack of support from top management; • Other issues have a higher priority in enterprises and within the organisational structure.
Circular Economy framework	• Lack of successful business models and frameworks for the circular economy • Other solutions might be more favourable than the circular economy framework.
Culture and Social	• Lack of enthusiasm towards enacting the circular economy, • Consumer perception towards reused products and the thrill of purchasing a new product.
Market	• Externalities that prevent companies from taking advantage of refurbished products, • Regulations around ownership and no industry standards on refurbishment products.

To summarise and develop a thematic synthesis of these barriers, these barriers are categorised in six categories: Social/ cultural, Market, Regulatory, Economic, Technological and Business models/ Framework (see Figure 2.8). Although some of these barriers are beyond the control of a company, companies do have a certain level of influence. There are others that a company can manage/ control directly such as culture, business models. These categories are interlinked with each other and are defined without any hierarchical order. They are briefly discussed below.

2.4.1 Social/ cultural barriers

Social and cultural barriers are related to both the internal and external environment of the companies. Organisational culture is essential in its strategic and operational directions. Since the linear approach is widely existent and the CE approach requires changes, companies are reluctant to make changes to their existing methods of operations. Due to lack of awareness and availability of information, the leadership of organisations are not taking any keen interest in adopting CE. Moreover the same goes for the customer as they tend to take less interest in re-manufactured and/or refurbished goods (Urbinati et al., 2017). Shortage of skills availability both in-house and externally in the market is also a significant barrier in adoption of CE initiatives (Geng et al., 2009; Lieder and Rashid, 2016; Liu et al., 2009; Liu and Bai, 2014; Ormazabal et al., 2016; Preston, 2012; Sauvé et al., 2016; Shahbazi et al., 2016; Shi et al., 2008; Su et al., 2013a; Van Weelden et al., 2016).

2.4.2 Market barriers

Scholarly research highlights market conditions, such as lack of awareness among customers hinder the consumer to buy the products made from re-extracted materials. In a similar manner businesses are not aware of the benefits and are not willing to explore their transition to CE due to accessibility to virgin materials at lower prices as opposed to what it takes to re-extract material from existing products (Geng and Doberstein, 2008; Kirchherr et al., 2018; Ormazabal et al., 2018; Pheifer, 2017; Preston, 2012; Ranta et al., 2018; Rizos et al., 2015; Shahbazi et al., 2016).

2.4.3 Regulatory barriers

Policies defined for the transition towards CE are not supportive and lack strength. It could be partly because there is no global consensus about CE and its adoption. In most countries, there is lack of significant governmental and industrial level smart policies to support/ direct the move towards CE (Ejik, 2015; Kirchherr et al., 2018; Pheifer, 2017; Preston, 2012; Ranta et al., 2018; Rizos et al., 2015).

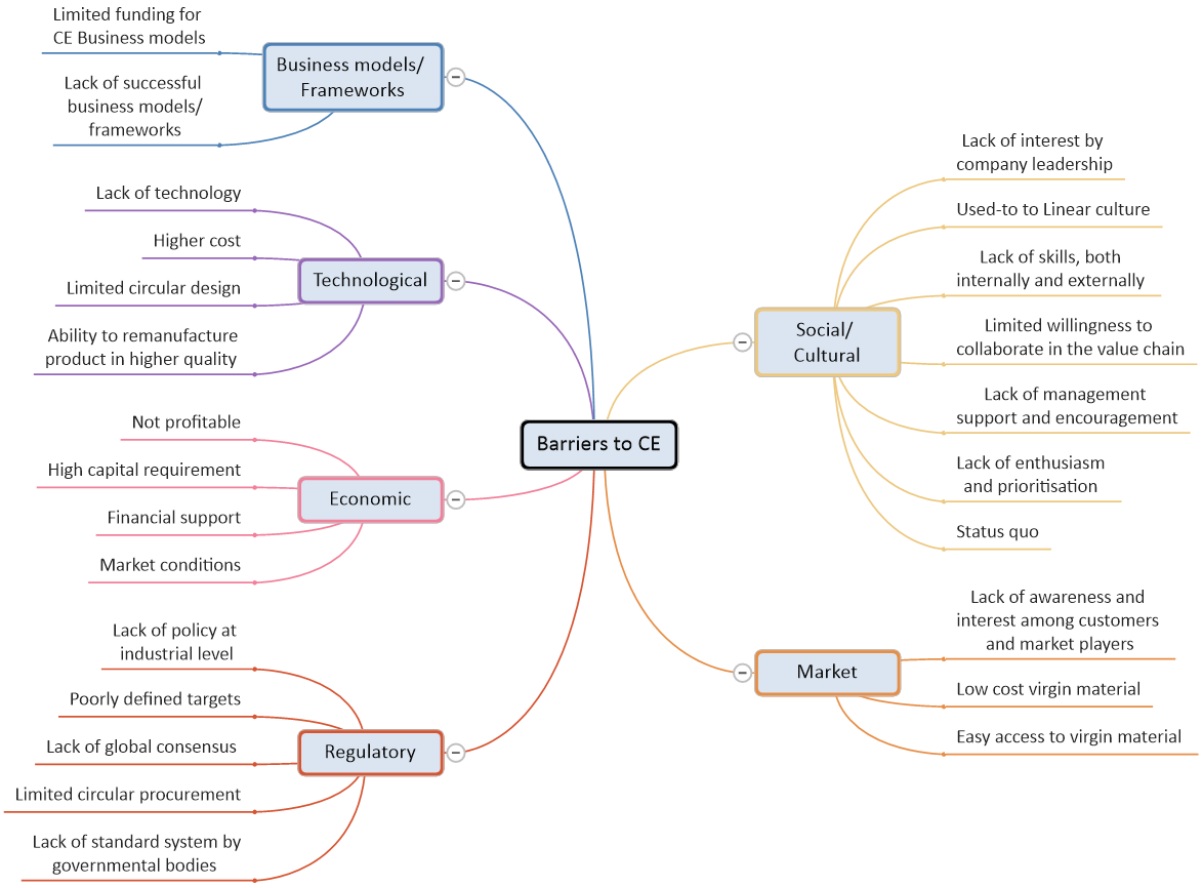


Figure 2.8 Barriers to Circular Economy

2.4.4 Economic barriers

It is noted in research by scholars that companies see no economic benefit in adopting CE, as either the cost increases due to extra processing involved in re-extracting materials and/or the customer is not willing to pay the right price for the product produced from re-extracted materials. Moreover the move to CE requires capital investment to change the existing method of production, which requires financial support that may not have quick return on investment (Geng and Doberstein, 2008; Ormazabal et al., 2016; Pan et al., 2015; Rizos et al., 2016; Shi et al., 2008; Su et al., 2013a).

2.4.5 Technological barriers

CE requires a new approach and methodology, for which either the technology currently is not sufficient and/or is too costly for companies to adopt. Likewise there is limited technological

advancement to support circular design with the ability to remanufacture products in higher quality and in cost-effective manner (de Jesus et al., 2018; Geng and Doberstein, 2008; Kirchherr et al., 2018; Ormazabal et al., 2016; Pan et al., 2015; Pheifer, 2017; Preston, 2012; Rizos et al., 2016; Shahbazi et al., 2016; Shi et al., 2008; Su et al., 2013b).

2.4.6 Business models/ frameworks barriers

Millar *et al.*, (2019) specifically highlight there is no comprehensive research as to how the CE is implemented. There is insufficient business models/ frameworks that the manufacturing sector could deploy to assist in their transition to CE (Govindan and Hasanagic, 2018; Lewandowski, 2016; Scheinberg et al., 2016).

2.5 Gap analysis

CE is well acknowledged and appraised, and many have joined hands to support this initiative. One such significant example is where 100 big companies (e.g. Apple, Dell, Cisco, HP, H&M, and IKEA) have joined CE initiative and are listed as member of CE100 category of Ellen MacArthur Foundation (2019), but the scope of what these companies have done in adopting CE is unclear (Millar et al., 2019). CE requires a change in both the production and consumption patterns (Shah, 2014). Scholars do acknowledge that more policy development is needed, but they also emphasise that its implementation is at early stages (Ghisellini et al., 2016; Kirchherr et al., 2018) and need radical improvement for current business models (Ghisellini et al., 2016) to adopt CE in their operations.

There is a growing acknowledgement that CE requires systematic transformation to move from Linear to the circular system (Whalen et al., 2018) and that it requires holistic and transdisciplinary thinking (Andrews, 2015; Moreno et al., 2016). So far the concept of CE is mainly discussed among business consultants, governments and non-governmental organisations, and has a focus towards policy development (Korhonen et al., 2018), however, research and scientific discussion on the concept of CE and its implementation is close to none (Korhonen et al., 2018; Millar et al., 2019). In this regard, Gregson et al., (2015) specifically emphasises that CE is *"a diverse bundle of ideas which have collectively taken hold"* and has *"more often been celebrated than critically interrogated"*. Thus there is a greater need for research to explore the concept of CE and explore potential possibilities to streamline its implementation.

Since the Earth has limited resources and ability to absorb the waste, it cannot provide sustained economic growth in the current linear production pattern (Suarez-Eiroa et al., 2019), thus the scholars have pointed to an important and most crucial element for the realisation of CE, and that is the development of strategies and approaches to change the current methods of production and consumption (Merli et al., 2018; Millar et al., 2019). Although CE's implementation is underway globally in a range of different industries, Millar et al., (2019) stress that there is lack of review as to how CE is being implementation globally and *"how the method of implementation pertains to accomplishing sustainable development"*. Korhonen et al., (2018) specifically highlight that "*CE offers fruitful ideas, but their implementation in practice remains an open question*". Millar et al., (2019) conclude that *"there is no consensus as to how best to implement the Circular Economy nor how all stakeholders can be equally incorporated"*.

There is limited progress in the implementation of CE (Kirchherr et al., 2018; McDowall et al., 2017; Stahel, 2014) due to the lack of CE tools, shared language, CE business models (Antikainen and Valkokari, 2016; Bocken et al., 2017; Lewandowski, 2016; Reike et al., 2018). This leads to lack of strategies and/or comprehensive methodologies/frameworks to guide practical steps that businesses could utilise to adopt CE (Urbinati et al., 2017) and to guide its application in company's operations (Merli et al., 2018; Murray et al., 2017). Scholars acknowledge the fact that academic research to guide industry for adaptation of CE principles is still insufficient (Chay et al., 2015; Lieder and Rashid, 2016; Manninen et al., 2018; Merli et al., 2018).

Development of a comprehensive and contemporary framework to guide the users can lead to easy and speedy adoption of CE in the manufacturing sector, especially for SMEs that contribute around 50% of the national GDP, but usually suffer from limited resources (Oliveira et al., 2018) in terms of capital, resources, and knowledge. Furthermore, manufacturing sector that has made significant capital investments in their existing infrastructure and processes are less likely to radically change the whole production/design processes for their products and business model, except if the change is introduced gradually. Moreover, not all manufacturing companies would see the urgency of action to the challenges faced by environment and resource depositories. Therefore, the motivation to move towards the adoption of CE must have elements that have proven successful approaches/concepts previously and are desired by manufacturing sectors.

In order to adopt CE in manufacturing SMEs, it is vital to understand that a radical change in their current operations would not be realistic due to requirements such as capital, knowledge, skills and resources. Therefore, a more contemporary solution would be needed that would speak the shared language and would seem realistic to the industries. For this purpose, amalgamating CE with existing operations management concept is needed, that share similar values in its core essence but presently lacks the full depth as presented in CE. One such Operation Excellence tool (discussed in the next chapter), Lean, is well established with observable results and is widely accepted among a range of manufacturing sectors as well as the service sector. Lean shares the same core features of waste reduction and value creation, like CE, therefore it is worth exploring their synergies and divergences and potential amalgamation/merger.

2.6 Conclusions

CE has emerged under the realisation of the fact of depleting resources, growing population, and predicted immense scarcity in the result of the current model of production and consumption. CE provides greater insight and directs to a newer model of the economy where nothing is wasted but waste becomes food.

Given the rising popularity, many organisations mostly based in the developed countries are developing CE awareness and promoting it aggressively. The need for adapting CE is crucial at the mass level. The concept of CE has been brought to the horizon and is being developed, but its practical implementation models are not fully established, especially for manufacturing SMEs. Moreover, the study of the CE with a concept such as LEAN has not been explored in its full depth.

This chapter concludes to explore the possible merger of CE with existing operations management strategies (i.e. LEAN) by exploring their synergies and divergences. These are further discussed in the next chapter.

Chapter 3 Lean, its synergies and divergences with Circular Economy

3.1 Introduction

The evolution of human endeavour to progress and innovation, faced with escalated global competition and a frequently changing business environment has always raised the bar for innovation from both the customers and competing industries (Jasti and Kodali, 2015). Such conditions require the businesses to continuously seek improvements to transform their operations in order to cope with the complex and heterogeneous business environment (Garza-Reyes, 2015a; Nadeem et al., 2017b).

For this purpose, businesses/ industries are always in pursuit of ways to optimise their operations and streamline their resources/ processes to achieve efficiency and effectiveness (Garza-Reyes, 2015a; Nadeem et al., 2017b; Tan et al., 2013); in order to deliver quality products/ services in a cost-effective, and efficient manner. In this regard, multiple models/ approaches have been developed e.g. Six Sigma, Agile, Business Process Reengineering, to meet the needs of a range of different industries (Flynn and Vlok, 2015). One of the most successful, popular, and influential paradigm in this regard to date is Lean (Forrester et al., 2010), also known as Lean Manufacturing (LM).

Faced with fierce competition from its US rival car manufacturers, Toyota developed the LM system (Garza-Reyes, 2015a; Herron and Hicks, 2008) after World War II, to achieve efficiency and effectiveness, and to gain competitive advantage and maintain growth (Garza-Reyes, 2015a). Ever since its conception, the concept has been highly esteemed and adopted by a wide range of industries/ businesses (Garza-Reyes et al., 2012), and it is not limited solely to automobiles, but has been adapted in different sectors of industry (Crute et al., 2003), thus gaining competitive advantages (Hines et al., 2004).

This chapter aims to understand the core concept of Lean and explore its possible synergies, divergences and a potential merger with the concept of CE.

With the above aim the objectives of this chapter are:

- To develop a brief understanding of the core principles of Lean
- To explore the synergies and divergences of Lean and CE concept
- To explore the possibility of a potential merger between CE and Lean

3.1.1 Why Lean?

There are multiple operations excellence concepts/tools to manage manufacturing operations. This research uses Lean to extend its scope through amalgamation with CE. In order to understand that why Lean is considered the most suitable operations excellence tools, it is best to benchmark the core essence of CE against some of the well-known operational excellence tools (BPR [Business Process Re-engineering], Lean, Six Sigma, TQM [Total Quality Management] and Scientific Management) and explore the closest alignment.

It is noteworthy that CE has three major pillars as its principles (discussed in section 2.2.3). These principles focus on waste elimination where waste becomes food (Webster, 2015) through closed-loop system to ensure resource recovery (Gregson et al., 2015; Li et al., 2013; Singh and Ordoñez, 2016), resource efficiency and effectiveness (Hu et al., 2011; Schulte, 2013). Furthermore, creating/enhancing value through optimisation of resource utility (Geng and Doberstein, 2008) as well as the resource conservation by making maximum effort to minimise the use of virgin material (Wübbeke and Heroth, 2014) and to maximise the effort to re-utilise previously extracted resources (Singh and Ordoñez, 2016) by optimising their lifespan (Pialot et al., 2017). A surrounding feature of systems effectiveness requires businesses to regard themselves in the setting of overall supply chain and its impact while thinking in cascades (Elia et al., 2017; Kobza and Schuster, 2016; Murray et al., 2017).

BPR focuses on redesigning processes to improve cost, quality, speed and service (AbdEllatif et al., 2018; Ozcelik, 2010). Its core focus remains on internal process improvements instead and not on waste elimination and value creation. Likewise, the Scientific Management approach concentrates on improving internal operations and performance of the company by focusing on cooperation and collaboration among its employees and management (Asyali and Bastug, 2014; Hodgetts and Greenwood, 1995). Six Sigma, on the other hand, focuses on optimising the process accuracy by reducing the variability of its outputs (Deeb et al., 2018) through statistical and scientific techniques (Linderman et al., 2006). TQM uses an organisation-wide approach to focus on improving product quality and employee performance (Iqbal and Asrar-ul-Haq, 2018; Psomas and Jaca, 2016; Vanichchinchai and Igel, 2009). While these approaches are not contradictory to the goals/emphasis of CE, they cannot be utilised for conceptual alignment and amalgamation with CE. The above-mentioned operations excellence approaches can be utilised at different stages to assist in the implementation of CE.

Lean, however, provides a broader spectrum where it not only focuses on internal improvements within the business but extends its scope to a business' supply chain participants. Moreover, the core focus of Lean being in Waste elimination and value creation makes it ideal to explore its alignment and potential amalgamation with CE. Lean's common elements with CE are further discussed in section 3.6.

To explore the existing literature, papers and journal articles were searched online using the keywords *'Lean'*, *'Lean and Green'*, and *'Lean or Green';* and were accessed using Science Direct (www.sciencedirect.com), Emerald Insight (www.emeraldinsight.com), Inderscience (www.inderscience.com), Springer (www.springer.com), Taylor & Francis (www.tandfonline.com), IEEE Xplore (ieeexplore.ieee.org/Xplore/home.jsp), Google Scholar (scholar.google.co.uk), and library of the University of Derby.

The chapter is organised in 7 sections: the overall scope, aim, objectives and methodology for this chapter (see section 3.1); exploring the concept of Lean (see section 3.2); understanding its principles (see section 3.3); brief overview of how Lean is structured through different tools/techniques (see section 3.4); Lean's impact on environmental performance (see section 0); the interrelated nature of CE and Lean (see section 3.6); and finally the conclusions (see section 3.7).

3.2 What is Lean?

Ohno (1988) developed the concept of Lean while Toyota faced fierce competition by its US rivals, after world war II (Garza-Reyes, 2015a). The concept is also known as *Toyota Production System* (Garza-Reyes, 2015a; Jasti and Kodali, 2015), as well as *Lean Production* (Krafcik, 1988; Nadeem et al., 2017b; Womack et al., 2007) and various other names. Historically there are three major production eras that are referred to as Craft production until the early 19th century, Mass production by Henry Ford from 1910, and Toyota Production System from the 1950s which later in 1990s is developed further as Lean Management (Holweg, 2007; Lean Management Institute of India, 2017). A brief overview of the evolution of Lean is portrayed in Table 3.1 with a brief overview of the preceding concepts/developments leading to the development of Lean.

Table 3.1 Major development in the evolution of Lean

School of Thoughts	Key idea(s)	Developed by	Year of Development
Scientific Management	Improving internal operations and performance by focusing on cooperation and collaboration among its employees and management (Asyali and Bastug, 2014; Hodgetts and Greenwood, 1995)	Fredrick Taylor	1880
Mass Production	Mass production through optimisation of assembly line (Shah and Ward, 2007)	Henry Ford	1915
Statistical Control	Utilises Statistical data to monitor and control the production process to minimize variability (Godina et al., 2018; Torrago, 2018)	Walter Andrew Shewhart	1920
Toyota Production System (TPS)	A management approach to systematically eliminate waste to reduce the costs (Thun et al., 2010), achieve efficiency and competitive advantage (Ohno, 1988b; Spear and Bowen, 1999).	Taichi Ohno	1943
Operational Quality	An iterative process of four steps (Plan – Do – Check – Act) to control the quality in production processes and to continuously improve it (Prashar, 2017; Torrago, 2018).	William Edwards Deming	1950
Six Sigma (DMAIC)	An approach to minimise waste and resources, and to enhance customer satisfaction by designing and monitor day-to-day business activities (Andersson et al., 2006; Magnusson et al., 2003).		1983
Lean Production and Lean Management	Further development of TPS to describe the systematic approach of eliminating waste and creating value throughout the business while engaging the supply chain members as well (Krafcik, 1988; Womack et al., 2007; Womack and Jones, 2003). Lean provides an integrated system and incorporates a variety of management practices such as just-in-time, quality systems, cellular manufacturing, supplier management (Shah and Ward, 2003).	John F. Krafcik James P. Womack	1988 1990

Lean's origins are also associated with the work of Henry Ford in 1927, where he laid the embryonic idea through optimisation of assembly line (Shah and Ward, 2007). The detailed and specific development of this concept is associated with the Toyota Production System (Garza-Reyes, 2015a; Jasti and Kodali, 2015) developed by Taiichi Ohno of Toyota (Ohno, 1988a). The term *'Lean Production'* was first devised by John F. Krafcik (Krafcik, 1988; Nadeem et al., 2017b; Womack et al., 2007) and is regarded as the most significant and suitable concept in the manufacturing sector (Zhan et al., 2018).

Although the concept of Lean has been massively appraised, adapted and researched by practitioners and academics, there still is no conclusive agreement on a common definition to fully comprehend the concept (Baines et al., 2009; Shah and Ward, 2007). This, in turn, makes it challenging to define the overall scope and goals of Lean (Andersson et al., 2006; Nadeem et al., 2017b). Following definitions are chosen to develop an overall understanding of the concept of Lean.

> *"The term lean denotes a system that utilizes less, in terms of all inputs, to create the same outputs, as those created by a traditional mass production system while contributing increased varieties for the end customer"*. (Womack and Jones, 2003)

> *"Lean is a management philosophy focussed on identifying and eliminating waste throughout a product's entire value stream, extending not only within the organization but also along its entire supply chain network"*. (Shah and Ward, 2007)

> *"Lean production is evidenced as a model where the persons assume a role of thinkers and their involvement promotes the continuous improvement and gives companies the agility they need to face the market demands and environmental changes of today and tomorrow"*. (Alves et al., 2012)

Bhamu and Sangwan (2014) compiled the thoughts of different scholars defining Lean in different ways such as, a set of principles (Womack et al., 1990), a way (Storch and Lim, 1999), a process (Womack et al., 1990), an approach (Taj and Morosan, 2011), a concept (Naylor et al., 1999), a set of tool and techniques (Bicheno, 2004), a philosophy (Comm and Mathaisel, 2011; De Treville and Antonakis, 2006; Liker, 1996; Reichhart and Holweg, 2007; Shah and Ward, 2007), a practice (MIT, 2000; Simpson and Power, 2005), a system (Shah and Ward, 2007; Womack and Jones, 1994), a program (Hallgren and Olhager, 2009), a manufacturing paradigm (Rothstein, 2004; Seth and Gupta, 2005), or a model (Alves et al., 2012). At the core of Lean concept is the unique blend of identifying and eliminating waste (non-value adding activity), and creating value by optimising performance (Omogbai and Salonitis, 2016; R. Jadhav et al., 2014; Womack et al., 2007). Subsequently, by doing more with less, while preserving value (Pampanelli et al., 2014) and improving productivity and quality (Wahab et al., 2013).

The distinguishing feature of Lean is that it eliminates the problem (waste) through system redesign (Kadarova and Demecko, 2016). Therefore it quickly gained popularity in the industrial sector to enhance production flexibility, quality and to minimise cost (EPA-USA, 2003; R. Jadhav et al., 2014) even in US industrial sector as early as the 1960s (Shah and Ward, 2007). Scholars and practitioners believe that the Lean concept is not limited to the manufacturing sector only but that its scope can be extended to other sectors and throughout the organisation (Ballard and Tommelein, 2012; Fynes and Ainamo, 1998; González-Benito and Suárez-González, 2001; Karlsson and Åhlström, 1996), and that it is also a business culture incorporating continuous improvement (Crute et al., 2003; Nadeem et al., 2017b; Pampanelli et al., 2014). Over the last few decades, Lean's adoption in sectors other than manufacturing is on the rise (Esain et al., 2008; Stone, 2012). Kadarova and Demecko (2016) map out the adoption of Lean in the industrial sector as follows: 1940 in the automotive industry, 1984 operations management, 1992 service management, 2002 hospital management, and 2010 IT management.

3.2.1 Waste as per Lean

Lean defines waste *('muda')* as any activity that absorbs resources but creates no value (Womack and Jones, 2003). These activities may include inefficiencies in the process (R. Jadhav et al., 2014), poorly designed processes and quality management issues. Lean defines 7 categories of waste, to which a further addition was made later by scholars.

3.2.1.1 Categories/ types of wastes identified/ addressed in Lean:

Lean categorise wastes under 7 dimensions (Jasti and Kodali, 2015; Monden, 2011; Womack et al., 1990); *(1) Overproduction*, *(2) Waiting (time on hand)*, *(3) Unnecessary transport*, *(4) Over processing/ incorrect processing*, *(5) Excess inventory*, *(6) Unnecessary movement*, and *(7) Defects*. The eighth addition of *(8) Unused employee creativity (people)*, to these wastes categorisation, was made by Liker (2004). Below is a broad overview of these wastes along with their descriptions.

- **Overproduction:** Liker (2004) defines overproduction as producing items for which there are no orders. In other words, producing more than what is required/ needed (Flynn and Vlok, 2015) with continuous production [push system] (Chlebus et al., 2015; Dunstan et

al., 2006). In the initial development of the concept, Ohno (1988) defined overproduction as the transformation of processes without any need (e.g. to avoid waiting when there is no need for it).

- **Waiting:** Unnecessary (and avoidable) delays in the process or movement of goods due to inappropriate conditions/ working environment (Klippel et al., 2008), due to unavailability of machines and spare parts (Chlebus et al., 2015; Dunstan et al., 2006), equipment breakdowns and plant downtime (Dunstan et al., 2006; Oware et al., 2015), maintenance downtime and unscheduled shutdowns (Indrawati and Ridwansyah, 2015), and/or equipment failures (Dunstan et al., 2006).

- **Unnecessary transport and conveyance:** This waste can occur both inside the production facility for the movement of raw materials and semi-finished products, as well as outside while delivering goods. It can occur due to inefficient layout for transportation (Garza-Reyes et al., 2016), stockpile material transportation (Indrawati and Ridwansyah, 2015), inefficient movement of raw material before reaching final stage (Dunstan et al., 2006), and long distances (Flynn and Vlok, 2015).

- **Over-processing or incorrect processing:** Spending more time than necessary on a process and/or having errors due to inefficient use of materials requiring re-work (Indrawati and Ridwansyah, 2015) or incorrect processing due to equipment breakdowns (Oware et al., 2015) or equipment failures (Dunstan et al., 2006). Similarly, the performance of tasks by one employee instead of having a parallel operation to achieve higher value adding time, process method (Klippel et al., 2008) is also considered a wasteful activity.

- **Excess inventory:** Having the space occupied by the inventory that is not needed and could have been delayed is also a waste of space, and resources utilised to store, record, and manage the inventory; due to inefficient inventory management (Dunstan et al., 2006). These excess inventories are not necessarily just of the raw material or in-process/ finished goods but could also be in the form of high inventory of spare parts (Chlebus et al., 2015; Flynn and Vlok, 2015).

- **Un-necessary movement:** Un-necessary movement of material or workforce also adds to

generate waste, such as interruptions due to inefficient location of tools/ gadgets (Dunstan et al., 2006; Klippel et al., 2008), transport material unavailability, non-compliance of workers (Indrawati and Ridwansyah, 2015), and/or walking of operators (Dunstan et al., 2006; Flynn and Vlok, 2015).

- **Defects:** Producing faulty products requiring rework/ repair (Dunstan et al., 2006; Oware et al., 2015) is a wasteful activity and could result from quality of raw materials (Indrawati and Ridwansyah, 2015), equipment failures (Dunstan et al., 2006), and/or physical material waste (Flynn and Vlok, 2015).

- **Unused employee creativity (people):** A business might waste proof itself or minimise the possibility of wastes discussed earlier but it might still have wasteful activity due to unskilled labour (Indrawati and Ridwansyah, 2015; Oware et al., 2015), inefficient shift schedule (Indrawati and Ridwansyah, 2015), absenteeism (Dunstan et al., 2006), incorrect assignment of people to tasks (Klippel et al., 2008), and lack of proper communication to its team/ workforce (Castillo et al., 2015; Flynn and Vlok, 2015). Also, at the same time, the organisation might be restricting its employees too much to the procedure that it may not allow the room for their creativity to surface and benefit the existing procedures and practices.

Lean's categorisation of wastes covers all the major aspects of any production/ business activity and the addition of 8th waste further expands the possible source of waste occurrence. While Lean clearly marks the *'waste'*, its other important element is *'Value'*, that must be understood to completely comprehend the idea of Lean and build on this concept.

3.2.2 Value as per Lean

Lean system argues that value is something very hard for a producer to define precisely although they are the one to create and deliver it, the role of defining value is of consumers (Oleghe and Salonitis, 2016; Pampanelli et al., 2014; Womack and Jones, 2003). This does mean that value in this sense might not necessarily be through the elimination of waste, rather it could be by creating it, as long as customer defines it in that way (Hines et al., 2004). However in Lean product development, the core philosophy is to add value to the customers and society (Anand and Kodali, 2008; Baines et al., 2006; Haque and James-moore, 2004;

Hines et al., 2006; Liker and Morgan, 2011; Wang et al., 2011)

The term *'value stream'* is utilised by Womack and Jones (1994) to broaden the understanding of the value and include functions of product design from concept to launch, as well as its supply chain beginning from raw material to finished product delivered to the customer (Found et al., 2012).

In order to deliver the value to the customer while eliminating waste, Lean is developed on five principles.

3.3 Lean principles

The five major principles are (i) *identifying value*, (ii) *mapping the value stream*, (iii) *creating flow*, (iv) *establishing pull*, and (v) *seeking perfection* (Mourtzis et al., 2016; Womack and Jones, 2003). Although the further extensions and additions to these principles were made by researchers, these five principles remain at the very core, through which the Lean concept focuses on two elements: waste elimination and value creation (Womack et al., 2007). These principles flow in sequential order and are briefly described below:

i. The major focus of these principles is to ensure that value is identified form the customer's perspective (Omogbai and Salonitis, 2016; Pampanelli et al., 2014).
ii. The next principle leads to identification/ mapping of the value stream (Pampanelli et al., 2014) in light of earlier defined value (Mostafa et al., 2013).
iii. The next principle is to create a smooth flow of both the information and materials/ goods while creating value (Seth et al., 2017) through streamlining the processes involved.
iv. Establishing pull to eliminate the overproduction and minimise inventory, where the production is not dependent upon scheduled but on customers' demand (Sundar et al., 2014).
v. Seeking perfection through the implementation of continuous improvement culture (Vlachos, 2015) while seeking to eliminate any successive layers of waste (Pampanelli et al., 2014).

To create value and eliminate waste in accordance with these principles, the Lean structure is developed to assist in achieving these goals.

3.4 Lean structure

The foundational system for Lean was structured on two pillars of Just in Time (JIT) and Jidoka (Liker, 2004; Ohno, 1988a).

Lean adopts a systematic approach and utilise best practices and concepts (R. Jadhav et al., 2014) to formulate the best approach for an efficient system of production, operations, and service. These approaches are summarised by Garza-Reyes (2016) in the form of 'Lean Manufacturing Temple' (see Figure 3.1) and are briefly discussed further.

'content removed for copyright reasons'

Figure 3.1 Lean Manufacturing Temple (source: Garza-Reyes, 2016)

- **Total productive maintenance (TPM):** The method in which all levels/ function of an organisation are engaged to ensure the overall effectiveness of equipment and processes (EPA-USA, 2003) through planned predictive and preventive maintenance (Shah and Ward, 2003).

- **Quick Changeover (QCO):** The concept of QCO was developed by Shingo (1985) and is

also well known as Single Minute Exchange of Dies (SMED). The concept divides the process into external (without stopping the machine) and internal (by stopping the machine) change over time. The main goal is to minimise the time of changeover through visualisation and standardisation (Sundar et al., 2014).

- **5S:** 5S refers to the 5 steps of separating, setting in order, shining and cleaning up, standardisation and sustaining (Brunet and New, 2003; Chiarini, 2014). The goal here is to ensure that the equipment, tools and the facility are kept in order to avoid wastage of resources and time.

- **Visual factory:** In visual factory, signs, infographics, labels, charts, infographics, and other similar visual tools are utilised to provide information in an efficient manner. Through visualisation of information, it helps to reduce the time spent on reading and understanding the information from manuals, or paper-based documents.

- **Standardisation of work:** Streamlining of the procedures and processes through standardisation to avoid and reduce variation and at the same time to enhance flexibility for predictable outcomes (Powell et al., 2014).

- **Just in Time (JIT):** JIT focuses on reducing inventory and producing the required product, at the right time, in the right quantity to avoid/ eliminate overstock of raw or finished products (Liker, 2004; Ohno, 1988a; Shah and Ward, 2003; Tiwari et al., 2011).

- **Jidoka:** A tool to improve the quality of the products through error detection and stopping the process immediately. The process reduces the waste generation in the result of faulty products being produced and allows to detect the error immediately by halting the production process (Andrés-López et al., 2015; Liker, 2004; Ohno, 1988a; Slack et al., 2016).

- **Takt time:** Having a production at the same pace as the sales/ demand by averaging the required process time to meet demand, and helps to avoid the overproduction. (Carvalho et al., 2011; EPA-USA, 2003; Hicks et al., 2015)

- **Andon:** A visual control system of indicating/ alerting the management of any error occurred by stopping the line along with a lit signal at each station where the error has occurred. (Boscari et al., 2016; De Haan et al., 2012)

- **Pull Production:** An integrated supply chain production system where no upstream supplier produces/ process any good/ materials until the demand has been signalled from the downstream customer. (EPA-USA, 2003). It helps to reduce inventory levels and assists in the implementation of JIT (Cherrafi et al., 2016).

- **Poka-Yoke:** A method to mistake-proof the process to prevent defects and malfunction of the equipment, resulting in a reduction in defects, energy utilisation and low emissions (BR et al., 2015; Cherrafi et al., 2016; Fercoq et al., 2016)

- **One piece flow:** Also known as single piece flow, is the process under which one complete unit goes through the process of design, production, order taking, without interruptions, backflows or scrap (Bhasin and Burcher, 2008; EPA-USA, 2003).

- **Full work system:** A system design to automate the production system as per the set inventory level. In such a case, if an inventory level falls below the minimum required, the machine would automatically start the production to replenish the inventory to the next level (Ohno, 1988a).

Other approaches:

There are few other approaches, models, and techniques, discussed further, that are also part of the Lean system.

- **Kanban:** A very visual approach whereby the process continuity (flow) is achieved while minimising the work in process (inventory), and achieving continuous improvement by delivering right product at the right time (Sundar et al., 2014), resulting in on-time performance (Slack et al., 2016; Thun et al., 2010).

- **Value stream mapping**: VSM is the process flow mapping methodology that portrays the visual diagram of material and information flow and helps to analyse the need for different Lean techniques deployment (AR and Al-Ashraf, 2012; Cherrafi et al., 2016; Durate and Cruz-Machado, 2013; Garza-Reyes, 2015a).

- **Kaizen:** A philosophy that focuses on processes for incremental improvement and their standardisation; by establishing a problem-solving culture in the organisation by engaging people in structured thinking and scientific approaches (Pampanelli et al., 2014).

- **Continuous flow:** A process whereby once the materials are on the production line, they are kept on continuous flow and are not held in a holding area. For this purpose, the layout is designed and all the equipment, materials are streamlined accordingly to avoid any delays/ holds, reducing time wastage (Shah and Ward, 2007).

- **Total quality management:** An approach that integrates all of the organisation to comprehensively take responsibility for the quality demanded, targeted, and expected by stakeholders, through continuous improvement. (Calvo-Mora et al., 2016; Gapp and Fisher, 2008).

Lean practices also believe to be contributing to Green initiatives for environmental performance, thus their relationship is explored further.

3.5 Lean's 7 wastes and environmental performance measures

Scholars have both the agreement and disagreement to the opinion that Lean practices have an impact on sustainability and that they contribute to addressing the environmental issues (Martínez León and Calvo-Amodio, 2017). Scholars believe that the two concepts of Lean and Green are similar (Torielli et al., 2011) but since they were developed independent of each other (Azevedo et al., 2012; Dhingra et al., 2014; Durate and Cruz-Machado, 2013) their perfect combination is not realistic (Garza-Reyes, 2015b).

Given the fact that Lean focuses on reducing waste, its positive impact on the environment is evident (King and Lenox, 2001; Martínez León and Calvo-Amodio, 2017). With further academic research scholars believe in the synergy between two concepts of Lean and sustainability (Martínez León and Calvo-Amodio, 2017), therefore developing the combined version as 'Lean Green' (Garza-Reyes et al., 2014b). This relationship is also affirmed by professional bodies such as the US Environmental Protection Agency (EPA-USA, 2003).

Nadeem, *et al.*, (2017) portrays the relationship between 7 wastes of Lean and the four core elements of environmental performance. These are outlined in Figure 3.2.

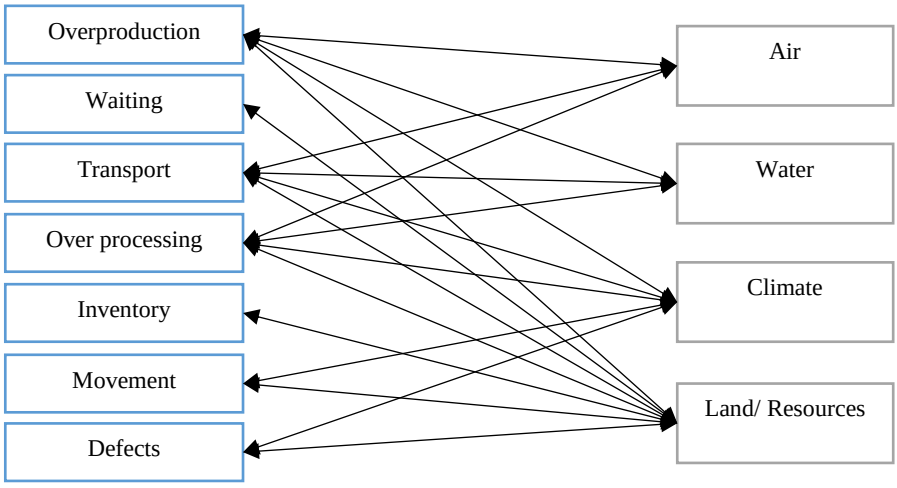


Figure 3.2 Relationship between Lean's 7 wastes and Environmental Performance Measures (source: Nadeem et al., 2017)

While the Lean does have an impact on enhancing environmental performance, its potential collaboration with CE seems feasible. The next section explores the interrelatedness of CE and Lean.

3.6 The interrelatedness of the Circular Economy and Lean

The core focus of Lean being on '*waste elimination*' and '*value creation*', (R. Jadhav et al., 2014; Womack et al., 2007), is similar to the core focus of CE. However, the Lean approach is not as holistic and lacks the closed loop systems element (see Table 3.2), which is CE's distinguishing feature/ characteristic.

Table 3.2 Waste and Value as per Lean and CE

	Lean approach	CE approach
Waste	• Is an activity that does not add value for the customers (Campos and Vazquez-brust, 2016) • "*anything other than the minimum amount of equipment, materials, parts, space and time which are absolutely essential to add value to the product*" (Russell and Taylor III, 2011) • Is inefficiency and is measured by KPI's (Sternberg et al., 2013)	• Waste = food (raw material) (Ellen MacArthur Foundation, 2015b; Webster, 2015) • Is seen in 4 dimensions: wasted resources, wasted life cycles, wasted capability, wasted embedded values (Lacy and Rutqvist, 2015).
Value	• Value is perceived from a customer's perspective (Martínez León and Calvo-Amodio, 2017) • Customer's requirement (Hines et al., 2004)	• Reduce waste by recycling and source from waste (Buren et al., 2016) • Prevent resources from exiting the economy (Buren et al., 2016) • Has 4 dimensions: Cost reduction, revenue generation, resiliency, legitimacy and image (Park et al., 2010).

Lean and CE have common goals of waste elimination and value creation, thus their combination seems natural to complement each other and benefit greatly to make CE's application realistic, smooth and easy. Moreover, due to the fact that Lean implementation is desired by most manufacturing companies, its amalgamation with CE would result in achieving circularity; which otherwise might not become a point of attraction for manufacturing industries. Figure 3.3 portrays the interrelated nature of the core principles of both the concepts of CE and Lean.

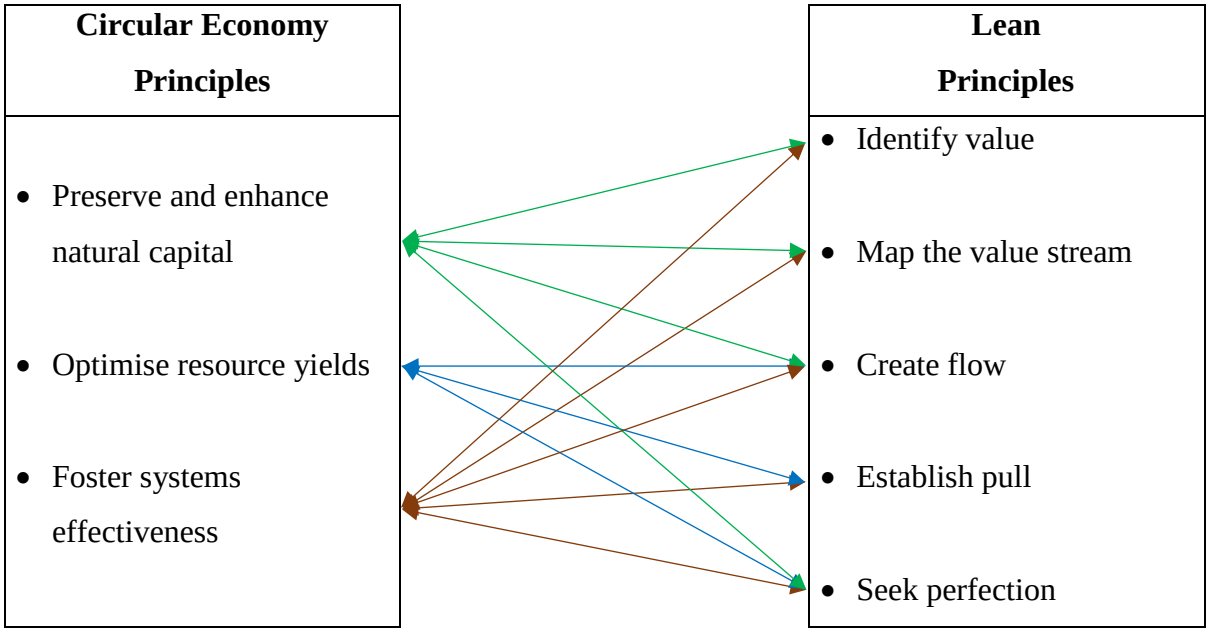


Figure 3.3 Interrelatedness of the Circular Economy and Lean principles

The interrelated nature of these principles can be observed by expanding the scope of Lean principles under the bigger perspective of systems thinking proposed by CE (see section 2.2.3). Lean's focus on process optimisation limits itself to within a specific organisation and its product's supply chain. However, under CE's perspective of systems effectiveness and thinking, the supply chain is expanded to a much bigger perspective, where value identification and the value stream is not limited to one life cycle of the product or supply chain but continues to evolve.

CE's focus on preserving and enhancing natural capital can easily be achieved by Lean's principle of mapping the value stream to identify value in the resource and creating a flow that is within the closed loop as well as to seek perfection through continuous improvement. In a similar manner, the resource yield optimisation can be achieved by establishing pull by producing only what is demanded, and again creating a flow that is within the closed loop while seeking perfection through continuous improvement.

3.7 Conclusions

The concept of Lean and CE have two strategic goals in common, Waste elimination and Value Creation. Both of these concepts have come to emergence for different needs and rationale,

with both concepts having different approaches to their core elements of waste and value. However, their combination seems natural to benefit from their synergies as they both have similar focuses but with differing perspectives. This chapter details the Lean principles, its structure and impact among different industrial sectors. Furthermore, the chapter elaborates on Lean's relationship with environmental performance indicator, affirming a positive causal relationship. Exploring the interrelated nature of CE and Lean principles, as well as their approaches to the core components of value and waste, asserted that their merger could be valuable. Combining their strengths and developing a hybrid approach to manage the issues of waste creation, resource scarcity and environmental damages would potentially make it an attractive approach, as Lean is a well-accepted and appraised concept in the manufacturing sector.

Chapter 4 Research methodology

This chapter aims to provide an overview of the overall research philosophy, approach and methodology adopted for this research.

All research has a specific purpose to investigate and develop on a specific theme (Myers, 2013; Remenyi et al., 2010), and needs a road map to define its philosophy, approach to theory development, methodological choice, strategy, time horizon and techniques (Saunders and Lewis, 2018). For the purpose to achieve the aim and objectives defined earlier in chapter 1 (see section 1.3), the research onion framework (see Figure 4.1) developed by Saunders et al., (2012) is utilised to deploy a systematic approach for this research.

'content removed for copyright reasons'

Figure 4.1 Research Onion, (Source: Saunders et al., 2012; Saunders and Lewis, 2018)

In this chapter, a brief overview of each layer of the research onion, developed by Saunders and Lewis (2018) is provided. An in-depth detail is not provided for each element, except for

the ones that are directly applicable and deployed in this research.

This chapter is organised in to 8 sections: detailing the purpose of the research (see section 4.1); research philosophy (see section 4.2); approach to theory development (see section 4.3); methodological choice (see section 4.4); research strategy (see section 4.5); time horizon (see section 4.6); data collection and analysis approach (see section 4.7); and finally the conclusions (see section 4.8).

4.1 Purpose of the research

In general, every research has different aims and purposes, which can be categorised under three categories of *exploratory*, *descriptive*, and *explanatory* (Saunders et al., 2012). The overall purpose of this research is exploratory, as it tends to understand the existing knowledge about the popular concept of CE, explore its potential and current barriers and resistances faced in its implementation in the manufacturing sector. Furthermore, the research is focused towards a potential merger of CE with Lean, to benefit from each other's strengths, which would make the implementation of CE smooth, attractive and realistic in the manufacturing sector, especially at SMEs level.

4.2 Research philosophy

Research philosophy relates to the development of knowledge in its relation to research. A total of five philosophical approaches are pointed out by Saunders and Lewis, (2018). While this research may not deploy all of the five philosophical approaches, it is still beneficial to have an understanding of each through their definitions by Saunders and Lewis (2018), presented in Table 4.1

With the brief overview of each of the five philosophical approaches to research, the current research deploys the pragmatic approach. Pragmatism focuses on research questions, aim and objectives of the research (Johnson and Onwuegbuzie, 2004) and as an outcome provides a practical solution while utilising mixed method approach (Saunders and Lewis, 2018). Philosophy of this research is directly under the parameters of the pragmatic approach as the major aim of this research is to develop a practical solution for CE's adoption in the manufacturing sector, especially among SMEs. With that in mind, the research design has developed the research aim and objectives defined in section 1.3.

Table 4.1 Definition for Research philosophies, adapted from Saunders and Lewis (2018)

Philosophy	Definition
Positivism	*A research philosophy similar to those used in the physical and natural sciences. Highly structured methods are employed to facilitate replication, resulting in law-like generalisation.*
Critical realism	*A philosophy which focuses on explaining what we see and experience with the emphasis on understanding the underlying structures of reality that shape the observable event.*
Interpretivism	*A philosophy which advocates the necessity to understand differences between humans in their role as social actors.*
Postmodernism	*A philosophy which emphasises the role of language and power relations that seeks to challenge accepted ways of thinking and give voice to alternative views.*
Pragmatism	*A philosophy which argues that the most important determinant of the research design adopted are the research question(s) and objectives, the aim often being to contribute practical solutions.*

4.3 Approach to theory development

According to the research onion, there are three approaches to theory development. A definition of each is presented in Table 4.2.

Table 4.2 Definitions for Approaches to theory development, adapted from Saunders and Lewis (2018)

Approach	Definition
Deduction	*A research approach which involves the testing of a theoretical proposition by using a research strategy specifically designed to collect data for the purpose of its testing.*
Induction	*A research approach which involves the building of theory from analysing data already collected.*
Abduction	*Approach to theory development involving the collection of data to explore a phenomenon, identify themes and explain patterns to generate a new – or modify an existing – theory which is subsequently tested.*

With the above brief overview of each of the three approaches to the theory development, the current research deploys the Abduction approach with the dominance of the Deduction approach. Scholars agree that there is no one blueprint to design research (Cohen et al., 2007) and that the best approach is the one which most accurately answers the questions (Salkind, 2011). Abduction approach combines both the deductive and inductive approach, with the dominance of one or the other (Saunders and Lewis, 2018). As mentioned previously, in this research the dominance is of a deductive approach as it first develops a causal relationship between the two concepts of CE and Lean, then combines the best of these two concepts to develop a framework which is both verified and validated; and confirms the aim and objectives of this research.

4.4 Methodological choice

This research deploys the *'mixed-method simple'* approach, where both the qualitative and quantitative aspects are included. Table 4.3 describes the methods/ tools utilised in this research and their categorisation.

Table 4.3 Methods/tools adopted and their categorisation

Method/ Tools	Categorisation
Delphi Study	Quantitative as well as Qualitative
Circularity Measurement Toolkit	Quantitative as well as Qualitative
Semi-structured in-depth interviews	Qualitative
Gemba Walk (observations)	Qualitative

The research deploys Delphi study to collect experts' opinion for the conceptually developed framework. The data received was analysed both quantitatively and qualitatively. Quantitative where the census was analysed and qualitative to analyse the feedback provided by the respective experts and developing thematic synthesis to utilise results in updating the framework.

To validate the developed framework, a case study approach was adopted where two manufacturing SMEs were visited. During these visits, Circularity Measurement Toolkit (CMT) developed by Garza-Reyes et al., (2018) was utilised to understand the current

circularity level/practices within the company (see section 7.3.1.1.1 and 7.4.1.1.1). CMT was followed by in-depth semi-structured interviews (see Appendix E) conducted at three levels of the strategic, tactical and operational level of the respective companies. These interviews provided in-depth knowledge of the companies; their policies, practices and aspirations (see section 7.3.1.4 and 7.4.1.4). This data was analysed qualitatively by including it in thematic synthesis mentioned earlier.

Furthermore, Gemba Walk assisted to conduct in-depth observations about the companies' practices and to identify potential improvement areas (see section 7.3.1.3.1 and 7.4.1.3.1), which otherwise would not have surfaced. This data was analysed qualitatively by including it in thematic synthesis mentioned earlier.

4.5 Research strategy

After the literature review and the conceptual development of the framework, it was necessary to ensure that the proposed framework is concurrent with academic grounding as well as is equally practically feasible (K. W. Platts, 1993). For this purpose, the research strategies are discussed along with the chosen research strategies for this research.

There are eight categories of research strategies defined by Saunders and Lewis (2018). These eight categories are summarised in Table 4.4 along with their definitions provided by Saunders and Lewis (2018).

Table 4.4 Research strategies definitions, adapted from Saunders and Lewis (2018)

Strategy	Definition
Experiment	A research strategy that involves the definition of a theoretical hypothesis; the selection of samples of individuals from known populations; the allocation of samples to different experimental conditions; the introduction of planned change on one or more of the variables; and measurement on a small number of variables and control of other variables.
Survey	A research strategy which involves the structured collection of data from a sizable population. Data collection may take the form of questionnaires or structured interviews.
Case Study	A research strategy which involves the investigation of a particular contemporary topic within its real life context, using multiple sources of

	evidence (data).
Action Research	Research strategy concerned with the management of a change and involving close collaboration between practitioners and researchers.
Grounded Theory	Research strategy in which theory is developed from data generated by a series of observations or interviews principally involving an inductive approach.
Ethnography	Research strategy which focuses on describing and interpreting the social world through first-hand field study.
Archival Research	Research strategy analyses administrative records and documents as the principal source of data.
Narrative	An account of an experience that is told in a sequenced way, indicating a flow of related events that, taken together, are significant for the narrator and which convey meaning to the researcher.

In terms of a research strategy for this research, first four categories (experiment, survey, case study, and action research) are the potential strategies that could have been utilised to meet the objectives of this research. Given the constraints/ restrictions (e.g. time, financial implications, approval requirements), experimentation was not found to be the best way for this research.

Action research, an important element that requires the researcher to not just be the observer during application but to have direct involvement (Hill, 1987). K. W. Platts (1993) of Cambridge University further emphasise that *action research takes participation one stage further*, where the researcher directs and influence the implementation of the research activities. As much as this research strategy is valuable and would provide significant insight into the practical relevance of the proposed framework, its adoption was constrained due to the factor described earlier. This strategy would require the organisation/company to commit resources needed and changes in their existing operations. However, the researcher is not an employee of the company and moreover was constrained by the time, as well as the companies' willingness for this strategy was more of exploratory. Thus this strategy was not utilised.

The two strategies of *Survey* and *Case study* were utilised. For the survey, this research utilised the Delphi study approach to verify the conceptually developed framework, where two rounds of surveys were conducted through questionnaires (see Appendix C and Appendix D). These questionnaires were pilot tested and modified accordingly. The research participants were

selected through purposive sampling by inviting experts of both academic and practitioner background. Description of the Delphi study is discussed in detail in section 6.2, with its objective defined for this research in section 6.3, and the research design of Delphi study itself in section 6.4.

Upon verification of the framework, it was necessary to validate its practical relevance that it claims at the time of its conception and development. K. W. Platts (1993) proposes *testing the strategy process* as stage 2 of his proposed *process research methodology for manufacturing strategy*. With the purpose to test the feasibility and refinement of the approach, K. W. Platts (1993) highlights three areas needing consideration while designing this aspect of research. These are summarised and presented in Table 4.5.

Table 4.5 Testing the strategy process (summarised from K. W. Platts, 1993)

The involvement of the researcher	Direct observation	Researcher endeavours to remain totally detached, recording what happens without influencing events.
	Participant observation	Researcher takes part in the activity under study and adopts two roles: one is as a member of the group being studied; the other is as recorder of the processes and behaviour occurring within the group.
	Action Research	A researcher not only participates in the activity but seeks to direct and influence the way in which the activity is conducted.
The consistency of the process	Consistent	A consistent process would facilitate comparison between sites.
	Modifying	Modifying the process in light of experience would result in a more robust and useful process at the end of the research.
The choice of sites to be studied	Consistent	A similar type of companies
	Inconsistent	Different types of companies

For the purpose of validation, the case study approach was utilised, where a partial implementation of the verified framework was done in two manufacturing SMEs in Pakistan. The companies chosen for this study are consistent in a way that they both are SMEs and are inconsistent due to the fact that they both operate in the completely unrelated industry (i.e.

electric transformer manufacturing and sanitary products. See section 7.3 and 7.4 for their profile). These two companies were chosen based on the criteria that they met the requirements of this study, whereby; a company that is operational in the manufacturing of goods and is an SME within their sector. Moreover, the agreement and permission of the respective company's leadership were crucial, as without that it would be completely impossible to test the developed framework. For the purpose of analysis (phase 1), a consistent approach in the process was adopted in terms of selection of analytical tools/methods, however, a modified approach in phase 2 (Plot) was adopted to ensure that the proposed changes and strategies for them are relevant within the context of each respective company. Researcher role was both as a *direct observer* where the observations were made, and data was collected regarding the current scenario of the company. The researcher also took the role of *participant observer* where the researcher engaged in in-depth discussions with the company's leadership/operation management team in identifying the potentially right solutions and ways to achieve circularity in their operations.

4.6 Time horizon

There are two possibilities in terms of time horizon, which are cross-sectional and longitudinal. Saunders and Lewis (2018) describe these two types of time horizon as follows:

Cross-sectional: *Study of a particular topic at a particular time, i.e. 'a snapshot'.*

Longitudinal study: *Study of a particular topic over an extended period of time.*

Saunders and Lewis (2018) put forth the idea that research is often constrained by time and as a result researcher mostly opts for cross-sectional research. This is reflected within this piece of research as it not only requires capital and approval for investment for proposed changes through this framework but also would need to be measured over a long period of time. Thus, this research takes a cross-sectional approach and examines the case studies during an extended visit to analyse their operations and develop a projected scenario to portray what the full-scale implementation would result in.

4.7 Data collection and data analysis

Since this research deploys two research strategies of survey and case studies, this section will

provide an overview of data collection and analysis approach during each of the research strategies deployed in this research (see Table 4.6). For both the survey and case study, a non-probabilistic sampling approach was adopted.

Table 4.6 Data collection and analysis approach for this research

Research Strategy / Approach	Survey (Delphi study)	Case Study
Sampling method	Purposive Sampling	Volunteer Sampling
Data Collection method	Online questionnaire	In-depth semi-structured interviews, Gemba walk
Analysis	Quantitative and Qualitative	Qualitative

Purposive sampling method was selected to choose participants for the Delphi study to ensure the invited personnel has the background, expertise, knowledge and capability to provide constructive criticism and feedback. A discussion on the selection of participants for this research is provided in section 0, with criteria for sample selection in Table 6.1 and the profile of the actual participants of this study is provided in Table 6.2. These participants were invited through email with information regarding the purpose of the study and process involved. Appendix A and Appendix B contain the letter of invitation sent through email to the participants of both the first and second round of Delphi study, respectively. An online link was provided for the research participants to access the questionnaire and provide their feedback. The questionnaire included both the closed-ended and open-ended questions. Responses to closed-ended questions were analysed quantitatively and the feedback through open-ended questions was analysed qualitatively with further thematic synthesis (see Figure 6.6) to incorporate the recommendations.

For selecting case studies, a volunteer sampling method was considered appropriate as the proposed framework is novel, and from a growing researcher who does not have much experience nor any contacts at an industrial level within UK/Europe to approach for the purpose of this study. Although the researcher tried to explore the possibilities of engaging with UK based companies, given the time constraints the selection was made on the basis that whichever company agrees first would be included within this study. Henceforth, two companies from Pakistan that agreed to participate were engaged within this study. Data from these companies

were collected through in-depth semi-structured interviews (see Appendix E) from all three levels of the strategic, tactical and operational level of the respective companies. This data was further assisted by the Gemba walk of the shop floors to observe the manufacturing operations for potential improvements as per the proposed framework. This data was then analysed in section 7.3.1 for Company A and in section 7.4.1 for Company B. This analysis fed into the next phases of the framework for further development and testing of the validity of the proposed framework.

With this description and overview of the research methodology adopted for this research, it is best to summarise it through Figure 4.2 to provide an overview of the adopted methodology for this research. Red outlined areas depict the pathway taken for this research.

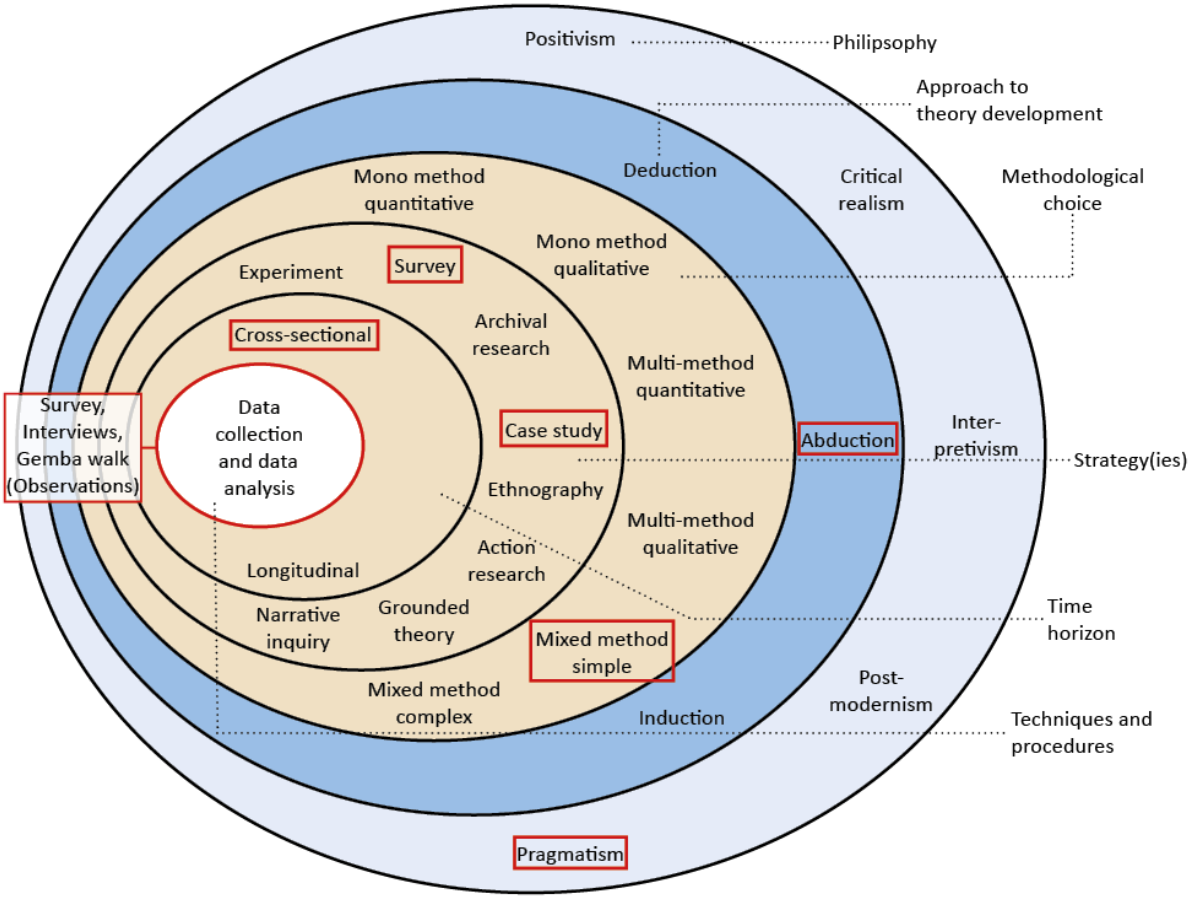


Figure 4.2 Adopted methodology for this research

4.8 Conclusions

For any research, there is no one specific way or predefined combination that can be adopted. Instead, there is flexibility which allows for the emergence of new ideas through the adoption of different methods as stand-alone or in combination, based on requirement and/or necessity.

This research adopts the research philosophy called pragmatism, a hybrid approach to theory called Abduction with more dominance of Deduction. In addition to this, the research employs a mixed method simple approach where both qualitative and quantitative methods are utilised through a survey (Delphi study) and case study approach in cross-sectional time horizon. The research participants were selected using purposive sampling for Delphi study and volunteer sampling for case studies. The collected data were analysed using both the qualitative and quantitative approach.

Chapter 5 C-LEAN, a conceptual framework integrating Circular Economy and Lean

5.1 Introduction

The distance between academia and industry is often lengthened due to lack of comprehensive methodologies (e.g. frameworks) to implement the developed theory/ concept (Chay et al., 2015). At the same time, the existing potential of earlier developed/ implemented tools is often ignored, and efforts/ resources are wasted in re-inventing the wheel. Scholars do acknowledge that generally, the concepts do have massive potential to benefit its users, as in the case of CE; but a major factor contributing to failure or ineffectiveness of a concept is the ill-defined implementation stage (Chay et al., 2015), despite considerable investment of resources (Garza-Reyes et al., 2015). Thus, there is a strong need to have a systematically developed framework for the implementation of a holistic approach, proposed under CE concept (discussed in Chapter 2), in manufacturing operations, especially at SME's level.

The two concepts of Lean and CE, as discussed in earlier chapters (see Chapter 2 and Chapter 3), have a greater synergy to benefit the manufacturing sector. Moreover, with their common elements to eliminate waste and create value, although with a different focus, complement each other in producing effective outcomes, therefore, their combination seems natural. The CE model presents an ideal solution to the current global problems of resource scarcity (Nadeem et al., 2017a) and environmental damages (Loon et al., 2017) by proposing the development of a closed-loop economic system (Webster, 2015). Lean on the other hand has been a proven success to eliminate waste and to create value (Mostafa et al., 2013) by achieving efficiency and optimising the economic benefit.

Yusof and Aspinwall (2000) describe that a model defines *'what is'* and a framework defines *'how to'*. On a similar note, Anand and Kodali (2010) define a framework as the *'guiding torch'* to manage the implementation of any change. Therefore, the aim of this chapter is to develop and present a comprehensive framework by integrating the best practices of the two concepts of *Circular Economy* and *Lean*, to allow the adoption of CE's principles within the operations management of manufacturing sector, especially at SMEs level.

With the above aim, this chapter's objective is to integrate the best practices of both CE and Lean, and to develop a novel conceptual framework, which provides a systematic/ structured approach with step-by-step guidance to manage and maintain CE's adoption in the

manufacturing sector especially at SMEs level; by utilising CE and Lean principles, tools and methods.

With this scope, the remaining chapter is structured in 3 sections of framework development (see section 5.2); conceptual framework (see section 5.3); and finally the conclusions (see section 5.4).

5.2 Framework development

Conceptual development of the framework was done in two major stages of comprehension and conception (see Figure 5.1), also known as intelligence and conception (Moreira et al., 2015).

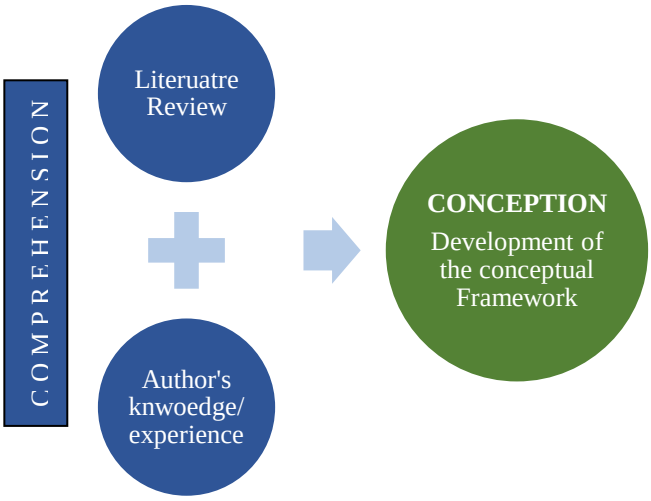


Figure 5.1 Stages of developing a conceptual framework

At comprehension stage literature review was conducted (see Chapter 2 and Chapter 3), ensuring that the most current and relevant theoretical knowledge is explored and embedded (Chen and Lyu, 2009), to develop an in-depth understanding of the existing literature and to map out the spectrum of CE and its implications. This stage explored the characteristics and principals of both the concepts of CE and Lean; their theoretical development, interrelated nature and synergetic properties to complement each other for effective adaptation in operations management. This stage defined the need for an integrated comprehensive framework by identifying the gap in the academic literature for a systematic approach to benefit from the integration of these two complementing concepts of CE and Lean.

Literature review blended with the author's experience in managing business operations (i.e.

hospital management and business operations management) and knowledge of production management operations honed the conception of the proposed conceptual framework. The need for CE's implementation is evident in the face of present-day challenges of resource scarcity (Nadeem et al., 2017a), fast production and consumption pattern in market (Ghisellini et al., 2016), with minimal to no responsibility and procedures for resource management (Geng and Doberstein, 2010), especially at the end of life cycle of products (Ghisellini et al., 2016).

This conceptual framework was developed using a systematic phase by phase approaches adapted and learned from the scholars' published articles (Cherrafi et al., 2017; Garza-Reyes et al., 2016, 2015; Mostafa et al., 2013). The framework consists of 6 phases (i.e. Delineate, Analyse/Identify, Plot, Execute, Evaluate, and Control). This phase by phase (also called stages) approach is often utilised by scholars (Cherrafi et al., 2017; Mostafa et al., 2013) to explicitly identify and segment key activities necessary to reach the aim/ objectives of a framework. At each phase, completion and output of one phase become an input for the next one. The phases in their macro level are adapted/ inspired from the DMAIC approach of Lean Six Sigma (George et al., 2005), as well as the frameworks proposed by Cherrafi et al., (2017) and Mostafa et al., (2013). However, there are fundamental differences in the very core and further developments within each phase, as well as their sequential order. For instance, the DMAIC approach sequence begins with Define, moving on to Measure, Analyse, Implement and ends with Control. On the contrary, the proposed framework adopts some of DMAIC's features in their generic nature (e.g. identify, control), as well as from the other two frameworks (e.g. phase 0) and utilise the best order for phases as well as the steps within those phases. Some of these phases (e.g. control) may not be completely different, but it presents a modified and contextualised approach that better complement the purpose of this framework's development.

By adapting and using only a few components of the earlier developed frameworks/ model, the researcher does not undermine their capability but rather builds on them to strengthen the application of CE's principle in a systematic and practical manner. Moreover the purpose of DMAIC and the proposed framework differ as DMAIC's focus is on problem-solving (Garza-Reyes et al., 2014a; George et al., 2005; Hammer and Goding, 2001) and the proposed framework is focused on adopting CE in the existing manufacturing operations, for which the existing system does not necessarily have to have a problem per se, although that could be one source of motivation for its adoption. Manufacturing companies might want to adopt circular initiatives inspired by growing awareness, demand and regulations.

5.3 Conceptual framework

The framework hinges on the principles of CE and Lean, to propose a holistic approach to deal with the present-day challenges of resource scarcity and environmental damages. These principles are discussed earlier in the literature review (see section 2.2.3 and section 3.3).

Since Lean and CE have common goals of waste elimination and value creation, their combination is natural to complement each other and benefit greatly to make CE's application realistic, smooth and easy. Therefore, the proposed framework combines the best of Lean and CE principles, characteristics and tools to develop a comprehensive framework for operations management in a systematic manner.

The proposed framework is developed to strongly promote/ encourages continuous improvement culture with flexibility for adaptability as needed. Therefore, the processes, design and strategies are to evolve throughout the organisation and can be developed by inter-organisation learning and cooperation. The focus is to utilise the knowledge from any and all sources that are available (e.g. nature, man-made developments) and build on them to ensure best practices at all levels of this framework's implementation.

Within this scope, the proposed framework integrates and merges CE and Lean principles to enable a comprehensive implementation/ adaptation of CE in manufacturing operations management. The framework is called 'C-LEAN' with its meaning being '*Circular Lean*'.

The proposed framework consists of six phases that include: phase 0 Delineate, phase 1 Analyse/ identify, phase 2 Plot, phase 3 Execute, phase 4 Evaluate, and phase 5 Control. Subsequently, these phases are broken down into 14 steps (activities) for systematic implementation of all phases (see Figure 5.2).

It is vital to emphasise the need for a person specifically assigned to take responsibility and lead the process as coordinator or manager, especially until the CE is embedded into the overall organisational culture. S/he will work in close coordination with team/ personnel assigned for this change and will serve as a point of reference, decision maker while being accountable for his/ her decisions.

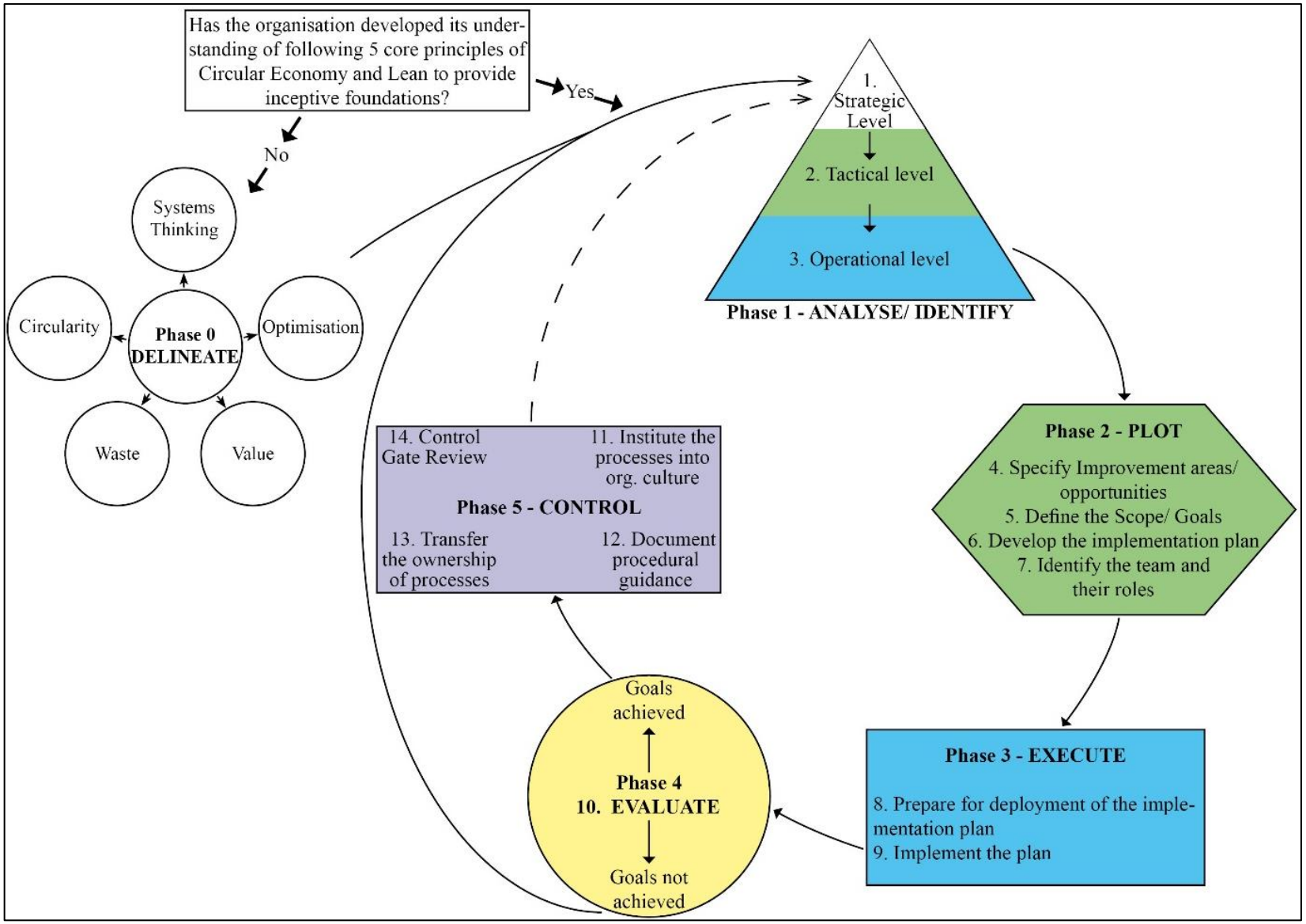


Figure 5.2 C-LEAN, a conceptually developed framework

Starting with Phase 1 the framework leads the users in a systematic manner to clearly analyse, map out and define strategies, implement, evaluate and control the adaptation of CE in operations management. The following sections further provide guidance into the 6 phases and their sub-steps.

5.3.1 Phase 0 – Delineate

For any framework, it is best to delineate the core principles of the concepts that it is moving towards/adopting. This enables an effective understanding to allow an efficient and well-grounded approach while implementing the framework. With this scope, the phase is called phase 0, as it will only be necessary if the adopting organisation has not previously developed its foundational understanding of these 5 core and key principles (Systems Thinking, Optimisation, Circularity, Waste, Value) of CE and Lean. If the organisation has already developed the understanding of these 5 principles, then it can straight away move into phase 1. However, it is highly recommended that any organisation adopting this framework skims through phase 0, even if it has already developed its understandings of these principles.

For the Framework to make sense for its adopters, it is vital to clarify the foundational definitions of key principles, so that the developments and implementations would have a systematic flow. In order to complement the two concepts of Lean and CE, their core features might needs updating to a hybrid version of definitions to elaborate on the developed ideas. In this scope, the researcher considers the following five overarching principles of CE and Lean (see Figure 5.3) in need of re-definition. These elements are considered to bear equal importance; thus, no sequential order is identified in this phase.

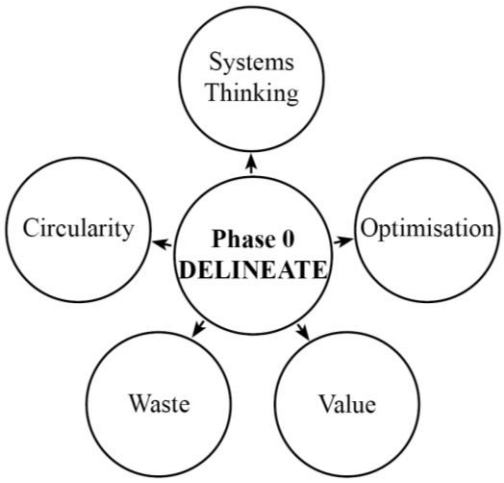


Figure 5.3 Pre-Defining characteristics of the framework

5.3.1.1 Systems thinking

Most business activities would make a direct or indirect impact on their customers, suppliers and the community/ environment they operate in; which creates the whole system. CE presents a contrasting approach of systems thinking compared to what is practised in the traditional linear economy. It requires businesses to regard themselves in the setting of overall supply chain and its impact while thinking in cascades (Elia et al., 2017; Kobza and Schuster, 2016; Murray et al., 2017). Businesses have a lot to learn from the natural environmental system around (biomimicry) (Romero and Noran, 2015), where the focus is on optimising the overall system and not the individual components alone (Webster, 2013). It is vital for the companies to engage in systems thinking where no functional divisions as well as companies, work in isolation or in subgroups but have common strategic goals to achieve in a responsible manner.

In the purview of systems thinking, the identification of stakeholders for a business is a necessary element (Billgren and Holmén, 2008; Soma and Vatn, 2014). Stakeholders' participation, influence and input is vital (Colvin et al., 2015; Soma and Vatn, 2014) to develop and maintain circularity in business operations, as it helps to explore multiple dimensions/ challenges (Billgren and Holmén, 2008) and enhance the acceptability of decisions/ strategies of the business (Fischer et al., 2014; Hall et al., 2013). In the broad spectrum of this framework stakeholders selection criteria is suggested to be in the bounds of who is and/or can be affected and impacted by the activities of the business (Billgren and Holmén, 2008; Fischer et al., 2014; Reed et al., 2009) and who might be interested in the activities of the business (Colvin et al., 2016; Soma and Vatn, 2014).

In this context following stakeholders are identified in their broader spectrum:

- **People** – Generally the concept of the stakeholder would think of people as those who are either directly (e.g. customers, supplier, etc.) or indirectly (e.g. community around etc.) impacted by the business and its activities and/or those who have interest in the business and its activities. This framework further expands these boundaries to includes the people who are not born yet, meaning future generations; as the businesses, today dealing with resources are impacting them by either adding value and/or by increasing depletion/ scarcity of resources.
- **Planet** – Identifying planet Earth and its environment as a stakeholder is necessary as all the resources are extracted from it, so in that sense, Earth is the supplier and any development in business activity and its outputs directly affect it on the long/ short run.

5.3.1.2 Optimisation

One of the most common elements in both concepts of CE and Lean is optimisation. CE aims to optimise the life cycle and end of the life cycle of the resources and products from the design stage of products as well as throughout their life cycle by enhanced and preventive maintenance (Ellen MacArthur Foundation, 2015b; Jabbour et al., 2017) while maintaining the maximum utility of resources. The major goal is to reduce the overall waste (Geng and Doberstein, 2008) through strategies such as reuse, disassembly and refurbishment (Singh and Ordoñez, 2016).

On the other hand, Lean's approach to optimisation is related to process (Hu et al., 2015) by minimising variations in process (Tokola et al., 2017) and creating flow (Mehrsai et al., 2014), through value stream mapping and its optimisation (Seth et al., 2017).

The contrasting difference between the approaches of these two concepts is that Lean focuses in terms of the immediate usage of the resource within a specific process, however, CE takes a more holistic approach from a systems perspective, as to optimise the utility of the resource even after one life cycle of the product. Therefore, for the convenience of the adopters of this framework, a redefinition of optimisation is provided as follows:

> *"Making every effort to maximise the output/ utility of a given resource (material, time, energy, and creativity) at all different stages of the life cycle in a closed loop system, while eliminating/ minimising any non-value adding impacts, throughout the life cycle of any resource."*

The above re-definition would be fully understandable when a user fully grasps it concurrently with other 4 principles discussed within this section 5.3.1 (see section 5.3.1.1, 5.3.1.3, 5.3.1.4, 5.3.1.5).

5.3.1.3 Value

For any given material or product, Lean's definition of value is/has been very subjective, as it highly denotes to owners'/ customers' need and willingness/ desire to acquire a product or material (Lucato et al., 2014; Neap and Celik, 1999). Its defining scope is further extended within the context of supply network management, from external (customers) to internal and is linked to product and service characteristics (Adamides et al., 2008). On the other hand, CE defines value as utilising highest utility of the resource at all times (Ellen MacArthur Foundation, 2015c), by caring for, contributing to and expanding the natural system (Greyson, 2015).

Mostly, the value of a resource/ product is only assumed from the perspective of one life cycle that it is being utilised for (product); however there yet remain residual value that can be utilised in one form or the other. This limited view of the value in a product or material is the core reason in contributing to the speedy depletion and scarcity of resources. Within this scope and under the purview of Lean and CE, it would be best to re-define value as follows:

> *"Any activity/output that utilises its required resources in manner that maximises its utility at all stages of its life cycle including the afterlife, as well as to ensure the longevity of its life cycle while satisfying the needs/ demands of the stakeholders (People [present and future] and Planet) and making impact for them."*

It is important to note that the above definition focuses on the life cycle of a resource, not just the product alone.

5.3.1.4 Waste

Waste as per Lean is anything that does not add value (Banawi and Bilec, 2014) and is also defined as being any non-value adding activity that the customer is not willing to pay for. On the contrary, CE defines waste as food where waste from one product becomes food (raw material) for the other (Webster, 2015). In light of these two broad spectrums, waste can be re-defined as follows:

> *"Any activity that leads to the harmful outputs for the stakeholders (People [present and future] and Planet) and does not incorporate the sustainability of the two in long term, is a wasteful activity."*

5.3.1.5 Circularity

Circular economy endeavours to develop a closed-loop system, where resources are used but not used up (Webster, 2015). In this scope, a product and its components utilising various raw materials are to be kept within the system to ensure their maximum utility. For this purpose, businesses need to understand and revisit the concept of Product Life Cycle (PLC). Traditionally the PLC has begun with the introduction of the product, led by market growth, maturity and eventually ending with decline. At the end of the life cycle mostly the products are doomed to be scrapped and dumped, leading to both the environmental damage as well as the loss of residual value of resources used in that product.

In the scope of CE and Lean, this framework proposes a new approach (see Figure 5.4) with

the following additions and modifications to the two stages of the existing PLC model:

- At the *'introduction'* stage of the product, sourcing is redefined and extended from three sources:
  - Material for production is sourced from re-utilisation of recovered products/ materials
  - Degraded materials from another industry which still meets or exceeds the quality standards required for the product under consideration, are re-purposed/ re-utilised to ensure the utility of their residual value
  - When and only if needed, the virgin raw material to be extracted to produce new components for the product under development
- The *'Decline'* stage is renamed and is now being called, *'Extended Maturity/ Decline'* stage. At this stage, the product has three possibilities of:
  - Extending the life cycle of the product/ material through the adoption of innovative approaches
  - Degradation of resources/ materials used in a product to be re-utilised as raw material for the production of other types of products.
  - The materials/ products that are impossible to be re-utilised and are marked as no good for further use must be disposed carefully while differentiating the technical and biological waste, and that also to be specified and thought for at the design stage of a product.

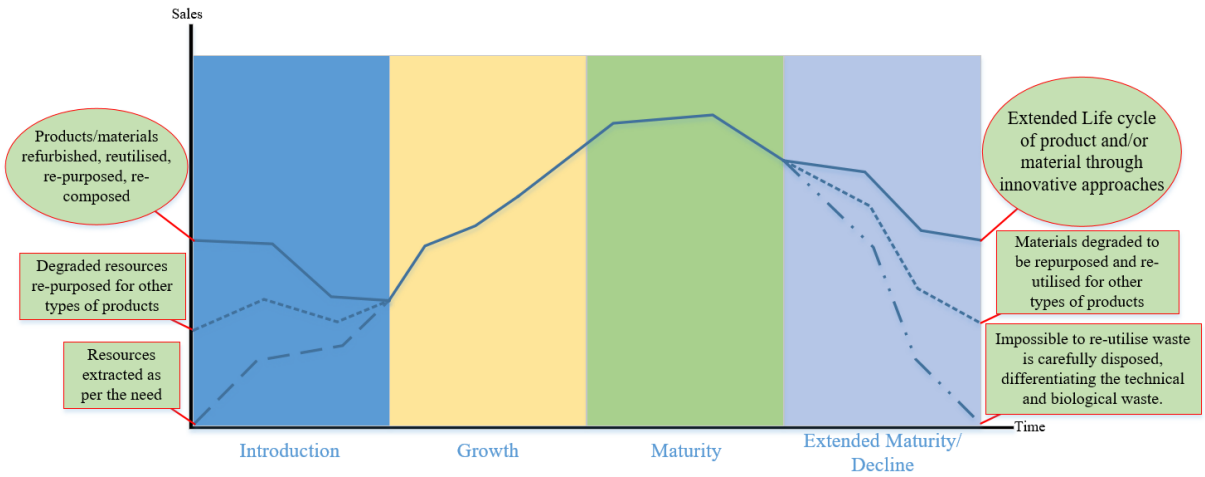


Figure 5.4 Re-defined Product Life Cycle for the proposed Framework

Once the adopting companies have developed a sound understanding of the earlier discussed 5 principles of CE and Lean, they can then move on to Phase 1 of the framework, Analyse/ Identify.

In all of the five upcoming phases different Lean and other tools/ methods/ techniques are suggested/ recommended for guidance purpose only. However, the adopter must understand that these suggestions/ recommendations are not bounding, and one must not restrict the scope of the framework to these tools only. The important element is the systematic approached to be adopted under the mindset of continuous improvement. The choices of tools/ methods/ techniques to assist in making that approach effective and efficient is completely dependent upon the organisation's scenario and context (e.g. availability of the resources, skills and purpose).

5.3.2 Phase 1 – Analyse/ identify

For any given organisation, three levels: Strategic, Tactical and Operational (see Figure 5.5) are fundamental to its existence. Strategic level deals with overall directions of the company (Jansson et al., 2017). Tactical level ensures that strategic goals/ directions set by the top-level management become realistic (Flin and Arbuthnot, 2002) through proper management of resources and planning. Operational level carries out the plans/ goals established by the Tactical level under the direction of Strategic level (Belekoukias et al., 2014). All these three levels are directly inter-linked and highly integrated with each other.

Figure 5.5 Phase 1 of the framework

Assumption: At this phase, it is assumed that organisation either have already a sound understanding of earlier discussed five principles (see section 5.3.1) or has utilised phase 0 and have redefined its foundational understandings. Phase 0 or its equivalent has a foundational role to play.

Team action: At this stage, an overarching analysis approach of VMOST (Vision, Mission,

Objectives, Strategy, and Tactical) can be adopted while utilising other tools/ methodologies to feed into and assist in exploring as much detail as possible. The major goal is to analyse the organisation as a whole at all three levels of Strategic, Tactical and Operational; and to identify gaps/ shortcomings at any one or all levels that are contrary to CE principles and can be changed/ modified to improve/ optimise the output for all stakeholders.

Analysis at this phase will help to scan the horizon of the organisation across all the levels and will identify the strengths and weaknesses of the company to further prioritise the possible transformations to pursue the goals of complying with CE's principles. For this purpose, different tools can be utilised, some of them are listed in each step but the list is not exhaustive.

An important thing to remember at this phase is to avoid "paralysis by analysis", where a lot of effort/ resources are utilised to collect irrelevant data; therefore, the tools/ methods must be carefully chosen.

5.3.2.1 Step 1 – Analysis/ identification at the strategic level

The strategic level of any organisation defines the interests of a company and determines its directions by providing a clear vision and mission for their organisation. Under this broad spectrum, the overall objectives and goals are developed/ followed throughout the organisation.

The organisation needs to be analysed in light of predefined and/or re-defined understandings as per the framework phase 0. If any inconsistencies exist between the organisation's strategic level and the desired/ possible level under CE's defined scope, they must be documented for further examination/ action.

For this purpose, the company's vision and mission statement, as well as the strategic plan, can be included in the analysis. Besides the interviews with CEO/ board members/ other top-level management, can be conducted to get an in-depth view of its strategic level. For this step, the user(s) can deploy any of the following tools in any combination or stand alone, but are not limited to:

- Balance Scorecard
- Strategy Map
- PEST Analysis

The results of analysis from this level will provide a foundational understanding of where the

company stands and where it aspires to be in terms of its strategic direction. This will assist the user to define the scope of analysis at the tactical level.

5.3.2.2 Step 2 – Analysis/ identification at the tactical level

The tactical level of an organisation serves as a bridge between strategic and operational level and ensures the realisation of the organisation's mission and vision. Here the organisation's strategy and goals are analysed in light of predefined and/or re-defined understandings as per the framework phase 0. Any major or minor gaps are to be identified and documented to be considered for future improvement and change. For the purpose of analysis following steps are to be followed:

1. Obtain the company's goals and strategies to achieve those goals
    a. If the documentary evidence does not exist, then the strategic personnel at the tactical level to be interviewed to understand their goals and strategies that they adopt to achieve those goals.
2. Identify any discrepancies that contribute negatively to the environment and/or do not keep the resources at their highest utility, and/or have a different understanding of value, waste, cost/profit and product life cycle.
3. Document the gaps.

For this step the user(s) can also deploy any of the following tools in any combination or stand alone, but are not limited to:

- Force Field Analysis
- Strategic Planning Gap
- SWOT Analysis

Analysis from this level will provide an ample understanding of the company's way of realising the strategic directions and aspirations. Based on the results from this analysis, the user then can define their scope for analysis at an operational level.

5.3.2.3 Step 3 – Analysis/ identification at the operational level

Operational level serves as hands and feet of the organisation, as it brings the vision and mission from virtual to physical existence. At this step organisation's operational activities/

outputs are analysed in light of predefined and/or re-defined understandings as per the framework phase 0. Any major or minor gaps are to be identified and documented to be considered for future improvement and change. For this, the user(s) can deploy any of the following tools in any combination or stand alone, but are not limited to:

- Value Stream Mapping
- Causes and effect relationship
- Strategic Planning Gap
- Root Cause Analysis

Author highly recommend utilising the value stream mapping (VSM) tool, however, any other tool/ method can be utilised if the expertise for VSM is not available or if through other methods the similar analysis can be conducted.

To compensate for VSM, the following procedure can be used accompanied by Gemba walk while utilising any one or multiple tools:

1. Obtain the company's product development process guidelines
2. Obtain the company's recorded data on generated waste
   a. Obtain the company's waste handling procedure/ records
3. Obtain the company's understanding of their responsibility for the product life cycle and end of the life cycle.
4. Identify any discrepancies that contribute negatively to the environment and/or do not keep the resources at their highest utility, and/or have the different understandings of value, waste, cost/ profit and product life cycle.
5. Document the gaps.

The overall output of the analysis at these three levels will provide sufficient details to identify the areas requiring improvements/ modifications and/or changes. The user(s) can then move into the next phase to prioritise, plan and develop the roadmap for improvements.

5.3.3 Phase 2 – Plot

Assumptions: At this phase, it is assumed that the coordinator/ manager along with another person/ team has conducted a detailed analysis of the organisation as a whole or in part (as per management's decision) and have identified potential areas/ aspects for improvement with

regards to adaptation of CE principles in their operations.

Team action: The team needs to ensure that management is aware of the findings from phase 1 and is coordinated with for further proceeding.

The Lean tool of *Hoshin Kanri* (Policy development) is to be kept along to ensure the alignment of goals at all three levels of strategic, tactical and operational.

At this phase, the following steps need to be followed (see Figure 5.6).

Figure 5.6 Phase 2 of the framework

5.3.3.1 Step 4 – Specify improvement areas/ opportunities

The documented list of areas requiring improvement needs to be reviewed by the coordinator/ manager and the person/ team alongside him/her. They then need to prioritise the identified areas/ aspects requiring change/ modification/ improvements and choose the areas/ aspects they define as highly important for the adoption of CE. For this purpose, the user(s) can deploy any of the following tools in any combination or stand alone, but are not limited to:

- *Pareto Analysis*
- *Action Priority Matrix*
- *Project Selection Matrix*
- *Decision Matrix Analysis*
- *Eisenhower's Urgent/ Important Principle*
- *The Modified Borda Count*

Once the areas for interventions are prioritised and chosen, the documentation along with justification needs to be discussed with the top management of the organisation to seek their approval to continue to the next stage of PLOT phase. It is crucial to involve top management at this stage and to obtain their consent as they might not agree for the proposed directions and

it would result in the wasted effort if the team continues without management's support. If the top management disagrees with the proposed areas for interventions, the review is to be done again along with top management's personnel and consensus to be reached. Once the top management has consented, the team then can move to the next step to define the scope of the change/ modification/ improvement.

5.3.3.2 Step 5 – Define the scope/ goals

Having a clear idea of which areas of the organisation to improve and which opportunities to exploit on, the team then needs to define the scope of improvement by defining what changes, modifications and intervention to work on and specifying goals/ task for their achievement. For this purpose, the team can also look for best practice case studies available already to avoid re-inventing the wheel and/or to benefit in developing more robust goals. The goals must be SMART:

S = Specific

M = Measurable

A = Achievable

R = Realistic

T = Time-bound

Besides having SMART goals, it is best to conduct Failure Modes and Effect Analysis (FMEA) to identify potential risks and formulate mitigations strategy at this stage.

Once the team has identified its strategy of intervention, developed its goals and conducted the risk analysis; they then can move further to develop the implementation strategy.

5.3.3.3 Step 6 – Develop the implementation plan

This step aims to develop the implementation plan along with the clearly defined Lean (including any extension e.g. Lean six sigma) and CE tools/ techniques for intervention. Different planning tools can be utilised, among which project management tools such as Gantt chart, resource planning etc. are highly recommended.

At this step, many Lean, and its extensions' tools can be deployed as stand-alone or in

combination, dependent upon need, strategy, as well as the skills/ capabilities of the users and availability of resources.

The implementation plan would provide a clear picture of what type of personnel are needed to execute the planned intervention. The team can then move to the next step to identify the team and define their roles.

5.3.3.4 Step 7 – Identify the team and their roles

At this step when the process map has been developed to eliminate/ minimise the identified gap/ discrepancies; another important bit is to identify the right person who will take the lead on the implementation. Some important features to consider while choosing the team are:

- Availability of the person(s)
- Skills of the personnel and their ability to take responsibilities
- Knowledge of their functions and the organisation
- Ability to be a team player and share knowledge with others
- Willingness/ motivation for CE
- Ideally, the experience of participation in improvement/ change management projects

The number of personnel for the team to implement the intervention can vary, as it completely depends on the type of activities, level of implementation, required skills and other factors related to the plotted intervention. There might be a need to recruit new staff and/or consultant if the required skills are not available in-house. Once the coordinating team has identified/ recruited the implementation team members, they can then move on to the next phase, Execute.

5.3.4 Phase 3 – Execute

This phase (see Figure 5.7) is the organisation's endeavour to begin the change implementation. At this phase following two steps are to be followed.

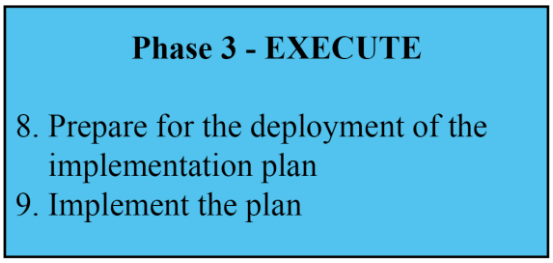


Figure 5.7 Phase 3 of the framework

5.3.4.1 Step 8 – Prepare for the deployment of the implementation plan

At this step, the team members must prepare for the deployment of the implementation plan with a clear understanding of the tasks. Preparation can include but is not limited to:

- All the team to have orientation, guidance and training (if necessary)
- Ensuring all resources are available
- Ensuring that any disruption in the regular operations are planned in line with expected outputs to meet the regular demands
- The contingency plan must be in place to avoid any problems and interruptions in the overall progress of the business.

Once the team is prepared and ready, they then can move to the next step of implementing the plan.

5.3.4.2 Step 9 – Implement the plan

With all the resources in place and preparation, the implementation step must begin. The coordinator/ manager must oversee all the process and provide full support and guidance to the implementation team. S/he must also ensure to record the progress on a regular basis. This can later be utilised to analyse any trends, deviation and can help build upon best practices or avoid any mistakes happened.

The ground rule of continuous improvement must be kept in mind and following Lean tools can be deployed but are not limited to, to ensure the effective execution of planned interventions:

- 5S (Sort, Set in Order, Shine, Standardise, Sustain)
- Kaizen
- KPIs to monitor
- PDCA (Plan – Do – Check – Act)
- Poka Yoke

Once the plan has been implemented, the team can then move to the next phase to evaluate against the goals set earlier at step 5 (see section 5.3.3.2) and the desired level of performance.

5.3.5 Phase 4 – Step 10 – Evaluate

At this phase, only one step is involved to evaluate the impact against the defined goals (see Figure 5.8). If the goals are achieved, then the team needs to move to phase 5 Control. The coordinator/ manager along with top management needs to define the criteria for goals achieved. For instance, if the goals were achieved by 90% or 80%, then move onto control. In case of goals not being achieved, the mistakes and shortcomings are to be documented and the team would make the decision to move to Phase 1 to re-analyse/ re-identify, or phase 2 to Plot again, or phase 3 to execute the same plot again. The decision would solely depend on the circumstances and need. In case if the coordinator/ manager along with team thinks that the goals are not achieved due to poor plotting or execution, in that case, the decision to move to that phase would occur.

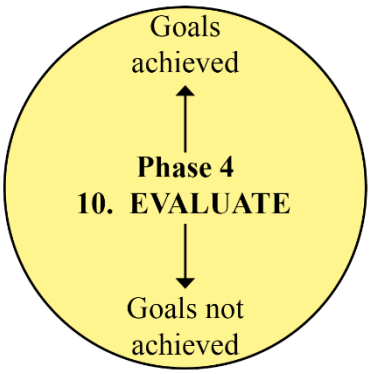


Figure 5.8 Phase 4 of the framework

For the purpose of evaluation, it is highly recommended to deploy Circularity Measurement Toolkit (CMT) (Garza-Reyes et al., 2018) along with benchmarking against the earlier set goals. So far CMT is the only best-published tool to understand the circularity level of a company.

Upon achieving success, the team can then move to the final phase to sustain the implemented intervention through the control phase.

5.3.6 Phase 5 – Control

In this phase, the general assumption is that the selected project and planned intervention goals have been achieved within the acceptable range defined earlier. At this phase, the coordinator/ manager needs to ensure that the completion/ success of the framework's implementation is made sustainable through systematic adherence to the following steps (see Figure 5.9).

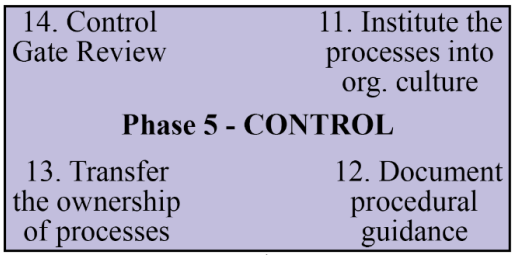


Figure 5.9 Phase 5 of the framework

5.3.6.1 Step 11 – Institute the processes into organisational culture

Since the CE's actual potential cannot be fully realised without systems thinking, therefore it is important to begin within the company first by embedding and replicating the CE's adaptation throughout the organisation. This would ensure benefiting the organisation by sustaining CE principles throughout, as well as to sustain the changes made in the pilot project.

For this step to take an effect and produce results would not happen overnight but would require similar efforts as done in the first intervention. Thus, it is important to document the procedural guidance, the next step.

5.3.6.2 Step 12 – Document procedural guidance

Documenting the procedural guidance in contextualised form would greatly benefit for the future adaptation within the organisation. It will also serve as evidence of success achieved; lessons learned and would be a great point of reference to build on for future improvements and adaptation.

At the completion of this step, the coordinator and team can start to prepare for closure by transferring the ownership of the process to the managers and everyday working people within the company.

5.3.6.3 Step 13 – Transfer the ownership of processes

All the documented details and procedural guidance are to be handed over to the right personnel for the continuity of its implementation at the organisational level. All three levels (Strategic, Tactical and Operational) of the organisation are to be involved on as needed basis and the process of transferring the ownership of the process is to be documented for future reference.

Once the transfer of ownership is done, the team can then do one last final checklist of the control gate review.

5.3.6.4 Step 14 – Control gate review

The DMAIC process of control gate review will highly benefit to ensure the sustainability of the framework and its outputs. For this purpose, the coordinator/ manager needs to ensure that:

- Reports of before and after scenario are documented and made available to the right personnel
- Process maps, control plans and procedural guidance are documented and in place
- Process owners as well as the management has taken over the process and are committed to its implementation
- Summary of lessons learned is developed
- Any issues/ opportunities for future implementation are documented
- A celebration to encourage the team and reporting the success is done.

Successful completion of this framework's phases and productive output would confirm and encourage the further adaptation of it throughout the organisation as well as among other supply chain members. It is important that any further adaptation teams bear in mind the very purpose, goals and characteristics of this framework. Moreover, there must be a periodical review for the purpose of continuous improvement.

5.4 Conclusions

The concept of CE has great potential and its widespread adaptation is the only way to see its promising outputs, as all different components in a system needs to function together to make the system completely operational. Although the concept of CE is relatively new and provides a completely contrasting approach to the existing linear economic model, this does not necessarily disqualify existing concepts and their possible combination with CE. Thus, this chapter develops a conceptual framework, C-LEAN, by integrating the best of both concepts of CE and Lean. The framework consisting of 6 phases containing 5 elements to delineate and 14 step to follow; provides a mechanism to systematically adapt CE principles in manufacturing operations management. The goals and benefits are summarised below:

- The developed framework and its criteria are non-prescriptive. The intent is not to define

and dictate the process but to focus on the end result achieved through a systematic approach utilising different tools and techniques as per the need, context and scenario.

- The criteria heavily focus on continuous development, which gives the place for learning from the past, focusing on the present with innovation, and heading towards the future in a pro-active manner rather than reactive.
- The goal is for the organisation(s) to embrace/ adopt circularity in their manufacturing practices, throughout its operations while achieving economic, social and environmental growth. These goals will be achieved by:
    - Making the move from the Linear economic model to a Circular economy model
    - Keeping resources to maximum utility
    - Ensuring resource conservation by minimising the usage of virgin material
    - Decreasing negative environmental impact
- By doing so the companies can utilise the framework to achieve the following outputs, but are not limited to:
    - Become a leader in adapting a systematic approach for CE's adaptation
    - Become an active responsible business that incorporates the interests of stakeholders (as per the re-defined understanding of phase 0 elements [see section 5.3.1.1])
    - Be the best in class practice and role model of CE practices
    - Economic growth mingled with a holistic sustainable approach
    - Model, inspire, and challenge others for innovation and drive towards CE model
    - Increase Market share
    - Increased productivity

Further guidance about the lean tools and their procedural guidance can be accessed through multiple online sources. Following handbooks are highly recommended for the team to consult, as and when needed.

- *The Lean Six Sigma Pocket Toolbook* by Michael L. George and others, published in 2005 by McGraw-Hill, New York, NY.
- *The Lean Management Systems Handbook* by Rich Charron and others, published in 2015 by Taylor & Francis Group.

The framework is developed solely based on literature and the author's expertise/ knowledge

of operations management. Every effort is made to ensure its usefulness and practical relevance, however before it could be validated through implementation, it is best to verify the conceptually developed framework by conducting Delphi study to ensure that any miss-alignments, errors, or missing elements are improved, modified and developed properly. The next chapter explores the Delphi study methodology adopted to verify this conceptually developed framework.

Chapter 6 Verification of conceptual framework through the Delphi study

6.1 Introduction

Once the conceptual framework and all of its elements/ steps have been developed thoroughly, the next stage is its verification before it could be validated through the case study method. In order to verify a novel framework that lacks research in the given area (Linstone and Turoff, 1975), deployment of Delphi study is a common practice (Okoli and Pawlowski, 2004) at postgraduate level (Skulmoski et al., 2007). Delphi study is a versatile research tool (Okoli and Pawlowski, 2004) to strengthen the novel development in light of experts' opinion and analysis.

For the conceptually developed framework in an earlier chapter (see Chapter 5), the conception stage continues to further verify it through the utilisation of Delphi study. This method of verification seems the most appropriate as through this a virtual panel of experts (Okoli and Pawlowski, 2004) both the academics and practitioners from vast geographic locations without any requirement to be present in a specific place, can be engaged to provide constructive criticism and share their opinion in a structured form. This would eventually strengthen the conceptually developed framework through the identification of any areas requiring improvement as well as embedding any further suggestions for which the consensus among research participants is reached.

This chapter aims to deploy a Delphi study in order to verify the conceptually developed framework. With this aim, the following objectives are identified for this chapter:

- To develop a Delphi research design for the verification of conceptually developed framework
- Develop an instrument (e.g. questionnaire) to be utilised for this Delphi study
- Conduct the Delphi study and consolidate the feedback to improvise the conceptual framework to be ready for validation through the case study method.

With the above aim and objectives the remaining chapter is organised in 6 sections to present the methodology of developing Delphi research design and instrument (see Figure 6.1) and to present the process of conducting the Delphi study (see Figure 6.4), with details of changes made in response to experts' feedback and finally the updated verified framework is presented (see Figure 6.8).

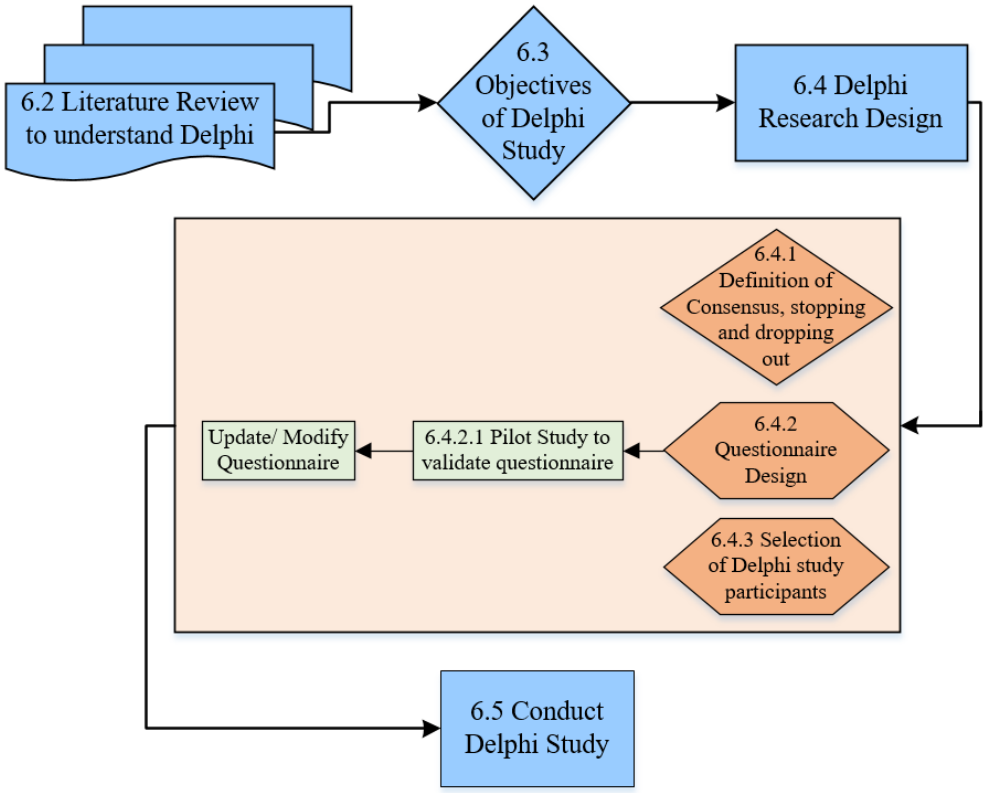


Figure 6.1 Methodology to develop Delphi research design and instrument

6.2 What is Delphi?

The term Delphi originates from the ancient Greek practice of using Oracle to predict the future (Thangaratinam, S. & Redman, 2005). Its adaptation and formal development in modern day world were developed by US military (Dalkey and Helmer, 1963; Linstone and Turoff, 2002) to verify the probable effect of the atomic bombing (Thangaratinam, S. & Redman, 2005). Delphi technique is often utilised in different disciplines such as, management (Brancheau et al., 1996), international business (Griffith et al., 2008), innovation management (Munier and Rondé, 2001), medical (C.P. et al., 2005), education (Broomfield and Humphris, 2001) and information systems (Paré et al., 2013). Delphi has been utilised for two purposes, one is to forecast and second is to verify a novel development of some kind (Culley, 2011; Fernández-Llamazares et al., 2013; McMillan et al., 2016; Okoli and Pawlowski, 2004), that does not have any other adequate source of reference to compare against (Linstone and Turoff, 1975). In such scenario, the experts in the field of the given era are communicated to express their opinion, criticism and suggestions (Reguant-Álvarez and Torrado-Fonseca, 2016; Skulmoski et al., 2007) to improve the novel development to be of practical relevance. The process of communication with experts is done through a series of questionnaires. The experts, however, are not aware of other experts involved in the same study. These experts could be a mixture of

academics and practitioners, as long as they have direct knowledge and/or hands-on expertise/ experience in managing the era that is being discussed. Upon receiving the feedback from Delphi study participants, the researcher conducting the study then compiles the results, make the changes for which there is consensus and re-send the updated framework with a questionnaire for another review by experts. This process of reiteration continues until the consensus has been reached (Delbecq et al., 1975; Meijering et al., 2013), however, it is also ensured to not lose the interest of participants by too many reiterations (Hasson et al., 2000). Having too many reiterations may result in lack of interest, anger and fatigue among participants and at the same time, too little reiterations may not produce meaningful results (Schmidt, 1997).

Although the process of Delphi is majorly the same as described earlier, its application differs in terms of a number of reiterations, criteria for the expert selection, size and makeup of the expert panel, evaluation methods, and the type of feedback shared with respondents (MacCarthy and Atthirawong, 2003). Like any other tool/ methodology, Delphi has its strengths as well as limitations, which one must keep in mind while utilising it.

6.2.1 Key characteristics of Delphi

A brief overview is presented below of major and distinguishing characteristics that make Delphi very useful and suitable methods to verify any novel framework.

- **Experts engagement**

  Delphi engages the experts in the field who have the knowledge of the given topic and/or are considered an expert in its practical approach, understanding and knowledge (Adler and Ziglio, 1996; Linstone and Turoff, 1975; Okoli and Pawlowski, 2004). This allows for a very detailed scanning of the subject under study/ review to allow for its relevance in the contemporary and future scenario.

- **Anonymity and flexibility**

  All the data about participants (e.g. name, affiliation, age, gender, contact) of the Delphi study is kept anonymous (Okoli and Pawlowski, 2004) to other research participants. Moreover, there is no group gathering for discussion, to eliminate the possibility of groupthink or domination by only a few people (von Briel, 2018). Any answers/ comments to be included in feedback are summarised by the researcher in a manner that does not

indicate or point to the identity of any participants. Since the study does not require participants to be present in face to face set as a group, it allows to reach a large number of experts and for them to undertake this study at the time/ place of their convenience without compromising their work priorities. The major focus is to encourage participants to share their genuine opinion, criticism and suggestion without any external or group process influence (Delbecq et al., 1975; Meijering et al., 2013).

- **Feedback and reiterations**

  Feedback and reiteration of the process while keeping anonymity allows for the enrichment (Okoli and Pawlowski, 2004) of the subject under study/ review. The researcher conducting the study needs to collate the feedback by reviewers and update any areas for which the consensus has been reached and resend the updated version of questionnaire and framework to the reviewers for another review (von Briel, 2018). The process of reiteration continues until the consensus has been reached (Dalkey and Helmer, 1963; Hung et al., 2008; Linstone and Turoff, 2002) to the level where the respondents do not differ significantly (von Briel, 2018). The reiteration process allows the reviewer to rethink and reconsider their earlier stand on the specific issue and the anonymity allows for them to change their opinion (Meijering et al., 2013) if they wish to.

6.2.2 Limitations of the Delphi study

While the Delphi study is appraised and utilised widely, it does have some limitations that are briefly outlined below:

- Scholars do acknowledge that the outcomes of the study are completely based upon the opinion of a group of experts and not necessarily facts and that another group of experts might portray a very different opinion (Goodman, 1987).
- Selection of experts to participate in a study is entirely dependent upon the researcher and can have a bias (Gracht, 2008).
- Scholars also critique that since the feedback is kept concise and during the process of reiteration the experts might ignore the feedback contradicting to their earlier opinion (Linstone and Turoff, 1975).
- Researcher’s selectivity bias is high in the feedback process as it’s upon him/her to choose

which elements to include in feedback. Thus the feedback may not be representative of all the opinions and criticism (Skulmoski et al., 2007).

These weaknesses can be overcome by ensuring the diversity to avoid expert selection bias, as well as to ensure the depth of feedback to allow enhanced understanding and participation of research participants. Considering the suitability of Delphi for the verification of the conceptually developed framework, the following section presents the objectives of this specific Delphi study.

6.3 Objectives of the Delphi study

In order to design this Delphi study, it is best to specify the objectives to provide the scope of the study. The research and questionnaire design focus on the following three objectives:

- To verify that the proposed structure of the conceptually developed framework has practical relevance,
- To ensure that the elements/ steps included in the framework are important and in the right order,
- To explore any additions, changes and/or modifications needed to improve the suitability of the conceptually developed framework.

6.4 Delphi research design

Since the practical utilisation of Delphi differs in terms of the number of reiterations, criteria for the experts selection, the size and makeup of the expert panel, evaluation methods, and the type of feedback shared with respondents (MacCarthy and Atthirawong, 2003); it is essential to define the criteria for consensus, stopping and dropping out, and selection of experts.

6.4.1 Definition of consensus, stopping and dropping-out criteria for this study

Delphi study's output is directly based upon the consensus by participants of the study, however, its definition is somehow unclear (Diamond et al., 2014; Duffield, 1993; Graham et al., 2003; Keeney et al., 2006). Numerous approaches have been adopted by researchers to define consensus, for example formal measures of agreement, level of uncertainty on a specific

point, level of variance in responses of participants and their agreement (Black et al., 1999; Diamond et al., 2014; Graham et al., 2003; Chia-Chien Hsu and Sandford, 2007; Linstone and Turoff, 2002).

Diamond et al., (2014) explores 72 different Delphi studies to understand their definition of consensus, of which 25 of them used *percent agreement*. For the purpose of this study, the percent agreement method is considered the most suitable, whereupon 80% of participants agreeing would be considered as a consensus and stopping point for the study. Moreover, if a topic becomes disputing to the level where the level of disagreement seems to continue after 2 re-iterations, then the specific element is to be dropped out.

6.4.1.1 Qualitative responses evaluation criteria

- Where a respondent is unable to evaluate the question, s/he can choose the option of '*Can't Answer*' or '*Unable to say*'. However, a number of such responses will not be considered in the accumulation of results.
- Where a respondent is not sure to agree or disagree with a statement/ question, s/he can choose the option of '*Undecided*'. However, a number of such responses will not be considered in the accumulation of results.
- Where a respondent has a different opinion than the given options, s/he can choose the option of '*other*' and then provide their opinion. These suggestions will then be analysed by the researcher to categorise it under any of the earlier set options, if possible OR to eliminate/ allocate the answer based upon its relevance and scope.
- For open-ended questions where respondents provided their suggestions/ recommendations; these were all imported to NVivo (software) for Emergent Thematic Coding (Castleberry and Nolen, 2018) which is an appropriate method of qualitative data analysis. In order to ensure the consistency and systematic approach to analysing this data, the five-step process proposed by Yin (2011) and further utilised/ recommended by Castleberry and Nolen (2018) is followed. These five steps are (1) Compiling, (2) Disassembling, (3) Reassembling, (4) Interpreting, (5) Concluding (Yin, 2011). The process is portrayed in Figure 6.2 and briefly described below.
    - At first, the responses were compiled in an excel sheet in a structured format/ flow.
    - Then the data was disassembled through the following stages:
        - See if the suggestion/ recommendation was already part of the framework, if so,

discard the suggestion or otherwise proceed to the next stage.

- Include for further discussion/ analysis
  - Include – all suggestions which are within the scope of aims/objectives of the research. These suggestions/ recommendations are then coded.
  - Discard – if the suggestion is beyond the scope of the framework and its plan

- Coded data were then reassembled by placing into the context with each other to create themes.
- Interpretation of the data, a simultaneous process during the first 3 stages (Castleberry and Nolen, 2018) continued to develop the thematic map.
- This thematic map was then concluded through the inclusion of emergent themes in the updated framework.

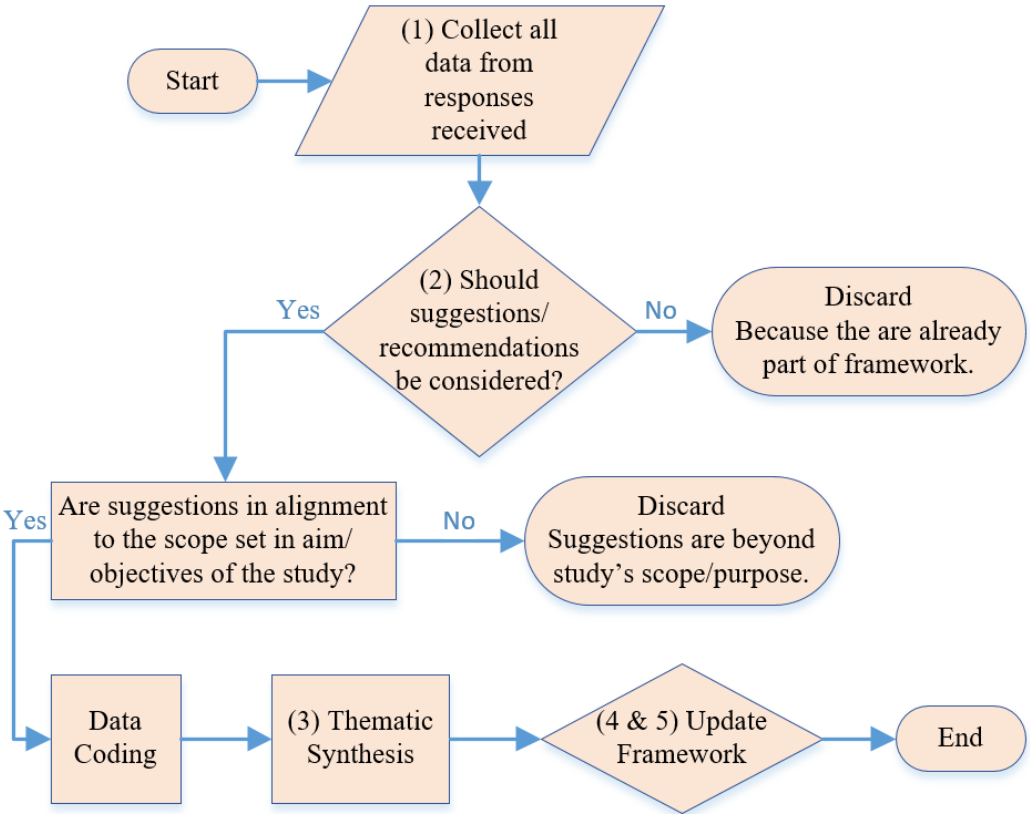


Figure 6.2 Qualitative data analysis process

6.4.2 Questionnaire design

Questionnaire design requires careful attention as their relevance and proper structuring would contribute to engaging or disengaging the research participants (Delbecq et al., 1975). It is a common practice in Delphi to initiate with brainstorming (Schmidt, 1997), therefore this study blends both the brainstorming questions, as well as to further elaborate the scope of three objectives of this Delphi study (see section 6.3).

For the purpose of this study, a mixed method approach of using the qualitative and quantitative method of analysis has been deployed. The qualitative method allowed for the expert's feedback to further enhance and enrich the quality of the developed framework, as well as to quantify their consensus through the utilisation of the quantitative method. Within this scope, the questionnaire includes both closed and open-ended questions.

6.4.2.1 A pilot study to validate the questionnaire

The developed questionnaire has been validated through a pilot study to refine the research instrument (Prescott and Soeken, 1989), ensure its relevance and workout any procedural problems (Skulmoski et al., 2007). In order for the pilot study to provide more comprehensive feedback, 6 participants from Academia and 6 participants from Industry practitioners were invited. 8 participants (3 academics and 5 practitioners) responded and provided their feedback. The feedback helped to strengthen the questionnaire through the following revisions/ modifications:

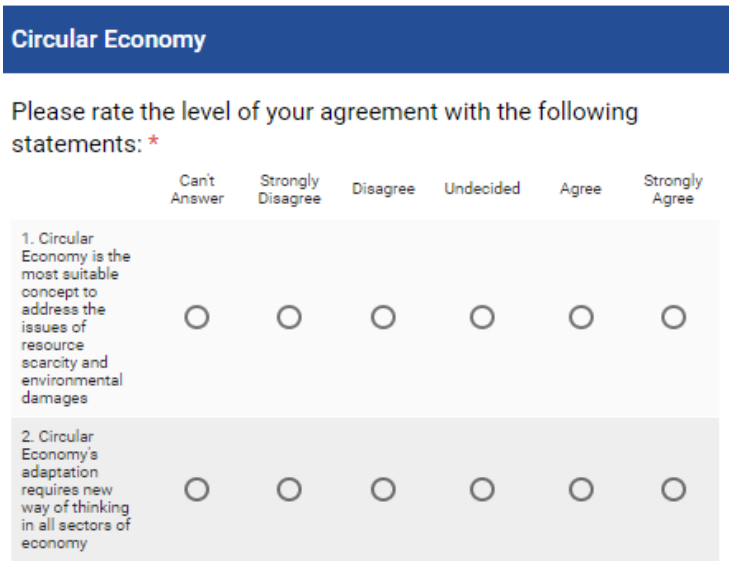
- A suggestion was made that since CE is a new concept and very few are familiar with it, so it would be best to provide details as to what the CE is. As a result, an introduction to CE was added in the first section of the questionnaire.
- A suggestion was given to add another option for people who may not know the answer to a particular question. As a result, the options of '*unable to say*' and '*can't say*' were added to all multiple-choice questions.
- A suggestion regarding questionnaire section 4 of 10 (Phase 0 – Delineate) was to provide a brief definition of those 5 principles mentioned in this phase. As a result, brief definitions were added to this section.
- A suggestion was given regarding questionnaire section 4 of 10 (Phase 0 – Delineate) to replace the answer option of '*maybe*' with a better response answer. As a result, the '*maybe*' option was eliminated and the previously mentioned option of '*unable to say*'

was added.

- Question 6 in section 2 was reworded to clarify what flexibility means.
    - Before: *A structured framework with flexibility will greatly benefit the manufacturing sector in adapting Circular Economy principles*
    - After: *A structured framework with flexibility (to choose from different tools) will greatly benefit the manufacturing sector in adapting Circular Economy principles*
- A suggestion was made regarding section 6 of 10 (Phase 2 – Plot), to add another question to further explore the reason, should the respondent answer be in negative to the following question: *Do you think the 4 steps are sufficient enough to plot (plan) the implementation of Circular Economy's principles?*

  In response, the following question has been added: *If your answer to the previous question is "No", please state why you think they are not enough and what should be included?*
- Another suggestion was incorporated to reverse the order of options to choose (e.g. (Strongly agree, …, disagree, etc.) from left to right – left side having a negative response and right side containing positive answers.
- A suggestion was made to include a section about participants' profile to gather data on their background. However, it was not considered due to the fact that the sampling method/ process ensured a thorough analysis of the participant's profile to be meeting the sample selection criteria (see Table 6.1). Moreover, the background information was also observed prior to inviting the participant, as part of purposive sampling.

A snippet of questionnaire 1 is below (see Figure 6.3), while the full questionnaire can be seen in Appendix C.



Circular Economy

Please rate the level of your agreement with the following statements: *

	Can't Answer	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1. Circular Economy is the most suitable concept to address the issues of resource scarcity and environmental damages	○	○	○	○	○	○
2. Circular Economy's adaptation requires new way of thinking in all sectors of economy	○	○	○	○	○	○

Figure 6.3 Questionnaire for Delphi study (snippet)

6.4.3 Selection of Delphi-study participants

Selection of experts defines the quality and depth of the Delphi study (Chiea-Chien Hsu and Sandford, 2007) alongside the research design. Adler and Ziglio (1996) define four requirements for someone to be on the expert panel: knowledge and experience for the topic under study; capacity and willingness to participate; time to participate; and effective communication skills. Thus, the purposive sampling is the best criteria to select the experts based on their skills, knowledge and ability to participate in this study.

The number of participants varies from study to study. Research by Skulmoski, Hartman, and Krahn (2007) reports the panel from 3 to 345 participants, while 80% of the studies had 20 – 50 participants. Another study by Skulmoski et al. (2007) provides data on 16 published Delphi study where the sample size varied from as low as 3 to as high as 171. Having too few participants runs the risk of missing out key elements and details that could have been discovered with a larger number of participants, however having too many can result in diverting the focus to irrelevant issues, information overload and unhealthy conflicts (Rowe and Wright, 2001). Delbecq, Ven, and Gustafson (1975) suggest that if a study uses the heterogeneous sample (as this study does), a number of 20 – 40 participants is ideal. Another study by Okoli and Pawlowski (2004) suggests that since the group dynamics are of higher significance than statistical power, therefore the size of 10 – 18 on the Delphi panel is sufficient.

Since the number of respondents agreeing to participate, as well as the possibility of drop-outs

during reiterations is likely, therefore for this research 64 experts were requested to participates, out of which 19 responded positively in the first cycle of the study. The responses were then summarised and shared for another review and a total of 16 participants responded and the consensus was reached through their feedback. The number of participants is an acceptable number for a Delphi-study (Gordon, 1994; Landeta, 1999). Table 6.1 presents the sample selection criterion.

Table 6.1 Criteria for sample selection

Study sample	At the very minimum 15 but ideally 20 participating respondents.
Sampling method	Purposive Sampling
Covering selection	Experts in the era of Operations Management with knowledge/ experience on sustainability; from both the academic and practitioners' side.
Sample profile and inclusion/ exclusion criteria	The participant of the study must have at least 3 years of working or teaching experience in managing sustainability in operations management. Candidates not meeting the above criterion will only be accepted based upon following exceptions: • If the participant is one of the founding/pioneering members for the initiatives of Circular Economy implementation, • If the participant has an active engagement and has gained considerable repute in the field of Circular Economy. Any candidate not meeting any of the above criteria will not be invited to participate in the study.
Recruitment	The sample will be recruited through a formal invitation via emails.

Table 6.2 presents the profile of the participants while keeping the anonymity of the names and affiliations.

Table 6.2 Delphi-study – participants' profile

Expert	Position	Affiliation	Academic/ Practitioner	Country
1	IT Specialist - Supply Chain	Beverage Company	P	Mexico
2	Strategy Director, Principal Teaching Fellow	University	A	UK
3	Supplier Development Engineer	Manufacturer	P	UK
4	Research Associate	University	A	UK
5	Business Engagement Manager	University	P	UK
6	Researcher	University	A	Morocco
7	Director, Global Logistics Education	Foundation	Both	Germany
8	Head	NGO	P	UK
9	Sustainable Development Educator	University	P	Netherlands
10	Professor	University	A	Mexico
11	Director, Industrial Engineering department	University	A	Costa Rica
12	Education Management Specialist	University/ NGO	Both	Kyrgyzstan
13	Professor	University	A	UK
14	Founder	NGO	P	UK
15	President/ Professor	University/ NGO	Both	USA
16	Academic Director in Engineering Management	University	A	Mexico
17	Coordinator	University	A	Mexico
18	Senior Staff	NGO	P	U. K.
19	Supply Chain and Operations Manager	Production company	P	Kyrgyzstan

The above-mentioned personnel (see Table 6.2) were briefed about the purpose of the study in the letter of invitation to participate (see Appendix A). An online link for google forms was shared which directed them to the framework and questionnaire.

6.5 Conducting the Delphi study

The researcher finds it of best interest to keep response and reiteration duration short but yet providing enough time for participants to think through and respond. The questionnaire will be shared with all research participants on the same day and 10 days' time will be considered as cut off time for respondents to respond. Thereafter the responses will be collated, and participants will be provided with the updated version of the framework, within following 10 days along with the next reiteration of the study.

The process adopted to conduct this Delphi study for verification is portrayed in Figure 6.4

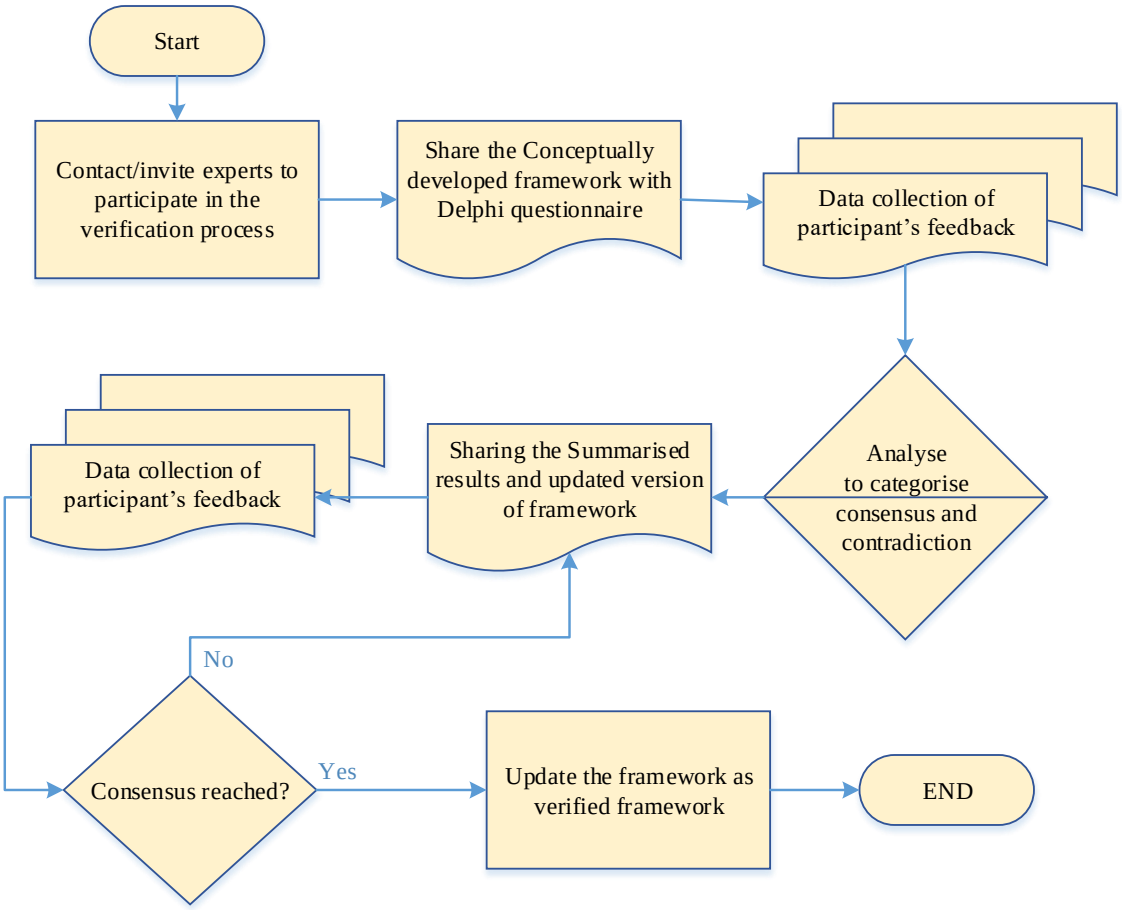


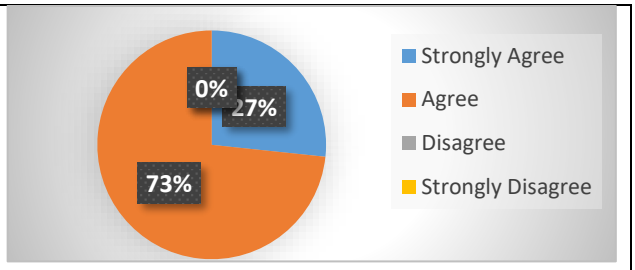
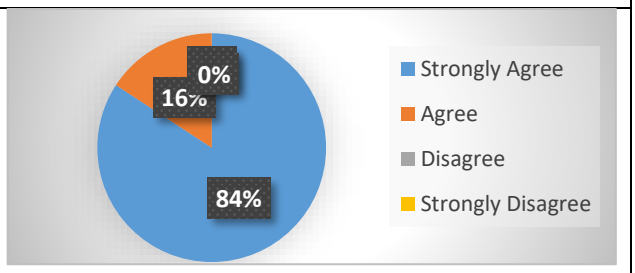
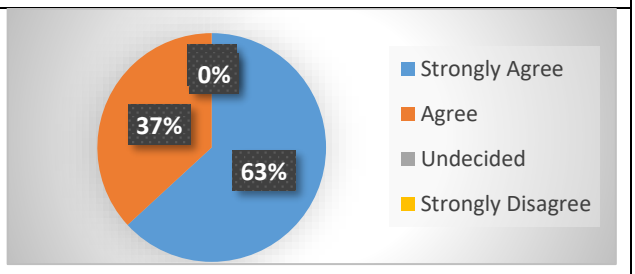
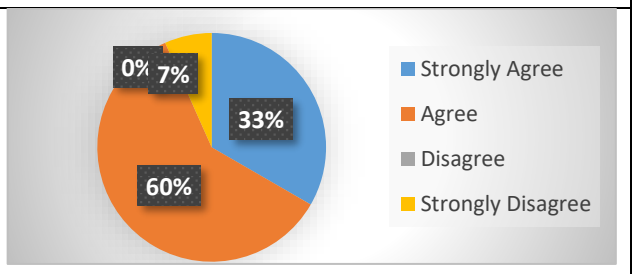
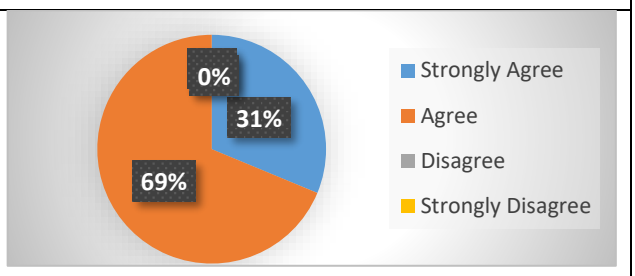
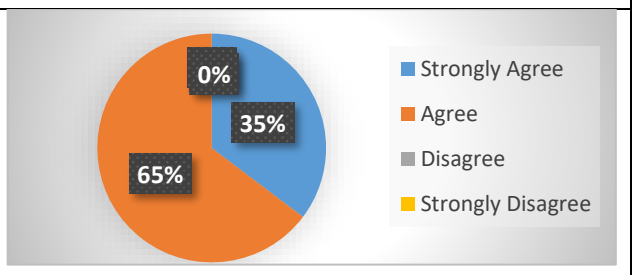
Figure 6.4 Process of conducting a Delphi study

6.5.1 Delphi study results

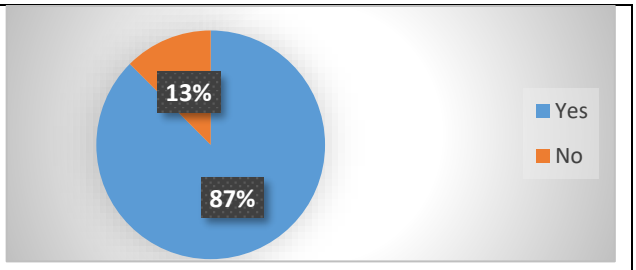
6.5.1.1 Results for the first round

The first Questionnaire consisted of 10 sections (see Appendix C), with section 1 containing information about the study and seeking respondents' consent to participate. The responses of the participants are presented further as per each section of the questionnaire. The tables below present the questions in the left column and responses on the right column, where the response is in quantitative terms. For open-ended questions, the response is in the left column and the analysis of the response is in the right column. Qualitative responses that were considered to be within the scope of this study and pointing to elements needing further attention are highlighted in green with the comment *'consider for further analysis'*.

Section 2 consisted of brainstorming questions and below are the results for it.

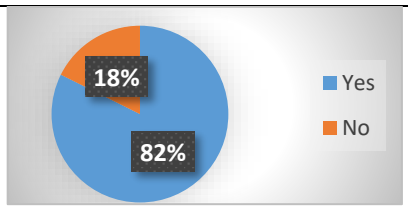
1. Circular Economy is the most suitable concept to address the issues of resource scarcity and environmental damages	
2. Circular Economy's adaptation requires a new way of thinking in all sectors of the economy	
3. Circular Economy's adaptation requires a new way of managing manufacturing operations	
4. Lean, a formerly developed tool can contribute to speed up the implementation of Circular Economy	
5. A new structured framework is much needed for implementation of Circular Economy	
6. A structured framework with flexibility (to choose from different tools) will greatly benefit the manufacturing sector in adapting Circular Economy principles	

Section 3 presented the overall framework

Do you think the phase by phase approach is feasible for this type of framework?	

Other	**Analysis/ response**
most likely	This response was included in the Yes section
Possibly. Difficult to ascertain from the model as it does not include the level of analysis. I am also unsure of what you mean by CE.	As this response is not so sure therefore it was included in No section.

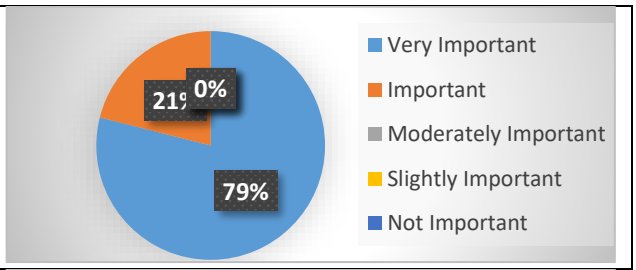
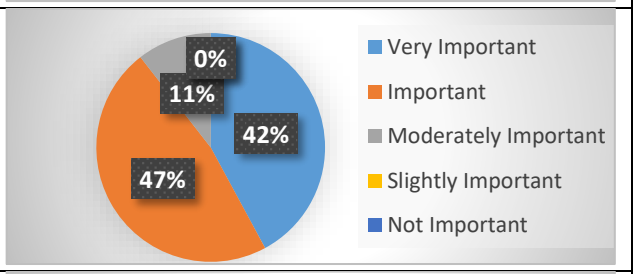
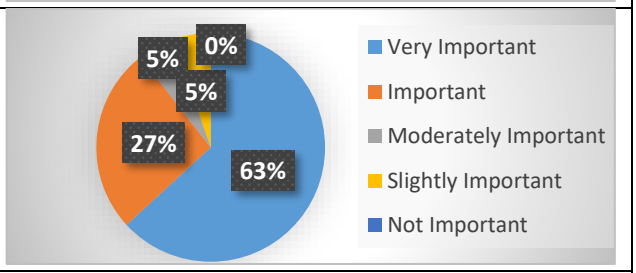
Section 4 presented phase 0 - Delineate

Do you think there is a need to delineate these five principles, before adopting circular economy in the manufacturing sector?	

Are there any other elements that you think should be included or should be taken off from phase 0? if yes please specify	
Responses	***Analysis/ response***
Optimisation	Already part of the framework (see phase 0)
Not only Value as Lean Way but Profitability or Return on Investment	Consider for further analysis
Leadership (including senior management commitment and support to CE and Lean)	Already part of the framework in its detailed descriptions
Waste - Its value - Closed loops (system thinking would go within closed loops) Optimisation I'm unsure what it means here or whether it's relevant.	Clarifications and descriptions are specified already in detailed descriptions.

not sure because systems thinking and optimisation could be as one step	Since two of them have their distinctive features, therefore its best to keep them as individual elements, to complement each other.
Perhaps. But they may be interlinked and reducing them to separate entities will not lead to the best solution. I	No action required
this phase is very process focussed. experience says if we don't get the people "baselined" there is a risk of failure. Should there be a box focussed on getting people aligned to vision/culture/values?	Consider for further analysis True. The whole purpose of this stage is to ensure that people understand and grasp the core purpose of the CE and its principles.
The commitment of all the people involved.	Already part of the framework in its detailed descriptions in Phase 1 and 2.
Complex Adaptive Systems (CAS)	Framework's description already mentions that for CE to make an impact, the concept has to be embraced throughout the supply chain. However, this framework is designed for any manufacturing business who plans to adopt/ implement CE in its operations.
The important elements have been captured within the existing five principles.	No action required.
how about greening and sustainable development, which can be a part of system thinking, to emphasise the environment thinking as well.	The CE concept is much broader and indeed covers the green and sustainability aspects. It is already part of the framework in its detailed descriptions.
No	No action required.
No	No action required.
Core competencies? Human/Social capital?	No action required. Recommended elements are already part of the framework in the planning and implementation phases, as well as in the overall description of the framework.
No	No action required.

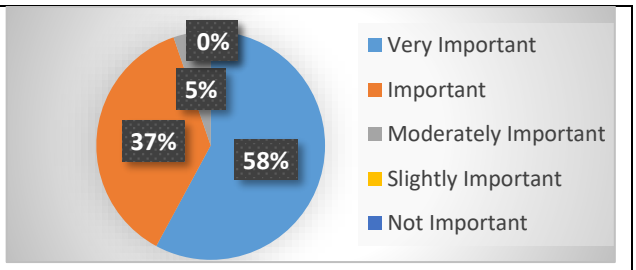
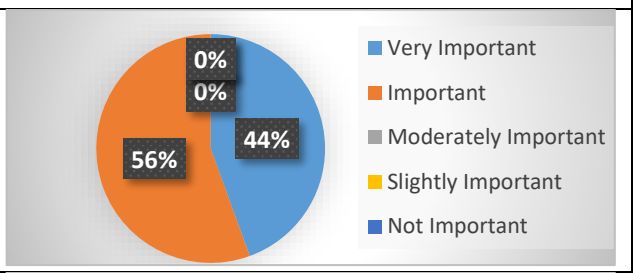
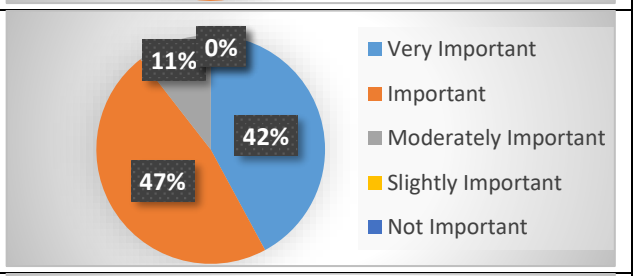
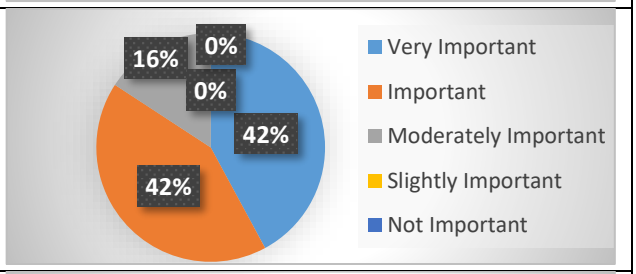
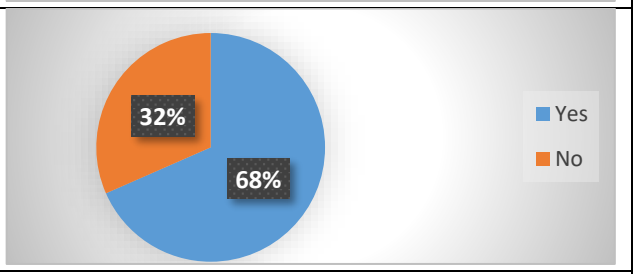
Section 5 presented phase 1 – Analyse/ identify

How would you rate the importance and necessity to analyse each of the 3 levels in this phase? Step 1. Strategic Level	
Step 2. Tactical Level	
Step 3. Operational Level	

Do you recommend/advice any changes, modification and improvement in this phase? If yes, please specify

Responses	***Analysis/ response***
Further clarity on how would the gap analysis be conducted at these various levels could be beneficial. What types of things are the industrial practitioners looking for?	No action required. The guidelines are included in detailed descriptions of the framework.
I would skip tactical. From strategy to implementation is what matters.	Discard, as 89% of respondents think that this stage is important.
It is quite clear. I think most of the challenges are at strategic and operational levels. Strategic because it is required to convince CEOs, managers/directors, and Operational since there is plenty of methods and tools to chose. Cost and time may be key drivers.	No action required.
This is a standard approach to looking at strategy.	No action required
Ongoing and meaningful communication and feedback between the three levels of the organisation is compulsory in achieving the desired results.	Consider for further analysis

Section 6 presented phase 2 – Plot

How would you rate the importance and necessity of each of the 4 steps in this phase? Step 4 - Specify Improvement areas/opportunities	
Step 5 - Define the Scope	
Step 6 - Develop the process map/ implementation strategy	
Step 7 - Identify the team and their roles	
Do you think the 4 steps are sufficient enough to plot (plan) the implementation of Circular Economy's principles?	

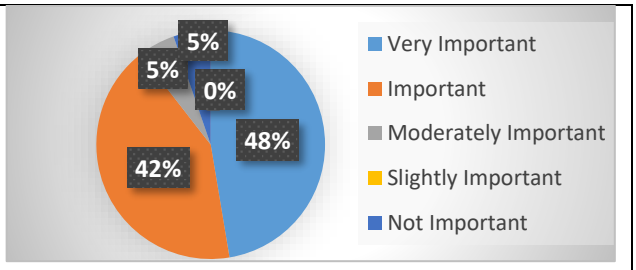
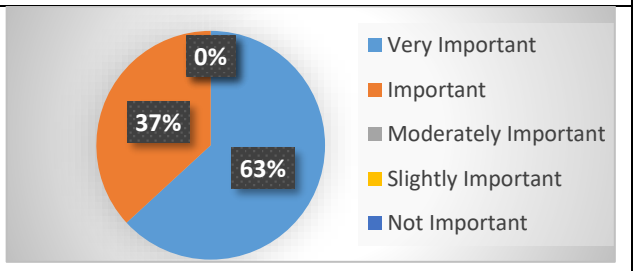
If your answer to the previous question is "No", please state why you think they are not enough and what should be included?

Responses	***Analysis/ response***
Financial Evaluation and resources required must be included	Consider for further analysis
I'd do a SWOT and then prioritize actions by the level of easiness and cost. Then assign to people (roles.	Already part of the framework under the details, that any tools including SWOT can be utilised.

All of the steps are important, but what you have not identified is the process by which the problems/opportunities will be addressed. This also assumes a bottom-up or incremental approach to improvement whereas some of the most significant improvements come from a new business model which this type of approach would not address.	Discard – as this framework focus is not to introduce a new business model but to use the existing tools to adapt/implement the new concept of CE.
Learning and Knowledge Management should be included to keep created knowledge and do not iterate the same loop again without progress	No action required. Already part of the control stage as well as throughout the framework.
Need to identify sponsors from the industry and the government	Consider for further analysis
You need to identify the training needs in order to plan the implementation. The human resources capabilities are very important for the implementation when you have a disruptive and new way of thinking.	Consider for further analysis
Do you recommend/advice any changes, modification and improvement in this phase? If yes, please specify	
change step 7 to step 4	Discard – Because identification of team and roles will depend on types of improvement and planned interventions, therefore it cannot be earlier.
Alignment of the opportunities with Business Model (for example, CANVAS) must be included.	Already part of the framework by providing flexibility to use any tools/models that could benefit the process.
This phase should go before the strategy for implementation. First, you plan it, then you assign the roles to the chief executives and the employees.	Consider for further analysis
We need to make sure people are properly trained to deploy their roles	Consider for further analysis
Your framework is only for incremental improvements.	No action required

should goals/scope be first?	Discard – As the scope/goals are defined specifically in relation to the improvement areas/ opportunities.
Each team member should be assigned a clear set of deliverables with a clear timeline, as part of the improvement opportunities.	Already part of the framework in its detailed descriptions.
need to consider a trade study investigating the potential value and impact of alternative options, again which can be a part of step 4.	Already part of the framework in its detailed descriptions.
Include training needs and human development as part of the plan	Consider for further analysis
no, is correct	No action required.
Perhaps more focus on the contextual opportunities and threat before embarking on strategy, tactics and implementation, by performing a PESTLE analysis or similar.	Already part of the framework in its detailed descriptions.

Section 7 presented phase 3 – Execute

How would you rate the importance and necessity of each of the 2 steps in this phase? Step 8. Prepare for modification/change the targeted areas	
Step 9. Implement the planned modification/change	
Do you recommend/advice any changes, modification and improvement in this phase?	

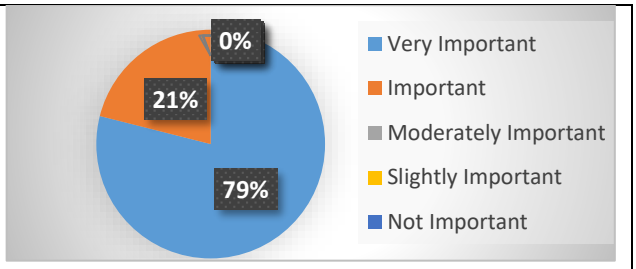
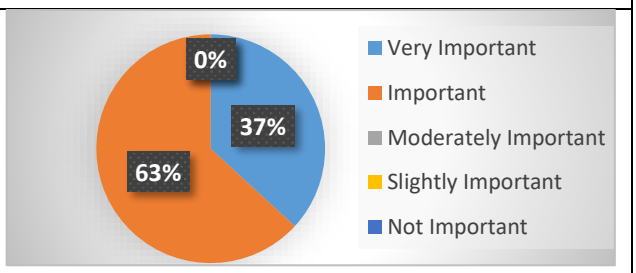
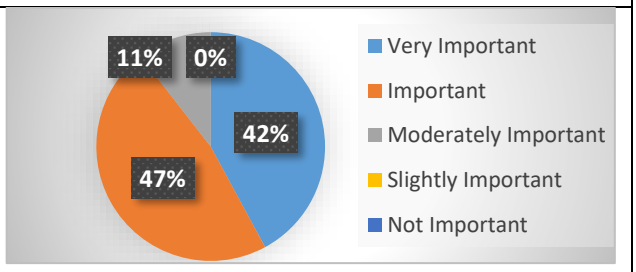
If yes, please specify	
Responses	***Analysis/ response***
If you execute you are not preparing to execute. Training should be a step in itself. Execution should be a separate one.	Consider for further analysis
you could have 2 phases of implementation, the one will be the trial and then the final one	Consider for further analysis
Here leadership is essential. This is a very dynamic stage. So two things to keep in mind: People well trained and strong leadership. In addition, make sure resource and capacities are adequate.	Consider for further analysis
Again this is extremely generic and about bottom-up improvements in a piecemeal fashion.	Discard as this is a comment.
stakeholder comms and testing/piloting are key prior to role out	Consider for further analysis
almost always nothing goes according to the plan, how about the risk management and expectation management	Consider for further analysis
no	No action required.
More specifically what is covered by prepare? An inclusion of the role of communication (particularly internal) could come within this, as a very important feature.	Consider for further analysis

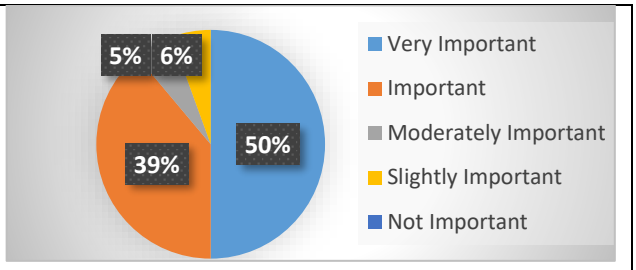
Section 8 presented phase 4 – Evaluate

Do you recommend/advice any changes, modification and improvement in this phase? If yes, please specify	
Responses	***Analysis/ response***
Reflection and optimisation considerations	Consider for further analysis
No	No action required
Sounds good.	No action required
No	No action required
That looks ok. I only would include what to do if goals are not achieved? where do we go on the diagram? what are actions	Already part of the framework, guided by

are necessary to be taken?	arrow-line to move to the analysis stage.
This is quite binary	No action required.
check that the goals are still valid at key checkpoints	Consider for further analysis
Documentation of learning and knowledge gained to make use of in the next decisions	Already part of the framework in Control stage.
with detailed description	Already part of the framework.
The implementation results and any changes should be revisited at regular intervals to ensure that the initial goals are still in line with the organisation's overall strategy.	Consider for further analysis
no	No action required.
No changes, but recommend that the evaluation be as robust and accountable as possible.	No action required.

Section 9 presented phase 5 – Control

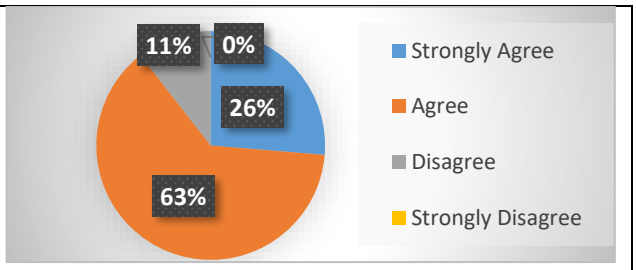
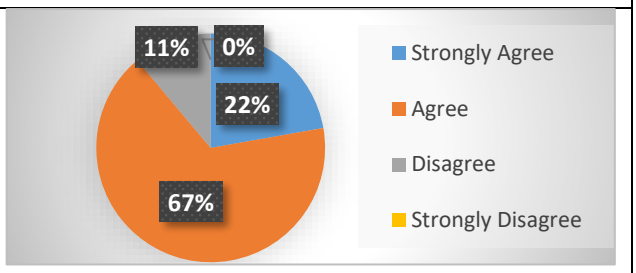
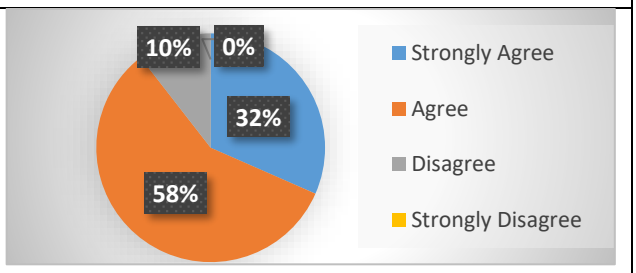
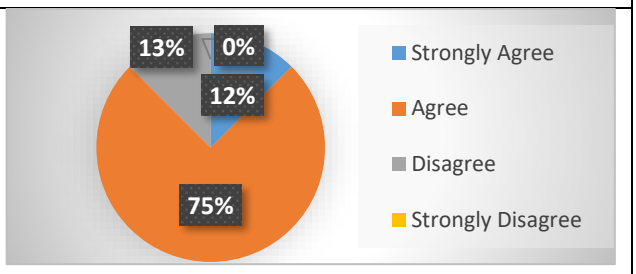
How would you rate the importance and necessity of each of the 4 steps in this phase? Step 11. Institute the process into organisational culture	
Step 12. Document procedural guidance	
Step 13. Transfer the ownership of processes	

Step 14. Control Gate Review	

Do you recommend/advice any changes, modification and improvement in this phase? If yes, please specify

Responses	***Analysis/ response***
Social Responsibility System goals must be included.	These elements are part of the systems thinking.
Step 11 is very high level (not as specific as the other steps). Institution of the process into organisational culture is a major concern with a number of steps feeding into it (Training, HR practices, Reward & Recognition etc.)	No action required as it's a comment
Not sure what control gate review is. I would not transfer the ownership of processes. People executing the processes should be the ones designing them, in order to feel they own them. That way you transfer ownership and add to the culture in one step.	Discard – as this framework proposes implementing a new way of managing operations, thus the transfer of ownership from the Circularity implementation/ design specific team to regular operating staff is important.
Again they are all important, but no detail about how you would embed. Creating cultural change may be a fundamental part of the transformation and something that needs to be built in from the start.	No action required. Already part of the framework in its detailed descriptions.
ensure company/dept KPIs are also realigned to drive new ways of working	Already part of step 11.
no	No action required.

Section 10 had concluding remarks regarding the overall framework

Please rate the level of your agreement with the following statements: 1. The framework is easy to understand	
2. The framework does contribute to the academic knowledge through combination of Lean and Circular Economy	
3. The phases and steps within the framework represent a systematic approach	
4. The framework is of practical use to manufacturing sector	

If any of your answer(s) are in the range of disagreement, please provide your suggestion/comments for further insight and improvement.

Responses	***Analysis/ Response***
Too many words. Some irrelevant. To be systemic it needs to involve other stakeholders outside of the organization (providers etc). The different shapes are confusing and irrelevant. Good luck, research in this area is needed.	Consider for further analysis Stakeholders' purview is part of systems thinking.
Reduce the scope of what you claim the framework is addressing	Consider for further analysis
The value component from the lean perspective could be added. How does the model help to reveal what really creates value for the customer in the process, i.e. what elements in the	Already part of the framework in its detailed descriptions.

circular economy are perceived as value adding and which are not?	

Are there any other comments/ advice/ suggestions that you recommend to improve the framework?	
Responses	***Analysis/ response***
Some initial scorings through the process	Consider for further analysis
It will important to integrate the indicators.	The description of the framework already proposes Circularity measurement toolkit that provides indicators as to where the company stands in terms of circularity.
Must compare the framework with DMAIC advantages, for example, the framework can include the necessity of measure and apply Statistical Thinking approach	No action required. Already part of the framework. The framework development chapter does have a discussion on DMAIC and utilises its parts (i.e. control stage).
To be practical, show it with an example of something easy to understand and how it would be implemented. For example, the process filled in with the steps for a specific manufacturer. Then people can understand your line of thought. And can show one filled in and one empty which would be your framework.	That will be the next stage of the framework which is validation through implementation.
Phase 0 could be added in the framework in a different way, it is a little confusing, do you really need it?	Consider for further analysis
Have you considered this framework in a service environment? You may do it as well.	No action required. At this stage, the framework is only for the manufacturing sector. Extension of its scope to the service sector is part of the further research directions.
I believe the circularity part could be more	Circularity is the key focus of this

detailed, the framework is more about lean.	framework, which is achieved by merging the two concepts of CE and Lean, with Lean as an enabler for CE's adaptation.
This concept is highly abstract, need more information or data to be able to embrace it.	Consider for further analysis
In the different steps of your proposal, I cannot identify the steps related to lean. I recommend adding steps where lean thinking is stated or where you plan to use the lean tools.	No action required. Framework information clearly states that Lean and CE principles are merged so they are present together. Moreover, in the detailed description of the framework, a suggested list of Lean tools is included for each stage of the framework.

The above recommendations/ suggestions were then coded initially as per each section of the questionnaire and responses received for them, using NVivo software. Figure 6.5 presents the coded data.

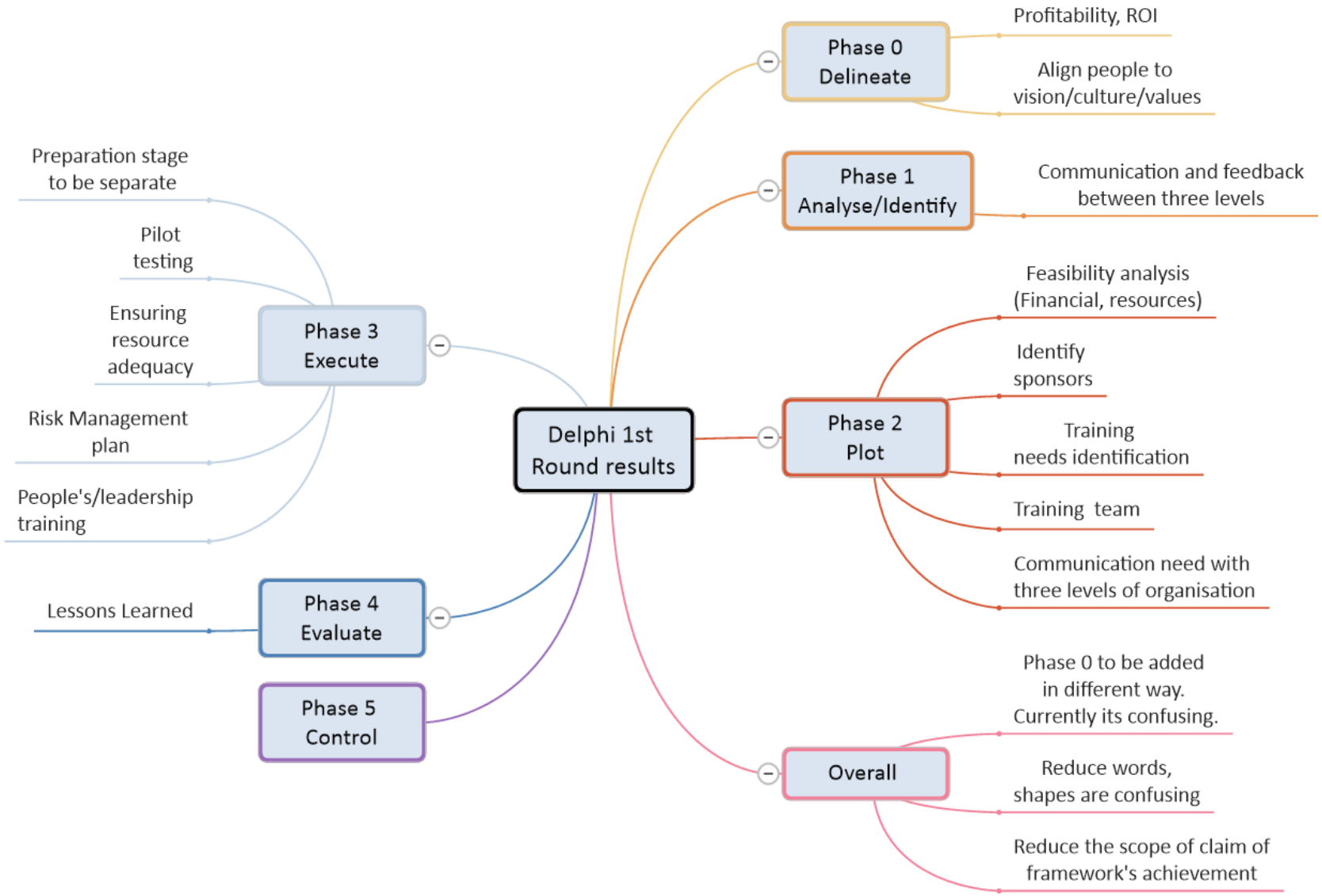


Figure 6.5 Coding of recommendations/ suggestion in Delphi Round 1

Further analysis results

Here the reassembly of the data was done by putting them in context with each other (Castleberry and Nolen, 2018) and creating themes that will then be interpreted and included in the framework. This thematic synthesis is presented in Figure 6.6

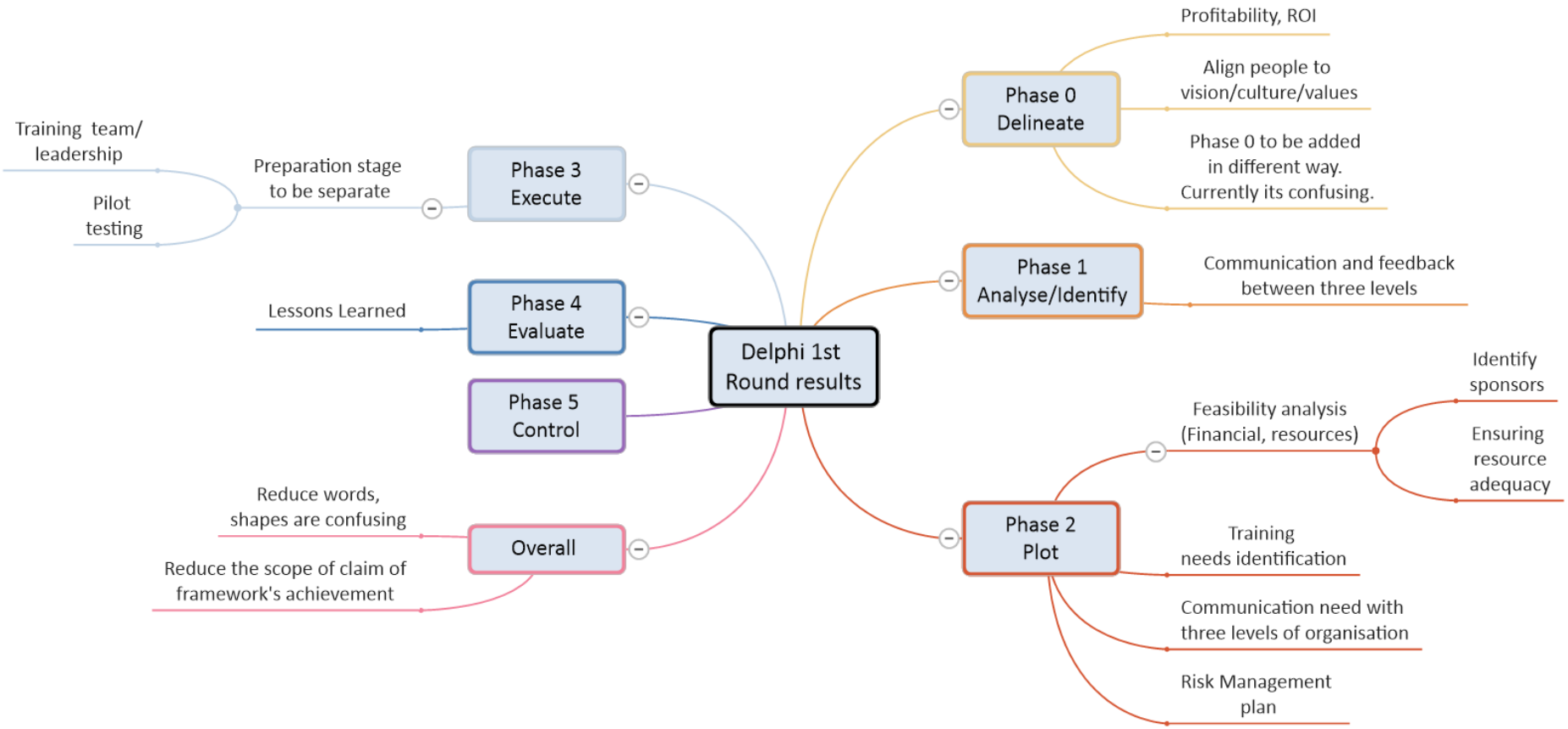


Figure 6.6 Thematic map of Delphi study's 1st round results

6.5.1.1.1 Changes made to the framework after Delphi study round 1

Phase 0

- In order to ensure that the value element captures the profitability and return on investment element, the proposed definition of value was modified as follows:

  Before

  "Any activity/output that utilises its required resources in manner that maximises its utility at all stages of its life cycle including the afterlife, as well as to ensure the longevity of its life cycle while satisfying the needs/demands of the stakeholders (People [present and future] and Planet) and making impact for them."

  After

  "Any activity/output that utilises its required resources in manner that maximises its utility at all stages of its life cycle including the afterlife, as well as to ensure the longevity of its life cycle while satisfying the needs/demands of the stakeholders (People [present and future] and Planet) while making economic benefit for all."

- To ensure that people capture the overall vision/ values and adopt it as a culture, phase 0 was no more left as an option but was added as the surrounding principles of the framework, where it serves as guiding principles and boundaries (see Figure 6.7).

Phase 1

- Continuous communication loop was added for all phases

Phase 2

Major changes took place in this phase as 32% of the respondents said that existing 4 steps were not sufficient for this phase and provided feedback about the elements that should be added. In light of the feedback, the following modifications were made:

- Feasibility analysis step was added that include ensuring resources are and/or can be made available for the planned changes. This can be done by identifying sponsors.
- Training need identification was added to see if the team has the necessary skills/ understanding.
- Risk Management planning step was added to have a contingency plan in case if things

don’t go as planned.

Phase 3

A new phase (phase 3) was added upon the recommendation/ suggestion of the experts. This phase is called ‘*Prepare/Pilot*’.

- ‘Train the team/leadership’ step was added to ensure everyone on the team understand and have the necessary skills to accomplish the plan.
- ‘Pilot testing’ step was added – to ensure the practicality of the framework before it is rolled out.
- ‘Make amendments’ step was added, in case if any changes are required after pilot testing.

Phase 4 (previously phase 3)

- This phase was then just reduced to execute the plan.

Phase 5 (previously phase 4)

- Lessons learned recording element was incorporated in descriptions of the framework to ensure that in both cases of success or failure the documentation is made to allow for future improvements and learning process.
- Goals achieved and Goals not achieved were made more specific by writings on the line and their further direction pointed through lines (see Figure 6.7).

Other general changes

Following changes/additions were made in responses to the expert’s opinion, suggestions and recommendations.

- The framework has been reshaped to eliminate confusion
- The scope of the framework is further made specific in its detailed descriptions

These changes are reflected in the revised framework in Figure 6.7

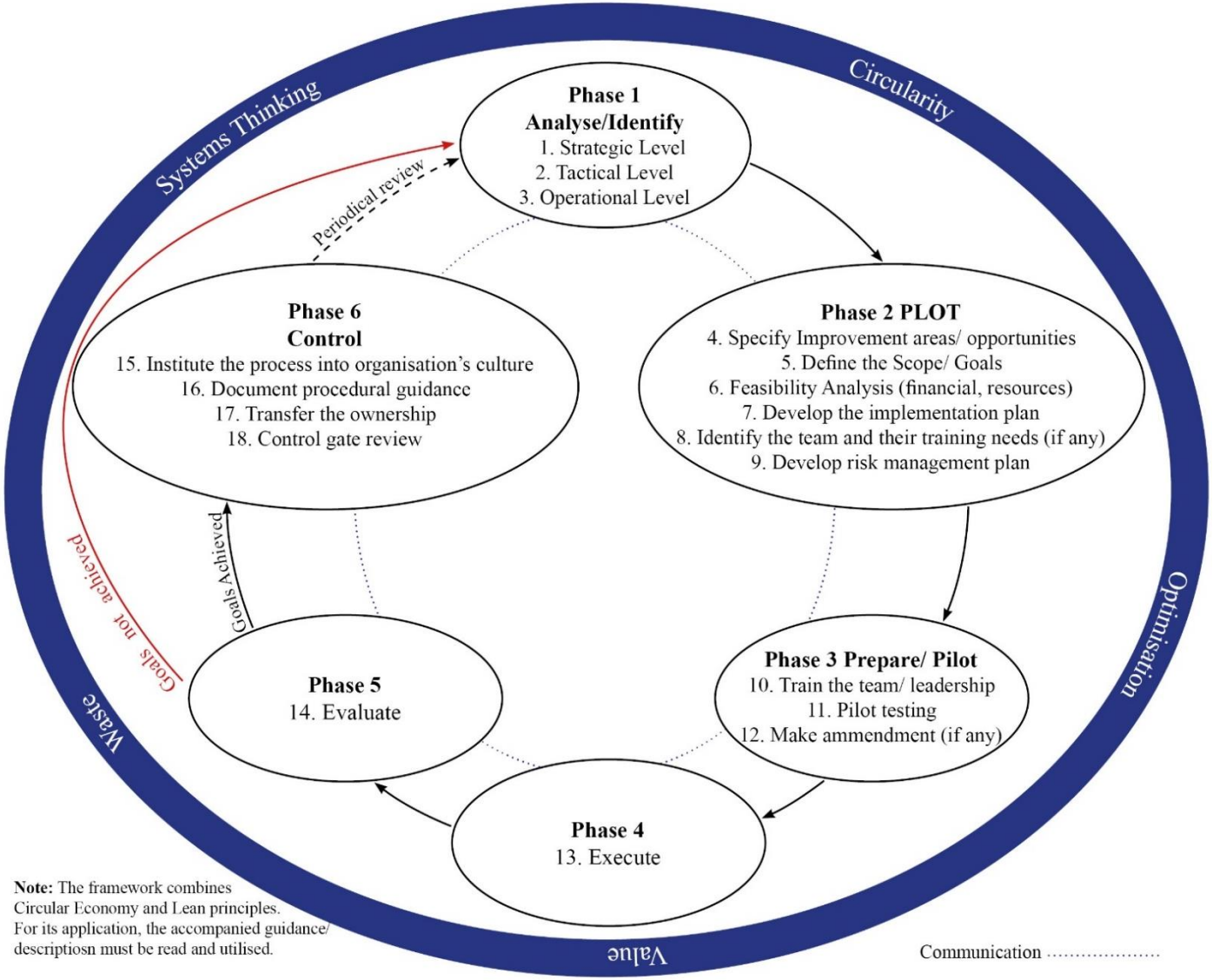
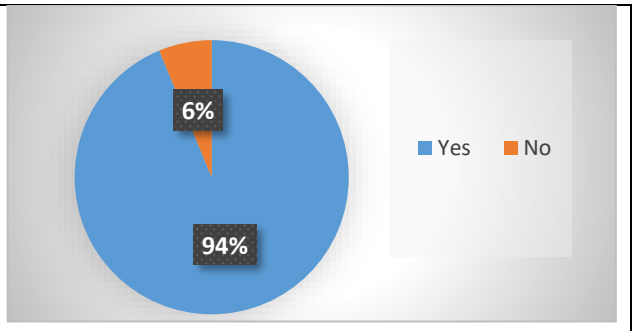
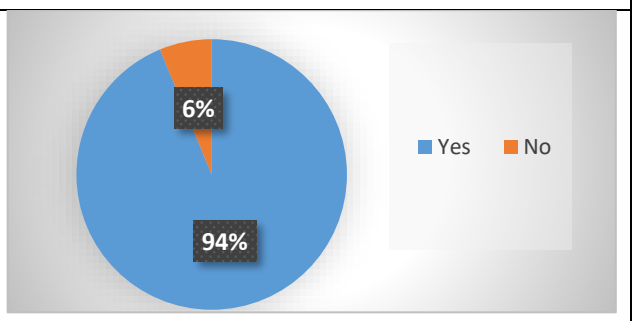
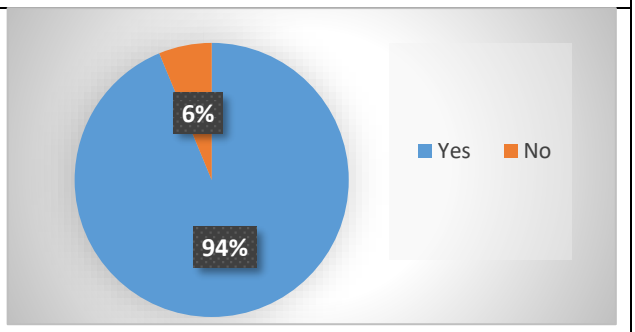


Figure 6.7 Revised framework after Delphi Study round 1

6.5.1.2 Results for the second round

The second round of the Delphi study consisted of 4 sections with 10 questions (see Appendix D), with section 1 containing information about the second round of the study and seeking respondents' consent to participate. Participants were provided with the results of the first round of Delphi study (see section 6.5.1.1) along with an updated framework in a PDF file and were advised to keep the file open for reference purpose while participating in round 2 of the study. The results of the second round are presented below.

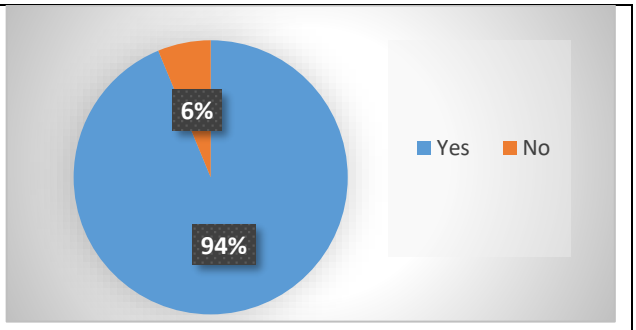
Section 2 consisted of questions related to changes made in Phase 2 – Plot.

1. Is the addition of Step 6. "Feasibility Analysis (financial, resources)", good?	
2. Is the addition of Step 8: "Identifying the team and their training needs", good?	
3. Is the addition of Step 9: "Develop risk management plan", good?	

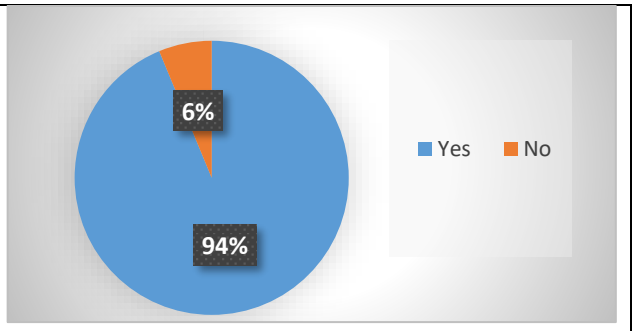
4. If any of your answer above is no, please provide your reason and suggestion below	
Responses	***Analysis/ eesponse***
These questions are too binary. They are possibly good things to consider for any change in strategy. I am not sure	It is more of a comment and does not require any change.

they are specific to the circular economy. Also difficult to know how you are going to utilise them.	Moreover, a case study approach is the next step to validate its utilisation. No action required.
I would first PILOT it in a small team and then PLOT it. Until you pilot it, you don't know what the training needs are etc.	The participant probably missed seeing the Pilot Phase, which is right after the PLOT phase. No action required.

Section 3 included questions about newly added phase 3 of Prepare/Pilot

5. Are the steps (i.e. 10, 11 and 12) in this phase good?	
6. If your answer above is no, please provide your reason and suggestion below	
Responses	***Analysis/ response***
1) I had to open the PDF to see these steps 2) Again they are so generic they have little meaning	Instructions provided in the second round of Delphi requested participants to keep the PDF file open for reference, as all details of changes could not be placed with questions themselves. Concerning the second comment, the researcher strongly believes that frameworks' descriptions and guidelines provide more in-depth understanding and thus must be accompanied by the framework. No action required.

Section 4 included questions about a general overview of the revised framework

7. Is the framework shaped better than before to allow better understanding?	
8. If your answer above is no, please provide your reason and suggestion below	
Responses	***Analysis/ response***
I don't understand how I would actually use this framework	Frameworks' descriptions and guidelines provide more in-depth understanding and thus must be accompanied by the framework. No action required.
9. Are there any other suggestions/ recommendations that you have to improve this framework?	
Responses	***Analysis/ response***
No!	No action required.
I think the framework must to include Technology Architecture and Innovation Strategy and Management	While the utilisation of technology is mentioned in the descriptions/ details of the framework to assist the user, it is however beyond the current scope of research to integrate technology architecture within the framework. The point made is of importance and will be included in recommendations for future research directions. No action required.
There is a bit of an imbalance between phases 4 + 5, and the remaining phase as all others have detailed steps whereas the two just have evaluate. E.g. why is "control" detailed and "evaluate" not. I am	Consider for minor modifications Since many tools can be used to evaluate therefore phase 4 and 5 are kept to one-step each, where phase 4 is implementing what has been Plotted and Phase 5 is evaluating what has

sure there can be many more steps under the phase "evaluate". The justification for dealing with the phases differently is difficult and unclear to me.	been implemented. However, to bring the balance with other phases, Phase 4 and 5 titles and steps are explicitly written down but they are kept to one step as before.
The principles of the CE need to be built into each of the stages so that it is clear how they shape the strategy development process. The current bubbles look totally generic.	CE and Lean principles are included at each stage. Moreover, they serve as surrounding principles and boundaries for the framework and are reflected in the blue oval shape. These are further described in detail in descriptions and guidance, which will be provided to the user. No action required.
There are too many steps and words which could be summarized. Also, I would create a word that includes all first initials of the steps so that the diagram it's easier to communicate. For example starting with A for Analyze, P for pilot, E of execute (including PLOT inside), etc	For the purpose of brevity and understanding, the current wording seems realistic. Since no suggestion is provided, therefore no action is required for this. Regarding creating an acronym from the first letters of each phase's title, it is under consideration to provide a title for the framework. No action required.
After the Phase 6 (Control), I would suggest introducing reviews/iterations at agreed intervals to ensure that the benefits are well embedded in the organisation.	The respected reviewer probably missed seeing the line indicating a periodical review. It is already included. The decision of the interval duration will be upon users' and management's decision. No action required.
There may be other loops that need including - such as the amendment loop may require going back to step 1 if the amendment is significant enough or if the risks are too great.	Consider for minor modifications Communication loop is for this purpose. However, to explicitly highlight its importance, it is now called 'communication and feedback' loop.

It looks good. My only suggestion is to make words bigger so that all information can be read. Other suggestion to improve the framework would be to do "a graphical version" of it. That would add a plus, and once people understand the framework, I am sure they will be very happy to work with the graphical version.	Increasing the font size is not possible, as it would require more space. In its current form, it is readable. Suggestions to include graphical description will be kept in mind for future research directions. No action required.
well done. this version of the framework seems really good. just a few comments: (1) each step would be nice to have a name and then inside to have a few steps e.g. phase 4 and 5 you don't give any title to the phase. (2) in phase 2 another step could be also helpful to add 8. develop monitoring and evaluation plan, (3) in phase 4 execute, another step can be added 14. identify any needed changes and update the implementation plan and you can call it phase 4 execute and reassess and then phase 5 evaluate and respond or you can add it in the phase 5 e.g. Phase 5 Evaluate and adopt 14. identify any needed changes and update the implementation plan (4) I am not sure if the words in the blue circle e.g. value, waste etc. add any value to your framework (5) phase 6 has the title control maybe it could be adapted to phase 6 control and report	Partially considered for modifications. Following modifications are made: (1) Phase 4 and 5 titles and steps are explicitly written down but they are kept to one-step as before. (2) Step 9 is modified to include the development of a monitoring plan. (3) Phase 4 and 5 are interlinked in this sense and in case of goals not achieved, a loop of 'Goals not achieved' is already included to direct the user to phase 1. (4) These have been explained in the description of the framework that these words represent the surrounding principles and boundaries of the framework. (5) A good suggestion, however, given the context it is considered best to keep it as it is. Moreover, other experts (participants of this study) have not pointed out anything in this regard.
in addition, I would suggest trying this	The framework is specially created in the oval

framework with the blocks	to reflect the circularity and closed-loop aspect. No action required.
No	No action required
I think it is pretty complete.	No action required

Since the consensus has been achieved, thus no further iterations of the Delphi study were required. An updated verified framework is presented in the next section.

6.6 Verified framework

The proposed verified framework C-LEAN consists of five surrounding principles that define the boundaries and scope of the framework for its implementation. Within this framework, six phases are included: phase 1 Analyse/ identify, phase 2 Plot, phase 3 Prepare/Pilot, phase 4 Execute, phase 5 Evaluate, and phase 6 Control. Subsequently, these phases are broken down into 18 steps (activities) for systematic implementation of all phases (see Figure 6.8). Continuous communication and feedback loop exist to enable open communication and to allow for any changes/ modifications/ amendments needed at any stage of the framework.

It is vital to emphasise the need for a person specifically assigned to take responsibility and lead the implementation process as a coordinator or manager, especially until the CE is embedded in the overall organisational culture. S/he will work in close coordination with team/ personnel assigned for this change and will serve as a point of reference and decision maker while being accountable for his/her decisions.

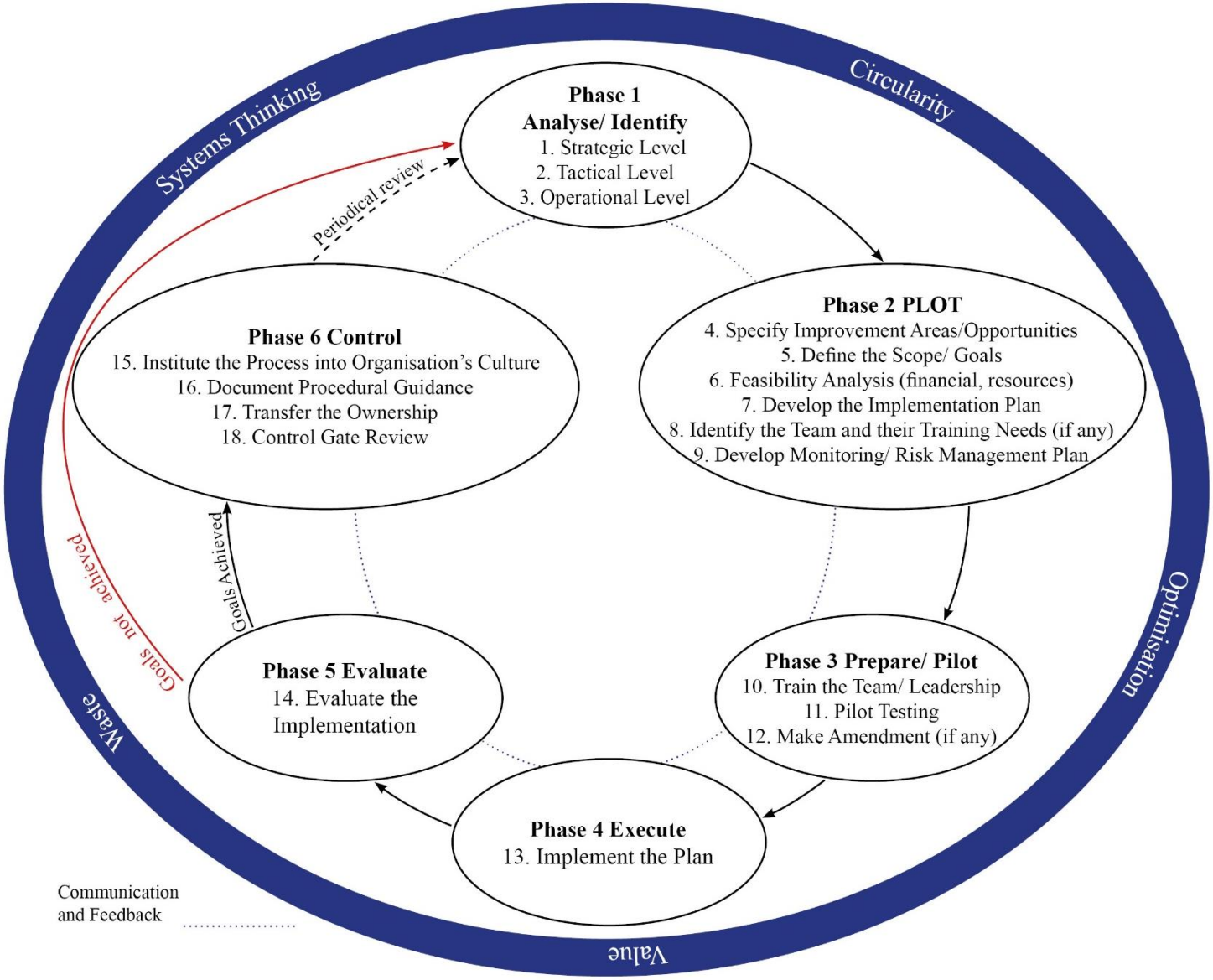


Figure 6.8 Verified Framework: C-LEAN

Starting with a clear understanding of five surrounding principles adapted from CE and Lean concepts and further redefined for enhanced understanding, the framework leads the users in a systematic manner to clearly analyse, plot, prepare/pilot, execute, evaluate and control the adoption of CE in manufacturing operations management. The following sections further provide guidance about the surrounding principles of the framework, its 6 phases and the steps within them.

6.6.1 Surrounding principles

For any framework to make sense for its user, it is best to delineate the core principles of the concepts that it is moving towards/adopting. This enables a comprehensive understanding to allow an efficient, effective and well-grounded approach with the systematic flow to implement the framework. Since the framework combines the two concepts of CE and Lean, it adapts 5 of their core principles/ features. These principles need updating to a hybrid version of definitions to allow/ benefit from coalescing of the two concepts of CE and Lean. These principles bear equal importance; thus, no sequential order is defined.

6.6.1.1 Systems thinking

Most business activities would make a direct or indirect impact on their customers, suppliers and the community/ environment they operate in; which creates the whole system. Circular Economy presents a contrasting approach of systems thinking compared to what is practised in the traditional linear economy/ business (Webster, 2015). It requires businesses to regard themselves in the setting of the overall supply chain and its impact while thinking in cascades (Elia et al., 2017; Kobza and Schuster, 2016; Murray et al., 2017). Businesses have a lot to learn from the natural environmental system around (biomimicry) (Romero and Noran, 2015), where the focus is on optimising the overall system and not the individual components alone (Webster, 2013). It is vital for the companies to engage in systems thinking where no functional divisions as well as companies, work in isolation or in subgroups but have common strategic goals to achieve in a responsible manner.

In the purview of systems thinking, the identification of all stakeholders for a business is a necessary element (Billgren and Holmén, 2008; Soma and Vatn, 2014). Stakeholders' participation, influence and input is vital (Colvin et al., 2015; Soma and Vatn, 2014) to develop and maintain circularity in business operations, as it helps to explore multiple dimensions/

challenges (Billgren and Holmén, 2008) and enhances the acceptability of decisions/ strategies of the business (Fischer et al., 2014; Hall et al., 2013). In the broad spectrum of this framework stakeholders selection criteria is suggested to be in the bounds of who is and/or can be affected and impacted by (Billgren and Holmén, 2008; Fischer et al., 2014; Reed et al., 2009) and/or might be interested in the activities of the business (Colvin et al., 2016; Soma and Vatn, 2014).

In this context, the following stakeholders are identified in their broader spectrum:

- **People** – Generally, the concept of the stakeholder would think of people as either those who are directly (e.g. customers, supplier) or indirectly (e.g. community around) impacted by the business and its activities and/or those who have interest in the business and its activities. This framework further expands these boundaries to includes the people who are not born yet, meaning future generations; as the businesses today dealing with resources are impacting them by either adding value and/or by increasing depletion/scarcity of resources.

- **Planet** – Identifying planet Earth and its environment as a stakeholder is necessary as all the resources are extracted from it, so in that sense, Earth is the supplier and any development in business activity and its outputs directly affect it on the long/ short run.

6.6.1.2 Optimisation

One of the most common elements in both concepts of CE and Lean is optimisation. CE aims to optimise the life cycle and the end of the life cycle of the resources and products from the design stage of products as well as throughout their life cycle by enhanced and preventive maintenance (Ellen MacArthur Foundation, 2015b; Jabbour et al., 2017) while maintaining the maximum utility of resources. The major goal is to reduce the overall waste (Geng and Doberstein, 2008) through strategies such as reuse, disassembly and refurbishment (Singh and Ordoñez, 2016).

On the other hand, Lean's approach to optimisation is related to process (Hu et al., 2015) by minimising variations in process (Tokola et al., 2017) and creating flow (Mehrsai et al., 2014), through value stream mapping and its optimisation (Seth et al., 2017).

The contrasting difference between the approaches of these two concepts is that Lean focuses in terms of the immediate usage of the resource within a specific process to achieve desired

outputs, however, CE takes a more holistic approach from a systems perspective, as to optimise the utility of the resource even after one life cycle of the product. Therefore, for the convenience of the users of this framework, a redefinition of optimisation is provided as follows:

> *"Making every effort to maximise the output/ utility of a given resource (material, time, energy, and creativity) at all different stages of the life cycle in a closed loop system, while eliminating/ minimising any non-value adding impacts, throughout the life cycle of any resource."*

The above re-definition would be fully understandable when a user fully grasps it concurrently with other 4 principles discussed within this section 6.6.1 (see section 6.6.1.1, 6.6.1.3, 6.6.1.4, 6.6.1.5).

6.6.1.3 Value

For any given material or product, Lean's definition of value is /has been very subjective, as it highly denotes to owners'/customers' need and willingness/desire to acquire a product or material (Lucato et al., 2014; Neap and Celik, 1999). On the other hand, CE defines value as utilising highest utility of the resource at all times (Ellen MacArthur Foundation, 2015c), by caring for, contributing to, and expanding the natural system (Greyson, 2015). The defining scope of value is further extended within the context of supply network management, from external (customers) to internal and is linked to product and service characteristics (Adamides et al., 2008).

Mostly, the value of a resource/ product is only assumed from the perspective of one life cycle that it is being utilised for (product); however, there yet remain residual value in the resources utilised in that product, that can be utilised in one form or the other. This limited view of the value of a product or material is the core reason in contributing to the speedy depletion and scarcity of resources. Within this scope and under the purview of Lean and CE, it would be best to re-define value as follows:

> *"Any activity/output that utilises its required resources in manner that maximises its utility at all stages of its life cycle, including the afterlife, as well as to ensure the longevity of its life cycle while satisfying the needs/ demands of the stakeholders (People [present and future] and Planet) while making economic benefit for all."*

It is important to note that the above definition focuses on the life cycle of a resource, and not

just the product alone.

6.6.1.4 Waste

Waste as per Lean is anything that does not add value (Banawi and Bilec, 2014) and is also defined as being any non-value adding activity that the customer is not willing to pay for. On the contrary, CE defines waste as food where waste from one product becomes food (raw material) for the other (Webster, 2015). In light of these two broad spectrums, waste can be re-defined as follows:

> *"Any activity that leads to the harmful outputs for the stakeholders (People [present and future] and Planet) and does not incorporate the sustainability of the two in long-term, is a wasteful activity."*

6.6.1.5 Circularity

CE endeavours to develop a closed loop system, where resources are used but not used up (Webster, 2015). In this scope, a product and its components utilising various raw materials are to be kept within the system to ensure their maximum utility. For this purpose, businesses need to understand and revisit the concept of the Product Life Cycle (PLC). Traditionally the PLC has begun with the introduction of the product, led by market growth, maturity and eventually ending with decline. At the end of the life cycle mostly the products are doomed to be scrapped and dumped, leading to both the environmental damage as well as to the loss of residual value of resources used in that product.

In the scope of CE and Lean, this framework proposes a new approach (see Figure 6.9) to be utilised at the design stage of the products. This approach makes the following additions/ modifications to the existing two stages of the PLC model:

- At the *'introduction'* stage of the product, sourcing is redefined and extended from three sources:
  - Material for production is sourced from re-utilisation of recovered products/ materials
  - Degraded material from another industry which still meets or exceeds the quality standards required for the product under consideration is re-purposed/ re-utilised to ensure the utility of their residual value
  - When and only if earlier two sources are not possible to be utilised, the virgin raw material to be extracted to produce new components for the product under

development

- The *'Decline'* stage is renamed and is now being called, *'Extended Maturity/ Decline'* stage. At this stage, the product has three possibilities of:
  - Extending the life cycle of the product/ material through innovative approaches
  - Degradation of resources/ materials used in a product to be re-utilised as raw material for the production of other types of products.
  - The materials/ products that are impossible to be re-utilised and are marked as no good for further use must be disposed carefully while differentiating the technical and biological waste, and that also to be specified and thought for at the design stage of a product.

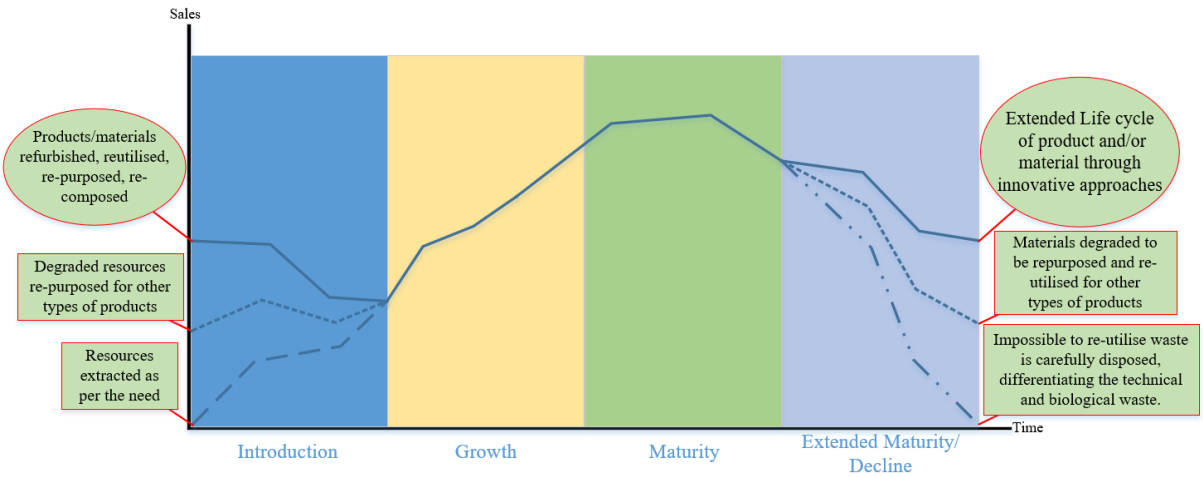


Figure 6.9 Re-defined Product Life Cycle according to the Framework

Once the adopting company/ organisation has developed a sound understanding of the earlier discussed 5 principles with their hybrid definitions combining the best of CE and Lean, they can then move on to the Phase 1 of the framework, Analyse/ Identify.

In all of the upcoming six phases, different Lean and other tools/ methods and techniques are suggested/ recommended for guidance purpose only. However, the users must understand that these suggestions/ recommendations are not bounding, and one must not restrict the scope of the framework to these tools only. The important element is the systematic approach to be adopted under the mindset of continuous improvement/ utility. The choices of tools/ methods/ techniques to assist in making that approach effective and efficient is completely dependent upon the organisation's scenario and context (e.g. availability of the resources, skills and purpose). An important thing to remember at this phase is to avoid "paralysis by analysis", where a lot of effort/ resources are utilised to collect irrelevant data or conduct unnecessary

activities that add no value. Therefore, tools/ methods must be chosen carefully.

6.6.2 Phase 1 – Analyse/ identify

For any given organisation, three levels: Strategic, Tactical and Operational (see Figure 6.10) are fundamental to its existence. Strategic level deals with the overall directions of the company (Jansson et al., 2017). Tactical level ensures that strategic goals/directions set by the top-level management become realistic (Flin and Arbuthnot, 2002) through proper management of resources and planning. Operational level carries out the plans/ goals established by the Tactical level under the directions of the Strategic and Tactical level (Belekoukias et al., 2014). All these three levels are directly inter-linked and highly integrated with each other.

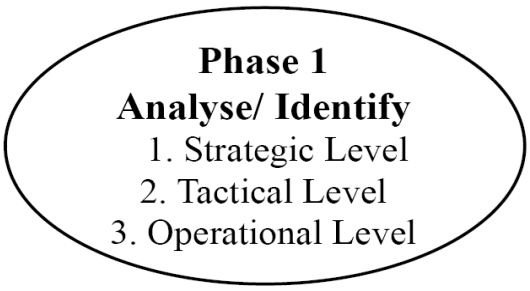


Figure 6.10 Phase 1 Analyse/Identify

Assumption: At this phase, it is assumed that organisation/ implementing personnel has developed foundational understandings of the 5 surrounding principles of this framework.

Team action: At this stage, an overarching analysis approach of VMOST (Vision, Mission, Objectives, Strategy, and Tactical) can be adopted while utilising other tools/ methodologies to feed into and assist in exploring as much detail as possible. The major goal is to analyse the organisation as a whole at all three levels of Strategic, Tactical and Operational; and to identify gaps/ shortcomings at any one or all levels that are contrary to CE principles and can be changed/ modified to improve/ optimise the output for all stakeholders.

Analysis at this phase will help scan the horizon of the organisation across all the levels and will identify the strengths and weaknesses of the company. To do so one of the tools that can be utilised is Circularity Measurement Toolkit (CMT) developed by Garza-Reyes et al., (2018) along with the other tools mentioned under each level discussed further. CMT will help understand the current circularity level of the company as well as provide a broad picture of areas for improvement in all three levels of the company. At each step/level, different tools can be utilised for analysis purpose, some of these tools are listed in each step but the list is neither

exhaustive nor binding.

6.6.2.1 Step 1 – Analysis/ identification at the strategic level

The strategic level of any organisation defines the interests of a company and determines its directions by providing a clear vision and mission for the organisation. Under this broad spectrum, the overall objectives and goals are developed/ followed throughout the organisation.

It is important to note that the organisation needs to be analysed in light of the redefined understanding of surrounding principles for this framework. If any inconsistencies/gaps exist between the organisation's strategic level and the desired and/or possible level under CE's defined scope, these must be documented for further examination/ action.

For this purpose, the company's vision and mission statement, as well as the strategic plan, can be included in the analysis. Besides, the interviews with CEO/ board member/ other top-level management can be conducted to get an in-depth view of its strategic level. For this step, the user(s) can deploy any of the following tools in any combination or stand alone, but are not limited to:

- Balance Scorecard
- Strategy Map
- PEST Analysis

The results of analysis from this level will provide a foundational understanding of where the company stands and where it aspires to be in terms of its strategic direction. This will assist the user to define the scope of analysis at the tactical level.

6.6.2.2 Step 2 – Analysis/ identification at the tactical level

The tactical level of an organisation serves as a bridge between the strategic and operational level and ensures the realisation of the organisation's mission and vision. Here the organisation's strategy and goals are analysed in light of the redefined understanding of surrounding principles for this framework. Any major or minor gaps are to be identified and documented to be considered for future improvements and changes. For the purpose of analysis, the following steps can be followed:

4. Obtain the company's goals and strategies to achieve those goals

a. If the documentary evidence does not exist, then the strategic personnel at the tactical level to be interviewed to understand their goals and strategies that they adopt to achieve those goals.

5. Identify any discrepancies that contribute negatively to the environment and/or do not keep the resources at their highest utility, and/or have a different understanding of value, waste, cost/profit and product life cycle.
6. Document the gaps.

Moreover, the user(s) can also deploy any of the following tools in any combination or stand alone, but are not limited to:

- Force Field Analysis
- Strategic Planning Gap
- SWOT Analysis

Analysis from this level will provide an ample understanding of the company's way of realising the strategic directions and aspirations. Based on the results from this analysis, the user then can define their scope for analysis at the operational level.

6.6.2.3 Step 3 – Analysis/ identification at the operational level

Operational level serves as hands and feet of the organisation, as it brings the vision and mission from virtual to physical existence. At this step organisation's operational activities/ outputs are analysed in light of the surrounding principles of this framework. Any major or minor gaps are to be identified and documented to be considered for future improvements and changes. For this, the user(s) can deploy any of the following tools in any combination or stand alone, but are not limited to:

- Value Stream Mapping
- Causes and Effect Relationship
- Strategic Planning Gap
- Root Cause Analysis

Author highly recommend utilising the value stream mapping (VSM) tool, however, any other tool/ method can be utilised if the expertise for VSM is not available or if through other methods the similar analysis can be conducted.

To compensate for VSM, the following procedure can be used accompanied by Gemba walk while utilising any one or multiple tools:

6. Obtain the company's product development process guidelines
7. Obtain the company's recorded data on generated waste
    a. Obtain the company's waste handling procedures/ records
8. Obtain the company's understanding of their responsibility for the product life cycle and end of the life cycle management.
9. Identify any discrepancies that contribute negatively to the environment and/or do not keep the resources at their highest utility, and/or have the different understandings of value, waste, cost/ profit and product life cycle.
10. Document the gaps.

The overall output of the analysis at these three levels of the organisation will provide sufficient details to identify the areas requiring improvements/ modification and/or change. The user then can move into the next phase to prioritise, plan and develop the roadmap for improvements/ changes.

6.6.3 Phase 2 – Plot

Assumptions: At this phase, it is assumed that the coordinator/ manager along with other personnel/ team has conducted a detailed analysis of the organisation as a whole or in part (as per management's decision) and have identified potential areas/ aspects for improvement with regards to adoption of CE principles in their operations.

Team action: The team needs to ensure that management is aware of the findings from phase 1 and is coordinated with for further proceeding (communication and feedback loop).

The lean tool of *Hoshin Kanri* (Policy development) is to be kept along to ensure the alignment of goals at all three levels of strategic, tactical and operational. At this phase, the following steps need to be followed (see Figure 6.11).

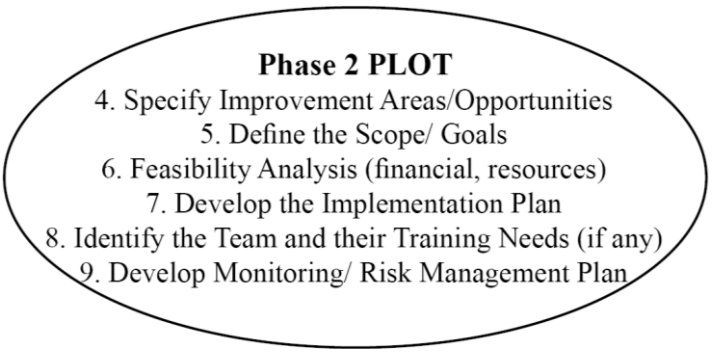


Figure 6.11 Phase 2 PLOT

6.6.3.1 Step 4 – Specify improvement areas/ opportunities

The documented list of areas requiring improvements needs to be reviewed by the coordinator/ manager and the personnel/ team alongside him/her. They then need to prioritise the identified areas/ aspects requiring changes/ modifications/ improvements and choose the areas/ aspects they define as highly important for the adoption of CE. For this purpose, the user(s) can deploy any of the following tools in any combination or stand alone, but are not limited to:

- *Pareto Analysis*
- *Action Priority Matrix*
- *Project Selection Matrix*
- *Decision Matrix Analysis*
- *Eisenhower's Urgent/ Important Principle*
- *The Modified Borda Count*

Once the areas for interventions are prioritised and selected, the documentation along with justification needs to be discussed with the top management of the organisation to seek their approval to continue to the next stage of PLOT phase. It is crucial to involve top management at this stage and to obtain their consent as they might not agree for the proposed directions and it would result in the wasted effort if the team continues without management's support. If the top management disagrees with the proposed areas for interventions, the review is to be done again along with top management's personnel and consensus to be reached. Once the top management has consented, the team then can move to the next step to define the scope of the changes/ modifications/ improvements.

6.6.3.2 Step 5 – Define the scope/ goals

Having a clear idea of which areas of the organisation to improve and which opportunities to

exploit on, the team then needs to define the scope of improvements by defining what changes, modifications and interventions to work on and specifying goals/ tasks for their achievement. For this purpose, the team can also look for best practices case studies available already to avoid re-inventing the wheel and/or to benefit in developing more robust goals. The goals must be SMART:

S = Specific
M = Measurable
A = Achievable
R = Realistic
T = Time-bound

Once the team has identified the areas for intervention and developed the scope/ goals for them; they then can move further to conduct a feasibility analysis for the viability of the developed scope/ goals.

6.6.3.3 Step 6 – Feasibility analysis (financial, resources)

At this step, a feasibility analysis should be done to ensure that resources are available or can be made available for the set goals. This analysis would greatly help to identify sponsors (if needed). The analysis can be done by using any tools, following are few recommended suggestions but the users are not limited to them:

- TELOS (Technology, Economics, Legality, Operations, Schedule)
- Mullin's Seven Domains

Once the feasibility of the scope/ goals is confirmed and there is an assurance of needed resources, the team then can move further to develop an implementation plan.

6.6.3.4 Step 7 – Develop the implementation plan

This step aims to develop the implementation plan along with the clearly defined Lean (including any extension e.g. Lean Six Sigma) and CE tools/ techniques for intervention. Different planning tools can be utilised, among which project management tools such as Gantt chart, resource planning etc. are highly recommended. Different tools can be deployed as stand-alone or in combination, dependent upon need, strategy, as well as the skills/ capabilities of the

users and the availability of resources.

The implementation plan would provide a clear picture of what type of personnel are needed to execute the planned intervention. The team can then move to the next step to identify the team, define their roles and to identify if any training is needed.

6.6.3.5 Step 8 – Identify the team and their training needs (if any)

At this step when the process map has been developed to eliminate/ minimise the identified gap/ discrepancies; another important bit is to identify the right person who will take the lead on the implementation. Some important features to consider while choosing the team are:

- Availability of the person(s)
- Skills of the personnel and their ability to take responsibilities
- Knowledge of the relevant functions and the organisation
- Ability to be a team player and share knowledge with others
- Willingness/ motivation for CE
- Ideally, the experience of participation in improvement/ change management projects

The number of personnel for the team to implement the intervention can vary, as it completely depends on the type of activities, level of implementation, required skills and other factors related to the plotted intervention. There might be a need to provide training to the team as the required skills/ understanding may not be available in-house. The coordinator/ manager must identify the need for such training and document it. Once the coordinating team has identified/ recruited the implementation team members and has identified their training needs, they then need to develop a monitoring/ risk management plan.

6.6.3.6 Step 9 – Develop monitoring/ risk management plan

At this step when the implementation plan is in place and the team is recruited, the coordinator/ manager along with the team need to develop a monitoring and risk management plan. It is best to conduct Failure Modes and Effect Analysis (FMEA) to identify potential risks and formulate mitigations strategy at this stage. Alternatively, a simple four-step approach can be adopted at this stage:

Identify Risks → Analyse → Response Planning → Monitor and review

Once the Risks are identified and a contingency plan is in place, the team then can move on to the next phase to prepare and pilot the plan.

6.6.4 Phase 3 – Prepare/ pilot

This phase (see Figure 6.12) is the organisation's endeavour to begin the change implementation but before it is done at a full scale, it is best to prepare the team (if needed) and conduct pilot testing of the plan.

At this phase, the team members must prepare for the deployment of the implementation plan with a clear understanding of the tasks. Preparation can include but is not limited to:

- All the team to have orientation, guidance and training (if necessary)
- Ensuring all resources are available
- Ensuring that any disruption in the regular operations are planned in line with expected outputs to meet the regular/ expected demands
- The contingency plan must be in place to avoid any problems and interruptions in the overall progress.

At this phase following three steps are to be followed.

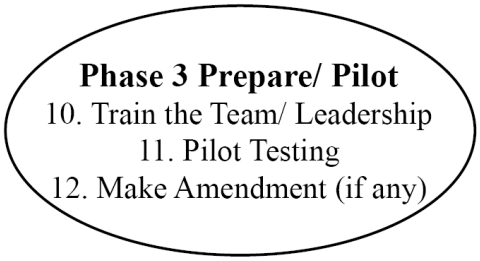


Figure 6.12 Phase 3 Prepare/ Pilot

6.6.4.1 Step 10 – Train the team/ leadership

Based on an assessment of the need for training, the coordinator/manager needs to decide about the following:

- Ensure the availability of place, materials, and other needed resources
- Decide the content of training, schedule and mode of delivery
- Preparing for delivering or recruiting the personnel to deliver the training
- Ensure that the training objectives have been met

Once the team is prepared and ready, it can then move to the next step of conducting pilot

testing.

6.6.4.2 Step 11 – Pilot testing

Despite the plan being well developed and the team ready with training for implementation, it is always best to conduct pilot testing to ensure practical rollout. For this purpose, small-scale pilot testing needs to be done and evaluated. Any discrepancies and/or weaknesses to be documented for further improvements through amendments.

6.6.4.3 Step 12 – Make amendments (if any)

All necessary amendments to be made to address any discrepancies and/or weaknesses identified in the earlier step.

Once the amendments are made, the coordinator/ manager can decide whether to re-do the pilot testing or to move ahead with the full scale planned implementation. This decision will completely depend on the type of issues found during pilot testing and the approach to address those issues. Once the coordinator/ manager and team are confident about the plan, they then need to execute it as plotted.

6.6.5 Phase 4 – Execute

At this phase, there is only one step, which is to execute (implement), the planned intervention (see Figure 6.13). At this phase, the whole team needs to ensure that they carefully follow the plan and document any variances along the way to avoid missing any details that could be helpful at a later stage.

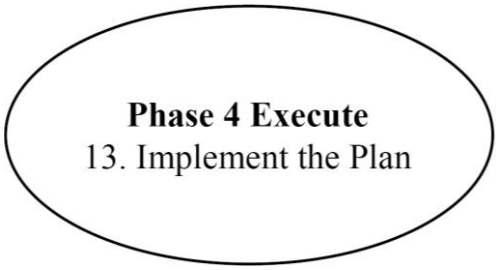


Figure 6.13 Phase 4 Execute

6.6.5.1 Step 13 – Implement the plan

With all the resources in place and preparation, the implementation step must begin. The coordinator/ manager must oversee all the process and provide full support and guidance to the implementation team. S/he must also ensure to record the progress on a regular basis. This can later be utilised to analyse any trends/deviations and can help build upon best practices or avoid any mistakes happened.

The ground rule of continuous improvement must be kept in mind and following Lean tools can be deployed but are not limited to, to ensure the effective execution of planned interventions:

- 5S (Sort, Set in Order, Shine, Standardise, Sustain)
- Kaizen
- PDCA (Plan – Do – Check – Act)
- KPIs to monitor
- Poka Yoke

Once the plan has been implemented, the team can then move to next phase to evaluate against the goals set earlier at step 5 (see section 6.6.3.2) and implementation plan (see section 6.6.3.4) to measure the desired level of performance.

6.6.6 Phase 4 – Evaluate

At this phase, only one-step is involved to evaluate the impact against the defined goals (see Figure 6.14). The coordinator/ manager along with top management needs to define the criteria for goals achieved. For instance, if the goals were achieved by 90% or 80%, then move onto control. In case of goals not being achieved, the mistakes and shortcomings are to be documented and the team would make the decision to move to Phase 1 to re-analyse/ re-identify, or phase 2 to Plot again, or phase 3 to execute the same plot again. The decision would solely depend on the circumstances and need. In case if the coordinator/ manager along with team thinks that the goals are not achieved due to poor plotting or execution, in that case, the decision to move to that phase would occur.

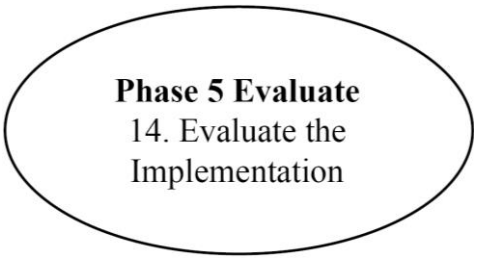


Figure 6.14 Phase 4 Evaluate

6.6.6.1 Step 14 – Evaluate the implementation

For the purpose of evaluation, it is highly recommended to deploy Circularity Measurement Toolkit (CMT) (Garza-Reyes et al., 2018) along with the benchmarking against the earlier set goals. So far CMT is the only best-published tool to understand the circularity level of a company, however, by no means, the team is restricted to this tool only.

Upon achieving success, the team can then move to the final phase (control) to sustain the implemented intervention.

6.6.7 Phase 6 – Control

In this phase, the general assumption is that the selected project and planned intervention goals have been achieved within the acceptable range defined earlier. At this phase, the coordinator/ manager needs to ensure that the completion/ success of the framework's implementation is made sustainable through systematic adherence to the following steps (see Figure 6.15).

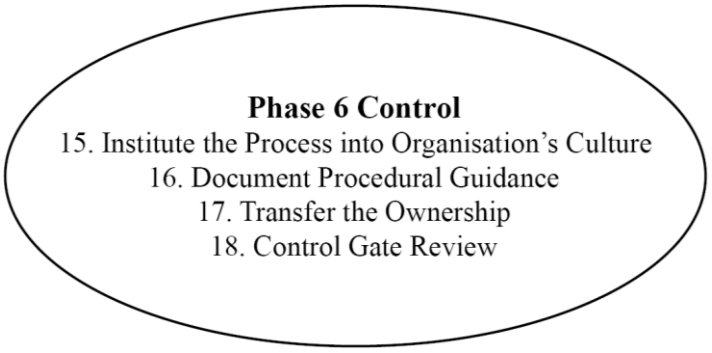


Figure 6.15 Phase 6 Control

6.6.7.1 Step 15 – Institute the processes into organisational culture

Since the CE's actual potential cannot be fully realised without systems thinking, therefore it is important to begin within the company first by embedding and replicating the CE's

adaptation throughout the organisation. This would ensure benefiting the organisation by sustaining CE principles throughout, as well as to sustain the changes made in the first execution of the plan.

Effective implementation of this step and its outputs would not happen overnight but would require repeated efforts as done in the first intervention. Thus, it is important to document the procedural guidance, the next step.

6.6.7.2 Step 16 – Document procedural guidance

Documenting the procedural guidance in contextualised form would greatly benefit the future utilisation of C-LEAN framework within the organisation. It will also serve as evidence of success achieved, lessons learned and would be a great point of reference to build on for future improvements and adaptation.

At the completion of this step, the coordinator and team can start to prepare for closure by transferring the ownership of the process to the managers and everyday working people within the company.

6.6.7.3 Step 17 – Transfer the ownership of processes

All the documented details and procedural guidance are to be handed over to the right personnel for the continuity of its implementation at the organisational level. All three levels (Strategic, Tactical and Operational) of the organisation are to be involved on as needed basis and the process of transferring the ownership of the processes is to be documented for future reference.

Once the transfer of ownership is done OR if it is not needed because the initial team is completely formed of actual working personnel from within the company, the team can then do one last final check of control gate review.

6.6.7.4 Step 18 – Control gate review

The DMAIC process of control gate review will highly benefit to ensure the sustainability of the framework and its outputs. For this purpose, the coordinator/ manager needs to ensure that:

- Reports of before and after scenario are documented and made available to the right personnel

- Process maps, control plans and procedural guidance are documented and in place
- Process owners as well as the management has taken over the process and are committed to its implementation
- Summary of lessons learned is developed
- Any issues/ opportunities for future implementation are documented
- A celebration to encourage the team and reporting the success is done.

Successful completion of this framework's phases and productive output would confirm and encourage the further adaptation of it throughout the organisation as well as among other supply chain members. It is important that any further adaptation teams bear in mind the very purpose, goals and characteristics of this framework. Moreover, there must be periodical reviews for the purpose of continuous improvement. The interval of these periodical reviews will depend upon the decision by the coordinator/ manager, as well as the nature of the business.

6.6.8 Concluding remarks about the framework

The framework consisting of 6 phases with 18 steps to follow, provides a mechanism to systematically adopt CE principles in manufacturing operations management. The goals and benefits are summarised below:

- The developed framework and its criteria are non-prescriptive. The intent is not to define and dictate the process but to focus on the end result achieved through a systematic approach utilising different tools and techniques as per the need, context and scenario.
- The criteria heavily focus on continuous development, which gives the place for learning from the past, focusing on the present with innovation, and heading towards the future in a pro-active manner rather than reactive.
- The goal is for the organisation(s) to embrace/adopt circularity in their manufacturing practices, throughout its operations while achieving economic, social and environmental growth. These goals will be achieved by:
    - Making the move from the Linear economic model to a Circular economy model
    - Keeping resources to maximum utility and in a closed-loop cycle
    - Ensuring resource conservation by minimising the usage of virgin material
    - Decreasing negative environmental impact
- By doing so the companies can utilise the framework to achieve the following outputs, but

are not limited to:

- Become a leader in adopting a systematic approach to CE's adaptation
- Become an active responsible business that incorporates the interests of stakeholders
- Be the best in class practice and role model of CE practices
- Economic growth mingled with the holistic sustainable approach
- Model, inspire, and challenge others for innovation and drive towards the CE model
- Increase market share
- Increased productivity

Further guidance about the lean tools and their procedural guidance can be accessed through multiple online sources. Following handbooks are highly recommended for the team to consult, as and when needed.

- *The Lean Six Sigma Pocket Toolbook* by Michael L. George and others, published in 2005 by McGraw-Hill, New York, NY.
- *The Lean Management Systems Handbook* by Rich Charron and others, published in 2015 by Taylor & Francis Group.

6.7 Conclusions

Any conceptual development needs screening to ensure that it is of sound quality and applicability. A conceptual framework, merging CE and Lean was developed (see section 5.3) based on academic literature exploration and understanding of the researcher. Thus, to verify it, a Delphi study method was adopted, which has been presented in this chapter. A group of experts (practitioners and academics) were requested to participate in this study to critique and provide feedback to improve the developed framework. Based on their feedback and input; many major and minor modifications/ changes have been made. As a result, a much improved and enriched verified version of the framework is developed and presented in this chapter.

In order to further ensure the practical relevance of this framework, a case study method is to be adopted to validate it. This validation process and its results are presented in the next chapter.

Chapter 7 Validation of the verified framework

7.1 Introduction

The framework C-LEAN is designed specifically for manufacturing SMEs, therefore its practicality and reliability (Burns, 2000) is important to test. In the previous chapter (see Chapter 6) the conceptually developed framework has been verified through Delphi study, where expert's option, criticism and feedback have been sought, from both the academic and industry background. As a result of the Delphi study, multiple re-alignment, modifications, and developments in the framework's phases and steps are made. With the verified conceptual framework, the next stage is to validate it.

This chapter aims to develop a brief understanding of what validation is and its methods, and then to validate the verified framework by choosing one of the approaches to validate its practicality and reliability. With this aim, the following objectives are defined for this chapter:

- To select and understand the validation method to validate the verified framework
- Develop an instrument (i.e. questionnaire, selection of tools) to be utilised for the validation process
- Validate the verified framework through the developed research design and instrument

With the above aim and objectives, the remaining chapter is organised in five sections; where section 7.2 presents a brief overview of what is validation, its methods and practical aspects. Further, each of the two case studies is presented along with their analysis and projected scenario (see section 7.3 and 7.4) and finally the conclusions drawn through this validation process are presented in section 7.5.

7.2 Validation

There are various descriptions, perspectives and approaches to define and utilise the term validation (Creswell and Creswell, 2018). However, its core purpose is to check and authenticate that the developed model, framework, tool and/or concept is right (Gass, 1983) and that it closely fulfils its claims (Sargent, 2013) that it made at the time of its development. Therefore validation helps to explore the suitability, competence and limitations (Macal, 2005) of the framework/ model and/or concept under review. It further affirms the confidence in reliability and value of the model/ framework (Burns, 2000). Often the term validation is

confused or used interchangeably with the term verification (Dzida, 1998; Jagdev et al., 1995; Maropoulos and Ceglarek, 2010). However, these two are independent processes with a common purpose. Project Management Institute (2008) draws a clear distinction between two by defining them as follows:

> **Verification**: '*The evaluation of whether or not a product, service or system complies with a regulation, requirement, specification, or imposed condition.'*
>
> **Validation**: '*The assurance that a product, service, or system meets the needs of the customer and other identified stakeholders. It often involves acceptance and suitability with external customers.'*

Thus, the verification in this research (as discussed in Chapter 6) ensured that the construct of the framework complies with specifications, requirements for its intended purpose and validation is to test the practicality of the developed framework, C-LEAN.

7.2.1 Methods of validation

Numerous methods exist to validate a framework/ model, each of which has its own suitability for the objectives of validation, type of study and the subject. These methods are briefly mentioned but are not discussed with exceptions for the one that is applicable and chosen to validate the current conceptually developed and verified framework. Some major methods utilised for validation are Face validity, Event validity, Extreme Condition tests, Historical data validation, Internal validity, Sensitivity analysis, Turing tests, comparison to other models, Degenerate tests, and Case study (Burns, 2000; Gass, 1983; Gray, 2018; McMillan et al., 2016; Sargent, 2013). For the purpose of this research, The case study approach was utilised to validate the framework's value and reliability (Burns, 2000).

7.2.1.1 Case study methodology

A case study is an authentic and useful tool for validation as it deals directly with its subject in its actual context (Yin, 2016). The advantage of utilising case study is that it keeps the subject (case) as the central element and not the variables, moreover, they can be used to make an analytic generalisation and elaborate theoretical developments (Schwandt, 2015). In order to lay a foundational understanding of the case study, it would be best to have a brief overview of how scholars define the case study:

"Case study is the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances" (Stake, 1995)

"Case study is the examination of an instance in action" (Macdonald and Walker, 1975)

Yin (2014) provides a two-fold definition that, *"A case study is an empirical inquiry that*

- *Investigates a contemporary phenomenon (the "case") in depth and within its real-world context, especially when*
- *The boundaries between phenomenon and context may not be clearly evident."*

It would be right, to sum up that case study provides an ample opportunity to test the C-LEAN framework within the specific context, for which the framework has been developed (i.e. manufacturing SMEs).

Yin (2014) provides three categorisations of case studies as *Exploratory, Descriptive and Explanatory.* Exploratory, where the core purpose is to explore and identify the point of interests to be utilised in research. Descriptive, where the purpose is to describe phenomena in the real world context. Explanatory, where the focus is to explain how and/or why something exists (Yin, 2014). The case study approach adopted in this research is more exploratory as it tests the developed framework in a real-world context.

Scholars also point to the fact that data in case studies is often unstructured and mostly analysed qualitatively (Gomm et al., 2000), however, it must not be confused as synonymous with the qualitative method (Stake, 1995).

As the case study methodology deals directly with individual cases in their actual context (Yin, 2016) thus it is important to adopt the triangulation approach to ensure the consistency of findings (Yin, 2014). Since a model, framework and/or concept is mostly developed for a specific purpose thus its validation must be done in the purview of that context (Sargent, 2013) therefore the research design and methodology cannot be entirely generic but must be adapted to fit the purpose of validation.

For this purpose, this research deploys three major tools to collect data from the case companies. These tools are Circularity Measurement Toolkit (Garza-Reyes et al., 2018) (see

Appendix F), semi-structured interview questionnaire (see Appendix E) for each of the three levels of the organisation (i.e. strategic, tactical and operational), and GEMBA walk to make thorough observations. These tools and their relevance to each of the three levels of the company are portrayed in Table 7.1

Table 7.1 Tools and their input to three levels of the organisation

Input Level / **Tool**	**Strategic**	**Tactical**	**Operational**
Semi-structured interviews	X	X	X
Circularity Measurement Toolkit	X	X	X
Gemba Walk			X

7.2.2 Practical aspects of validation

Sargent (2013) points to an important element that an absolute validity could be often too costly as well as time-consuming, and such has been the case in this research for the validation of the verified framework. A full-scale implementation of the framework would require a significant amount of time, changes in the existing procedures as well as the investment of both the capital and knowledge transfer. Therefore, a partial implementation was carried out, where first 2 phases of the framework are implemented and the remaining phases are presented in the form of a projected scenario, as to how the manufacturing operations would function if the input from first two phases (Analysis/identify and Plot) were followed. For reference purpose, the proposed framework, C-LEAN is provided in Figure 7.1

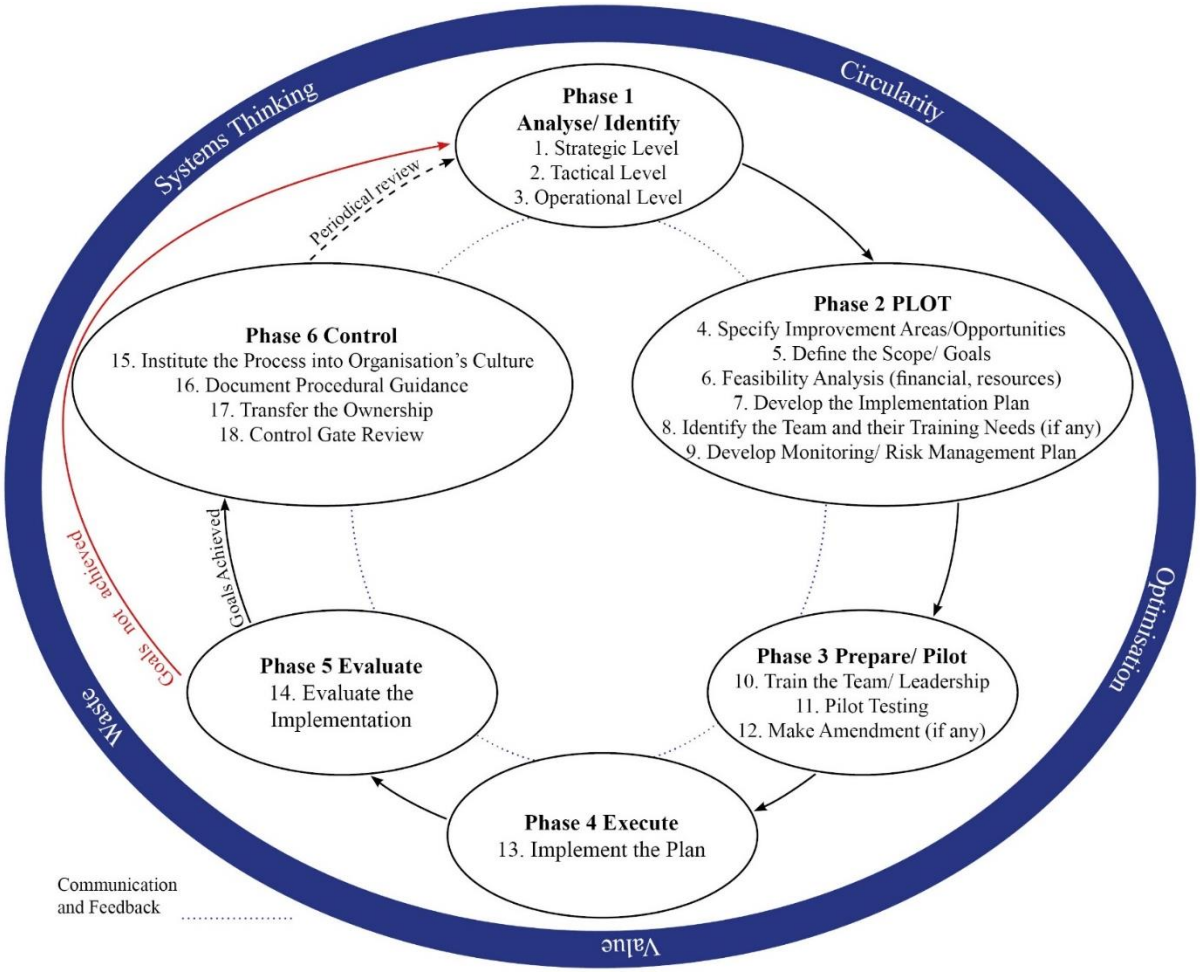


Figure 7.1 C-LEAN Framework - for CE implementation in manufacturing SMEs

7.2.3 Case studies for this research

A total of two SMEs from the manufacturing sectors located in Pakistan were selected due to the following reasons:

- The companies being in the manufacturing sector falls directly within the scope of this research
- The leadership of the company agreed to permit the visit, accommodating meetings with the senior management team as well as the visit to the shop floor and the possibility to interview their staff.

The researcher travelled from the UK to Pakistan for this very purpose and made visits to the companies' sites as well as to meet the leadership and staff to have multivariate input.

In compliance with the agreement with the respective companies, their names and any other

information that could lead to the identification of the company is anonymised. For this purpose, they are referred to as company A and B.

7.3 Case study - Company A

Established form the early 1950s, Company A is a wholly owned family business and is registered as a private limited company. The company has a very niche market with its expertise in the business of Electrical Engineering where they produce transmission and distribution products (e.g. CT [current transformers], PT [potential transformers], control panels, short circuit security). At present, the company employs over 65 staff members, of which 45 are on the shop floor and 21 are in management/ office to oversee the business and manage the facility. One of their major clients is the national power authority of Pakistan (WAPDA) followed by other international companies such as Siemens, Schneider Electric, and other international companies based in UAE, UK, etc. Beside national certifications, the company has also acquired ISO9001-2008, 14001, 18001 and other industry related certification.

The company's leadership maintain a very high ethical and professional work environment and acclaims following as their core values: *'Work Ethic, Safety, Quality, People, Environmentally Conscious, Integrity, Innovation, Excellence, Team Work, and Customer Focus*'. Company's mission and vision statement along with quality policy are as follows:

> **Mission Statement:** Company A *is committed to providing the highest quality products, competitively priced, with services exceeding our customer's expectations. We will continue to invest in facilities, systems and highly trained technical personnel providing added-value to our business relationships.*
>
> **Vision Statement:** *Electrical energy is a cornerstone of our quality of life. There will be a continuing need for products and services to harness its use.* Company A *will strive to be best-in-class as a distributor of quality products and services and a responsible corporate citizen.*
>
> **Quality Policy:** *The policy of* Company A *is to empower all employees to create, implement, and improve our services to meet and exceed external and internal customer expectations.* Company A *pledges to train all personnel in Continuous Process Improvement (CPI); to provide the financial resources necessary to*

Continuous Process Improvement; and to create a work environment which develops motivated, knowledgeable employees committed to the corporate mission. Continuous Process Improvement will be driven toward improved customer satisfaction and enhanced customer loyalty.

With this brief overview of the company, the next subsections utilise the phases of the developed framework to analyse Company A.

7.3.1 Phase 1 – Analyse/ identify

Phase 1 (see Figure 7.1) of the framework is to analyses three levels (strategic, tactical and operational level) of company A.

7.3.1.1 Strategic level analysis

Company's MD (Managing Director) was interviewed utilising semi-structured questionnaire (see Appendix E). The discussion was very insightful and since many parts of discussion related directly with operational as well as tactical level, therefore that information has been incorporated in those sections later.

In terms of its **strategic goals** for the next 3-5 years, the company strives to:

- Expand internationally, especially in the Middle East and Asia
- Add another technical product (i.e. switchgear, transformer)
- Buy insulator of the capacity of 11kva, (which will be first in the country)
- Update testing facility to the capacity of 95kva

When asked about the company's **strategic and operational goals regarding Circular and/or Green/ Environmental initiatives**, the company only strive to comply with the requirements to maintain ISO certification. Since they don't have any knowledge of CE, therefore they don't have any goals/ plans in that direction but are open to exploring the possibilities. The MD showed a very keen interest in exploring LEAN implementation as he has learned about the potential benefits of such a strategy through his visit to other international companies in a similar industry.

Company leadership was asked to define their priorities while doing strategic/ operational planning. Their responses are summarised in Table 7.2

Table 7.2 Company A's priorities while defining strategic direction

	N/A	Never	Rarely	Sometimes	Often	Almost always
Reduce Carbon Emission	X					
Reduce negative environmental damage						X
Longevity of product						X
Longevity of Resources	X					
Re-utilise resources	X					
Financial Growth/ Stability						X
CSR activities						X

The company does not consider carbon emission reduction as applicable to them due to the nature of the business. However, they do prioritise to reduce any negative environmental damage. Moreover, given the nature of business and type of the product, the longevity of the product life cycle is a high priority. At present, the company does not re-utilise any of the resources nor have any methodology to ensure the longevity of resources used in their products. The company is a for-profit business and financial growth/ stability is a priority. Moreover, the company's leadership ensures that CSR activities are well incorporated in their day to day business as well as overall business strategy (see SWOT analysis in Table 7.4).

The company has made significant investments to develop an in-house research and development department and has a specified budget allocation to promote innovation. They regularly participate in national/ international exhibitions to learn about new technology and innovation within their industry sector. The company has an open communication policy where they engage tactical level on a regular basis, in planning and defining the strategic directions of the company.

In order to understand the current circularity level of Company A, further analysis was conducted through Circularity measurement toolkit (CMT) (Garza-Reyes et al., 2018).

7.3.1.1.1 Circularity measurement

CMT explored different aspects related to the three levels of the company (strategic, tactical and operational). Table 7.3 below present an overview of the CMT assessment with the full assessment tool results in Appendix F.

Table 7.3 Summary of CMT results for Company A

Rating \ Factors	A	B	D	E	F	G	H	I	Result	RANGE Min	Max
1. Circular developer	1	0	0	0	0	0.5	0	0	**1.50**	6.5	8
2. Circular Promoter	1	0	0	0	0	0.5			**1.50**	5.5	6
3. Circular	1	0	0	0	0				**1.00**	3.5	5
4. Waved	1	0	0						**1.00**	2.5	3
5. Curved (where A = 1 and B = 1)	1	0							**0.00**	2	2
6. Saw tooth (where A = 0.5 to 1 and B = 0.5 to 1)	1	0							**0.00**	1	1.5
7. V-shape up (where A=0 and B = 0.5 to 1)	1	0							**0.00**	0.5	1
8. ∧-shape down (where A - 0.5 to 1 and B = 0)	1	0							**1.00**	0.5	1
9. Linear	1	0	0	0	0	0.5	0	0	**1.50**	0	0

As per the CMT's calculation, Company A's rating is *'∧-shape down*'. This rating's definition is, *"Organisations that without noticing, are already applying some internal CE practices generally related to the resource consumption, utilisation and efficiency. They are not aware of CE, however, they realised that economic benefits can be obtained with the adoption of certain practices."* (Garza-Reyes et al., 2018)

This indicates that the company have no knowledge of CE, but they do have some practices and are aware of economic benefit by adopting the practice of CE. A further analysis was conducted at the tactical level to gain more insight.

7.3.1.2 Tactical level analysis

Production Manager of the company was interviewed, who has been with the company for over 18 years and is the backbone of the company. Most of the inputs were provided by himself, however, at times he did call other peers to get their input; for instance, about the scrap handling strategy, inventory management, etc.

The tactical level is aware of Green production and Environment-friendly initiatives, mainly due to the compliance requirements to maintain ISO certification. However, they are completely unaware of the CE.

All of the major raw material utilised in production is imported either directly and/or through a third-party supplier. When asked about the type of resources they find difficult to source and/or are likely to become scarce, '*electrical silicon steel'* was identified as a resource that could become scarce in the coming decades. However, the only way to re-utilise it was by downgrading it to be utilised in other products (e.g. fans, motors for water pumps).

Regarding operations optimisation, the company try to keep their inventory as low as possible and use trial and error method to optimise operations. In order to be environment-friendly, the company ensures that the fumes from chemical mixing unit and fine dust from the grinding of resin are controlled through a specially designed exhaust system where the outflow is not disposed in the air but is captured to be disposed-off in a responsible manner.

To choose suppliers, the company ensures that all suppliers are registered taxpayers entities. Each supplier is requested samples of their materials to be tested for quality. The order is given to the supplier presenting a good combination of quality and cost.

The average product life cycle for their product is 12-15 years under proper usage. At the end of the product life cycle, the company does not offer any buy-back or take-back options nor does it provide any responsible disposal services. Therefore, the customer is responsible for the product's end of life management. Likewise, there is no system to monitor the resource life cycle.

When shared about CE and asked about **potential barriers/ challenges to the implementation of CE initiatives**, the following points surfaced:

- Company A's major product is CT/PT, which is all covered in epoxy resin. Therefore, no material can be extracted unless the Epoxy resin is first removed.
- This resin is hardened to the level that it cannot be broken easily, without specialised equipment.
- Epoxy can be burnt to extract the inside materials (e.g. copper, steal) but burning epoxy can release highly damaging emissions.

For the purpose to precisely categorise the current standing of the company and its potential possibilities and threats, a SWOT analysis is presented in Table 7.4.

Table 7.4 SWOT analysis of Company A

Strength	**Weaknesses**
• Long-standing reputation and expertise • Leading pioneers in the industry • Superior HR practices • Active engagement in CSR activities • On the job training for employees • Regular maintenance and calibration of equipment • Up to date equipment • Great supply chain/ inventory management • Bottom-up communication model to allow for innovation, growth and productivity	• Nearly 60% of the shop-floor staff are unqualified • Health and safety rules are not completely complied with • No integrated supply chain management system with supplier • No end of product and resource life cycle management system • Paper-based (forms) record keeping and internal communication
Opportunities	**Threats**
• International expansion • Develop integrated supply chain management to reduce inventory level • To move to electronic record keeping/ approval system and communication • In-house refurbishing facility • Adopting CE through involving and integrating SC both horizontally and vertically • Utilise another type of epoxy that is used in China, India and other parts of the world	• Competitors might develop a bigger capacity setup • Political instability – e.g. strikes

Company A benefits from a long-standing reputation as a pioneer in their specific business sector, as well as being the supplier of quality products to both the government and private sector. Moreover, the company's leadership has high standards of CSR and HR practices where all employees are treated with greater respect, provided with decent wages as well as safe working conditions, and are provided ample skill development opportunities which benefits both the employees as well as the company to gain competitive advantage through greater employee commitment and quality production. The company runs a very flat structured

management approach and employs bottom-up methodology in forming their business strategies.

While the business has multiple strength avenues which are evident by its successful presence in the market, it also has certain weaknesses that it needs to address to sustain its competitiveness and growth in the market. Providing on the job training is beneficial to upskill their employees but is not necessarily a replacement for technical knowledge/ skills obtained through certified qualifications. Nearly 60% of the shop-floor staff are unqualified which limits the scope and potential for innovation, as the majority of the shop-floor staff is just repeating the processes for which they are trained on the job. However, if they would have a broader understanding, it would contribute to allowing for thinking outside of the box.

Since the company operates in a country where sustainability and environment-friendly factors are neglected at a large scale, thus perhaps the company has not paid much attention to this aspect nor has made any strong commitment to such initiatives, except where required for certification purposes.

Due to a great reputation in the market, the Company A stands a greater chance and have a competitive edge over its competitors for international expansion. For this purpose, the company needs to expand its compliance with environmental factors and consideration to contemporary issues faced by the industries worldwide (e.g. concerns for the environment, resource scarcity).

Although the company currently holds a major market share in the given sector, this does not guarantee that it cannot be outstripped by its competitors. Thus, staying competitive is very much a necessity for the survival and growth of the business. The company is also faced with certain threats to which they have no control over, such as political instability as well as the law and order situation in the country.

Further analysis at the operational level was carried out to understand the potential for CE integration.

7.3.1.3 Operational level analysis

Production manager and shop floor staff were interviewed to provide further insight at the operational level. The production manager is heavily involved on the shop floor and in fact hardly ever uses his office space but spends 99% of his working time on the shop floor.

Therefore, he provided the overall information but again shop floor supervisors were engaged on as and when need basis.

The current annual output is 14000 units, of which faulty products are around 10 – 15 which is way below than the anticipated error probability of 0.5%.

Each electricity transformer, as a final product, contains 3 units of CT/PT and is sold at an average price of £36000 (GBP). Each of the three units contains the following metals inside:

- Copper = 2.5 – 13kg
- Brass = Quantity is very little
- Steel = 7 – 8 kg

The above quantity does not include the outer body of an electricity transformer, as that is not produced by the company A. Given the above calculation each ready transformer contains on average 22kg of steel and 30kg of copper, which goes into waste after the average product life cycle of 12 years.

Supply chain management functionality has to be of higher accuracy as the supplies come from different countries mentioned below.

- Chemicals are sourced from India
- Steel is sourced from France
- Copper is sourced from Thailand and other vendors locally
- The insulation material is sourced from China
- Wires are sources from Turkey
- Other minor supporting materials are sourced locally.

To ensure minimal inventory level, software is utilised to closely monitor the inventory level and ensure accurate forecasting. Overall the inventory of raw material is kept for the next 15 days.

Communication with suppliers, buyers and logistics companies is conducted through email, telephone and post. All raw material and finished goods are transported by road using trucks. Shipping frequency of both supplies and finished goods is almost daily, of which the quantity is based on demand and ready goods. Inventory is closely monitored to match the demand. All internal communication is through phones and pre-developed forms to keep the physical record.

The company has a maintenance schedule (twice a week) and ensures that all equipment is calibrated as per the schedule provided by regulatory authorities and industry standards. Moreover, the company makes a needful and significant investment to keep their equipment up to date. In the past 2 years, Company A has innovated two of its major processes by introducing a mixing plant for epoxy resin and an authentic CT/PT testing unit.

Company's HR and CSR practices are of a very high standard where the company provides lunch for all employees for 4 out of 5 working days of a week. All employees are given bonuses on religious events (e.g. Eid, Christmas) in the form of 13th-month pay. A flexible work environment is provided where employees are not stressed but yet keep to good standards of practice. Untrained employees are given on the job training.

There is no specific operations management strategy (e.g. Lean, Six Sigma) to manage production operations, however, the company do utilise some aspects of such concepts. For instance, reducing the inventory, continuous development, maintenance schedule.

Wastage - The Company utilise 3D drawing technology to minimise wastage of any raw material and to optimise their product's durability and output. However, they do have direct and indirect waste output from their operations. Direct wastage of copper ranges between 250 – 300 kg annually. This waste is sold to the scrap dealer. Indirect wastage is from multiple factors:

- No refurbishment facility for faulty products and/or returned items from customers
- No end of life cycle management results in loss of residual value of resources that can either be reutilised or re-purposed/ downgraded to be utilised in other types of products. An approximate calculation at current rate of production, would be:
    - Copper 10kg x 14000 = 140,000kg annually
    - Steel 8kg x 14000 = 112,000kg annually

SWOT analysis in the previous section contains some information from the operational aspect as well. In order to understand the overall analysis of the company, it is best to make observations from Gemba Walk and conduct Spaghetti flow analysis, as the MD of the company specifically requested as well, to identify any discrepancies in the production flow system. These will further help to identify the gaps where the company can optimise their operations as well as how by using this framework, they can adopt CE in their operations.

7.3.1.3.1 **Observations from Gemba walk**

Detailed observations were made, where the production manager accompanied the researcher and explained the production process and flow. Following observations were made in addition to earlier inputs from interviews and CMT.

- The workplace is not kept tidy – tools, equipment and the area are not kept clean and this can lead to hazardous incidents as well as the equipment/ tool breakage
- Although the company has ISO certification and in compliance, they have signs to mark the areas and provide safety instruction, etc. but in reality, those signs are not readable as they are not cleaned and have gathered dust over them.
- Health and safety rules are not completely followed, for instance, workers do not wear safety shoes, masks and gloves, there is no uniform or jumpsuit requirement to minimise employee's exposure to hazardous material as well as to avoid the clothes getting in the way of production (i.e. the local dress '*shalwar-kameez*' can fly into the machine/ process).
- There is an unnecessary movement in the process of production, and the flow is not established.

7.3.1.4 Summary of phase 1 (analysis) outputs:

Thematic synthesis approach was considered the most appropriate to summarise the interview results in a categorical manner. Figure 7.2 below presents a summary of the interview results, insights from CMT and Gemba walk observations.

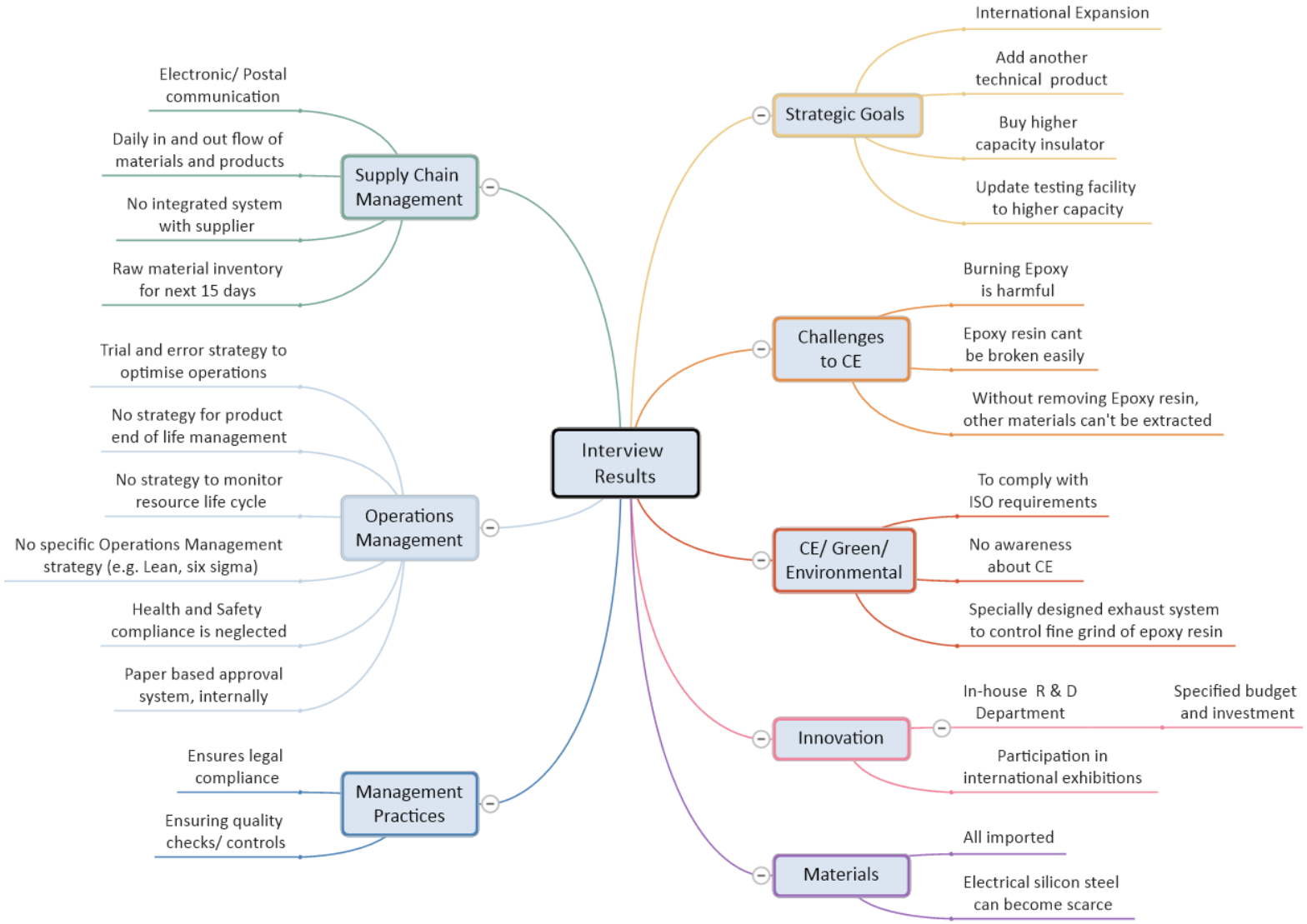


Figure 7.2 Summary of interview results (phase 1) for Company A

With the inputs from phase 1, the next phase of the framework, PLOT, leads to the selection of areas for improvement and planning for intervention.

7.3.2 Phase 2 – Plot

In order to ensure that the efforts are made in the right direction, it is best to plan in a systematic manner, for which the steps provided in Phase 2 are followed (see Figure 7.1).

7.3.2.1 Specify improvement areas/ opportunities

Following avenues (see Table 7.5) are specified as the improvement area/ opportunities.

Table 7.5 Improvement areas/ opportunities for Company A

Improvement Areas	Improvement Opportunities
Strategic	• To include environment and resource preservation/ enhancement into the overall mission and vision of the company.
Tactical	• Deploy Lean as an operations management strategy • Develop an integrated Supply Chain System and require SC members to engage in CE adoption
Operational	• Change the layout of the floor • Train current staff for CE and Green initiatives • Introduce new machinery/ procedures for CE initiatives

While all the above-mentioned improvement areas/ opportunities are worthwhile pursuing, not everything might be possible at once due to different factors (e.g. cost, ease, time requirement). For the purpose to prioritise the intervention strategy, it is found best to utilise the '*Priority Matrix'*, a Lean approach. The template provided by Lean Methods Group (2018) is utilised for this purpose. Table 7.6 presents the criteria ranking for the prioritisation matrix and Table 7.7 presents the prioritisation matrix, weighing the 6 improvement opportunities presented in Table 7.5.

Table 7.6 Criteria ranking for prioritization matrix

	Ease of Implementation	Circular Economy Initiative	Green/ Environment friendliness	Cost Effective	Resource Availability	Cultural Acceptance	Attribute Criteria Weight	Percent of Total Criteria
Ease of Implementation		10.0	5.0	5.0	1.0	1.0	22.00	38.4%
Circular Economy Initiative	0.1		1.0	5.0	1.0	5.0	12.10	21.1%
Green/ Environment friendliness	0.2	1.0		0.2	1.0	5.0	7.40	12.9%
Cost Effective	0.2	0.2	5.0		1.0	1.0	7.40	12.9%
Resource Availability	1.0	1.0	1.0	1.0		1.0	5.00	8.7%
Cultural Acceptance	1.0	0.2	0.2	1.0	1.0		3.40	5.9%
								100.0%

10	Attribute in the white column is extremely more important than the attribute in green column
5	Attribute in the white column is slightly more important than the attribute in green column
1	Attributes are equal in importance
0.2	Attribute in the white column is slightly less important than the attribute in green column
0.1	Attribute in the white column is extremely less important than the attribute in green column

Table 7.7 Project prioritisation matrix for Company A

SCORING PARAMETER	9 (Best)	
	3 (OK)	
	1 (Poor)	

OPTION / PROJECT	EVALUATION CRITERIA							SCORING		
	Ease of Implementation	Circular Economy Initiative	Green/ Environment friendliness	Cost Effective	Resource Availability	Cultural Acceptance	Total & Weighted Project Scores	Priority	Data Availability	Project Complexity
	38.4%	21.1%	12.9%	12.9%	8.7%	5.9%				
A Change the layout of the floor	5	4	6	4	5	6	30 4.85	4		
B Introduce new machinery/ procedures for CE initiatives	5	9	9	3	7	3	36 6.16	3		
C Deploy Lean as operations management strategy	4	4	5	7	5	2	27 4.49	5		
D Train current staff for CE and Green Initiatives	9	9	9	4	7	3	41 7.82	2		
E Develop an integrated Supply Chain System and require SC members to engage in CE adoption	1	9	6	3	3	1	23 3.77	6		
F To include environment and resource preservation/ enhancement into the overall mission and vision of the company	9	9	9	6	9	6	48 8.43	1		

As a result of the priority matrix, the top four interventions are selected to develop further. These four interventions are:

A. To include environment and resource preservation/ enhancement into the overall mission and vision of the company
B. Train current staff for CE and Green Initiatives
C. Introduce New Machinery/ Procedure for CE Initiative
D. Change the Layout of the floor

With these chosen initiatives, it is best to define their scope and goals.

7.3.2.2 Define the scope/ goals

For the earlier mentioned interventions following SMART goals are defined:

Goal 1: Modify the vision and mission statement as well as the quality policy to include environmental and resource preservation as strategic elements with effect from July 2019.

Goal 2: Develop a plan for the next year, for the organisation wide training to increase awareness and knowledge about Circular Economy, Green and Environmental aspect of business and their implications for the company operations.

Goal 3: To innovate the current operations by introducing new equipment and procedures to integrate Circular Economy principles by the end of 2019.

Goal 4: Redesign the layout of the shop floor, by mid-2020, to develop flow and avoid the waste identified by Lean as *'Motion'*, which is an unnecessary movement of people, parts and/or semi-finished products between or within the processes.

7.3.2.3 Feasibility analysis (financial, resources)

Financial and resources feasibility is of utmost importance as without financial support and availability of resources required, no good goals can ever see the realm of reality. Section 7.3.2.1 has included these two factors to weigh in projection (intervention) selection criteria.

Moreover, the company is strongly recommended to re-visit the goals to make any changes, should they find that financial and/or resource feasibility is not in favour.

7.3.2.4 Develop the implementation plan

In order to achieve each of the four goals defined earlier (see section 7.3.2.2), the following action-plan is defined.

Implementation plan for goal 1:

Step 1 – Develop a draft proposal to incorporate CE, Green and Environmental initiatives into corporate strategy and circulate to the company board of directors.

Step 2 – based on the feedback from the board members, a summary of feedback to be shared with all the board members along with a call for a meeting.

Step 3 – A board meeting to further discuss and officially incorporate circular economy, green and environmental initiatives in the company's corporate strategy, values and mission.

Implementation plan for goal 2:

Step 1 – Sort the list of potential training providers (e.g. university, consulting firm).

Step 2 – Choose the training provider and develop a plan to run organisation wide training at different intervals, during the next 12 months starting August 2019. It is important to ensure that training has evaluation criteria which would weigh on the employees' HR records, with better compliance resulting in promotion, rewards and acknowledgement.

Step 3 – Arrange 3-4 full day training seminars over the weekends to create general awareness about the issues

Step 4 – Conduct workshops to share ideas of CE integration in production operations and seek employee's feedback

Step 5 - Periodical refresher training day (every three months) to be organised on a regular basis.

Implementation plan for goal 3:

Step 1 – Request call for quotations by the suppliers of equipment needed to break/ melt the epoxy resin

Step 2 – Select the supplier that provide good quality equipment which matches the requirement criteria

Step 3 – Purchase the equipment to allow for the extraction of re-usable raw material at

the end of product life cycle (i.e. equipment to melt and/or break epoxy).

Step 4 – For future production, upgrade to the utilisation of epoxy resin which can be deformed in jelly form through the application of heat and allow for the extraction of metals inside

Step 6 – Create awareness among customers and offer the take-back option to existing and future customers for responsible disposal/ repurposing of the resources at the end of the product's life.

Implementation plan for goal 4:

For the purpose to identify the product/ people flow the Spaghetti Flow Diagram is utilised and a restructure is proposed to allow for a smooth flow resulting in less movement which potentially could lead to time and cost savings.

Figure 7.3 presents the current layout of the shop floor in Company A and the product flow throughout. Figure 7.4 is the proposed layout, proposing a reconfiguration of the entire first floor. Given the fact that most of the space is an open area and that different working sections are not separated by walls (except for few), it would only take few days and some capital investment to re-configure the layout. Moreover, it is suggested for the company to utilise green construction where blocks are utilised allowing for easy relocation of the lab and other areas that require wall separation. The proposed restructuring follows the same sequence of product flow as before, with relocation of the different functional units to develop a good flow.

The current structure and product flow on the second floor (see Figure 7.5) is appropriate in its current form, therefore no changes are proposed for it.

Step 1 – Make plans with a construction company and the staff of the company A

Step 2 – Develop a contingency plan for the worst-case scenario

Step 3 – Plan for the change implementation schedule and prepare by having enough ready products in storage to meet the demand while the production is stopped.

Step 4 – Initiate the change and closely monitor for timely completion

Step 5 – Upon completion, ensure that all staff are aware of the new structure and that everything is clearly marked (e.g. tools, section) for easy and smooth resuming of the production operations.

As a result of this restructure, an estimated product travel time, collectively between different processes will be reduced by 90% and subsequently better utilisation of the workforce.

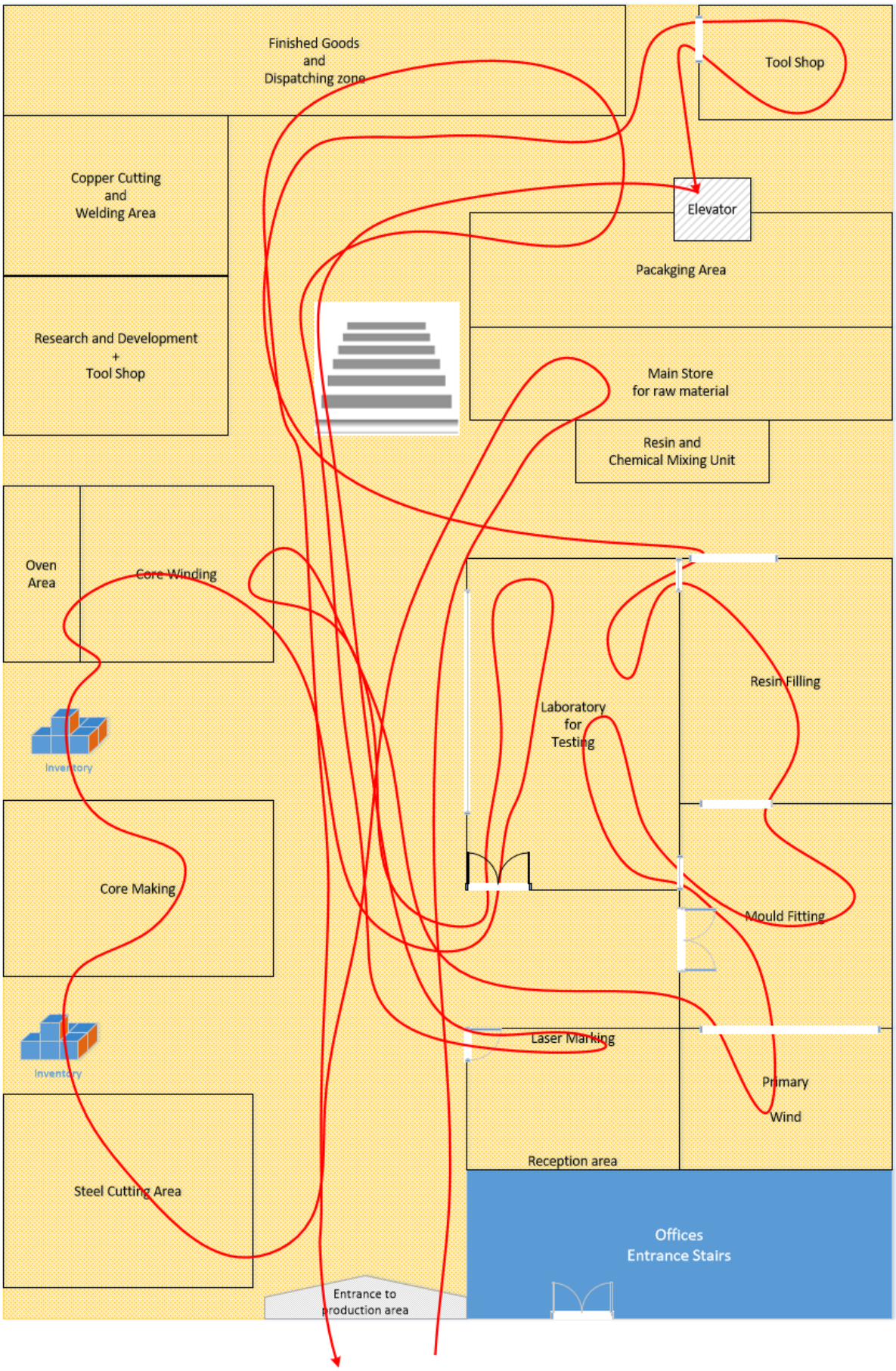


Figure 7.3 Current layout of the shop floor in Company A and the product flow

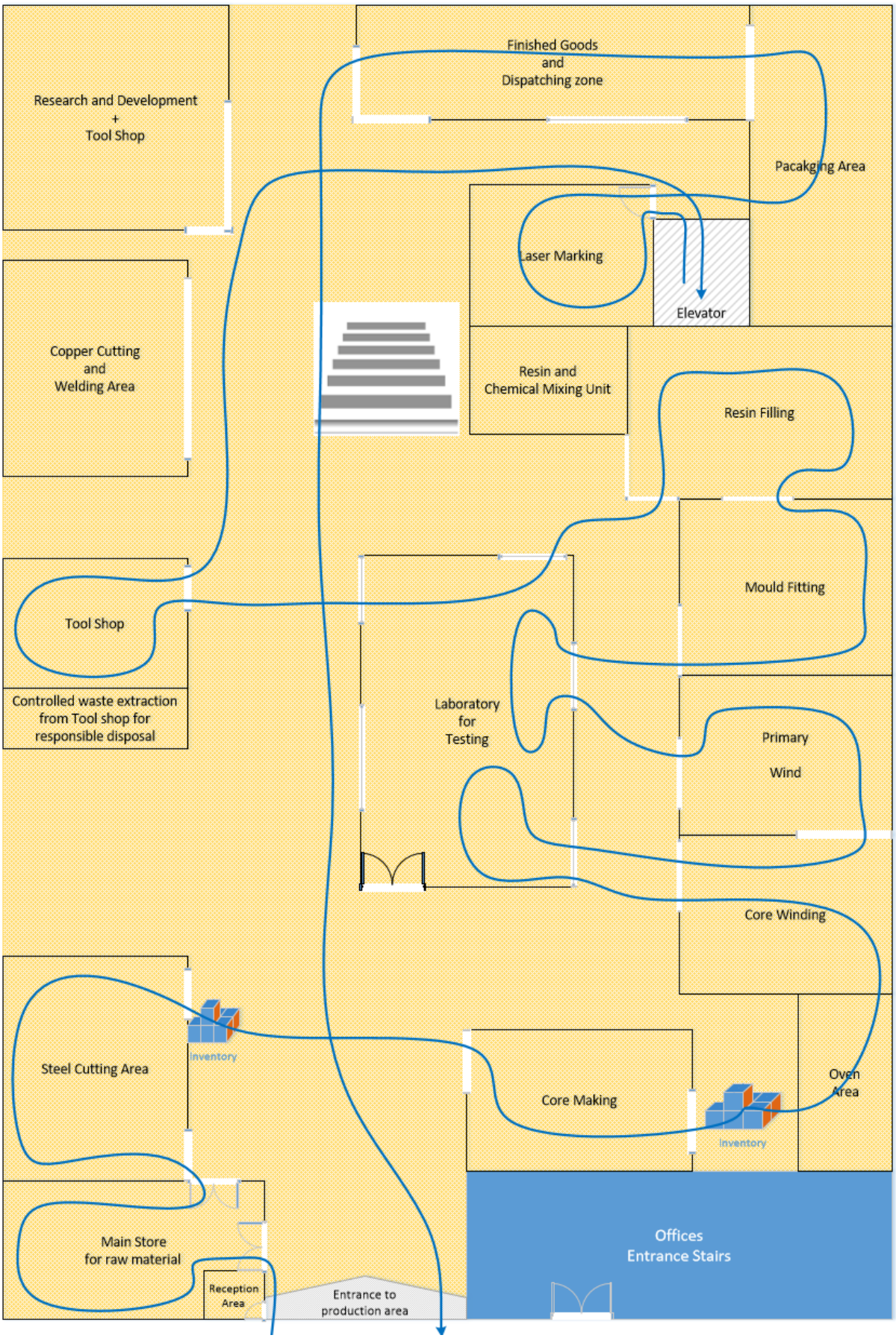


Figure 7.4 The proposed restructuring of the shop floor and product flow in Company A

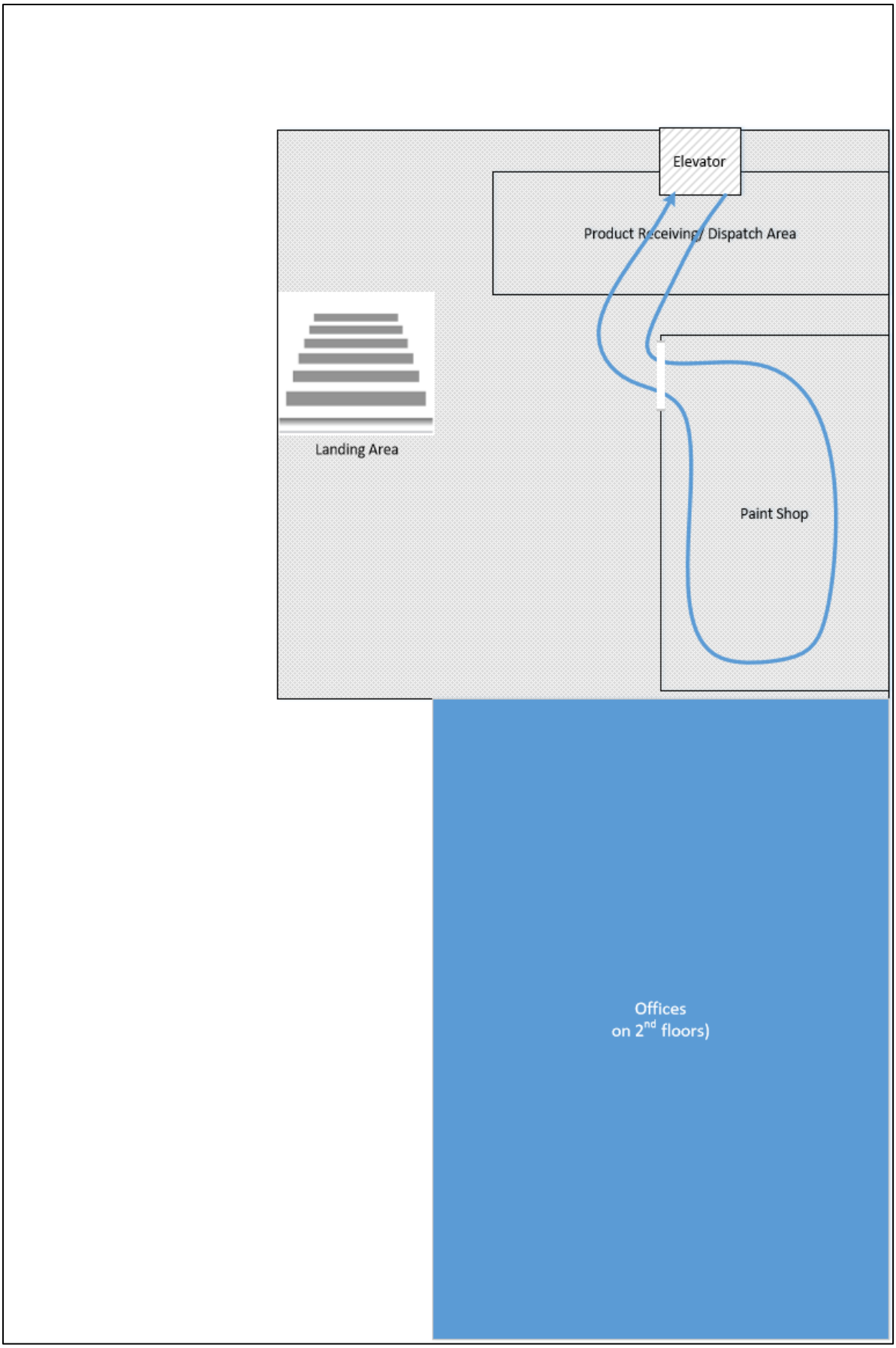


Figure 7.5 Second floor of the production area and product flow in Company A

7.3.2.5 Identify the team and their training needs (if any)

For each goal, the personnel involved and their training needs are mentioned below

Goal 1: Top Management and managerial level staff

Training needs – none, except for awareness about the possible engagement of the company

Goal 2: External organisation and Company A's staff

Training needs – Good coordination and planning for training

Goal 3: Production manager will need to identify at least 3-5 shop floor staff who can be trained to operate the machinery that can be used to break the resin and/or to melt it. Moreover, the adoption of utilising resin that can be melted in the jelly form will require training for employees engaged in that functional division as well as the operations manual made available for reference purpose.

Goal 4: Construction company personnel, production manager, MD, and supervisors of functional divisions

Training needs – Good coordination and planning

7.3.2.6 Develop monitoring/ risk management plan

A plan must be closely monitored for its compliance and progress. For this purpose, the company's production manager along with Technical Director needs to closely monitor the responsible people and have twice a week report on the progress of change at the time of implementation. Thereafter to monitor through bi-weekly progress report to ensure that the implemented change and compliance to them are progressing well with sound outcomes.

No plan is completely free of risk, therefore it is best to identify potential risks and have a plan to manage them to avoid any delays and problems. For the purpose of Risk Management, FMEA (Failure Modes and Effect Analysis) approach is one of the most utilised tools. For Company A, FMEA analysis is conducted and presented in Table 7.8

Table 7.8 FMEA analysis for Company A.

Process Step/Input	Potential Failure Mode	Potential Failure Effects	SEVERITY (1 - 10)	Potential Causes	OCCURRENCE (1 - 10)	Current Controls	DETECTION (1 - 10)	RPN	Action Recommended	Resp.	Actions Taken	SEVERITY (1 - 10)	OCCURRENCE (1 - 10)	DETECTION (1 - 10)	RPN
What is the process step, change or feature under investigation?	In what ways could the step, change or feature go wrong?	What is the impact on the customer if this failure is not prevented or corrected?		What causes the step, change or feature to go wrong? (how could it occur?)		What controls exist that either prevent or detect the failure?			What are the recommended actions for reducing the occurrence of the cause or improving detection?	Who is responsible for making sure the actions are completed?	What actions were completed (and when) with respect to the RPN?				
Arranging training through external trainers	Misunderstanding of training purpose - making it too general	Employees won't be able to adopt it in everyday work life.	6	Miscommunication about expected outcomes	6	Written and verbal communication with training providers	5	180	To request the training plan and expected outcomes	Chief Operations Officer and Production Manager	More rigorous communication and joint planning	3	2	2	12
Training attendance may be poor or training may not be taken seriously	Employees may miss training sessions and/or may not pay attention to the content of the training	Little to no impact of training and as a result, no change/ innovation could be experienced	9	Lack of clarity to employees about the purpose. Also, the lack of a control system to measure and its knowledge to employees.	5	Communication to employees about the purpose of training and expectation from them.	3	135	Supervisors to ensure that employees are aware that the training assessment will impact an employee's HR records	Supervisors	Clear communication and reminders both in written and verbal form	4	1	2	8
Periodical Training	Periodical training needs are not assessed/ planned	Employees feel that training is a waste of time and unnecessary	7	Lack of engagement between training planner and shop floor manager to analyse the need	5	Planning meeting for training	3	105	Develop a plan for the next 12 months and review before each training session to understand current needs. A written report to be submitted to management	Shop floor supervisors/ manager, one member of senior staff, training organiser	Clear communication and reminders both in written and verbal form. All meeting notes are recorded and made available to upper management.	2	2	2	8
Equipment purchase	It is delayed due to financial constraint and/or cheaper quality equipment is purchased	Circular practices are not established and/or the machine functionality is not good due to poor quality	7	Lack of budget allocation and prioritisation.	4	Budgetary allocation and quality inspection before purchase	2	56	Specify budget allowing flexibility on price variation. Request quotations from a different supplier with quality specification and warranty	Procurement Officer	A specific budgetary allocation is made with the flexibility of 10% variance in price. The supplier is chosen based on the best quality and price.	2	2	2	8
Take back of products at the end of their life cycle	The customer might not engage due to the cost of the shipment and the possibility of selling end of life product as scrap.	The residual value of the product component is lost and resources are not kept in the closed-loop system	8	The customer has no awareness of the benefits of engaging in CE. No incentive for the customer to engage in such CE initiatives.	6	Customers are informed of the option to return the end of life product for responsible disposal and extraction of internal components.	4	192	Market about CE initiative and its impact. Provide incentive to customer (e.g. certificate, money). Cover shipping cost.	Supply Chain Manager	A marketing campaign has been launched. Customers are provided with a certificate to market themselves as a participant in CE, as well as the shipment cost is covered.	3	3	2	18
Re-configure the shop floor.	Delay in completion of the project.	Delay in production and meeting the customer's demand	9	Poor planning and lack of a contingency plan	7	An external construction company is hired to plan and a buffer of 2 days is planned while promising the order supplies to customers	3	189	Engage key shop floor staff, production manager and construction company personnel to review the plan and conduct worst case scenario planning.	Production Manager and construction supervisor	The plan is made soundproof with a contingency plan for the worst case scenario.	4	3	3	36

7.3.3 Phase 3 Prepare/ pilot

Any new project requires thorough preparation for the implementation of planned changes. For this purpose, this phase recommends three steps (see Figure 7.1). Company A's Technical Director and Production Manager are to take the lead role as change coordinators, to closely monitor this phase.

7.3.3.1 Train the team/ leadership

The chosen team needs to be trained for the training needs identified in the earlier phase (see section 7.3.2.5). The core purpose of the training is to ensure that everyone involved is aware of the expected outcome and have enough knowledge and skills to be the change maker as part of the team. Moreover, the training is to ensure that the team takes ownership and that the Leadership of the company is equally engaged.

7.3.3.2 Pilot testing

Pilot testing's core purpose is to detect any pitfalls/ error at an early stage and take corrective actions. However, given the interventions recommended for company A, not all interventions can have pilot testing. Therefore, a forecasted scenario analysis (sort of simulation) with key shop floor staff would supplement for pilot testing.

7.3.3.3 Make amendment (if any)

At this stage, the change coordinators need to make a final check and make amendments for any errors/ pitfalls identified during the process of training and forecasted scenario analysis. If the amendments are of major nature then the repetition of phase 3 might be worth pursuing, for which the decision will solely depend on the change coordinator. Thereafter the actual implementation can begin.

7.3.4 Phase 4 Execute

Execute the plan, where the whole team closely follows the planned changes and ensure compliance with, as well as the accuracy of the planned intervention. Change coordinator(s) is to closely monitor the progress.

7.3.5 Phase 5 Evaluate

At this stage, the change coordinators can utilise Circularity Measurement Toolkit (Garza-Reyes et al., 2018) as well as compare the outputs against the set goals to see if they have achieved the desired results. Once the goals are achieved the coordinators can easily move to the next phase. However, in case of negative results, the coordinators need to move to phase 1 or another phase of the framework, depending on the need (see Figure 7.1).

7.3.6 Phase 6 Control

In order to ensure that the implemented change is adopted well and would sustain throughout the company, the coordinators need to follow the four steps suggested in the sixth phase (see Figure 7.1) of the proposed framework. These steps are adapted from the Lean Six Sigma approach of DMAIC (George et al., 2005).

7.3.6.1 Institute the process into the organisation's culture

Since Company A is a medium size company and given the nature and scale of the proposed changes, the majority of the operational staff will be involved in the execution of the plan. However, for the CE to be embraced throughout the company, it is best to institutionalise the CE values and practices throughout the company. To do so, the leadership needs to make sure that the compliance to CE initiatives is not an optional but a regular practice in day to day operations/ practices of the company.

7.3.6.2 Document procedural guidance

For the procedures to be instituted, sustained, practised and embraced throughout the company, it is best to document the CE values, practices and procedural steps adopted through the utilisation of this framework. This would serve as a point of reference for any further development and future employees.

7.3.6.3 Transfer the ownership

Although the change coordinators have taken the main lead throughout the development/ adaptation of the planned changes, it is best to transfer the ownership of its regular practice,

accountability and development to the relevant personnel in different functional divisions. This means authorising them to make the decision to a certain level within the extent of their operations as well as holding them accountable for it.

7.3.6.4 Control gate review

At this stage the change coordinators conclude the process by ensuring the following:

- All documentation of procedural guidance, reference documents, reports of before and after are recorded,
- Process maps and procedural guidance are documented and made available for anyone needing them in everyday operations,
- Any shortcomings and opportunities for future considerations are documented

A celebration of success is important to mark the achievement as well as to acknowledge the team effort and encourage the staff.

7.3.7 Expected outcomes for Company A

Given the successful implementation of 4 improvements discussed earlier, the company A can cherish in being the pioneer in adopting CE and can inspire others within their supply chain as well as outside, to replicate such initiatives.

In order to understand the impact of these improvements, the major outcomes are presented in the form of before and after scenario in Table 7.9 below

Table 7.9 Before and After scenario of Company A

Before	After
Company A's leadership and staff were not aware of CE and its implications for their operations	Company A's staff and leadership is well aware of CE and have taken necessary actions to become a key player in making CE a reality and have become responsible global citizens by caring for resources and environment.

Company A had no CE practice	Company A has adopted CE in its corporate strategy and taken serious initiatives to integrate CE into their operations
The equipment/ practices didn't exist to responsibly manage the product at the end of its life cycle	Company A is offering the take-back option for end of life cycle/ faulty/ damaged products and is extracting metal materials to be re-used in the different form of production (downgrading).
Product flow was not established well and lots of unnecessary movement existed, resulting in a lack of efficiency.	Company A has re-structured its shop floor and now has a remarkable production flow layout which makes the operations smooth and efficient.

7.4 Case study - Company B

Established form the early 1980s, the company is a wholly owned family business and is registered as a private limited company. The company has expertise in the manufacturing of sanitary fittings made of brass and steel. At present, the company employs over 35 staff members, of which 25 are on the shop floor and 10 are in management/ office to oversee the business and manage the facility. Although the company sells its products both nationally and internationally, their major clients are based in the USA, Europe, SAARC region, Middle East and Africa. Company B was awarded *'Export Trophy Award'* by the Federation of Pakistan Chambers of Commerce and Industry; for a significant increase in export in the year 2002 and 2003. Beside national certifications, the company did acquire ISO9000:2000 and ISO9002 certification, however currently these certifications have expired, and company's leadership do not plan on renewing due to costs and efforts involved with little to no impact on sales.

The company's vision is to become a Market leader as a major exporter of the country with high-quality products. The company's mission is to design and develop high-quality products in a cost-effective manner and to expand its market share through international expansion.

The company's leadership maintains a professional work environment and acclaims following as its core values: *Quality, Integrity, Innovation, and Excellence.* Company B's quality policy is as follows:

Quality Policy: *"We have adopted the total quality management approach which has resulted in the maximization of our clients' satisfaction. Stringent quality control inspection includes material tests, dimensional & threading checks with standard gauges, hydraulic pressure test, flow rate test, nickel & chrome adhesion test, coating thickness test and life span test of spindle assembly."*

With this brief overview of the company, the next subsections utilise the phases of the proposed framework to analyse Company B.

7.4.1 Phase 1 – Analyse/ identify

Phase 1 (see Figure 7.1) of the framework suggests to analyses three levels (strategic, tactical and operational level) of Company B.

7.4.1.1 Strategic level analysis

Company's Director was interviewed utilising semi-structured questionnaire (see Appendix E). It is noteworthy that the company's director also oversees all production operations of the company. The discussion was very insightful and since many parts of discussion related directly with operational as well as tactical level, therefore they have been incorporated in those sections later.

In terms of its **strategic goals** for the next 3-5 years, the company strives to:

- Increase the production level and output
- Expand more internationally
- Continuously innovate production processes on a regular basis
- Fully utilise production facility by Dec 2019

When asked about the company's **strategic and operational goals regarding CE and/or Green/ Environmental initiatives**, Company B has no pre-defined goals or strategy specifically designed for such initiatives. Moreover, the company has no knowledge of CE, therefore they don't have any goals/ plans for its adoption.

Company's director was asked to define their priorities while doing strategic/ operational planning. Their responses are summarised in Table 7.10

Table 7.10 Company B's priorities while defining strategic direction

	N/A	Never	Rarely	Some times	Often	Almost always
Reduce Carbon Emission						X
Reduce negative environmental damage						X
Longevity of product						X
Longevity of Resources	X					
Re-utilise resources						X
Financial Growth/ Stability						X
CSR activities				X		

The company makes every effort to reduce carbon emissions and comply with national regulations. Given the nature of business and type of the products, the longevity of the product life cycle is a high priority. However, there is no possibility of control over the end of the life cycle of the product, due to the type of products and usage in a way that it is almost impossible to track it.

When asked about the reason for not having goals related to CE and/or Green/ Environmental initiatives; the director pointed to the fact that they actually never thought about such things. Moreover, the director said that the lack of knowledge of such initiatives, skilled workforce, and a system from regulatory authorities are the major factors that they never thought of developing CE/ Green/Environment-friendly goals.

When shared about CE and asked about potential barriers and challenges in the implementation of CE initiatives, the director pointed to the following factors:

- Lack of interest
- Lack of skills and skilled labour
- Lack of system/ environment
- Lack of supplier and equipment due to lack of skilled labour

The company is a for-profit business and financial growth/ stability is a priority. Company's engagement in CSR activities is occasional and not incorporated in their overall business strategy (see SWOT analysis in Table 7.12).

The company has an in-house research and development department and encourages its employees for innovation in both the production process and product development.

To allow for innovation, the management of the company make visits to other international companies engaged in similar businesses, moreover, they recruit external trainers to provide training for process and skill development of their employees. They also engage with local technical training institutions, however, there is not much input for innovation from that end. The company has an open communication policy where they engage tactical level on a regular basis, in planning and defining the strategic directions of the company.

In order to understand the current circularity level of Company B, further analysis was conducted through Circularity Measurement Toolkit (CMT) (Garza-Reyes et al., 2018).

7.4.1.1.1 Circularity measurement

CMT explored different aspects of the company related to the three levels of the company (strategic, tactical and operational). Table 7.11 below present an overview of the CMT assessment with the full assessment tool results in Appendix G.

Table 7.11 Summary of CMT results for Company B

Rating\Factors	A	B	D	E	F	G	H	I	Result	RANGE Min	RANGE Max
1. Circular developer	0.5	0	0	0.5	1	0	0	0	**2.00**	6.5	8
2. Circular Promoter	0.5	0	0	0.5	1	0			**2.00**	5.5	6
3. Circular	0.5	0	0	0.5	1				**2.00**	3.5	5
4. Waved	0.5	0	0						**0.50**	2.5	3
5. Curved (where A = 1 and B = 1)	0.5	0							**0.00**	2	2
6. Saw tooth (where A = 0.5 to 1 and B = 0.5 to 1)	0.5	0							**0.00**	1	1.5
7. V-shape up (where A=0 and B = 0.5 to 1)	0.5	0							**0.00**	0.5	1
8. ∧-shape down (where A - 0.5 to 1 and B = 0)	0.5	0							**0.50**	0.5	1
9. Linear	0.5	0	0	0.5	1	0	0	0	**2.00**	0	0

As per CMT's calculation, Company B's rating is '*∧-shape down*'. This indicates that the company have no knowledge of CE but they do have some practices of CE. A further analysis was conducted at a tactical level to gain more insight.

7.4.1.2 Tactical level analysis

Company B's Director also manages all the production operations, therefore the previous interview was continued.

Although the company have no former knowledge of CE, an interesting insight surfaced, when asked about the raw material. The company only utilises scrap material as its raw material. The reason to do so is that scrap material is low cost and easy to source through effective management of contracts and supply chain with different scrap dealers in the region. Moreover, no waste goes out from the production area, as the company re-utilises all of the wastage from raw material or faulty products.

When asked about innovation/ process improvement, the company has taken the following initiatives in the last 3 years:

- Manual Lathe machines have been replaced by CNC Lathe machines
- Replaced casting with forging
- Updated nearly all the major machines/equipment to up-to-date technology
- Chinese experts were invited to provide training for CNC lathe and forging processes

Sanitary products are fitted in both commercial and private buildings and are only replaced as and when needed, thus there is currently no possible way for the company to engage in the recollection of the end of the life cycle product for the following reasons, except through scrap dealers:

- The products are scattered geographically in small quantities
- During demolition and/or replacement of sanitary fittings, mostly the old fittings are sent to scrap with other mixed materials (e.g. steel/iron pipes, and ceramic materials)
- The product life cycle depends on the usage and conditions in which it is fitted (e.g. placed inside of walls with cement covering the product partly and/or fully, product exposed to extreme weather conditions), thus there is no specified age for the end of the product life cycle.

For the above reasons, the customer and/or the contractor who is replacing these products is responsible for the product's end of life management. Likewise, there is no system to monitor the resource life cycle. However, the product's material gets re-cycled through scrap collectors and dealers.

For the purpose to precisely categorise the current standing of the company and its potential possibilities and threats, a SWOT analysis is presented in Table 7.12.

Table 7.12 SWOT analysis of Company B

Strength	**Weaknesses**
• Long-standing reputation and expertise • Leading pioneers in this industry • On the job training for employees • Up-to-date equipment – great recent investments for this purpose. • Re-utilisation of wastage from raw material and faulty products • Total Quality Management approach • Great supply chain/ inventory management • Bottom-up communication model to allow for innovation, growth and productivity	• Over 70% of the shop floor staff is unqualified • Health and safety rules are not completely complied with • No integrated supply chain management system with supplier • Production areas are not kept tidy • No maintenance schedule for preventive maintenance • Outdated furnace facility and no measurement of emissions during furnace operations • No copyright of the product designs • Different production functions are not separated properly • Production sections are not fitted with the needed electricity supply. • Lack of advanced technology for prototyping • No strategy to engage in CE, environment-friendly initiatives and CSR activities
Opportunities	**Threats**
• International expansion • Develop integrated supply chain management to reduce inventory level • Adopting CE through involving and integrating SC both horizontally and vertically • To develop new marketing strategies to expand market share. • Utilise 3D printing for prototyping	• A new innovation can be replicated by competitors due to the lack of copyright registration • Competitors might develop a bigger capacity setup • Political instability – e.g. strikes

Company B benefits from a long-standing reputation in the sanitary fitting production sector, as well as are one of the respectable exporters of these products. Company's leadership is committed to expansion and growth of business and has made major investments in the past 3

years, by replacing all the major production equipment. Since the work is mainly labour intensive and most staff is unqualified, thus company bring in external trainers; from both locally and internationally to provide training to their workforce.

The company utilises a Total Quality Management approach in their production operations, where no wrong product is passed on to the next level of processing. This makes the process error proof and allows the company to guarantee 100% functionality of their products. The company runs a very flat structured management approach and employs bottom-up methodology in forming their operations management strategies.

While the business has multiple strength avenues, which are evident by its successful presence in the market, it also has certain weaknesses that it needs to address to sustain its competitiveness and growth in the market. Providing on the job training is beneficial to upskill their employees but is not necessarily a replacement for technical knowledge/ skills obtained through certified qualifications. Over 70% of the shop-floor staff is unqualified which limits the scope and potential for innovation, as the majority of the shop-floor staff is just repeating the processes for which they are trained on the job. However, if they would have a broader understanding, it would contribute to allowing for thinking outside of the box.

Since the company operates in a country where sustainability, environment-friendly factors are neglected at large scale, thus perhaps the company has not paid attention to this aspect nor has made any strong commitment to such initiatives, except where required for certification purposes (e.g. not using harmful material to burn in a furnace). The current furnace unit at Company B is an old style facility and the emissions from it are not measured; therefore, there is no control system placed.

The company also does not have any specific operations management strategy (e.g. Lean), thus the process streamlining and management is weak. For instance, electric wires are kept loose and not fixed in a safe manner, employees do not use safety shoes, areas are not clearly marked therefore semi-finished products are sometimes on the walk-way.

Since all current prototyping is done utilising wood. This is not an environment-friendly methodology as a lot of wood waste occurs, which is then utilised for fire in the furnace. Company B needs to adopt additive manufacturing technologies (e.g. 3D printing) for prototyping.

The company strives to expand its market share, however, the competitors have the same equal

opportunity. Moreover, since the Company B do not copyright their product designs, there is a strong possibility that a product might become very popular due to its unique design features but is replicated by competitors or even worse, that competitors might copyright it under their name. Like other businesses in Pakistan, company B is also faced with certain threats to which they have no control over, such as political instability as well as the law and order situation in the country.

Further analysis at the operational level was carried out to understand the potential for CE integration.

7.4.1.3 Operational level analysis

Production manager assistant and shop floor staff were interviewed to provide further insight at the operational level.

Since the products are of a different type, sizes and the production is based on demand, therefore the production output is calculated in terms of weight. Current production capacity is to process 30 tons of materials (brass and/or steel) per month, however, presently the monthly output is 50% of the capacity. The company is targeting to utilise full capacity by expanding the market share.

There is no specific maintenance schedule, other than just oiling the machines before starting the operations. Maintenance is only carried out when a fault is observed in the output or a break down occurs. When asked about incidents causing disruption in operations in the past 3 years, there is no specific record kept of such but around 10 incidents did occur in the last 3 years; of the following nature:

- Equipment downtime/ damage/ defect – due to electricity voltage fluctuation and power cuts
- Wrong placement of pieces while forging due to human error, resulting in wastage of semi-finished products

Employees are encouraged to seek innovation for both the process and the product. Over the past 3 years, the company has completely replaced all the production equipment and changed the overall processes and layout of the shop floor. There is no specific strategy (e.g. Lean, Six Sigma) to manage production operations, however, the company do utilise Total Quality Management to ensure that every single unit is faultless when presented in the market.

Wastage - Company has an in-house facility where they use AutoCAD system to develop the drawings of the product design, to minimise wastage of any raw material and to optimise their product's durability and output. From the production process, 40-50% of the material goes into wastage but all of this waste is re-utilised in further production. For faulty product, they do try to refurbish the product but mostly it is reutilised as raw material.

SWOT analysis in the previous section contains some information from the operational aspect as well. Gemba Walk helped to make further observations and to gain insights about the company's manufacturing operations. This further helped to identify the gaps where the company can optimise their operations as well as how by using this framework they can adopt CE in their operations.

7.4.1.3.1 Observations from Gemba walk

Detailed observations were made, where the production manager assistant accompanied the researcher and explained the production process and flow. Following observations were made in addition to earlier inputs from interviews and CMT.

- The workplace is not kept tidy – tools, equipment and the area is not kept clean and this can lead to hazardous incidents as well as the equipment/ tool breakage (see pictures in Appendix H)
- Areas are not clearly marked for new and existing employees' ease to identify the different functional zones
- Health and safety rules are not completely followed, for instance, workers do not wear safety shoes, masks and gloves. There is no uniform or jumpsuit requirement to minimise their exposure to hazardous conditions, as well as to avoid the clothes getting in the way of production (i.e. the local dress '*shalwar-kameez*' can fly into the machine/ process).

7.4.1.4 Summary of phase 1 (analysis)

Overall, it is evident that Company B has some exemplary practices of CE, however, they themselves are not aware of it. Moreover, their motivation to do so is not from the perspective of resource preservation and other environmental factors but is purely for economic reasons. Due to lack of awareness, they are also unable to market their involvement in CE and utilise it

as a competitive advantage. There are areas that need improvements that will lead to more efficiency and participation in CE initiatives. In order to summarise the interview results and other inputs, the thematic synthesis approach was considered the most appropriate. Figure 7.6 below presents a summary of the interview results, insights from CMT and Gemba walk observations.

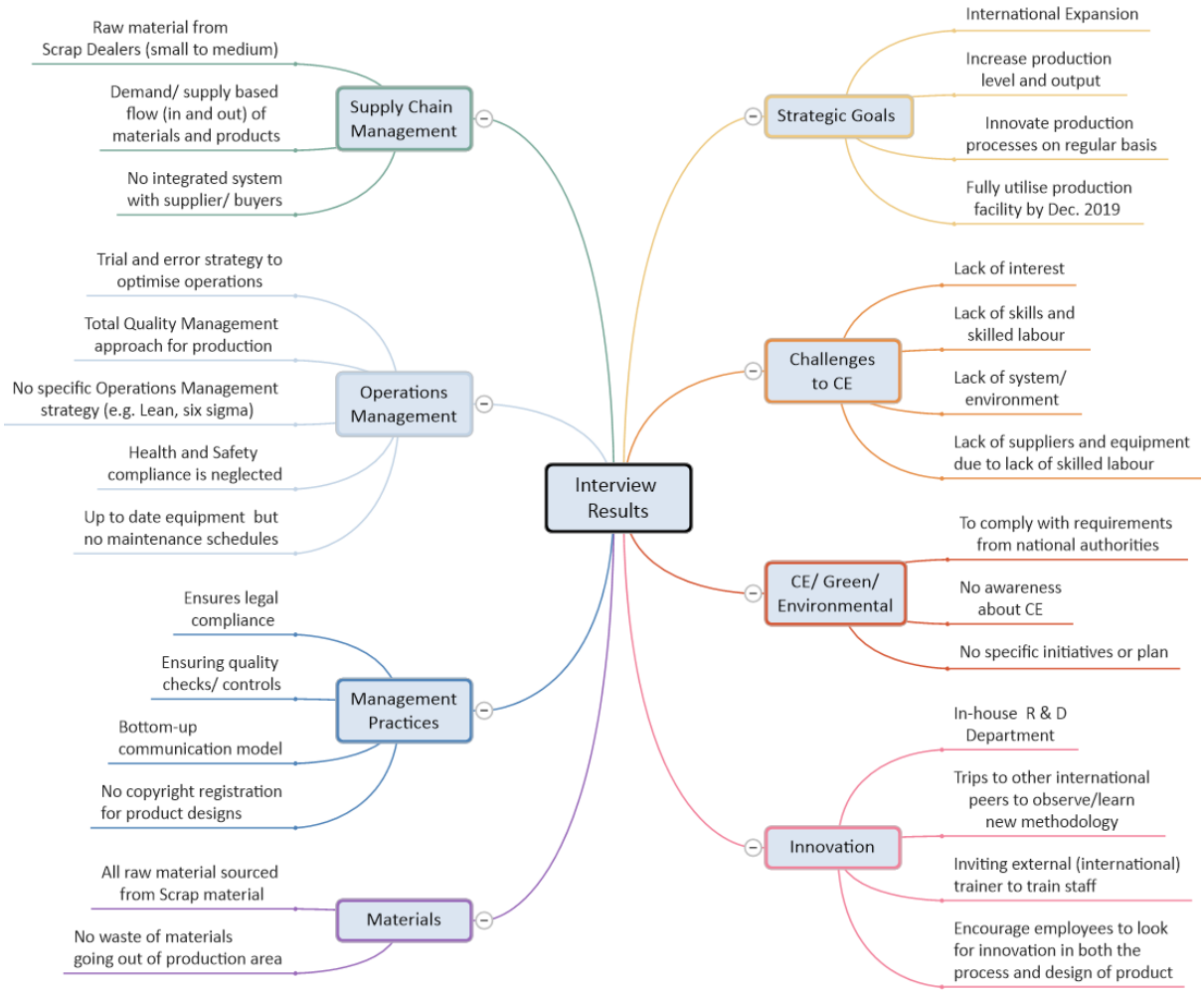


Figure 7.6 Summary of interview results (phase 1) for Company B

With the input from phase 1, the next phase of the framework, PLOT, leads to the selection of areas for improvement and planning for intervention.

7.4.2 Phase 2 – Plot

In order to ensure that the efforts are made in the right direction, it is best to plan in a systematic manner, for which the steps provided in Phase 2 are followed (see Figure 7.1).

7.4.2.1 Specify improvement areas/ opportunities

Following avenues (see Table 7.13) are specified as the improvement area/ opportunities.

Table 7.13 Improvement areas/ opportunities for Company B

Improvement Areas	Improvement Opportunities
Strategic	• Include environment and resource preservation/ enhancement into the overall strategic plans, as well as in the mission and vision of the company.
Tactical	• To recognise Company B's current practices of sourcing raw materials from scrap dealers, as CE initiatives and market accordingly • Deploy Lean as an operations management strategy • Develop an integrated Supply Chain System and require SC members to engage in CE initiatives
Operational	• Provide training about Circular Economy to the existing staff so they also understand that their work is actually a great contributor to CE implementation and encourage innovative ideas. • Develop furnace emission measurement system and update the current furnace (if needed)

While all the above-mentioned improvement areas/ opportunities are worthwhile pursuing, however not everything might be possible at once due to different factors (e.g. cost, ease, and time requirement). For the purpose to prioritise the intervention strategy, '*Priority Matrix'*, a Lean approach is used by utilising a template provided by Lean Methods Group (2018). Table 7.14 presents the criteria ranking for prioritisation matrix and Table 7.15 presents the prioritisation matrix, weighing the 6 improvement opportunities presented in Table 7.13.

Table 7.14 Criteria ranking for prioritization matrix

	Ease of Implementation	Circular Economy Initiative	Green/ Environment friendliness	Cost Effective	Resource Availability	Cultural Acceptance	Attribute Criteria Weight	Percent of Total Criteria
Ease of Implementation		10.0	5.0	5.0	1.0	1.0	22.00	38.4%
Circular Economy Initiative	0.1		1.0	5.0	1.0	5.0	12.10	21.1%
Green/ Environment friendliness	0.2	1.0		0.2	1.0	5.0	7.40	12.9%
Cost Effective	0.2	0.2	5.0		1.0	1.0	7.40	12.9%
Resource Availability	1.0	1.0	1.0	1.0		1.0	5.00	8.7%
Cultural Acceptance	1.0	0.2	0.2	1.0	1.0		3.40	5.9%
								100.0%

10	Attribute in the white column is extremely more important than the attribute in green column
5	Attribute in the white column is slightly more important than the attribute in green column
1	Attributes are equal in importance
0.2	Attribute in the white column is slightly less important than the attribute in green column
0.1	Attribute in the white column is extremely less important than the attribute in green column

Table 7.15 Project prioritisation matrix for Company B

SCORING PARAMETER	9 (Best)	
	3 (OK)	
	1 (Poor)	

OPTION / PROJECT	EVALUATION CRITERIA							SCORING		
	Ease of Implementation	Circular Economy Initiative	Green/ Environment friendliness	Cost Effective	Resource Availability	Cultural Acceptance	Total & Weighted Project Scores	Priority	Data Availability	Project Complexity
	38.4%	21.1%	12.9%	12.9%	8.7%	5.9%				
A. Include environment and resource preservation/ enhancement into the overall strategic plans, as well as in the mission and vision of the company.	9	9	6	7	8	7	**46** **8.15**	**1**		
B. To recognise Company B's current practices of sourcing raw materials from scrap dealers, as CE initiatives and market accordingly	9	9	6	5	7	6	**42** **7.74**	**2**		
C. Deploy Lean as Operations Management Strategy	6	5	5	6	5	6	**33** **5.57**	**4**		
D. Develop an integrated Supply Chain System and require SC members to engage in CE	1	8	6	3	3	1	**22** **3.56**	**6**		
E. Provide training about CE to the existing staff so they also understand that their work is actually a great contributor to CE implementation, and encourage innovative ideas.	7	9	6	5	6	8	**41** **7.01**	**3**		
F. Develop furnace emission measurement system and update current furnace (if needed)	3	4	9	2	4	4	**26** **4.00**	**5**		

As a result of the priority matrix, the top four interventions are selected to develop on further steps. These four interventions are:

1. **A.** Include environment and resource preservation/ enhancement into the overall strategic plans, as well as in the mission and vision of the company.
2. **B.** To recognise Company B's current practices of sourcing raw materials from scrap dealers, as CE initiatives and market accordingly
3. **E.** Provide training about CE to the existing staff so they also understand that their work is actually a great contributor to CE implementation, and encourage innovative ideas.
4. **C.** Deploy Lean as Operations Management Strategy

With these chosen initiatives, it is best to define their scope and goals.

7.4.2.2 Define the scope/ goals

For the earlier mentioned interventions following goals are defined:

Goal 1: To update the vision and mission statement as well as the quality policy of Company B, to include environmental and resource preservation as strategic elements with effect from July 2019.

Goal 2: To calculate the overall resource preservation through Company B's policy of sourcing from scrap metal and its impact in providing business to scrap dealers with a ripple effect to the customers by recycling the waste related to brass and steel. Then develop a marketing strategy to highlight this as a competitive edge by Dec. 2019

Goal 3: To develop a plan for the next 1 year, for organisation wide training to increase awareness and knowledge about CE, Green and Environmental aspect of business and their implications for the company operations.

Goal 4: To begin implementing Lean management strategies throughout the production floor by July 2019 and have the implementation complete by Dec 2019.

7.4.2.3 Feasibility analysis (financial, resources)

Financial and resource feasibility is of utmost importance as without financial support and

availability of resources required, no good goals can ever see the realm of reality. Section 7.4.2.1 has included these two factors to weigh in selection criteria.

Moreover, the company is strongly recommended to re-visit the goals to make any changes, should they find that financial and/or resource feasibility is not in favour.

7.4.2.4 Develop the implementation plan

In order to achieve each of the four goals defined earlier (see section 7.4.2.2), the following action-plan is defined.

Implementation plan for goal 1:

Step 1 – Develop a draft proposal to incorporate CE, Green and Environmental initiatives into corporate strategy and circulate to the company board of directors.

Step 2 – based on the feedback from the board members, a summary of feedback to be shared with all the board members along with a call for a meeting.

Step 3 – A board meeting to further discuss and officially incorporate CE, green and environmental initiatives in the company's corporate strategy, values and mission.

Implementation plan for goal 2:

Step 1 – To utilise a project management tool called '*what-if scenario analysis*', where the calculations are made if the company would utilise virgin raw material for its production.

- Calculate the direct impact, (e.g. cost, change in supplier agreements and benefits of using virgin material)
- Calculate indirect impact (e.g. scrap dealers will lose the market and loss of residual value of the resource)

Step 2 – Compare both scenarios and highlight the benefits of utilising the residual value of resources (i.e. brass, steel), and the difference it makes without compromising the quality of the product.

Step 3 – Engage marketing team to develop on it as one of the unique selling propositions,

that the company does not utilise any virgin material and is a great example of a CE adopter.

Step 4 – Make aggressive marketing through all types of channels (e.g. social media, tv and magazines)

Implementation plan for goal 3:

Step 1 – Sort the list of potential training providers (e.g. university and consulting firm)

Step 2 – Choose the training provider and develop a plan for organisation wide training every 3 months starting August 2019, for one year. It is important to ensure that the training has evaluation criteria, which would weigh on the employees' HR records, with better compliance resulting in promotion, rewards and acknowledgement.

Step 3 – Arrange 2-4 full day training seminars to create general awareness about the issues

Step 4 – After the first year, periodical refresher training day (every six months) to be organised on a regular basis.

Implementation plan for goal 4:

For the purpose to understand the benefits of Lean implementation, company B needs to designate one of the shop floor personnel as 'Lean supervisor'. This person should be provided with necessary training (if needed), tools, and authority to make changes in order to make operations as Lean as possible with the given budgetary allocation.

The Lean supervisor can benefit from an analysis conducted in this research and can build on it further by following these steps:

Step 1 – Utilise following tools to analyse the potential areas for Lean implementation

- Identify the product flow and develop the Spaghetti flow diagram of the current structure
- Conduct value stream mapping (VSM) and find areas needing improvement
- Try to find different types of waste occurring in the production process, using Lean's 8 waste categorisations (defects, overproduction, waiting, transportation, inventory, motion, extra-processing, and un-utilised talent)

Step 2 – Identify potential lean strategies to be utilised and to develop a plan for implementation. Some of the recommended tools are (but company B is not limited to these and can explore more):

- Deploy a Kaizen approach and encourage all employees to continuously seek ways to improve production operations.
- Utilise 5S (Sort, Shine, Set in Order, Standardise, Sustain) as day-to-day practice.
- Adopt a preventative maintenance schedule and strictly follow it
- Develop flow in production processes

Step 3 – Plan for the change implementation schedule and prepare by having enough ready products in storage to meet the demand if the production processes needs to be stopped.

Step 4 – Initiate the change and closely monitor for timely completion

Step 5 – Upon completion, ensure that all staff are aware of the new system and that everything is clearly marked (e.g. tools and functional zones) for easy and smooth resuming of the production operations.

7.4.2.5 Identify the team and their training needs (if any)

For each goal, the personnel involved and their potential training needs are mentioned below

Goal 1:Top Management and managerial level staff

Training needs – none, except for awareness about CE, environment-friendly and Green initiatives.

Goal 2:Procurement manager, account officer, operations manager, marketing manager

Training needs – none, as they just need to get quotations and do a comparative analysis.

Goal 3:External organisation and company B's staff

Training needs – Good coordination and planning for training

Goal 4: One shop floor staff as Lean supervisor and all the shop floor staff

Training needs – Lean supervisor might need Lean management skills training from an external source and then s/he can conduct an in-house seminars/ workshops to develop an understanding of Lean concept and its implications among all staff members.

7.4.2.6 Develop monitoring/ risk management plan

A plan must be closely monitored for its compliance and progress. For this purpose, company Director/ production and operations manager along with the Lean supervisor needs to closely monitor and have a weekly report on the progress of new initiatives at the time of implementation. Thereafter to monitor through bi-weekly progress report to ensure that the implemented initiatives and their adoption is progressing well with expected outcomes.

No plan is completely free of risk, therefore it is best to identify potential risks and have a plan to manage them to avoid any delays and problems. For the purpose of risk management, FMEA (Failure Modes and Effect Analysis) approach is one of the most utilised tools. For Company B, FMEA analysis is conducted and presented in Table 7.16

Table 7.16 FMEA analysis for Company B

Process Step/Input	Potential Failure Mode	Potential Failure Effects	SEVERITY (1 - 10)	Potential Causes	OCCURRENCE (1 - 10)	Current Controls	DETECTION (1 - 10)	RPN	Action Recommended	Resp.	Actions Taken	SEVERITY (1 - 10)	OCCURRENCE (1 - 10)	DETECTION (1 - 10)	RPN
What is the process step, change or feature under investigation?	In what ways could the step, change or feature go wrong?	What is the impact on the customer if this failure is not prevented or corrected?		What causes the step, change or feature to go wrong? (how could it occur?)		What controls exist that either prevent or detect the failure?			What are the recommended actions for reducing the occurrence of the cause or improving detection?	Who is responsible for making sure the actions are completed?	What actions were completed (and when) with respect to the RPN?				
Arranging training through external trainers	Misunderstanding of training purpose - making it too general	Employees won't be able to adopt it in everyday work life.	6	Miscommunication about expected outcomes	6	Written and verbal communication with training providers	5	180	To request the training plan and expected outcomes	Chief Operations Officer and Production Manager	More rigorous communication and joint planning	3	2	2	12
Training attendance may be poor or training may not be taken seriously	Employees may miss sessions and/or may not pay attention to the content of the training	Little to no impact of training and as a result, no change/ innovation could be experienced	9	Lack of clarity to employees about the purpose. Also, the lack of a control system to measure and its knowledge to employees.	5	Communication to employees about the purpose of training and expectation from them.	3	135	Supervisors to ensure that employees are aware that the training assessment will impact an employee's HR records	Supervisors	Clear communication and reminders both in written and verbal	4	1	2	8
Periodical Training	Periodical training needs are not assessed/ planned	Employees feel that training is a waste of time and unnecessary	7	Lack of engagement between training planner and shop floor manager to analyse the need	5	Planning meeting for training	3	105	A written plan to be developed for the next 12 months with the review before each training session to understand current needs, with a report to the top management	Shop floor supervisors/ manager, one member of senior staff, training organiser	Clear communication and reminders both in written and verbal. All meetings notes are recorded and made available to upper management.	2	2	2	8
Calculating the impact of existing CE practices and utilising them as a competitive edge in marketing strategy	The fact that company B is actually not going to buy virgin material, the estimations may not be made accurately	Wrong/ incorrect information can result in misleading marketing, providing an opportunity for competitors	6	Lack of understanding that this has serious implications and that the activity must be done with accuracy	4	Target to utilise this as the competitive edge of the company	5	120	Ensure that each functional division member working on this task is accountable independent of others in the team. This will break the groupthink.	Procurement manager, Account Officer, Operations Manager, Marketing Manager	Each functional division person has made sure that the information gathered is correct to the best of their knowledge.	3	3	3	27
Marketing Strategy development	Lack of clarity and information in marketing approach can lead customers to think that the products are not durable as they are made of recycled materials	Customers will not buy the product and demand can decline	7	Improper design of marketing strategy	4	Engagement of Marketing team in the estimation processes	4	112	Marketing team to have data on quality checks within the company. Moreover, the marketing team to explore the durability of brass and steel after recycling and use it as a validation benchmark.	Marketing Team and Operations Manager	Marketing team included the quality control information in marketing material along with the mention of similar international practices as validation benchmark.	3	3	3	27
Lean Implementation	Since the business works without it at present, so employees might not adopt/ engage fully.	Poor adaptation of Lean would not make any actual impact on business efficiency/ effectiveness	7	Status quo can lead to the ignorance/ poor adaptation of Lean	6	Seminar/ Workshop for all shop floor staff	4	168	Involve employees to plan for Lean implementation within their functional divisions.	Lean Supervisor and Shop floor staff	Employees feel engaged and responsible for implementation. As a result, a good adaptation of Lean is observed.	3	3	2	18

7.4.3 Phase 3 Prepare/ pilot

Any new project requires thorough preparation for the implementation of planned changes. For this purpose, this phase recommends three steps (see Figure 7.1). Company B's Director and chosen Lean supervisor are to take the lead roles as change coordinators, to closely monitor this phase.

7.4.3.1 Train the team/ leadership

The chosen team needs to be trained for the training needs identified in the earlier phase (see section 7.4.2.5). The core purpose of the training is to ensure that the team fully understands and takes the ownership of the initiatives and that the Leadership of the company is equally engaged.

7.4.3.2 Pilot testing

Pilot testing's core purpose is to detect any pitfalls/ error at an early stage and take corrective actions. However, given the nature of interventions recommended for company B, not all interventions can have pilot testing. Therefore, a forecasted scenario analysis (sort of simulation) with key shop floor staff would supplement for pilot testing. Goal 2 (marketing strategy) and Goal 4 (Lean implantation) can be pilot tested at a smaller scale. For instance, a marketing strategy can be tested in a specific region only (e.g. USA, Europe) and Lean implementation can be tested in one functional division first before rolling it off in all the shop floor divisions.

7.4.3.3 Make amendment (if any)

The team and the change coordinators, need to make a final check and make amendments for any errors/ pitfalls identified during the process of training, forecasted scenario analysis, and pilot testing. If the amendments are of major nature then the repetition of phase 3 might be worth pursuing, for which the decision will solely depend on the change coordinators. Thereafter the actual implementation can begin.

7.4.4 Phase 4 Execute

Execute the plan, where the whole team closely follows the planned changes and ensure compliance with, as well as the accuracy of the planned intervention. Director and Lean supervisor (change coordinators) need to closely monitor the progress.

7.4.5 Phase 5 Evaluate

To measure/ evaluate the progress of implemented changes, the change coordinators can utilise circularity measurement toolkit (Garza-Reyes et al., 2018) as well as compare the outputs against the set goals to see if they have been achieved. Once the goals are achieved, the coordinators can easily move to the next phase. However, in case of negative results, the coordinators need to move to phase 1 or another phase of the framework, depending on the need (see Figure 7.1).

7.4.6 Phase 6 Control

In order to ensure that the implemented change is adopted well and would sustain throughout the company, the Director and Lean supervisor along with other responsible personnel need to follow the four steps suggested in the sixth phase (see Figure 7.1) of the proposed framework. These steps are adapted from the Lean Six Sigma approach of DMAIC (George et al., 2005).

7.4.6.1 Institute the process into the organisation's culture

Since Company B is a medium size company and given the nature and scale of the proposed changes, the majority of the operational staff will be involved in the execution of the plan. However, it is best to institutionalise the CE values and practices throughout the company. To do so, the leadership needs to make sure that the acknowledgement of and compliance to CE initiatives is not an optional but is a regular practice in day-to-day operations/practices of the company.

7.4.6.2 Document procedural guidance

For the procedures to be instituted, sustained, practised and embraced throughout the company, it is best to document the CE values, operational practices and procedural steps adopted through

the utilisation of this framework. This would serve as a point of reference for any further development and future employees.

7.4.6.3 Transfer the ownership

Although the Director, Lean supervisor and other functional division supervisors have taken the main lead throughout the development/ adoption of the planned changes, it is best to transfer the ownership of its regular practice, accountability and development to the relevant personnel in different functional divisions. This means authorising them to make the decision to a certain level within the extent of their operations as well as holding them accountable for it.

7.4.6.4 Control gate review

At this stage the change coordinators conclude the process by ensuring the following:

- All documentation of procedural guidance, reference documents, reports of before and after are recorded
- Process maps and procedural guidance are documented and made available for anyone needing them in everyday operations
- Any shortcomings and opportunities for future considerations are documented

A celebration of success is important to mark the achievement as well as to acknowledge the team effort and encourage the staff.

7.4.6.5 Expected outcomes for Company B

Given the successful implementation of 4 improvements discussed earlier, the company B can cherish in being the pioneering example of CE and can inspire others within their supply chain as well as outside, to replicate such initiatives.

In order to understand the impact of these improvements, the major outcomes are presented in the form of before and after scenario in Table 7.17

Table 7.17 Before and After scenario of Company B

Before	After
Company B's leadership and staff were not aware of CE, and that some of their business practices are already complying with CE implications for their operations	Company B's staff and leadership are now well aware of CE and have taken necessary actions to make them a key player in making CE a reality
Company B had not integrated CE into their corporate strategy	Company B has adopted CE as its corporate strategy and taken serious initiatives to integrate CE into its operations
Company B didn't utilise CE as a competitive edge in their marketing strategy	Company B has utilised CE as a competitive edge in their marketing strategy. Since Western Markets are well aware of resource scarcity and have growing awareness about CE initiatives, therefore Company B is seeing market expansion as a result.
Company B had all resources but didn't manage them under specific strategy (e.g. Lean) and as a result, the efficiency was not monitored/ optimised, incidents occurred, and potential possibilities of business growth went overlooked.	Company B has now adopted a Lean production management strategy. As a result, processes are streamlined and flow is developed. Moreover, due to the preventive maintenance schedule, the equipment/ process breaks down is close to none.

7.5 Conclusions

This chapter further tests the verified framework (C-LEAN) in the real-world scenario to validate it. The framework is tested in two medium size manufacturing firms from the electrical and sanitary industry. Due to time constraint, cost implications, and approval requirements from the company leadership, the full-scale implementation could not be conducted. Only the first two phases of the framework have been utilised with the industry personnel. These are further developed by the researcher as a projected scenario. While this is a limitation of the validation, scholars (discussed earlier) also point to the fact that a full-scale application is often not realistically possible. However, this partial application does not affect the potential of the proposed framework.

The case studies discussed in this chapter and potential outputs through analysis and implementation of C-LEAN framework further confirms that the proposed framework is well developed to deliver the purpose it has been developed for, achieving CE integration in manufacturing operations.

Chapter 8 Conclusions, limitations and future research directions

A total of 7 chapters preceded this chapter providing information regarding the overall aims, and objectives exploring the concept of CE and existing gaps in academic literature regarding its implementation in Manufacturing SMEs. The literature review in chapter 2 and 3 provides an overview of the current academic research with its limitations and explores the potential merger of CE with Lean. Chapter 4 provides an overall research methodology adopted throughout this research. Chapter 5 details information about the conceptual development of the proposed C-LEAN framework for manufacturing SMEs, followed by its verification through a Delphi study in Chapter 6. Delphi study deployed the experts from both the academic and industrial backgrounds to ensure that the construct of the framework is valid and relevant for its intended purpose. Thereafter Chapter 7 validates the proposed framework through partial implementation utilising case study method, affirming the usefulness and practical relevance of the proposed framework. With that, this chapter now presents overall conclusions with limitations and future research directions.

8.1 Conclusions

CE is at its developing stage and has attracted considerable attention from both academics and practitioners. As a result, much research on the concept of CE has been conducted over the last decade. Published research affirms the scope of CE to be promising to address the present day challenges of resource scarcity, environmental damage, and waste creation. However, there is a lack of implementation strategies/ frameworks for the manufacturing sector to assist their transition towards CE.

So far only larger firms (e.g. Dell, Apple and P&G) have adopted CE, however, the results are yet to be seen from this adoption. There is limited research regarding practical implementation strategies and tools for CE, especially among manufacturing SMEs. SMEs contribute a major proportion to national GDPs globally and are an important element of any economy. Often SMEs lack the resources and capabilities that a larger firm usually have or can easily afford. In this manner, it becomes hard for SMEs to adopt a new concept such as CE.

Most of the literature suggests that CE requires radical changes to the existing system. As much as it is true, one cannot neglect the success of existing production operation models/ concepts. For this purpose, this research explores the potential merger of CE with Lean as both concepts

focus on waste elimination and value creation, although both have a different approach to these two core elements. A thorough study proved that Lean can be adapted and merged with CE principles. In result, a conceptual framework (C-LEAN) was developed.

The proposed framework merges the principles of Lean and CE, and develops a hybrid understanding of the 5 elements: Systems Thinking, Value, Waste, Optimisation, and Circularity. Under the broad spectrum of these 5 surrounding principles, a phase by phase approach is adopted to systematically analyse, plan, pilot, implement, evaluate, and control the process of transitioning to CE adoption in manufacturing SMEs.

The conceptually developed framework was further verified through a Delphi study by reaching a consensus among experts (academic and practitioners) on its construct and usefulness. Even with participant anonymity, the two cycles of the Delphi study reached consensus among the participants. Constructive criticism from the two cycles of Delphi study greatly helped in streamlining the conceptual framework by ensuring its academic rigour and practical relevance. As a result, many changes proposed by the experts were incorporated and a verified framework was developed.

The verified framework was then validated through a case study approach whereby, partial application of the framework was done in two manufacturing SMEs in Pakistan. Full implementation was not possible as it requires capital investments, changes in the existing system and procedures at the respective companies and above all longer duration to observe the results. However, the partial implementation mingled with the projected scenario is found sufficient to confirm the validity of the framework and its practical relevance.

8.2 Theoretical contributions of this research

This research contributes to both the theory and practice by achieving its aim *to explore the potential amalgamation of the two concepts of Lean and CE to benefit from each other's strengths and build on their synergetic properties to benefit the manufacturing sector, especially at SMEs level*.

In terms of its theoretical contribution, the research has expanded the knowledge base on the practical implementation/ adoption of CE. The study has achieved this by developing on the emerging theoretical concept of Circular Economy and a well-established existing concept of Lean. An in-depth review of these two concepts has led to the identification of their common

aims of eliminating waste and creating value. Both concepts have a different approach to their common aims and thus the need for their amalgamation arose, under which the proposed framework, C-LEAN, has been developed. In essence, this research has the following major theoretical contributions. Firstly the alignment of the two concepts of CE and Lean through an in-depth analysis of the literature to identify the core philosophies of both the concepts. Both CE and Lean focus on elimination of waste and creation of value, however, their approach to these two elements is different. CE focuses on creating a circular loop where no waste is generated, instead waste becomes food (raw material) for another or the same product. On the other hand, the Lean approach is purely from the economic and operational point of view where the optimisation is achieved in a linear fashion to satisfy the value desired by the customer. In order to do so, the Lean concept proposes the identification and elimination of waste activities that do not add value to the product/service desired by the customer. However, the Lean approach does not incorporate the bigger picture scenario where the resource depletion, environmental degradation and related factors would be incorporated. CE does address these issues, nevertheless, its adoption in the manufacturing sector requires the development of a solid pathway that would be both practical as well as attractive for the manufacturing sector.

With this, the second major theoretical contribution of this research is the framework C-LEAN. In the purview of this framework 5 overarching principles (Systems thinking, Circularity, Optimisation, Value, and Waste) are adapted by combining the core principles of both concepts of CE and Lean. To benefit from the synergy of the two concepts and to ensure their coherence, a re-definition of each of the five overarching principles have been developed. These redefinitions pave the way to extend the scope of earlier definitions and to envelop the spectrum of CE. Furthermore, the framework defines the pathway that a company can utilise to achieve circularity in their existing operations while benefitting from Lean tools within the scope of redefined overarching principles under C-LEAN framework.

Another novelty of this research framework is that a company/ organisation does not necessarily have to have a problem to utilise it. It might be that a company's operations are running effectively in its current context and do not necessarily have any operational issues. However, the framework C-LEAN can be adapted to move towards Circularity, which perhaps was not part of the company's priorities due to lack of awareness, skills, etc.

8.3 Managerial contributions of this research

In terms of the practical contribution of this research that the managers can benefit from, the research has provided a roadmap for the manufacturing sector, especially at SMEs level to achieve circularity in their manufacturing operations while achieving efficiency and effectiveness (to its fullness as per CE) promised by Lean tools. The manufacturing sector is more open to Lean since it closely resembles their core aims of efficiency and effectiveness while achieving economic growth, as well as its widespread adoption and successful outcomes. Therefore, an integrated approach through the framework C-LEAN makes it attractive for managers to adopt. Moreover, the proposed approach does not require the companies and its management to make radical changes that might require a complete changeover of the process, but it helps to identify the path that could lead to achieving efficiency, effectiveness while achieving circularity in their operations.

The framework's use of phase by phase approach makes it easier for the managers to ensure the systematic approach to the application which would not only result in achieving circularity as the end result but would also ensure that the approach to do so is mistake proof (called *Poka Yoke* in Lean approach). Through careful planning and following the steps under each phase before moving to the next, would enable managers and workforce to have clear directions for moving forwards with firm confidence from the success of the previous phase.

Another major managerial contribution of this research and its proposed framework C-LEAN is that it provides a comprehensive method which is easy to understand, utilise, and at the same time does not require radical changes into the existing operations. SMEs that usually are constrained on resources such as financial, human and other aspects related to acquiring knowledge to adopt the concept of CE, can benefit by adopting C-LEAN in their operations to achieve circularity. This will also benefit SMEs to become a supply chain member for larger firms who are more conscious of circularity practices and requires the suppliers to comply with its principles as well.

With these contributions of the research, it has achieved its aim and objectives defined at the beginning of the research. Following five objectives were defined and below the conclusion on each of those objectives is provided.

RO 1 – To understand the concept of Circular Economy, its scope and implications

The above research objective has been achieved through the exploration of literature and the research conducted thus far in the field of CE. The literature review provided an in-depth understanding of the CE, its dimensions and implications for different players in any economy. It helps understand the urgency to action as the current linear economic system is doomed to the destruction that could lead to extreme levels of resource scarcity as well as the negative impact to the environment around. The literature further helped to understand that CE as a contrasting approach demands for new rules of the game which means that businesses need to change their current way of production and business. This led to the identification of the gap that exists as there is a lack of comprehensive frameworks for its adaptation in the manufacturing sector, especially at SMEs level.

RO 2 – To explore the synergies and divergences between Circular Economy and Lean

The above objective was achieved through exploring literature about the concept of Lean, its principles, structure and strategies. This led to the identification of the fact that both Lean and CE focuses on reduction/elimination of waste and creation/preservation of value. However, both the concept of CE and Lean have a different approach to these core elements. Although the two concepts of CE and Lean emerged independently at a very different time and due to purely different stipulations, their combination seems natural as their core focus is same with a narrow and broader view of the context, respectively. Thus, further exploration of literature led to the identification of synergies between CE and Lean and directed to their potential merger for the manufacturing sector.

RO 3 – To amalgamate the strengths of the two concepts and develop an implementation framework for the manufacturing sector, especially at SMEs level

The above objective was achieved through the development of conceptual development of the framework called *'C-LEAN'*, providing an integrated approach to optimise manufacturing operations to achieve circularity along with efficiency and effectiveness. In this amalgamation, the core principles of both concepts have been merged and five surrounding principles (Systems Thinking, Circularity, Optimisation, Value, and Waste) have been defined. Since both concepts of CE and Lean had their distinct approach to their individual principles, a redefinition of the earlier mentioned five principles was necessary.

This resulted in a hybrid version of definitions to envelop the spectrum of the two concepts and explicitly define their breadth. Furthermore, a phase by phase approach was utilised to develop a systematic approach in defining the steps of the framework. In result, a conceptual framework was developed.

RO 4 – To verify the developed framework through experts' opinion

The above objective was achieved through verification of the conceptually developed framework. Delphi study approach was utilised where experts from both the academic and industry background were sought for their critique, opinion and feedback. This helped to ensure that the construct of the framework is both in line with theory as well as is of practical relevance. Two rounds of Delphi study led to re-shape the framework with additions, deletion, and amendments to the first conceptually developed framework. In result, a much refined and enriched framework, which has both solid grounds in academic literature and practical relevance, was developed.

RO 5 – To validate the developed framework through implementation

The above objective was achieved by validating the verified framework through a case study approach. Two manufacturing SMEs were selected through volunteer sampling method and a partial implementation of the verified framework was done. A full-scale implementation was not possible due to several constraints such as time, capital, approval requirements, skills, and technology. Partial implementation for initial phases of the framework provided sufficient and insightful information to develop the projected scenario for the remaining phases of the framework. It affirmed and validated that the framework is both capable and realistic for the purpose it has been developed for and the claim that it has made at the time of its conception and development.

8.4 Limitations

Like any other research, this research is no exception to limitations. One of the major limitations in this research is the lack of quantitative approach. Since the research is primarily qualitative with few quantitative elements. The utilisation of increased quantitative measures would further strengthen and validate the reliability of the framework developed and its

outcomes. Furthermore, the quantitative aspect will also enhance the analysis to guide the user in the precise direction as well as to predict the outputs in more quantifiable terms.

Another limitation of this research is that it has been validated only through two case studies in one country. Although the two companies are from different industrial sectors, both companies share a similar business context. By having the same economic, cultural and business context, the companies are faced with similar challenges, barriers, and are similar regulatory framework/authorities. This limits the exploration of other potential challenges that could occur in the implementation of the framework, which can point to the requirement of potential additions for further flexibility and enrichment of the framework to make it more practical for users.

Furthermore, the validation of the developed framework is done employing part of the framework (only the first two phases) with the remaining phases presented as a projected scenario for the company. A full-scale implementation could help expose areas requiring improvements/ modifications in the construct of the framework from a practical point of view. It also would lead to further identification of its limitations.

8.5 Future research directions

The above-mentioned limitations affirm that there is a need to further explore other potential avenues to incorporate in future research. Following research directions are considered vital for future research:

- Conducting a focus group and in-depth interviews with scholars will greatly help to further explore the depth and potential scrutiny of the framework
- More case studies in different countries can provide the possibility to benchmark the findings
- More time spent with companies for a more thorough analysis, such as Value Stream Mapping, would further benefit to highlight the impact of CE adoption through the proposed framework
- The proposed framework should also be tested in the service sector, as Lean has been widely adopted across different sectors of business. Doing so might further expand the scope of the framework and its impact.

During the Delphi study, experts pointed to a few elements that were not incorporated in current

research to ensure that the research focus does not deviate. These are included for future research directions:

- To include Technology Architecture and Innovation Strategy and Management
- To expand the scope of the framework to the service sector
- To provide a more graphical version with symbols and signs, that would make it easier for users to utilise it

REFERENCES

AbdEllatif, M., Farhan, M.S., Shehata, N.S., 2018. Overcoming business process reengineering obstacles using ontology-based knowledge map methodology. Futur. Comput. Informatics J. 3, 7–28.

Abreu, M.C.S. de, Ceglia, D., 2018. On the implementation of a circular economy: the role of instituional capacity-building through industrial symbiosis. Resour. Conserv. Recycl. 138, 99–109.

Adamides, E.D., Karacapilidis, N., Pylarinou, H., Koumanakos, D., 2008. Supporting collaboration in the development and management of lean supply networks. Prod. Plan. Control 19, 35–52.

Adler, M., Ziglio, E., 1996. Gazing into the oracle: The Delphi method and its application to social policy and public health. Jessica Kingsley Publishers, London.

Alves, A.C., Dinis-carvalho, J., Sousa, R.M., 2012. Lean production as promoter of thinkers to achieve companies ' agility. Learn. Organ. 19, 219–237.

Anand, G., Kodali, R., 2008. Development of a Conceptual Framework for Lean New Product Development Process. Int. J. Prod. Dev. 6, 190–224.

Anand, G., Kodali, R., 2010. Analysis of Lean Manufacturing Frameworks. J. Adv. Manuf. Syst. 09, 1–30.

Andersen, M.S., 2007. An introductory note on the environmental economics of the circular economy 133–140.

Andersson, R., Torstensson, H., Håkan, E., 2006. Similarities and differences between TQM, six sigma and lean. TQM Mag. 18, 282–296.

Andrés-López, E., González-Requena, I., Sanz-Lobera, A., 2015. Lean Service: Reassessment of Lean Manufacturing for Service Activities. Procedia Eng. 132, 23–30.

Andrews, D., 2015. The circular economy, design thinking and education for sustainability. Local Econ. 30, 305–315.

Antikainen, M., Valkokari, K., 2016. A Framework for Sustainable Circular Business Model Innovation. Technol. Innov. Manag. Rev. 6, 5–12.

AR, R., Al-Ashraf, M., 2012. Production Flow Analysis through Value Stream Mapping : A Lean Manufacturing Process Case Study. Eng. Procedia 41, 1727–1734.

Araujo Galvão, G.D., De Nadae, J., Clemente, D.H., Chinen, G., De Carvalho, M.M., 2018. Circular Economy: Overview of Barriers. Procedia CIRP 73, 79–85.

arc21, 2017. Waste Management Plan [WWW Document]. URL https://www.arc21.org.uk/what-we-do/waste-management-plan (accessed 3.3.17).

Asyali, E., Bastug, S., 2014. Influence of scientific management principles on ISM Code. Saf. Sci. 68, 121–127.

Azevedo, S., Carvalho, H., Duarte, S., 2012. Influence of Green and Lean Upstream Supply Chain Management Practices on Business Sustainability. IEEE Trans. Eng. Manag. 59, 753–765.

Baines, T., Lightfoot, H., Williams, G.M., Greenough, R., 2006. State-of-the-art in lean design engineering: A literature review on white collar lean. Proc. Inst. Mech. Eng. Part B J. Eng. Manuf. 220, 1539–1547.

Baines, T.S., Lightfoot, H.W., Benedettini, O., Kay, J.M., 2009. Defining lean production: some conceptual and practical issues. TQM J. 21, 127–142.

Ballard, G., Tommelein, I., 2012. Lean management methods for complex projects. Eng. Proj. Organ. J. 2, 85–96.

Banawi, A., Bilec, M.M., 2014. A framework to improve construction processes: Integrating lean, green and six sigma. Int. J. Constr. Manag. 14, 45–55.

Belekoukias, I., Garza-Reyes, J.A., Kumar, V., 2014. The impact of lean methods and tools on the operational performance of manufacturing organisations. Int. J. Prod. Res. 52, 5346–5366.

Bey, N., Hauschild, M.Z., McAloone, T.C., 2013. Drivers and barriers for implementation of environmental strategies in manufacturing companies. CIRP Ann. - Manuf. Technol. 62, 43–46.

Bhamu, J., Sangwan, K.S., 2014. Lean manufacturing: literature review and research issues. Int. J. Oper. Prod. Manag. 34, 876–940.

Bhasin, S., Burcher, P., 2008. Lean viewed as a philosophy. J. Manuf. Technol. Manag. 17,

56–72.

Bicheno, J., 2004. The Lean Toolbox. PICSIE Books, Buckingham.

Billgren, C., Holmén, H., 2008. Approaching reality: Comparing stakeholder analysis and cultural theory in the context of natural resource management. Land use policy 25, 550–562.

Black, N., Murphy, M., Lamping, D., McKee, M., Sanderson, C., Askham, J., Marteau, T., 1999. Consensus development methods: a review of best practice in creating clinical guidelines. J. Health Serv. Res. Policy 4, 236–248.

Bocken, N.M.P., Olivetti, E.A., Cullen, J.M., Potting, J., Lifset, R., 2017. Taking the Circularity to the Next Level: A Special Issue on the Circular Economy. J. Ind. Ecol. 21, 476–482.

Boscari, S., Danese, P., Romano, P., 2016. Implementation of lean production in multinational corporations: A case study of the transfer process from headquarters to subsidiaries. Int. J. Prod. Econ. 176, 53–68.

Boulding, K.E., 1966. The Economics of the Coming Spaceship Earth. Environ. Qual. Issues a Grow. Econ. 1–8.

BR, R.K., Sharma, M.K., Agarwal, A., 2015. An experimental investigation of lean management in aviation: Avoiding unforced errors for better supply chain. J. Manuf. Technol. Manag. 26, 231–260.

Brancheau, J.C., Janz, B.D., Wetherbe, J.C., 1996. Key Issues in Information Systems Management: 1994-95 SIM Delphi Results. MIS Q. 20, 225–242.

Braungart, M., McDonough, W., 2002. Cradle to Cradle. North Point Press, New York.

Braungart, M., McDonough, W., Bollinger, A., 2007. Cradle-to-cradle design: creating healthy emissions - a strategy for eco-effective product and system design. J. Clean. Prod. 15, 1337–1348.

Braw, E., 2014. Five countries moving ahead of the pack on circular economy legislation [WWW Document]. Guard. URL https://www.theguardian.com/sustainable-business/2014/oct/29/countries-eu-circular-economy-legislation-denmark-sweden-scotland (accessed 4.3.17).

Broomfield, D., Humphris, G.M., 2001. Using the Delphi technique to identify the cancer education requirements of general practitioners. Med. Educ. 35, 928–937.

Brunet, A.P., New, S., 2003. Kaizen in Japan: an empirical study. Int. J. Oper. Prod. Manag. 23, 1426–1446.

Buren, N. Van, Demmers, M., Heijden, R. Van Der, Witlox, F., 2016. Towards a Circular Economy: The Role of Dutch Logistics Industries and Governments. Sustainability 8, 1–17.

Burns, R.B., 2000. Introduction to Research Methods, 4th ed. Sage Publications Ltd., London.

C.P., F., M.P., P., C., B., H., B., L., F., M., G., K., H., K., H., H., H., Y., H., A., J., C., M., P.R., M., E., R., M., S., 2005. Global prevalence of dementia: a Delphi consensus study. Lancet 366, 2112–2117.

Calvo-Mora, A., Navarro-García, A., Rey-Moreno, M., Periañez-Cristobal, R., 2016. Excellence management practices, knowledge management and key business results in large organisations and SMEs: A multi-group analysis. Eur. Manag. J. 34, 661–673.

Campos, L.M.S., Vazquez-brust, D.A., 2016. Lean and green synergies in supply chain management. Supply Chain Manag. An Int. J. 21, 627–641.

Capital Institute, 2017. Co-creating the Regenerative Economy [WWW Document]. URL http://capitalinstitute.org/ (accessed 11.15.17).

Carvalho, H., Duarte, S., Machado, V.C., 2011. Lean, agile, resilient and green: divergencies and synergies. Int. J. Lean Six Sigma 2, 151–179.

Castillo, G., Alarcón, L.F., González, V.A., 2015. Implementing Lean Production in Copper Mining Development Projects: Case Study. J. Constr. Eng. Manag. 141, 05014013.

Castleberry, A., Nolen, A., 2018. Thematic analysis of qualitative research data: Is it as easy as it sounds? Curr. Pharm. Teach. Learn.

Chay, T., Xu, Y., Tiwari, A., Chay, F., 2015. Towards lean transformation: the analysis of lean implementation frameworks. J. Manuf. Technol. Manag. 26, 1031–1052.

Chen, M., Lyu, J., 2009. A Lean Six-Sigma approach to touch panel quality improvement. Prod. Plan. Control 20, 445–454.

Cherrafi, A., Elfezazi, S., Chiarini, A., Mokhlis, A., Benhida, K., 2016. The integration of lean

manufacturing, Six Sigma and sustainability: A literature review and future research directions for developing a specific model. J. Clean. Prod. 139, 828–846.

Cherrafi, A., Elfezazi, S., Govindan, K., Garza-Reyes, J.A., Benhida, K., Mokhlis, A., 2017. A framework for the integration of Green and Lean Six Sigma for superior sustainability performance. Int. J. Prod. Res. 55, 4481–4515.

Chiarini, A., 2014. Sustainable manufacturing-greening processes using specific Lean Production tools: An empirical observation from European motorcycle component manufacturers. J. Clean. Prod. 85, 226–233.

Chlebus, E., Helman, J., Olejarczyk, M., Rosienkiewicz, M., 2015. A new approach on implementing TPM in a mine - A case study. Arch. Civ. Mech. Eng. 15, 873–884.

Circle Economy, 2016. About the Circular Economy [WWW Document]. URL http://circle-economy.com/circular-economy/ (accessed 3.7.16).

Cohen, L., Manion, L., Morrison, K., 2007. Research methods in education, 6th ed. Routledge, Taylor and Francis Group, London.

Colvin, R.M., Witt, G.B., Lacey, J., 2015. The social identity approach to understanding socio-political conflict in environmental and natural resources management. Glob. Environ. Chang. 34, 237–246.

Colvin, R.M., Witt, G.B., Lacey, J., 2016. Approaches to identifying stakeholders in environmental management: Insights from practitioners to go beyond the "usual suspects." Land use policy 52, 266–276.

Comm, C.L., Mathaisel, D.F.X., 2011. A case study in applying lean sustainability concepts to universities. Int. J. Sustain. High. Educ. 6, 134–146.

Creswell, J.W., Creswell, J.D., 2018. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 5th ed. Sage Publications, Inc., California, USA.

Crute, V., Ward, Y., Brown, S., Graves, A., 2003. Implementing Lean in aerospace - Challenging the assumptions and understanding the challenges. Technovation 23, 917–928.

Culley, J.M., 2011. Use of a computer-mediated delphi process to validate a mass casualty conceptual model. Comput. Informatics Nurs. 29, 272–279.

Dalkey, N., Helmer, O., 1963. An Experimental Application of the DELPHI Method to the Use of Experts. Manage. Sci. 9, 458–467.

De Haan, J., Naus, F., Overboom, M., 2012. Creative tension in a lean work environment: Implications for logistics firms and workers. Int. J. Prod. Econ. 137, 157–164.

de Jesus, A., Antunes, P., Santos, R., Mendonça, S., 2018. Eco-innovation in the transition to a circular economy: An analytical literature review. J. Clean. Prod. 172, 2999–3018.

De Treville, S., Antonakis, J., 2006. Could lean production job design be intrinsically motivating? Contextual, configurational, and levels-of-analysis issues. J. Oper. Manag. 24, 99–123.

Deeb, S., Haouzi, H.B. El, Aubry, A., Dassisti, M., 2018. A generic framework to support the implementation of six sigma approach in SMEs. IFAC-PapersOnLine 51, 921–926.

Dekoninck, E.A., Domingo, L., O'Hare, J.A., Pigosso, D.C.A., Reyes, T., Troussier, N., 2016. Defining the challenges for ecodesign implementation in companies: Development and consolidation of a framework. J. Clean. Prod. 135, 410–425.

Delbecq, A.L., Ven, A.H. Van de, Gustafson, D.H., 1975. Group Techniques for Program Planning: A Guide To Nominal Group and Delphi Processes (Book), Personnel Psychology. Scott Foresman, Glenview, Illinois.

Dhingra, R., Kress, R., Upreti, G., 2014. Does lean mean green? J. Clean. Prod. 85, 1–7.

Diamond, I.R., Grant, R.C., Feldman, B.M., Pencharz, P.B., Ling, S.C., Moore, A.M., Wales, P.W., 2014. Defining consensus: A systematic review recommends methodologic criteria for reporting of Delphi studies. J. Clin. Epidemiol. 67, 401–409.

Duffield, C., 1993. The Delphi technique: a comparison of results obtained using two expert panels. Int. J. Nurs. Stud. 30, 227–237.

Dunstan, K., Lavin, B., Sanford, R., 2006. The application of lean manufacturing in a mining environment. In: International Mine Management Conference. pp. 16–18.

Durate, S., Cruz-Machado, V., 2013. Modelling lean and green: a review from business models. Int. J. Lean Six Sigma 4, 228–250.

Dzida, W., 1998. Making use of scenarios for validating analysis and design. IEEE Trans. Softw. Eng. 24, 1182–1196.

Ejik, F. van, 2015. Barriers and Drivers towards a Circular Economy. Netherlands.

Elia, V., Gnoni, M.G., Tornese, F., 2017. Measuring circular economy strategies through index methods: A critical analysis. J. Clean. Prod. 142, 2741–2751.

Ellen MacArthur Foundation, 2015a. Growth within: a circular economy vision for a competitive europe. Ellen MacArthur Found. 100.

Ellen MacArthur Foundation, 2015b. Towards the Circular Economy: Economic and business rationale for an acelerated transition. Isle of Wight.

Ellen MacArthur Foundation, 2015c. Delivering the Circular Economy - A toolkit for Policymakers. Ellen MacArthur Foundation, Isle of Wight.

Ellen MacArthur Foundation, 2017a. Circular Economy System Diagram [WWW Document]. URL https://www.ellenmacarthurfoundation.org/circular-economy/infographic (accessed 11.9.18).

Ellen MacArthur Foundation, 2017b. Circular Economy in Action. Isle of Wight, UK.

Ellen MacArthur Foundation, 2017c. Building Blocks [WWW Document]. URL https://www.ellenmacarthurfoundation.org/circular-economy/concept/building-blocks (accessed 3.6.17).

Ellen MacArthur Foundation, 2019. Directory CE 100 [WWW Document]. URL https://www.ellenmacarthurfoundation.org/ce100/directory (accessed 1.5.19).

EPA-USA, 2003. Lean Manufacturing and the Environment : Research on Advanced Manufacturing Systems and the Environment and.

Esain, A., Williams, S., Massey, L., 2008. Combining planned and emergent change in a healthcare lean transformation. Public Money Manag. 28, 21–26.

European Commission, 2015. Eco-innovation in Poland. Eco-Innovation Observatory, Belgium.

Fercoq, A., Lamouri, S., Carbone, V., 2016. Lean/Green integration focused on waste reduction techniques. J. Clean. Prod. 137, 567–578.

Fernández-Llamazares, C.M., Hernández-Gago, Y., Pozas, M., Cabañas, M.J., Feal, B., Villaronga, M., Álvarez-Del-Vayo, C., Valverde, E., 2013. Two-round Delphi technique for the consensual design of a paediatric pharmaceutical care model. Pharmacol. Res. 68,

31–37.

Fischer, A.R.H., Wentholt, M.T.A., Rowe, G., Frewer, L.J., 2014. Expert involvement in policy development: A systematic review of current practice. Sci. Public Policy 41, 332–343.

Flin, R., Arbuthnot, K., 2002. Incident Command: Tales from the Hot Seat. Routledge, London.

Flynn, J.R., Vlok, P.J., 2015. Lean Approaches in Asset Management Within the Mining Industry. In: Amadi-Echendu, J., Hoohlo, C., Mathew, J. (Eds.), 9th WCEAM Research Papers: Volume 1 Proceedings of 2014 World Congress on Engineering Asset Management. Springer International Publishing, Cham, pp. 101–118.

Forrester, P., Shimizu, U., Soriano-Meier, H., Garza-Reyes, J., Basso, L., 2010. Lean production, market share and value creation in the agricultural machinery sector in Brazil. J. Manuf. Technol. Manag. 21, 853–871.

Found, P., Harrison, R., Found, P., Harrison, R., 2012. Understanding the lean voice of the customer.

Franco, M.A., 2017. Circular economy at the micro level: A dynamic view of incumbents' struggles and challenges in the textile industry. J. Clean. Prod. 168, 833–845.

Fynes, B., Ainamo, A., 1998. Organisational learning and lean supply relationships: the case of Apple Ireland. Supply Chain Manag. An Int. J. 3, 96–107.

Gapp, R., Fisher, R., 2008. Achieving organisational transformation: An action learning approach. Total Qual. Manag. Bus. Excell. 19, 609–625.

Garza-Reyes, J.A., 2015a. Lean and green-a systematic review of the state of the art literature. J. Clean. Prod. 102, 18–29.

Garza-Reyes, J.A., 2015b. Green lean and the need for Six Sigma. Int. J. Lean Six Sigma 6, 226–248.

Garza-Reyes, J.A., Al-Balushi, M., Antony, J., Kumar, V., 2016. A Lean Six Sigma framework for the reduction of ship loading commercial time in the iron ore pelletising industry. Prod. Plan. Control 27, 1092–1111.

Garza-Reyes, J.A., Flint, A., Kumar, V., Antony, J., Soriano-Meier, H., 2014a. A DMAIRC approach to lead time reduction in an aerospace engine assembly process. J. Manuf. Technol. Manag. 25, 27–48.

Garza-Reyes, J.A., Parkar, H.S., Oraifige, I., Meier, H.S., Harmanto, D., 2012. An empirical-exploratory study of the status of lean manufacturing in India. Int. J. Bus. Excell. 5, 395–412.

Garza-Reyes, J.A., Rocha-Lona, L., Kumar, V., 2015. A conceptual framework for the implementation of quality management systems. Total Qual. Manag. Bus. Excell. 26, 1298–1310.

Garza-Reyes, J.A., Salomé Valls, A., Nadeem, S.P., Anosike, A., Kumar, V., 2018. A circularity measurement toolkit for manufacturing SMEs. Int. J. Prod. Res. In press.

Garza-Reyes, J.A., Winck Jacques, G., Lim, M.K., Kumar, V., Rocha-Lona, L., 2014b. Lean and Green - Synergies, Differences, Limitations, and the Need for Six Sigma. In: International Conference on Advances in Production Management Systems (APMS) 2014, Part II. pp. 71–81.

Garza-Reyes, J.A., 2016. Class Notes: Introduction to Operations Management. Derby, UK.

Gass, S.I., 1983. Decision-Aiding Models: Validation, Assessment, and Related Issues for Policy Analysis. Oper. Res. 31, 603–631.

Geng, Y., Doberstein, B., 2008. Developing the circular economy in China: Challenges and opportunities for achieving “leapfrog development.” Int. J. Sustain. Dev. World Ecol. 15, 231–239.

Geng, Y., Doberstein, B., 2010. Developing the circular economy in China : Challenges and opportunities for achieving ’ leapfrog development ’ Developing the circular economy in China : Challenges and opportunities for achieving ‘ leapfrog development ’ 4509.

Geng, Y., Zhu, Q., Doberstein, B., Fujita, T., 2009. Implementing China’s circular economy concept at the regional level: A review of progress in Dalian, China. Waste Manag. 29, 996–1002.

George, D.A.R., Lin, B.C., Chen, Y., 2015. Environmental Modelling & Software Short communication A circular economy model of economic growth. Environ. Model. Softw. 73, 60–63.

George, M.L., Rowlands, D., Price, M., Maxey, J., 2005. The Lean Six Sigma Pocket Toolbook. McGraw-Hill, New York, NY.

Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. J. Clean. Prod. 114, 11–32.

Godina, R., Pimentel, C., Silvac, F.J.G., Matias, J.C.O., 2018. Improvement of the Statistical Process Control Certainty in an Automotive Manufacturing Unit. Procedia Manuf. 17, 729–736.

Goldsby, T., Martichenko, R., 2005. Lean Six Sigma Logistics. J. Ross Publishing, USA.

Gomm, R., Hammersley, M., Foster, P. (Eds.), 2000. Case study method: Key issues, Key texts. Sage Publications Ltd., London.

González-Benito, J., Suárez-González, I., 2001. Effect of organizational variables in JIT purchasing implementation. Int. J. Prod. Res. 39, 2231–2249.

Goodman, C.M., 1987. The Delphi technique: a critique. J. Adv. Nurs. 12, 729–734.

Gordon, T.J., 1994. The Delphi Method, Futures Research Methodology.

Govindan, K., Hasanagic, M., 2018. A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective. Int. J. Prod. Res. 7543, 1–34.

Gracht, H.A. von der, 2008. The Delphi technique for futures research. Futur. Logist. Scenar. 2025 21–68.

Graedel, T.E., 1996. On the Concept of Industrial Ecology. Annu. Rev. Energy Environ. 21, 69–98.

Graham, B., Regehr, G., Wright, J.G., 2003. Delphi as a method to establish consensus for diagnostic criteria. J. Clin. Epidemiol. 56, 1150–1156.

Gray, D., 2018. Doing Research in the Real World, 4th ed, SAGE publications Ltd. Sage Publications Ltd., London.

Gregson, N., Crang, M., Fuller, S., Holmes, H., Gregson, N., Crang, M., Fuller, S., Interrogating, H.H., Gregson, N., Crang, M., Fuller, S., 2015. Interrogating the circular economy: the moral economy of resource recovery in the EU. Econ. Soc. 44, 218–243.

Greyson, J., 2015. A Glance at Waste-Free Economy [WWW Document]. URL http://www.ecomena.org/tag/linear-economy/ (accessed 5.8.16).

Griffith, D.A., Cavusgil, S.T., Xu, S., 2008. Emerging themes in international business research. J. Int. Bus. Stud. 39, 1220–1235.

Hall, N., Ashworth, P., Devine-Wright, P., 2013. Societal acceptance of wind farms: Analysis of four common themes across Australian case studies. Energy Policy 58, 200–208.

Hallgren, M., Olhager, J., 2009. Lean and agile manufacturing: External and internal drivers and performance outcomes. Int. J. Oper. Prod. Manag. 29, 976–999.

Hammer, M., Goding, J., 2001. Putting Six Sigma in Perspective. Quality 40, 58–63.

Haque, B., James-moore, M., 2004. Applying lean thiniking to new production introduction. J. Eng. Des. 15, 1–31.

Hasson, F., Keeney, S., McKenna, H., 2000. Research guidelines for the Delphi survey technique. J. Adv. Nurs. 32, 1008–1015.

Herron, C., Hicks, C., 2008. The transfer of selected lean manufacturing techniques from Japanese automotive manufacturing into general manufacturing (UK) through change agents. Robot. Comput. Integr. Manuf. 24, 524–531.

Hicks, C., McGovern, T., Prior, G., Smith, I., 2015. Applying lean principles to the design of healthcare facilities. Int. J. Prod. Econ. 170, 677–686.

Hill, T.J., 1987. Teaching and research directions in production/operations management: The Manufacturing sector. Int. J. Oper. Prod. Manag. 7, 5–12.

Hines, P., Francis, M., Found, P., 2006. Towards lean product lifecycle management: A framework for new product development. J. Manuf. Technol. Manag. 17, 866–887.

Hines, P., Holweg, M., Rich, N., 2004. Learning to Evolve. Int. J. Oper. Prod. Manag. 24, 994–1011.

Hodgetts, R.M., Greenwood, R., 1995. Fredrick Taylor. Alive and well and ready for the 21st Century. Acad. Manag. Proc. 55, 218–222.

Holweg, M., 2007. The genealogy of lean production. J. Oper. Manag. 25, 420–437.

Homrich, A.S., Galvão, G., Abadia, L.G., Carvalho, M.M., 2018. The circular economy umbrella: Trends and gaps on integrating pathways. J. Clean. Prod. 175, 525–543.

Hsu, C.-C., Sandford, B.A., 2007. The delphi technique: making sense of consensus. Pract.

Assessment, Res. Eval. 12, 1–8.

Hsu, C.-C., Sandford, B.A., 2007. Minimizing non-response in the Delphi process: How to respond to non-response. Pract. Assessment, Res. Eval. 16, 1–8.

Hu, J., Xiao, Z., Zhou, R., Deng, W., Wang, M., Ma, S., 2011. Ecological utilization of leather tannery waste with circular economy model. J. Clean. Prod. 19, 221–228.

Hu, Q., Mason, R., Williams, S.J., Found, P., 2015. Lean implementation within SMEs: a literature review. J. Manuf. Technol. Manag. 26, 980–1012.

Hung, H.L., Altschuld, J.W., Lee, Y.F., 2008. Methodological and conceptual issues confronting a cross-country Delphi study of educational program evaluation. Eval. Program Plann. 31, 191–198.

Indrawati, S., Ridwansyah, M., 2015. Manufacturing Continuous Improvement Using Lean Six Sigma: An Iron Ores Industry Case Application. Procedia Manuf. 4, 528–534.

Iqbal, A., Asrar-ul-Haq, M., 2018. Establishing relationship between TQM practices and employee performance: The mediating role of change readiness. Int. J. Prod. Econ. 203, 62–68.

Jabbour, C.J.C., Jabbour, A.B.L. de S., Sarkis, J., Filho, M.G., 2017. Unlocking the circular economy through new business models based on large-scale data: An integrative framework and research agenda. Technol. Forecast. Soc. Chang. In press.

Jagdev, H.S., Browne, J., Jordan, P., 1995. Verification and validation issues in manufacturing models. Comput. Ind. 25, 331–353.

Jansson, J., Nilsson, J., Modig, F., Hed Vall, G., 2017. Commitment to Sustainability in Small and Medium-Sized Enterprises: The Influence of Strategic Orientations and Management Values. Bus. Strateg. Environ. 26, 69–83.

Jasti, N.V.K., Kodali, R., 2015. Lean production: literature review and trends. Int. J. Prod. Res. 53, 867–885.

Jiao, W., Boons, F., 2015. Policy durability of Circular Economy in China: A process analysis of policy translation. "Resources, Conserv. Recycl.

Johnson, R.B., Onwuegbuzie, A.J., 2004. Mixed Methods Research: A Research Paradigm Whose Time Has Come. Educ. Res. 33, 14–26.

Jowit, J., 2008. World is facing a natural resources crisis worse than financial crunch [WWW Document]. URL https://www.theguardian.com/environment/2008/oct/29/climatechange-endangeredhabitats (accessed 9.25.17).

K. W. Platts, 1993. A Process approach to researching manufacturing strategy. Int. J. Oper. Prod. Manag. 13, 4–17.

Kadarova, J., Demecko, M., 2016. New Approaches in Lean Management. Procedia Econ. Financ. 39, 11–16.

Karlsson, C., Åhlström, P., 1996. Assessing changes towards lean production. Int. J. Oper. Prod. Manag. 16, 24–41.

Keeney, S., Hasson, F., McKenna, H., 2006. Consulting the oracle: Ten lessons from using the Delphi technique in nursing research. J. Adv. Nurs. 53, 205–212.

King, A.A., Lenox, M.J., 2001. Lean and green? An empirical examination of the relationship between lean production and environmental performance. Prod. Oper. Manag. 10, 244–256.

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., Hekkert, M., 2018. Barriers to the Circular Economy: Evidence From the European Union (EU). Ecol. Econ. 150, 264–272.

Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: An analysis of 114 definitions. Resour. Conserv. Recycl. 127, 221–232.

Klippel, A.F., Petter, C.O., Antunes, J.A. V, 2008. Lean management implementation in mining industries. Dyna 75, 81–89.

Kobza, N., Schuster, A., 2016. Building a a responsible Europe - the value of circular economy. IFAC-PapersOnLine 49, 111–116.

Korhonen, J., Honkasalo, A., Seppälä, J., 2018. Circular Economy: The Concept and its Limitations. Ecol. Econ. 143, 37–46.

Krafcik, J.F., 1988. Triumph of the lean production system. Sloan Manage. Rev. 30, 41–52.

L. Kok, Wurpel, G., Ten-Wolde, A., 2013. Unleashing the Power of the Circular Economy. Report by IMSA Amsterdam for Circle Economy.

Lacy, P., Rutqvist, J., 2015. Waste to Wealth. Palgrave Macmillan, Basingstoke, U.K.

Lai, K.H., Wu, S.J., Wong, C.W.Y., 2013. Did reverse logistics practices hit the triple bottom line of Chinese manufacturers? Int. J. Prod. Econ. 146, 106–117.

Landeta, R.J., 1999. El método Delphi. Una técnica de previsión para la incertidumbre. Ariel, Barcelona.

Lean Management Institute of India, 2017. History of Lean [WWW Document]. Whatis Lean? URL http://www.leaninstitute.in/what-is-lean/history-of-lean (accessed 6.10.19).

Lean Methods Group, 2018. Prioritization Matrix [WWW Document]. URL https://www.leanmethods.com/resources/tools-templates/prioritization-matrix/ (accessed 12.8.18).

Lewandowski, M., 2016. Designing the Business Models for Circular Economy — Towards the Conceptual Framework. Sustainability 8, 1–28.

Li, N., Zhang, T., Liang, S., 2013. Reutilisation-extended material flows and circular economy in China. Waste Manag. 33, 1552–1560.

Lieder, M., Rashid, A., 2016. Towards circular economy implementation: A comprehensive review in context of manufacturing industry. J. Clean. Prod. 115, 36–51.

Liker, J., 2004. The Toyota Way: Fourteen Management Principles From the World's Greatest Manufacturer. McGraw-Hill, NY, USA.

Liker, J.K., 1996. Becoming Lean. Productivity Press, Portland, OR.

Liker, J.K., Morgan, J., 2011. Lean product development as a system: A case study of body and stamping development at ford. Eng. Manag. J. 23, 16–28.

Linderman, K., Schroeder, R.G., Choo, A.S., 2006. Six Sigma: The role of goals in improvement teams. J. Oper. Manag. 24, 779–790.

Linstone, H.A., Turoff, M. (Eds.), 1975. The Delphi Method: Techniques and Applications. Addison-Wesley Educational Publishers Inc, MA.

Linstone, H.A., Turoff, M., 2002. The Delphi Method - Techniques and Applications. delphi method - Tech. Appl. 1–616.

Liu, Q., Li, H., Zuo, X., Zhang, F., Wang, L., 2009. A survey and analysis on public awareness

and performance for promoting circular economy in China : A case study from Tianjin. J. Clean. Prod. 17, 265–270.

Liu, Y., Bai, Y., 2014. Resources , Conservation and Recycling An exploration of firms ' awareness and behavior of developing circular economy : An empirical research in China. "Resources, Conserv. Recycl. 87, 145–152.

Loon, P. van, Delagarde, C., Van Wassenhove, L.N., 2017. The role of second-hand markets in circular business: a simple model for leasing versus selling consumer products. Int. J. Prod. Res. 7543, 1–14.

Lucato, W.C., Calarge, F.A., Junior, M.L., Calado, R.D., 2014. Performance evaluation of lean manufacturing implementation in Brazil. Int. J. Product. Perform. Manag. 63, 529–549.

Macal, C.M., 2005. Model verification and validation. Work. "Threat Anticip. Soc. Sci. Methods Model.

MacCarthy, B.L., Atthirawong, W., 2003. Factors affecting location decisions in international operations – a Delphi study. Int. J. Oper. Prod. Manag. 23, 794–818.

Macdonald, B., Walker, R., 1975. Case-study and the Social Philosophy of Educational Research. Cambridge J. Educ. 5, 2–12.

Magnusson, K., Kroslid, D., Bergman, B., 2003. Six Sigma – The Pragmatic Approach. Studentlitteratur AB, Lund.

Manninen, K., Koskela, S., Antikainen, R., Bocken, N., Dahlbo, H., Aminoff, A., 2018. Do circular economy business models capture intended environmental value propositions? J. Clean. Prod. 171, 413–422.

Maropoulos, P.G., Ceglarek, D., 2010. Design verification and validation in product lifecycle. CIRP Ann. - Manuf. Technol. 59, 740–759.

Martínez León, H.C., Calvo-Amodio, J., 2017. Towards lean for sustainability: Understanding the interrelationships between lean and sustainability from a systems thinking perspective. J. Clean. Prod.

Mass, N.J., 2005. The relative value of growth. Harv. Bus. Rev. 83, 102–112.

McDowall, W., Geng, Y., Huang, B., Barteková, E., Bleischwitz, R., Türkeli, S., Kemp, R., Doménech, T., 2017. Circular Economy Policies in China and Europe. J. Ind. Ecol. 21,

651–661.

McKinnon, A., Cullinane, S., Browne, M., Whiteing, A. (Eds.), 2010. Green Logistics. Kogan Page, London.

McKinsey&Company, 2014. Moving toward a circular economy [WWW Document]. URL https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/moving-toward-a-circular-economy (accessed 11.10.17).

McMillan, S.S., King, M., Tully, M.P., 2016. How to use the nominal group and Delphi techniques. Int. J. Clin. Pharm.

Mehrsai, A., Thoben, K.-D., Scholz-Reiter, B., 2014. Bridging lean to agile production logistics using autonomous carriers in pull flow. Int. J. Prod. Res. 52, 4711–4730.

Meijering, J. V., Kampen, J.K., Tobi, H., 2013. Quantifying the development of agreement among experts in Delphi studies. Technol. Forecast. Soc. Change 80, 1607–1614.

Merli, R., Preziosi, M., Acampora, A., 2018. How do scholars approach the circular economy? A systematic literature review. J. Clean. Prod. 178, 703–722.

Millar, N., Mclaughlin, E., Börger, T., 2019. The Circular Economy: Swings and Roundabouts? Ecol. Econ. 158, 11–19.

Ministry of Economy, T. and I., 2004. Handbook on Resource Recycling Legislation and Trends in 3R. Recycling Promotion Divisions, Tokyo.

MIT, 2000. Transitioning to a lean enterprise: a guide for leaders, 1st ed. MIT, USA.

Monden, Y., 2011. Toyota production system: An integrated approach to Just-In-Time, CRC Press. CRC Press.

Moreira, N., De Santa-Eulalia, L.A., Aït-Kadi, D., Wood-Harper, T., Wang, Y., 2015. A conceptual framework to develop green textiles in the aeronautic completion industry: A case study in a large manufacturing company. J. Clean. Prod. 105, 371–388.

Moreno, M., De los Rios, C., Rowe, Z., Charnley, F., 2016. A conceptual framework for circular design. Sustainability 8.

Mostafa, S., Dumrak, J., Soltan, H., 2013. A framework for lean manufacturing implementation. Prod. Manuf. Res. 1, 44–64.

Mourtzis, D., Papathanasiou, P., Fotia, S., 2016. Lean Rules Identification and Classification for Manufacturing Industry. Procedia CIRP 50, 198–203.

Mouzas, S., 2006. Efficiency versus effectiveness in business networks. J. Bus. Res. 59, 1124–1132.

Munier, F., Rondé, P., 2001. The role of knowledge codification in the emergence of consensus under uncertainty: Empirical analysis and policy implications. Res. Policy 30, 1537–1551.

Muranko, Z., Andrews, D., Newton, E.J., Chaer, I., Proudman, P., 2018. The Pro-Circular Change Model (P-CCM): Proposing a framework facilitating behavioural change towards a Circular Economy. Resour. Conserv. Recycl. 135, 132–140.

Murray, A., Skene, K., Haynes, K., Murray, A., Skene, K., Haynes, K., 2017. The Circular Economy : An Interdisciplinary Exploration of the Concept and Application in a Global Context. J. Bus. Ethics 140, 369–380.

Myers, M.D., 2013. Qualitative research in business & management, 2nd ed, Sage Publications. Sage Publications Ltd., London.

Nadeem, S.P., Garza-Reyes, J.A., Anosike, A.I., Kumar, V., 2017a. Spectrum of Circular Economy and its Prospects in Logistics. In: Proceedings of the 2017 International Symposium on Industrial Engineering and Operations Management (IEOM) Bristol, UK, July 24-25, 2017. Bristol, UK, pp. 440–451.

Nadeem, S.P., Garza-Reyes, J.A., Glanville, D., 2018. The Challenges of the Circular Economy. In: Conway, E., Byrne, D. (Eds.), Contemporary Issues in Accounting. Palgrave Macmillan, pp. 37–60.

Nadeem, S.P., Garza-Reyes, J.A., Leung, S., Cherra, A., Anosike, A.I., Lim, M.K., 2017b. Lean Manufacturing and Environmental Performance – Exploring the Impact and Relationship. In: Lödding, H., Riedel, R., Thoben, K., von Cieminski, G., Kiritsis, D. (Eds.), Advances in Production Management Systems. The Path to Intelligent, Collaborative and Sustainable Manufacturing. APMS 2017. IFIP Advances in Information and Communication Technology. Springer Cham, pp. 331–340.

Naylor, J. Ben, Naim, M.M., Berry, D., 1999. Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain. Int. J. Prod. Econ. 62, 107–118.

Neap, H.S., Celik, T., 1999. Value of a product: A definition. Int. J. Value - Based Manag. 12,

181–191.

Ohno, T., 1988a. Toyota Production System: Beyond Large-Scale Production, Productivity Press. Productivity Press, Portland, OR.

Ohno, T., 1988b. Toyota Production System: Beyond Large-Scale Production, Productivity Press.

Okoli, C., Pawlowski, S.D., 2004. The Delphi method as a research tool: An example, design considerations and applications. Inf. Manag. 42, 15–29.

Oleghe, O., Salonitis, K., 2016. Variation modeling of lean manufacturing performance using fuzzy logic based quantitative lean index. Procedia CIRP 41, 608–613.

Oliveira, G.A., Tan, K.H., Guedes, B.T., 2018. Lean and green approach: An evaluation tool for new product development focused on small and medium enterprises. Int. J. Prod. Econ. 205, 62–73.

Omogbai, O., Salonitis, K., 2016. A Lean Assessment Tool Based on Systems Dynamics. Procedia CIRP 50, 106–111.

Ormazabal, M., Prieto-Sandoval, V., Jaca, C., Santos, J., 2016. An overview of the circular economy among SMEs in the Basque Country: A multiple case study. J. Ind. Eng. Manag. 9, 1047–1058.

Ormazabal, M., Prieto-Sandoval, V., Puga-Leal, R., Jaca, C., 2018. Circular Economy in Spanish SMEs: Challenges and opportunities. J. Clean. Prod. 185, 157–167.

Oware, K.M., Samanhyia, S., Ampong, G.O.A., 2015. Elimination of waste and inefficiencies through lean maintenance management in mining industries, Ghana. Int. J. Econ. Commer. Manag. 3, 836–845.

Ozcelik, Y., 2010. Do business process reengineering projects payoff? Evidence from the United States. Int. J. Proj. Manag. 28, 7–13.

Pampanelli, A.B., Found, P., Bernardes, A.M., 2014. A Lean & Green Model for a production cell. J. Clean. Prod. 85, 19–30.

Pan, S., Alex, M., Huang, I., Liu, I., Chang, E., Chiang, P., 2015. Strategies on implementation of waste-to-energy (WTE) supply chain for circular economy system : a review. J. Clean. Prod. 108, 409–421.

Paré, G., Cameron, A.F., Poba-Nzaou, P., Templier, M., 2013. A systematic assessment of rigor in information systems ranking-type Delphi studies. Inf. Manag. 50, 207–217.

Parida, V., Burstrom, T., Visnjic, I., Wincent, J., 2019. Orchestrating industrial ecosystem in circular economy: A two-stage transformation model for large manufacturing comapnies. J. Bus. Res. In Press.

Park, J., Sarkis, J., Wu, Z., 2010. Creating integrated business and environmental value within the context of China ' s circular economy and ecological modernization. J. Clean. Prod. 18, 1494–1501.

Pearce, D.W., Turner, R.K., 1989. Economics of Natural Resources and the Environment. Harvester Wheatsheaf, London.

Pheifer, A.G., 2017. Barriers & Enablers to Circular Business Models. Netherlands.

Pialot, O., Millet, D., Bisiaux, J., 2017. "Upgradable PSS": Clarifying a new concept of sustainable consumption/production based on upgradablility. J. Clean. Prod. 141, 538–550.

Pieroni, M.P.P., McAloone, T.C., Pigosso, D.C.A., 2019. Business mdoel innovation for circular economy and sustainability: A review of approaches. J. Clean. Prod. 215, 198–216.

Powell, D., Strandhagen, J.O., Tommelein, I., Ballard, G., Rossi, M., 2014. A New Set of Principles for Pursuing the Lean Ideal in Engineer-to-Order Manufacturers. Procedia CIRP 17, 571–576.

Prashar, A., 2017. Adopting PDCA (Plan-Do-Check-Act) cycle for energy optimization in energy-intensive SMEs. J. Clean. Prod. 145, 277–293.

Prescott, P.A., Soeken, K.L., 1989. The Potential Uses of Pilot Work. Nurs. Res. 38, 60–62.

Preston, F., 2012. A Global Redesign? Shaping the Circular Economy. London.

Project Management Institute, 2008. A Guide to the Project Management Body of Knowledge (PMBOK Guide), 4th ed. Project Management Institute, Inc, Pennsylvania, USA.

Psomas, E.L., Jaca, C., 2016. The impact of total quality management on service company performance: evidence from Spain. Int. J. Qual. Reliab. Manag. 33, 380–398.

R. Jadhav, J., S. Mantha, S., B. Rane, S., 2014. Exploring barriers in lean implementation. Int.

J. Lean Six Sigma 5, 122–148.

Ranta, V., Aarikka-Stenroos, L., Ritala, P., Mäkinen, S.J., 2018. Exploring institutional drivers and barriers of the circular economy: A cross-regional comparison of China, the US, and Europe. Resour. Conserv. Recycl. 135, 70–82.

Reed, M.S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C.H., Stringer, L.C., 2009. Who's in and why? A typology of stakeholder analysis methods for natural resource management. J. Environ. Manage. 90, 1933–1949.

Reguant-Álvarez, M., Torrado-Fonseca, M., 2016. El método Delphi. Rev. d' Innovació i Recer. em Educ. 9, 87–102.

Reh, L., 2013. Process Engineering in Circular Economy. Particuology 11, 119–133.

Reichhart, A., Holweg, M., 2007. Lean distribution: concepts, contributions, conflicts. Int. J. Prod. Res. 45, 3699–3722.

Reike, D., Vermeulen, W.J.V., Witjes, S., 2018. The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. Resour. Conserv. Recycl. 135, 246–264.

Remenyi, D., Williams, B., Money, A., Swartz, E., 2010. Doing research in business and management an introduction to process and method. Sage Publications Ltd., London.

Rizos, V., Behrens, A., Kafyeke, T., Hirschnitz-Garbers, M., Ioannou, A., 2015. The Circular Economy: Barriers and Opportunities for SMEs. Ceps 25.

Rizos, V., Behrens, A., van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., Flamos, A., Rinaldi, R., Papadelis, S., Hirschnitz-Garbers, M., Topi, C., 2016. Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers. Sustainability 8, 1212.

Rizos, V., Tuokko, K., Behrens, A., 2017. The Circular economy: A review of Definitions, Processes and Impacts, CEPS. Brussels.

Romero, D., Noran, O., 2015. Green Virtual Enterprises and and their Breeding Environments: Engineering their Sustainability as Systems of Systems for the Circular Economy. IFAC-PapersOnLine 48, 2258–2265.

Rothstein, J., 2004. Creating lean industrial relations: general motors in Silao, Mexico. Compet. Chang. 8, 203–221.

Rowe, G., Wright, G., 2001. Expert opinions in forecasting: The role of the Delphi technique. In: Principles of Forecasting. International Series in Operations Research & Management Science. Springer, Boston, MA.

Russell, R.S., Taylor III, B.W., 2011. Operations Management, 7th ed. John Wiley & Sons, Inc., New Jersey, USA.

Salkind, N.J., 2011. 100 Questions and Answers About Research Methods. Sage Publications, California.

Sargent, R.G., 2013. Verification and validation of simulation models. J. Simul. 7, 12–24.

Saunders, M., Lewis, P., 2018. Doing research in business and management, 2nd ed. Pearson Eductiion Ltd., Harlow.

Saunders, M., Lewis, P., Thornhill, A., 2012. Research Methods for Business Students, 6th ed. Pearson.

Sauvé, S., Bernard, S., Sloan, P., 2016. Environmental sciences , sustainable development and circular economy : Alternative concepts for trans-disciplinary research. Environ. Dev. 17, 48–56.

Scheinberg, A., Nesic, J., Savain, R., Luppi, P., Sinnott, P., Petean, F., Pop, F., 2016. From collision to collaboration - Integrating informal recyclers and re-use operators in Europe: A review. Waste Manag. Res. 34, 820–839.

Schmidt, R.C., 1997. Managing Delphi Surveys Using Nonparametric Statistical Techniques. Decis. Sci. 28, 763–774.

Schulte, U.G., 2013. New business models for a radical change in resource efficiency. Environ. Innov. Soc. Transitions 9, 43–47.

Schwandt, T.A., 2015. The Sage Dictionary of qualitative inquiry, 4th ed. London.

Seth, D., Gupta, V., 2005. Application of value stream mapping for lean operations and cycle time reduction: An Indian case study. Prod. Plan. Control 16, 44–59.

Seth, D., Seth, N., Dhariwal, P., 2017. Application of value stream mapping (VSM) for lean and cycle time reduction in complex production environments: a case study. Prod. Plan.

Control 28, 398–419.

Shah, R., Ward, P.T., 2003. Lean manufacturing: Context, practice bundles, and performance. J. Oper. Manag. 21, 129–149.

Shah, R., Ward, P.T., 2007. Defining and developing measures of lean production. J. Oper. Manag. 25, 785–805.

Shah, V., 2014. The circular economy's trillion-dollar opportunity [WWW Document]. URL https://www.eco-business.com/news/circular-economys-trillion-dollar-opportunity/ (accessed 12.2.18).

Shahbazi, S., Wiktorsson, M., Kurdve, M., Jönsson, C., Bjelkemyr, M., 2016. Material efficiency in manufacturing: swedish evidence on potential, barriers and strategies. J. Clean. Prod. 127, 438–450.

Shi, H., Peng, S.Z., Liu, Y., Zhong, P., 2008. Barriers to the implementation of cleaner production in Chinese SMEs: government, industry and expert stakeholders' perspectives. J. Clean. Prod. 16, 842–852.

Shingo, 1985. A Revolution in Manufacturing: The SMED System. Productivity Press, Portland.

Simpson, D.F., Power, D.J., 2005. Use the supply relationship to develop lean and green suppliers. Supply Chain Manag. An Int. J. 10, 60–68.

Singh, J., Ordoñez, I., 2016. Resource recovery from post-consumer waste: important lessons for the upcoming circular economy. J. Clean. Prod. 134, 342–353.

Skulmoski, G.J., Hartman, F.T., Krahn, J., 2007. The Delphi Method for Graduate Research. J. Inf. Technol. Educ. 6, 1–21.

Slack, N., Brandon-Jones, A., Johnston, R., 2016. Operations Management, Operations Management. Pearson, Harlow.

Soma, K., Vatn, A., 2014. Representing the common goods - Stakeholders vs. citizens. Land use policy 41, 325–333.

Spear, S., Bowen, H.K., 1999. Decoding the DNA of the Toyota Production System. Harv. Bus. Rev. 77, 96–106.

Stahel, W., 2014. Reuse is the Key to the Circular Economy [WWW Document]. URL

https://ec.europa.eu/environment/ecoap/about-eco-innovation/experts-interviews/reuse-is-the-key-to-the-circular-economy_en (accessed 11.6.18).

Stake, R.E., 1995. The art of case study research. Sage Publications, Inc., Thousand Oaks, CA.

Sternberg, H., Stefansson, G., Westernberg, E., Gennas, R.B. af, Allenstrom, E., Nauska, M.L., 2013. Applying a lean approach to identify waste in motor carrier operations. Int. J. Product. Perform. Manag. 62, 47–65.

Stone, K.B., 2012. Lean transformation: Organizational performance factors that influence firms' leanness. J. Enterp. Transform. 2, 229–249.

Storch, R.L., Lim, S., 1999. Improving flow to achieve lean manufacturing in shipbuilding. Prod. Plan. Control 10, 127–137.

Su, B., Heshmati, A., Geng, Y., Yu, X., 2013a. A review of the circular economy in China: Moving from rhetoric to implementation. J. Clean. Prod. 42, 215–227.

Su, B., Heshmati, A., Geng, Y., Yu, X., 2013b. A review of the circular economy in China : moving from rhetoric to implementation. J. Clean. Prod. 42, 215–227.

Suarez-Eiroa, B., Fern, E., Gonzalo, M., Soto-Onate, D., 2019. Operational principles of Circular Economy for Sustainable Development : Linking theory and practice. J. Clean. Prod. 214, 952–961.

Sundar, R., Balaji, A.N., Satheesh Kumar, R.M., 2014. A review on lean manufacturing implementation techniques. Procedia Eng. 97, 1875–1885.

Taj, S., Morosan, C., 2011. The impact of lean operations on the Chinese manufacturing performance. J. Manuf. Technol. Manag. 22, 223–240.

Tan, K.H., Denton, P., Rae, R., Chung, L., 2013. Managing lean capabilities through flexible workforce development: A process and framework. Prod. Plan. Control 24, 1066–1076.

Thangaratinam, S. & Redman, C.W.E., 2005. The Delphi Technique. Obstet. Gynaecol. 7, 120–125.

The Danish Government, 2013. Denmark without waste [WWW Document]. URL http://eng.mst.dk/media/mst/Attachments/Ressourcestrategi_UK_web.pdf

The Waste and Resource Action Programme, 2016. WRAP and the circular economy [WWW Document]. URL http://www.wrap.org.uk/about-us/about/wrap-and-circular-economy

(accessed 9.7.16).

Thun, J.H., Drüke, M., Grubner, A., 2010. Empowering Kanban through TPS-principles - An empirical analysis of the Toyota Production System. Int. J. Prod. Res. 48, 7089–7106.

Tiwari, S., Dubey, R., Tripathi, N., 2011. The Journey of Lean. Indian J. Commer. Manag. Stud. 2, 200–208.

Tokola, H., Niemi, E., Kyrenius, P., 2017. How Lean transformation affects scheduling. Robot. Comput. Integr. Manuf. 43, 171–178.

Torielli, R.M., Abrahams, R.A., Smillie, R.W., Voigt, R.C., 2011. Using lean methodologies for economically and environmentally sustainable foundries. In: China Foundry. China, pp. 74–88.

Torrago, J., 2018. 8 Heroes of Lean Manufacturing [WWW Document]. Key Fig. Hist. Lean. URL https://www.mamtc.com/blog/2018/10/19/key-figures-in-the-history-of-lean (accessed 6.6.19).

Urbinati, A., Chiaroni, D., Chiesa, V., 2017. Towards a new taxonomy of circular economy business models. J. Clean. Prod. 168, 487–498.

Van Weelden, E., Mugge, R., Bakker, C., 2016. Paving the way towards circular consumption: Exploring consumer acceptance of refurbished mobile phones in the Dutch market. J. Clean. Prod. 113, 743–754.

Vanichchinchai, A., Igel, B., 2009. Total quality management and supply chain management: Similarities and differences. TQM J. 21, 249–260.

Velis, C.A., 2015. Circular economy and global secondary material supply chains. Waste Manag. Res. 33, 389–391.

Vlachos, I., 2015. Applying lean thinking in the food supply chains: A case study. Prod. Plan. Control 26, 1351–1367.

von Briel, F., 2018. The future of omnichannel retail: A four-stage Delphi study. Technol. Forecast. Soc. Change.

Wahab, A.N.A., Mukhtar, M., Sulaiman, R., 2013. A Conceptual Model of Lean Manufacturing Dimensions. Procedia Technol. 11, 1292–1298.

Walter R. Stahel, 2016. Circular economy: a new relationship with our goods and materials

would save resources and energy and create local jobs. Nature 531, 435–439.

Wang, F., Huisman, J., Stevels, A., Baldé, C.P., 2013. Enhancing e-waste estimates: Improving data quality by multivariate Input-Output Analysis. Waste Manag. 33, 2397–2407.

Wang, L., Ming, X.G., Kong, F.B., Li, D., Wang, P.P., 2011. Focus on implementation: a framework for lean product development. J. Manuf. Technol. Manag. 23, 4–24.

Webster, K., 2013. What Might We Say about a Circular Economy ? Some Temptations to Avoid if Possible. World Futures 69, 542–554.

Webster, K., 2015. The Circular Economy A Wealth of Flows. Ellen MacArthur Foundation Publishing, UK.

Whalen, K.A., Berlin, C., Ekberg, J., Barletta, I., Hammersberg, P., 2018. 'All they do is win': Lessons learned from use of a serious game for Circular Economy education. Resour. Conserv. Recycl. 135, 335–345.

Winans, K., Kendall, A., Deng, H., 2017. The history and current applications of the circular economy concept. Renew. Sustain. Energy Rev. 68, 825–833.

Winston, A., 2018. The Story of Sustainability in 2018: "We have about 12 years left" [WWW Document]. Harvard Bus. Rev. URL https://hbr.org/2018/12/the-story-of-sustainability-in-2018-we-have-about-12-years-left (accessed 1.19.19).

Womack, J.P., Jones, D.T., 1994. From Lean Production to the Lean Enterprise. Haravard Bus. Rev. 72, 93–103.

Womack, J.P., Jones, D.T., 2003. Lean Thinking. Simon & Schuster, London.

Womack, J.P., Jones, D.T., Roos, D., 1990. The Machine that Changed the World. Rawson Associates, New York, NY.

Womack, J.P., Jones, D.T., Roos, D., 2007. The Machine that Changed the World: The Story of Lean Production. Simon & Schuster, London.

Wübbeke, J., Heroth, T., 2014. Challenges and political solutions for steel recycling in China. Resour. Conserv. Recycl. 87, 1–7.

Yin, R.K., 2011. Qualitative research from start to finish. The Guildford Press, New York, NY.

Yin, R.K., 2014. Case Study Research: Design and Methods, 5th ed. Sage Publications Ltd.,

London.

Yin, R.K., 2016. Qualitative Research from Start to Finish, 2nd ed. The Guildford Press, New York.

Yuan, Z., Bi, J., Moriguichi, Y., 2006. The circular economy: A new development strategy in China. J. Ind. Ecol.

Yusof, S.M., Aspinwall, E., 2000. Total quality management implementation frameworks: Comparison and review. Total Qual. Manag. 11, 281–294.

Zero Waste Scotland, 2016. Zero Waste Scotland [WWW Document]. URL http://www.zerowastescotland.org.uk/

Zhan, Y., Tan, K.H., Ji, G., Chung, L., Chiu, A.S.F., 2018. Green and lean sustainable development path in China: Guanxi, practices and performance. Resour. Conserv. Recycl. 128, 240–249.

Zhou, K., Fernandez Bonet, D., Wan, C., Akumba, D., Julliard, G.-M., 2014. A Study on Circular Economy Implementation in China. Work. Pap. 312, 1–14.

Zhu, Q., Geng, Y., Lai, K., 2010. Circular economy practices among Chinese manufacturers varying in environmental-oriented supply chain cooperation and the performance implications. J. Environ. Manage. 91, 1324–1331.

APPENDICES

Appendix A Letter to the participants of the first round of Delphi study

Dear _____,

I am writing to request your participation in a Delphi study. As an established expert, your opinion and input is of great value/importance at this pioneering stage of framework, to construct an expert consensus implementation framework.

This research aims to provide a comprehensive framework by combining the best practices of two concepts of *Circular Economy* and *Lean* in structured/systematic manner to allow the adaptation of Circular Economy's principles within the manufacturing operations at SMEs level.

Delphi Study is a technique that seeks to obtain consensus on the opinions of experts (like yourself), termed panel members, through a series of questionnaires. As part of the process, the responses from each round are fed back in summarised form to the Delphi study participants who are then given an opportunity to respond again to the emerging data. The Delphi is, therefore, an iterative multi-stage process designed to combine opinion of specialists into group consensus.

It is envisaged that it should take between 10-15 minutes to complete this questionnaire. This will then be deliberated along with the responses of other researchers from the same field of study. After verifying the framework, it will be empirically tested using the case study tool to validate it.

Your expertise would be extremely beneficial to develop a credible sustainable operations management framework. I would like to convey my utmost gratitude for your contribution by participating in this Delphi study.

I would be very grateful if you please respond by 31st of May, thereafter I will follow-up about your participation. Please access the questionnaire through the following link: https://goo.gl/forms/CASQtMoIK3MRMTi32

Kind regards,

Simon Peter Nadeem
PhD Candidate,
Centre for Supply Chain Improvement,
College of Business Law and Social Sciences,
University of Derby, UK

Office: +441332593498
Mobile: +447857098919
Skype: Nadeem_sp

Appendix B Letter to the participants of the second round of Delphi study

Dear _____,

At first, I would like to convey my sincere gratitude for your participation in first round of the Delphi study and for providing your valuable insight to improve the conceptually developed framework.

After compiling all responses their analysis has resulted in a much improved version of the framework and its descriptions that will be accompanied with it to guide the implementation process.

Please see attached the updated framework along with analysis of data and details of changes made to the framework itself.

This second round of Delphi is based upon the changes made to the framework. It is envisaged that it will take between 10-15 minutes to complete this questionnaire. After verifying the framework, it will be empirically tested using the case study tool to validate it.

Your expertise are of greater value to develop a credible sustainable operations management framework.

I would be very grateful if you please respond by 23rd July, thereafter I will follow-up about your participation. Please access the questionnaire through the following link: https://goo.gl/forms/DP0h4QHMR7fhVs003

Kind regards,

Simon Peter Nadeem
PhD Candidate,
Centre for Supply Chain Improvement,
College of Business Law and Social Sciences,
University of Derby, UK

Office: +441332593498
Mobile: +447857098919
Skype: Nadeem_sp

Appendix C Delphi study questionnaire – round 1

Delphi Study to Verify the Conceptually Developed Framework

INTRODUCTION:
Circular Economy is a relatively new concept promoting closed loop system where resources are 'used but not used up'. The core idea is to control the problem of resource scarcity/depletion at the very Design stage as well as throughout the resource life cycle. The main purpose is to ensure that a product is designed and managed in a way that the resources are kept at maximum utility throughout their life cycle, as well as the residual value in the components of the products is not wasted.
Circular Economy concept is highly practical and much needed in the face of present day challenges of resource scarcity and environmental damages.

Lean a formerly developed technique to manage manufacturing operations, and Circular Economy have common goals of waste elimination and value creation. Thus their combination seems natural to complement each other and benefit greatly to make Circular Economy's application realistic, smooth and easy.

In this regards a framework has been developed for its adaptation in Manufacturing sector. This framework combines the best of Lean and Circular Economy principles, characteristics and tools to develop a comprehensive framework to implement circularity in manufacturing operations management in a systematic manner.

In order for this framework to be of practical relevance and to encircle the depth and breadth of the concept, your input is highly appreciated through answering a series of questionnaire, for which the first round is this one.

* Required

Email address *

Your email

1. Do you consent to participate in this study and for your input to be utilised in anonymous form? *

- Yes
- No

NEXT

Page 1 of 10

Circular Economy

Please rate the level of your agreement with the following statements: *

	Can't Answer	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1. Circular Economy is the most suitable concept to address the issues of resource scarcity and environmental damages	○	○	○	○	○	○
2. Circular Economy's adaptation requires new way of thinking in all sectors of economy	○	○	○	○	○	○
3. Circular Economy's adaptation requires new way of managing manufacturing operations	○	○	○	○	○	○
4. Lean, a formerly developed tool can contribute to speed up the implementation of Circular Economy	○	○	○	○	○	○
5. A new structured framework is much needed for implementation of Circular Economy	○	○	○	○	○	○
6. A structured framework with flexibility (to choose from different tools) will greatly benefit manufacturing sector in adapting Circular Economy principles	○	○	○	○	○	○

BACK NEXT

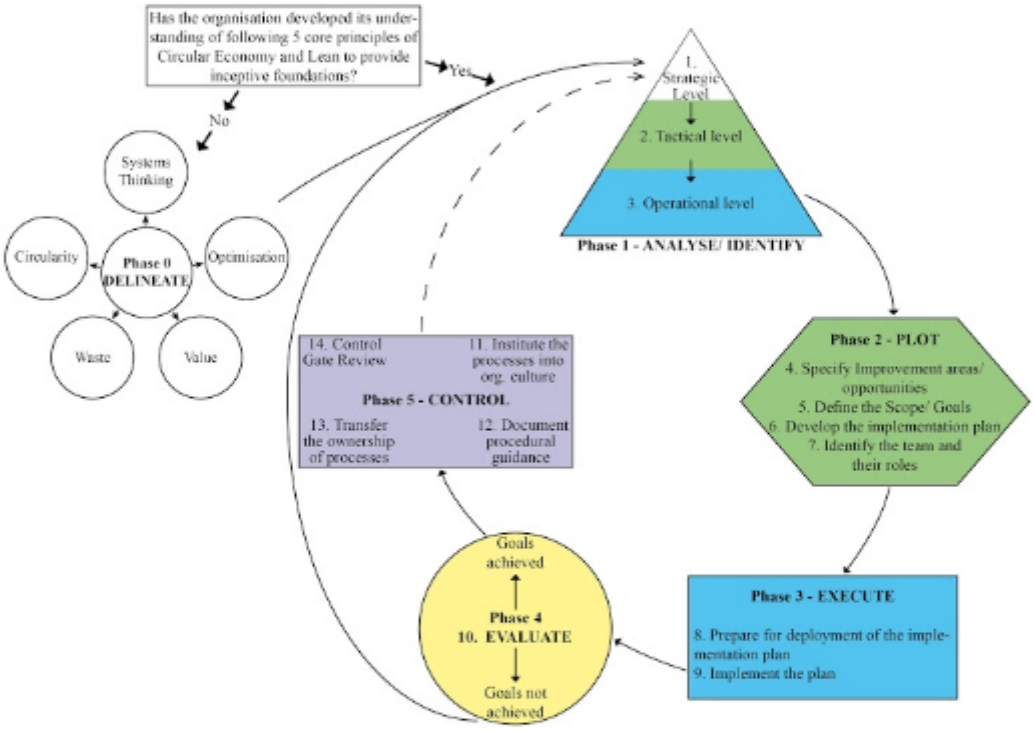
Page 2 of 10

An integrated framework to implement Circular Economy principles in manufacturing sector, especially at SME's level

The framework is developed by integrating the best practices of Circular Economy and Lean concepts as they have synergies to complement each other.

The framework deploy Phase by Phase approach with sub-elements and steps to follow under each of the 6 phases of this framework. At each step and phase Lean tools and Circular Economy are integrated to move form Linear to Circular model of manufacturing.

Conceptually Developed Framework



Do you think the phase by phase approach is feasible for this type of framework? *

- ○ Yes
- ○ No
- ○ Can't Answer
- ○ Other: _____

BACK NEXT

Page 3 of 10

Phase 0 - Delineate

At this phase the framework proposes the Delineate the 5 core principles that are foundational to the concept of Circular Economy and Lean, as. These principles will serve as reference point through out the implementation of the framework.

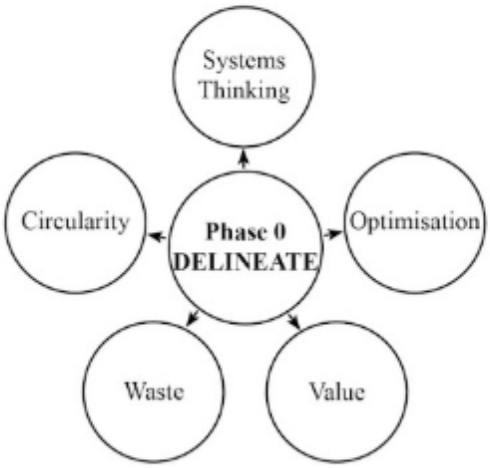
Systems Thinking: Businesses have a lot to learn from natural environmental system around (biomimicry), where the focus is on optimising the overall system and not the individual components alone. Therefore the business should think of themselves in a bigger supply chain and their role/contribution in that term.

Optimisation: Making every effort to maximise the output/ utility of a given resource (material, time, energy, and creativity) at all different stages of life in closed loop system, while eliminating/ minimising any non-value adding impacts, through-out the life-cycle of any resource.

Value: Any activity/output that utilises its required resources in manner that maximises its utility at all stages of its life-cycle including the afterlife, as well as to ensure the longevity of its life-cycle while satisfying the needs/demands of the stakeholders (People [present and future] and Planet) and making impact for them.

Waste: Any activity that leads to the harmful outputs for the stakeholders (People [present and future] and Planet) and does not incorporate the sustainability of the two in long term, is a wasteful activity.

Circularity: Ensuring that all resources are kept their highest utility and are designed to stay within the closed loop system.



Do you think there is need to delineate these five principles, before adopting circular economy in manufacturing sector? *

- ◯ Yes
- ◯ No
- ◯ Unable to say

Are there any other elements that you think should be included or should be taken off from phase 0? if yes please specify

Your answer

BACK NEXT Page 4 of 10

Phase 1 - Analyse/ Identify

This phase proposes to analyse the 3 levels of organisation in sequential order; to highlight the gaps and areas needing change from Linear to Circular approach.

Phase 1 - ANALYSE/ IDENTIFY

How would you rate the importance and necessity to analyse each of the 3 levels in this phase? *

	Can't Answer	Not Important	Slightly Important	Moderately Important	Important	Very Important
Step 1. Strategic Level	○	○	○	○	○	○
Step 2. Tactical Level	○	○	○	○	○	○
Step 3. Operational Level	○	○	○	○	○	○

Do you recommend/advice any changes, modification and improvement in this phase? If yes, please specify

Your answer

BACK NEXT

Page 5 of 10

Phase 2 - PLOT

At this phase 4 steps are followed after analysis and identification of gaps.

How would you rate the importance and necessity of each of the 4 steps in this phase? *

	Can't Answer	Not Important	Slightly Important	Moderately Important	Important	Very Important
Step 4 - Specify Improvement areas/opportunities	○	○	○	○	○	○
Step 5 - Define the Scope	○	○	○	○	○	○
Step 6 - Develop the process map/ implementation strategy	○	○	○	○	○	○
Step 7 - Identify the team and their roles	○	○	○	○	○	○

Do you think the 4 steps are sufficient enough to plot (plan) the implementation of Circular Economy's principles? *

○ Yes

○ No

If your answer to previous question is "No", please state why you think they are not enough and what should be included?

Your answer

Do you recommend/advice any changes, modification and improvement in this phase? If yes, please specify

Your answer

BACK NEXT

Page 6 of 10

Phase 3 - Execute

This phase has two steps to prepare for and implement the improvements plotted in previous phase

Phase 3 - EXECUTE

8. Prepare for deployment of the implementation plan
9. Implement the plan

How would you rate the importance and necessity of each of the 2 steps in this phase? *

	Can't Answer	Not Important	Slightly Important	Moderately Important	Important	Very Important
Step 8. Prepare for modification/change the targeted areas	○	○	○	○	○	○
Step 9. Implement the planned modification/change	○	○	○	○	○	○

Do you recommend/advice any changes, modification and improvement in this phase? If yes, please specify

Your answer

BACK NEXT

Page 7 of 10

Phase 4 - Evaluate

This phase only have one step: Step 10. Evaluate whether the plot and its execution has been successful or not. If successful then users move to control stage or otherwise to re-analyse.

Do you recommend/advice any changes, modification and improvement in this phase? If yes, please specify

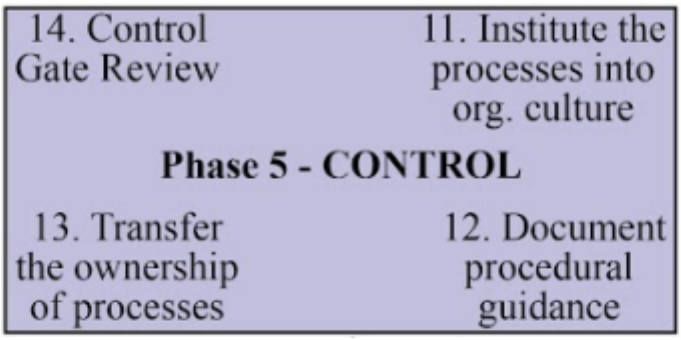
Your answer

BACK NEXT

Page 8 of 10

Phase 5 - Control

Upon successful achievement of goals the users then follow following 4 steps in this phase of Control:



How would you rate the importance and necessity of each of the 4 steps in this phase? *

	Can't Answer	Not Important	Slightly Important	Moderately Important	Important	Very Important
Step 11. Institute the process into organisational culture	○	○	○	○	○	○
Step 12. Document procedural guidance	○	○	○	○	○	○
Step 13. Transfer the ownership of processes	○	○	○	○	○	○
Step 14. Control Gate Review	○	○	○	○	○	○

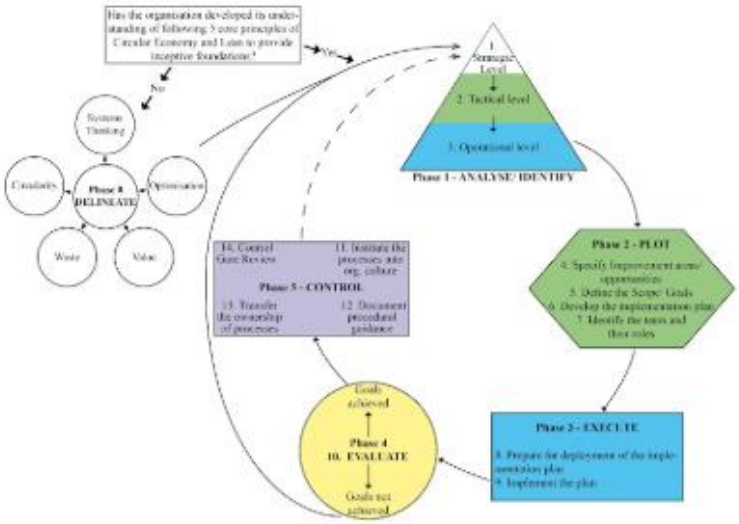
Do you recommend/advice any changes, modification and improvement in this phase? If yes, please specify

Your answer

BACK NEXT

Page 9 of 10

Concluding Remarks



Please rate the level of your agreement with the following statements: *

	Can't Answer	Strongly Disagree	Disagree	Agree	Strongly agree
1. The framework is easy to understand	○	○	○	○	○
2. The framework does contribute to the academic knowledge through combination of Lean and Circular Economy	○	○	○	○	○
3. The phases and steps within the framework represent a systematic approach	○	○	○	○	○
4. The framework is of practical use to manufacturing sector	○	○	○	○	○

If any of your answer(s) are in the range of disagreement, please provide your suggestion/comments for further insight and improvement.

Your answer

Are there any other comments/ advice/ suggestions that you recommend to improve the framework?

Your answer

BACK SUBMIT Page 10 of 10

Appendix D Delphi study questionnaire – round 2

Delphi Study - 2nd Round

Once again, my sincere gratitude to each one of you for your support through your input by participating in Delphi study to verify the conceptually developed framework.

In light of your feedback, suggestions and guidance/advice, the framework has been updated to incorporate your changes. Please see the process of analysis and details of those changes in the file attached to the email sent to you. Please keep that file open for reference purpose.

This is second round as continuation of Delphi study and once again your feedback is greatly appreciated.

* Required

Email address *

Your email

1. Do you consent to participate in this study and for your input to be utilised in anonymous form? *

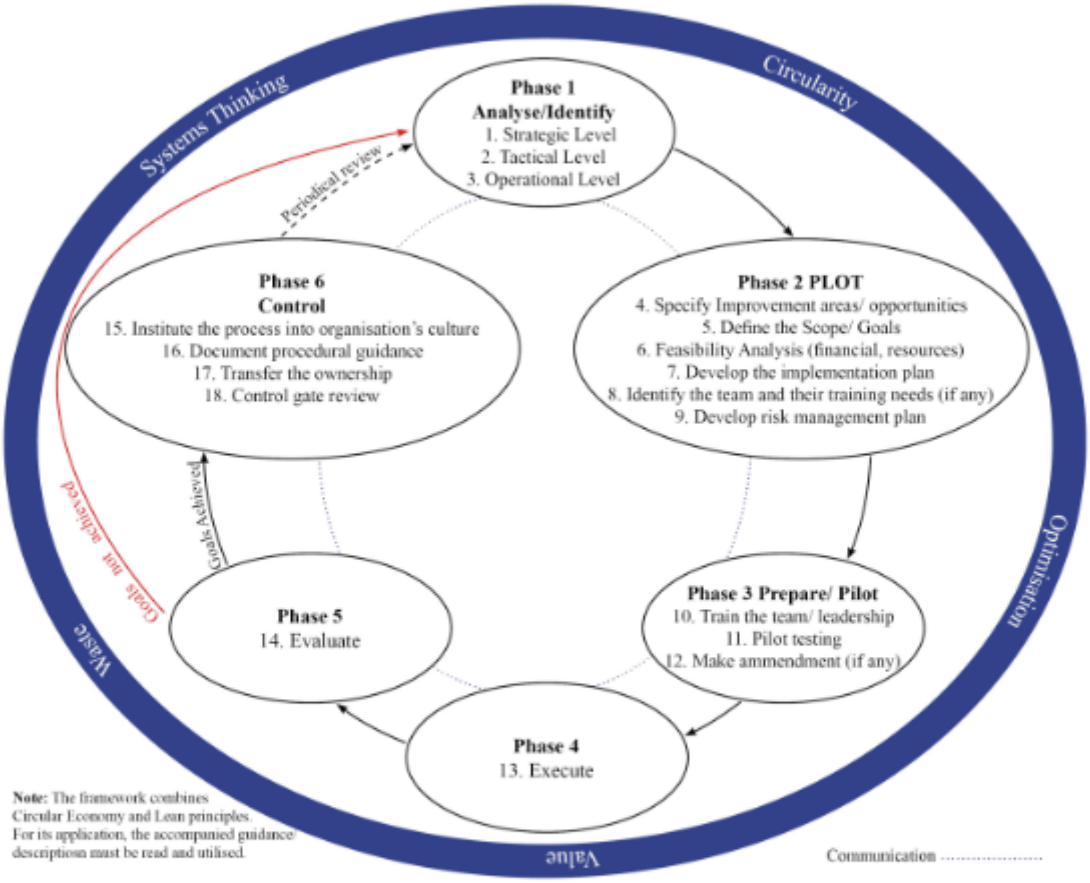
- Yes
- No

NEXT

Page 1 of 4

Phase 2 - PLOT

Few additions are made at this stage in light of your feedback. In that regard please answer following questions:



2. Is the addition of Step 6. "Feasibility Analysis (financial, resources)", good? *

- ○ Yes
- ○ No

3. Is the addition of Step 8: "Identifying the team and their training needs", good? *

- ◯ Yes
- ◯ No

4. Is the addition of Step 9: "Develop risk management plan", good? *

- ◯ Yes
- ◯ No

5. If any of your answer above is no, please provide your reason and suggestion below

Your answer

BACK NEXT

Page 2 of 4

Phase 3 - Prepare/ Pilot

Based upon suggestions, this new phase is added to prepare for implementation and conducting pilot run.

6. Are the steps (i.e. 10, 11 and 12) in this phase good? *

- ◯ Yes
- ◯ No

7. If your answer above is no, please provide your reason and suggestion below

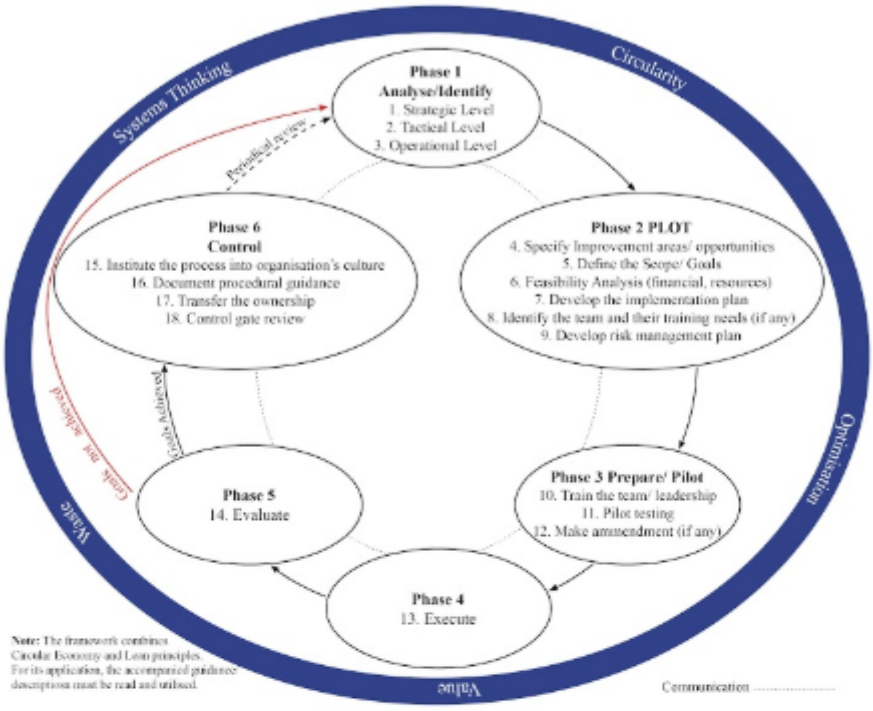
Your answer

BACK NEXT

Page 3 of 4

General Overview about revised framework

Revised Framework



8. Is the framework shaped better than before to allow better understanding? *

- ○ Yes
- ○ No

9. If your answer above is no, please provide your reason and suggestion below

Your answer

10. Are there any other suggestions/ recommendations that you have to improve this framework?

Your answer

BACK SUBMIT

Page 4 of 4

Appendix E Semi-structured questionnaires for interviews

Questionnaire for CEO or Strategic level personnel

Company's name: .....
City, Country: .....
Main product types: .....
Type of industry sector: .....
Type of processes used: .....
Waste types: .....
Amount of employees: .....
Name of the person responsible for the assessment: .....
Number of people employed for circular practices: .....
Has the company identified savings due to circular practices?

1. What are the companies' strategic goals in terms of sustainable growth?
2. What are the companies' strategic goals with regards to Green/Environmental initiatives?
3. Do the company have Circular Economy goals?
   a. If NOT, do the company plan to develop/include them in future OR to explore the possibility of incorporating CE in their strategic goals?
   b. If YES
      i. How far these goals are incorporated in next 5 – 10 years plans?
      ii. What % of the total budget is allocated for CE initiatives or similar ones such as Green, Environment-friendly production, etc.?
      iii. What support is gathered from external sources (e.g. academic, consultants, funding etc.)
4. What potential challenges/barrier do you see in the adoption of CE initiatives?
5. While doing strategic planning, how do you define a priority for following:

	N/A	**Never**	**Rarely**	**Some-times**	**Often**	**Almost always**
Reduce Carbon Emission						
Reduce negative environmental damage						
Longevity of product						
Longevity of Resources						
Re-utilise resources						
Financial Growth/ Stability						
CSR activities						

6. How do you support innovation for your organisation?
7. Questions related to Balance Score Card (If needed)

Questionnaire for Tactical level personnel

1. Request the copy of goals, objectives, defined by tactical level.
2. How often does the upper management communicate with you to update regarding the company's strategic directions (long-term goals)?
3. How often you meet with other members of the team to set goals?
4. How aware are you of Circular Economy? Green Production? Environment-friendly initiatives? Or similar.
5. What type of resources (utilised in your production) you find difficult to source or are likely to become scarce?
6. What strategies do you adopt to optimise your operations?
7. What strategies do you adopt to reduce environmental impact?
8. What is the supplier selection criteria/methodology?
9. What is the average product life cycle of your products? (More specific with 2-3 products examples.
10. What happens at the end of the product life cycle?
11. Do you monitor the resource life cycle?
    a. If yes, how? And how and for what purpose?
12. What Strengths, Weaknesses, Opportunities, and Threats (SWOT) do you see for your operations and organisation?
13. While doing operations planning, how do you define a priority for following:

	N/A	**Never**	**Rarely**	**Some-times**	**Often**	**Almost always**
Reduce Carbon Emission						
Reduce negative environmental damage						
Longevity of product						
Longevity of Resources						
Re-utilise resources						

14. How is the innovation incorporated in goal settings?

Questionnaire for Operational level

1. What is Production Capacity?
2. What is Annual Output (Month by Month)?
3. How often the equipment is calibrated/ serviced?
4. Is there a regular maintenance schedule?
    a. If yes, how often?
5. How many incidents in past 1-3 years has caused disruption in operations?
    a. What were the causes of these incidents?
6. Do you conduct in-house refurbishment facilities?
    a. If yes, what % of total output?
7. How much waste occurs during the production process? (weekly or monthly)
8. Where does this waste go?
9. Has there been any reduction in waste creation over the past 1- 3 years?
    a. If yes, what %?_____
    b. If not, is it steady OR has it increased? _____
10. How often a systematic plan is developed to ensure re-utilisation of resources utilised in products?
11. How many employees are technically trained for their job? (% of total employees)
12. Does the operational level make suggestions to the tactical level to change strategies in achieving the desired goals?
13. Are the employees at the operational level, asked to participate in planning meetings? OR are asked to share their ideas to be considered in goal settings?
14. How many operations have been innovated in past 1-2 years?
15. Do you adopt Additive Manufacturing?
    a. If not, is the possibility explored?

Appendix F Circularity measurement toolkit for Company A

Company's name:	*Company A*
Country:	*Pakistan*
Main product types:	Electrical Transmission & distribution products, Control Panel products to measure and short circuit security
Type of industry sector:	Electrical Engineering
Type of processes used:	
Waste types:	Copper, Steel, MS scrap
Amount of employees:	Workshop 45, Admin 10, GM 1, Other staff 10 = total 66
Name of the person responsible for the assessment:	Simon, with M.D./ Technical Director, and Production Manager
Number of people employed for circular practices:	Nil
Has the company identified savings due to circular practices?	None

Rating\Factors	A	B	D	E	F	G	H	I	**Result**	**RANGE Min**	**RANGE Max**
1. Circular developer	1	0	0	0	0	0.5	0	0	**1.50**	6.5	8
2. Circular Promoter	1	0	0	0	0	0.5			**1.50**	5.5	6
3. Circular	1	0	0	0	0				**1.00**	3.5	5
4. Waved	1	0	0						**1.00**	2.5	3
5. Curved (where A = 1 and B = 1)	1	0							**0.00**	2	2
6. Saw tooth (where A = 0.5 to 1 and B = 0.5 to 1)	1	0							**0.00**	1	1.5
7. V-shape up (where A=0 and B = 0.5 to 1)	1	0							**0.00**	0.5	1
8. ∧-shape down (where A - 0.5 to 1 and B = 0)	1	0							**1.00**	0.5	1
9. Linear	1	0	0	0	0	0.5	0	0	**1.50**	0	0

Questionnaire for factor A

A. Internal Practices – Resource utility and efficiency

Design			
A.a) Designing of product for reduced consumption of resources	**Yes**	**Partially**	**No**
The design of products in the company consider the utilisation of the minimum amount or resources?	1		
Does the company avoid the use of non-renewable resources in the design unless it is impossible?			1

A.b) Designing products for reuse, recycle, and/or recovery of material and/or component parts	**Yes**	**Partially**	**No**
Does the company consider and apply design for reuse?			1
Does the company consider and apply design for disassembly?			1
Does the company consider and apply design for refurbish?			1
Does the company consider and apply design for remanufacture?			1
Does the company consider and apply design for recycling?			1
A.c) Designing processes for minimisation of waste	**Yes**	**Partially**	**No**
Does the company consider and apply design for minimisation of waste?			1
A.d) Designing products for durability	**Yes**	**Partially**	**No**
Does the company consider and apply design for durable products?	1		
Production			
A.e) Reducing Material (i.e. raw material and/or water)	**Yes**	**Partially**	**No**
Raw Material			
Does the company keep register of material consumption?	1		
Is the company already analysing and identifying possible ways to reduce the amount of materials?	1		
Is the company already implementing actions to reduce the amount of material use?	1		
Water			
Does the company keep register of the rate of discharged water and water consumption?	N/A	N/A	N/A
Does the company apply water conservation measures?	N/A	N/A	N/A
Does the company treat waste water?	N/A	N/A	N/A
A.f) Reducing energy (i.e. electricity, coal, gas) consumption	**Yes**	**Partially**	**No**
Does the company keep register of energy consumption?	1		
Is the company already analysing and identifying possible ways to reduce the amount of energy consumed?	1		
Is the company already implementing actions to reduce the amount of energy consumed?	1		
Is the company already analysing or identifying if any of their processes can produce energy?			N/A
Is the company using energy produced by themselves?			N/A
Is the company using renewable energy?			N/A
A.g) Using renewable materials and energy in the production process	**Yes**	**Partially**	**No**
Renewable materials			
Does the company keep register of non-renewable materials consumption?	N/A	N/A	N/A

Is the company already analysing and identifying possible ways to reduce or eliminate the amount of non-renewable materials by substituting them with renewable materials?	N/A	N/A	N/A
Is the company already implementing actions to reduce the use of non-renewable materials?	N/A	N/A	N/A
Renewable energy			
Does the company keep register of non-renewable energy resource consumption?	N/A	N/A	N/A
Is the company already analysing and identifying the possibility of manufacturing their products with the use of renewable energy?	N/A	N/A	N/A
Is the company already implementing actions to substitute non-renewable energy with source of renewable energy?	N/A	N/A	N/A
A.h) Reducing pollutants emissions	**Yes**	**Partially**	**No**
Does the company keep records of pollution?			1
Does the company keep register of their Greenhouse Gas (GHG) emissions?	N/A	N/A	N/A
Is the company already analysing and identifying possible ways to reduce the amount of GHG emissions?	N/A	N/A	N/A
Is the company already implementing GHG reduction actions?	N/A	N/A	N/A
Does the company keep register of the use of fertilizers?	N/A	N/A	N/A
Is the company already analysing and identifying possible ways to reduce the amount of fertilizers?	N/A	N/A	N/A
Is the company already implementing fertilizers reduction actions?	N/A	N/A	N/A
Does the company keep register of the use of pesticides?	N/A	N/A	N/A
Is the company already analysing and identifying possible ways to reduce the amount of pesticides?	1		
Is the company already implementing pesticides reduction actions?	1		
Does the company keep register of the use of petrol?	1		
Is the company already analysing and identifying possible ways to reduce the amount of petrol?	1		
Is the company already implementing petrol reduction actions?	1		
Does the company keep records of the use of diesel?	1		
Is the company already analysing and identifying possible ways to reduce the amount of diesel?	1		
Is the company already implementing diesel reduction actions?	1		
Does the company keep records of the use of natural gas?	N/A	N/A	N/A
Is the company already analysing and identifying possible ways to reduce the amount of natural gas?	N/A	N/A	N/A
Is the company already implementing natural gas reduction actions?	N/A	N/A	N/A
A.i) Reducing wastes	**Yes**	**Partially**	**No**
Does the company support landfill prevention?	N/A	N/A	N/A
Does the company keep records of waste generation?	1		

Does the company separate waste in an efficient way?	1		
Does the company support the circulation of waste, understanding waste as an input?		1	
In case of disposing, is the company doing it in an adequate form regarding the environment?	N/A	N/A	N/A
Packaging and distribution			
A.j) Green Packaging	**Yes**	**Partially**	**No**
Does the company use green and efficient packaging?	N/A	N/A	N/A
A.k) Green distribution	**Yes**	**Partially**	**No**
Does the company choses transport options with comparatively less environmental impact like rail or water for the distribution of their products?		1	
Is the company using nay management tools, techniques, and technologies to optimise the distribution and shipping efficiency?		1	
Total number of positive answers	**18**	**3**	**8**
	62.07%	**10.34%**	**27.59%**
		A =	**1**

Questionnaire for factor B

B. Internal awareness

B.a) Circular management, culture and continuous monitoring	**Yes**	**Partially**	**No**
Does the organisation have formulated a circular economy strategy?			1
Has the company assigned a person to be responsible for environmental and circular matters?			1
Does the company have a functional structure in charge of the circularity practices?			1
Is management committed and involved in circularity?			1
Are shareholders and investors involved and supporting circularity?			1
Is the organisation developing the circular economy as a culture?			1
Is circularity part of the values of the organisational culture of the company?			1
Has the company assigned a yearly budget for environmental expenditures?			
Is the company creating and sharing annual environmental reports with their stakeholders?			
Is the company applying continuous monitoring regarding circularity?			1
Is the company using systems and information technologies to generate and communicate accurate data?	1		
Has the company recognised any competitive and reputational advantage due to circular practices?			1

Has the company recognised any economic benefits or cost avoidance due to circular practices?			1
B.b) Special training for workers on environmental issues and circular economies	**Yes**	**Partially**	**No**
Is the company contributing to increase environmental awareness among all the members of the organisation?		1	
Is the company offering formal and periodic training, sharing of information and achievements regarding circular economy to new and existing members of the organisation?			1
B.c) Including environmental factors in the internal performance evaluation system	**Yes**	**Partially**	**No**
Has the company established targets of reduction of water, energy, waste, raw materials, etc.?	1		
Is the company taking into account environmental factors when assessing internal performance?			1
Does the organisation uses an indicators dashboard to understand and visualise their targets?	1		
B.d) Environmental auditing program	**Yes**	**Partially**	**No**
Is the company identifying the environmental risks?	1		
Does the company measure and monitor their environmental impacts through tools like ISO14000, lifecycle analysis or material flow analysis?	1		
Is the company following a sustainability framework such as Carbon Disclosure Project (CDP), Global Reporting Initiative (GRI) or Dow Jones Sustainability Index (DJSI)?			1
Does the company have an environmental policy?	1		
Is the company doing something to reduce the environmental impact of their activities in the energy sector?			1
Is the company doing something to reduce the environmental impact of their activities in the water sector?			N/A
Is the company doing something to reduce the environmental impact of their activities in the conservation of the environment?		1	
Total number of positive answers	**6**	**2**	**14**
	27.27%	**9.09%**	**63.64%**
		B =	**0**

Questionnaire for factor D

D. External Awareness

D.a) Awareness within customers	**Yes**	**Partially**	**No**
Is the company measuring or doing something to understand the level of awareness of their customers?			1
Is the company contributing to increase circular awareness among their customers?			1
Is the company contributing to increase circular awareness			1

among the community?			
D.b) Eco-labelling of products	**Yes**	**Partially**	**No**
Is the company sharing with the customers the environmental benefits in order to motivate the purchase of their products?			N/A
D.c) Awareness within suppliers	**Yes**	**Partially**	**No**
Is the company measuring or doing something to understand the level of awareness of their suppliers?			1
Is the company contributing to increase social awareness among their suppliers?			1
Total number of positive answers	**0**	**0**	**5**
	0.00%	**0.00%**	**100.00%**
		D =	**0**

Questionnaire for factor E

E. Value Chain Support

E.a) Selecting suppliers using environmental criteria	**Yes**	**Partially**	**No**
Is the company using sustainable/circular procurement to improve materials?			1
Is the company using sustainable/circular procurement to secure future sustainable resources?			1
Is the company using sustainable/circular procurement to find recycled or second hand materials if possible?			N/A
Is the supply chain involved in circularity?		1	
Are suppliers required to provide environmental information on their activities and products?			1
Is the company using sustainable/ circular procurement to develop suppliers?			1
Is the company using sustainable/circular procurement to assess suppliers' circularity?			1
Is the company basing their purchasing decision in a total cost assessment which considers transportation, use and waste management costs?	1		
Is the company communicating the environmental purchasing criteria with all the stakeholders?			1
E.b) Cooperating with other firms to establish eco-industrial chains	**Yes**	**Partially**	**No**
Is the company working in partnerships with companies from the same sector?			1
Is the company working in partnerships with companies from different sector?	1		
Is the company working in partnerships with suppliers?	1		
Is the company working in partnerships with educational institutions?	1		
Has the company identified the amount of direct and indirect	1		

employments generated by the creation of partnership?			
E.c) Reusing energy and/or water across the value chain	**Yes**	**Partially**	**No**
Is the company sharing energy produced by their processes with another company for future utilisation?			N/A
Is the company sharing used water with another company for further utilisation?			N/A
Is the company utilising energy generated by another company?			1
Is the company utilising water generated by another company?			1
Total number of positive answers	**5**	**1**	**9**
	33.33%	**6.67%**	**60.00%**
		E =	**0**

Questionnaire for factor F

F. External practices for longevity

F.a) Taking back products from consumers after the end of their functional life	**Yes**	**Partially**	**No**
Is the company already taking back products from consumers at the end of their functional life?			1
Does the company work to avoid the misconception or misunderstanding of recovering at the end of their products functional life?			N/A
Is the company already implementing methods to avoid or reduce variability of conditions in waste recovery even if they were manufactured together?			N/A
F.b) Taking back products from consumers after the end of their usage	**Yes**	**Partially**	**No**
Is the company already taking back products from consumers at the end of usage?			1
Does the company work to avoid the misconception or misunderstanding of recovering at the end of their product usage?	N/A	N/A	N/A
Is the company already implementing methods to avoid or reduce variability of conditions in waste recovery even if they were manufactured together?	N/A	N/A	N/A
F.c) Reusing products	**Yes**	**Partially**	**No**
Is the company already implementing reusing as a business model?	N/A	N/A	N/A
Does the company work to avoid the misconceptions or misunderstanding of reused products against second hand products?	N/A	N/A	N/A
F.d) Refurbishing products (i.e. returning them to good working condition by replacing or repairing major faulty components)	**Yes**	**Partially**	**No**

Is the company already implementing refurbishing as a business model?			1
Does the company work to avoid the misconception or misunderstanding of refurbishing against second hand products and obsolescence risk?	N/A	N/A	N/A
Does the company work to avoid the lack of spare parts for refurbishing?	N/A	N/A	N/A
F.e) Remanufacturing products	**Yes**	**Partially**	**No**
Is the company already implementing remanufacturing as a business model?	N/A	N/A	N/A
Does the company work to avoid the misconception or misunderstanding of remanufacturing against second hand products?	N/A	N/A	N/A
Does the company work to avoid the lack of spare parts for remanufacturing?	N/A	N/A	N/A
F.f) Use of recycled materials	**Yes**	**Partially**	**No**
Is the company already using recycled materials for production?	N/A	N/A	N/A
Does the company work to avoid the misconception or misunderstanding of recycling materials?	N/A	N/A	N/A
F.g) Recycling of scrap	**Yes**	**Partially**	**No**
Is the company already recycling the scrap generated by production processes?		1	
F.h) Recycling of products recovered after the end of functional life	**Yes**	**Partially**	**No**
Is the company already recycling products recovered from the customers at the end of their functional life?			1
F.i) Recycling of products recovered after usage	**Yes**	**Partially**	**No**
Is the company already recycling products recovered from the customers at the end of their usage?			1
F.j) Adopting a leasing or service-based marketing strategy	**Yes**	**Partially**	**No**
Is the company already implementing leasing as a business model?			1
Does the company work to avoid the misconception or misunderstanding of leasing?			1
F.k) Adopting an updating market strategy?	**Yes**	**Partially**	**No**
Is the company already implementing updating as a business model?		1	
Does the company work to avoid the misconception or misunderstanding of updating?	1		
F.l) Cascading use (i.e. multiple usages/applications) of	**Yes**	**Partially**	**No**

components and materials once its properties are lost and cannot be recycled anymore			
Is the company already implementing cascading actions for the materials that are not adequate anymore or have lost their properties?	1		
Total number of positive answers	**2**	**2**	**7**
	18.18%	**18.18%**	**63.64%**
		F =	**0**

Questionnaire for factor G

G. Increasing green market

G.a) Targeting 'green' segments of the market	**Yes**	**Partially**	**No**
Does the company fully understand the needs of the green or environmentally aware market?		1	
Is the company implementing actions to fully satisfy the needs of the green or environmentally aware market?		1	
Does the company have an expansion plan or strategy for the green market?	1		
Does the company marketing strategy includes the environmental aspects of their products?	1		
G.b) Incentives	**Yes**	**Partially**	**No**
Is the company offering price incentives in recovered, reused, refurbished, remanufactured, recycled, leased, and updated products to persuade the growth and development of circular economy?			N/A
Is the company offering incentives such as warranty services for reused, refurbished, remanufactured, recycled, leased and updated products to relieve obsolescence risk?			N/A
Is the company offering incentive such as trial periods for reused, refurbished, remanufactured, recycled, leased and updated products to generate confidence?			1
Is the company offering incentives within the organisation in order to persuade the growth and development of circular economy?			1
Is the company offering incentives within their suppliers to persuade the growth and development of circular economy?			1
Total number of positive answers	**2**	**2**	**3**
	28.57%	**28.57%**	**42.86%**
		G =	**0.5**

Questionnaire for factor H

H. Technological development

H.a) Cross-functional cooperation for environmental improvements	**Yes**	**Partially**	**No**
Is the company investing in infrastructure to support the circular			1

economy?			
Is the company following the environmental innovations and productivity improvements within their sector?		1	
Is the company evaluating the environmental costs of capital purchases and new technologies to be acquired?			N/A
Is the company making any research and development in circularity? For example, recycling processes.	1		
Is the company continuously looking for financing programs in order to create development programs?			N/A
Is the company working in collaboration with other companies to develop useful technologies for circular economies?			1
Is the company working in collaboration with educational institutions to develop useful technologies for circular economies?			1
Total number of positive answers	**1**	**1**	**3**
	20.00%	**20.00%**	**60.00%**
		H =	**0**

Questionnaire for factor I

I. Legislation development

I.a) Legislation and policies	**Yes**	**Partially**	**No**
Is the company complying with the environmental legislation and policies according to the geographies of their operations?	1		
Is the company working with ONG's to improve the circular economies outside their value chain?			1
Is the company working with governmental agencies in the development of environmental legislation and policies such as taxation against non-renewable resources?			1
Is the company contributing to increase awareness in the government?			1
Total number of positive answers	**1**	**0**	**3**
	25.00%	**0.00%**	**75.00%**
		I =	**0**

Appendix G Circularity measurement toolkit for Company B

Company's name:	*Company B*
Country:	*Pakistan*
Main product types:	Sanitary Products
Type of industry sector:	Sanitary
Type of processes used:	Extude, Forging, CNC Lathe (Manual + semi-automatic, dependent on type of requirement).
Waste types:	Brass, Steel
Amount of employees:	35
Name of the person responsible for the assessment:	Simon, Director/COO
Number of people employed for circular practices:	Nil
Has the company identified savings due to circular practices?	None

										RANGE	
Rating\Factors	A	B	D	E	F	G	H	I	**Result**	**Min**	**Max**
1. Circular developer	0.5	0	0	0.5	1	0	0	0	**2.00**	6.5	8
2. Circular Promoter	0.5	0	0	0.5	1	0			**2.00**	5.5	6
3. Circular	0.5	0	0	0.5	1				**2.00**	3.5	5
4. Waved	0.5	0	0						**0.50**	2.5	3
5. Curved (where A = 1 and B = 1)	0.5	0							**0.00**	2	2
6. Saw tooth (where A = 0.5 to 1 and B = 0.5 to 1)	0.5	0							**0.00**	1	1.5
7. V-shape up (where A=0 and B = 0.5 to 1)	0.5	0							**0.00**	0.5	1
8. ∧-shape down (where A - 0.5 to 1 and B = 0)	0.5	0							**1.00**	0.5	1
9. Linear	0.5	0	0	0.5	1	0	0	0	**2.00**	0	0

Questionnaire for factor A

A. Internal Practices – Resource utility and efficiency

Design			
A.a) Designing of product for reduced consumption of resources	**Yes**	**Partially**	**No**
The design of products in the company consider the utilisation of the minimum amount or resources?	1		
Does the company avoid the use of non-renewable resources in the design unless it is impossible?	1		
A.b) Designing products for reuse, recycle, and/or recovery of material and/or component parts	**Yes**	**Partially**	**No**
Does the company consider and apply design for reuse?			1

Does the company consider and apply design for disassembly?			1
Does the company consider and apply design for refurbish?		1	
Does the company consider and apply design for remanufacture?			1
Does the company consider and apply design for recycling?	1		
A.c) Designing processes for minimisation of waste	**Yes**	**Partially**	**No**
Does the company consider and apply design for minimisation of waste?	1		
A.d) Designing products for durability	**Yes**	**Partially**	**No**
Does the company consider and apply design for durable products?	1		
Production			
A.e) Reducing Material (i.e. raw material and/or water)	**Yes**	**Partially**	**No**
Raw Material			
Does the company keep register of material consumption?	1		
Is the company already analysing and identifying possible ways to reduce the amount of materials?	1		
Is the company already implementing actions to reduce the amount of material use?	1		
Water			
Does the company keep register of the rate of discharged water and water consumption?			1
Does the company apply water conservation measures?			1
Does the company treat waste water?			N/A
A.f) Reducing energy (i.e. electricity, coal, gas) consumption	**Yes**	**Partially**	**No**
Does the company keep register of energy consumption?	1		
Is the company already analysing and identifying possible ways to reduce the amount of energy consumed?		1	
Is the company already implementing actions to reduce the amount of energy consumed?		1	
Is the company already analysing or identifying if any of their processes can produce energy?			1
Is the company using energy produced by themselves?			1
Is the company using renewable energy?			1
A.g) Using renewable materials and energy in the production process	**Yes**	**Partially**	**No**
Renewable materials			
Does the company keep register of non-renewable materials consumption?			N/A
Is the company already analysing and identifying possible ways to reduce or eliminate the amount of non-renewable materials by substituting them with renewable materials?			N/A

Is the company already implementing actions to reduce the use of non-renewable materials?			N/A
Renewable energy			
Does the company keep register of non-renewable energy resource consumption?			1
Is the company already analysing and identifying the possibility of manufacturing their products with the use of renewable energy?		1	
Is the company already implementing actions to substitute non-renewable energy with source of renewable energy?			1
A.h) Reducing pollutants emissions	**Yes**	**Partially**	**No**
Does the company keep records of pollution?			1
Does the company keep register of their Greenhouse Gas (GHG) emissions?			1
Is the company already analysing and identifying possible ways to reduce the amount of GHG emissions?			N/A
Is the company already implementing GHG reduction actions?			N/A
Does the company keep register of the use of fertilizers?			N/A
Is the company already analysing and identifying possible ways to reduce the amount of fertilizers?			N/A
Is the company already implementing fertilizers reduction actions?			N/A
Does the company keep register of the use of pesticides?			N/A
Is the company already analysing and identifying possible ways to reduce the amount of pesticides?			N/A
Is the company already implementing pesticides reduction actions?			N/A
Does the company keep register of the use of petrol?			N/A
Is the company already analysing and identifying possible ways to reduce the amount of petrol?			N/A
Is the company already implementing petrol reduction actions?			N/A
Does the company keep records of the use of diesel?			N/A
Is the company already analysing and identifying possible ways to reduce the amount of diesel?			N/A
Is the company already implementing diesel reduction actions?			N/A
Does the company keep records of the use of natural gas?			N/A
Is the company already analysing and identifying possible ways to reduce the amount of natural gas?			N/A
Is the company already implementing natural gas reduction actions?			N/A
A.i) Reducing wastes	**Yes**	**Partially**	**No**
Does the company support landfill prevention?	1		
Does the company keep records of waste generation?	1		
Does the company separate waste in an efficient way?	1		
Does the company support the circulation of waste, understanding waste as an input?	1		

In case of disposing, is the company doing it in an adequate form regarding the environment?	N/A		
Packaging and distribution			
A.j) Green Packaging	**Yes**	**Partially**	**No**
Does the company use green and efficient packaging?			1
A.k) Green distribution	**Yes**	**Partially**	**No**
Does the company choses transport options with comparatively less environmental impact like rail or water for the distribution of their products?	1		
Is the company using any management tools, techniques, and technologies to optimise the distribution and shipping efficiency?			1
Total	**14**	**4**	**14**
	43.75%	**12.50%**	**43.75 %**
		A =	**0.5**

Questionnaire for factor B

B. Internal awareness

B.a) Circular management, culture and continuous monitoring	**Yes**	**Partially**	**No**
Does the organisation have formulated a circular economy strategy?			1
Has the company assigned a person to be responsible for environmental and circular matters?			1
Does the company have a functional structure in charge of the circularity practices?			1
Is management committed and involved in circularity?			1
Are shareholders and investors involved and supporting circularity?			1
Is the organisation developing the circular economy as a culture?			1
Is circularity part of the values of the organisational culture of the company?			1
Has the company assigned a yearly budget for environmental expenditures?			1
Is the company creating and sharing annual environmental reports with their stakeholders?			1
Is the company applying continuous monitoring regarding circularity?			1
Is the company using systems and information technologies to generate and communicate accurate data?	1		
Has the company recognised any competitive and reputational			1

advantage due to circular practices?			
Has the company recognised any economic benefits or cost avoidance due to circular practices?	1		
B.b) Special training for workers on environmental issues and circular economies	**Yes**	**Partially**	**No**
Is the company contributing to increase environmental awareness among all the members of the organisation?			1
Is the company offering formal and periodic training, sharing of information and achievements regarding circular economy to new and existing members of the organisation?			1
B.c) Including environmental factors in the internal performance evaluation system	**Yes**	**Partially**	**No**
Has the company established targets of reduction of water, energy, waste, raw materials, etc.?		1	
Is the company taking into account environmental factors when assessing internal performance?			1
Does the organisation uses an indicators dashboard to understand and visualise their targets?			1
B.d) Environmental auditing program	**Yes**	**Partially**	**No**
Is the company identifying the environmental risks?			1
Does the company measure and monitor their environmental impacts through tools like ISO14000, lifecycle analysis or material flow analysis?			1
Is the company following a sustainability framework such as Carbon Disclosure Project (CDP), Global Reporting Initiative (GRI) or Dow Jones Sustainability Index (DJSI)?			1
Does the company have an environmental policy?			1
Is the company doing something to reduce the environmental impact of their activities in the energy sector?			1
Is the company doing something to reduce the environmental impact of their activities in the water sector?			N/A
Is the company doing something to reduce the environmental impact of their activities in the conservation of the environment?			1
Total	**2**	**1**	**21**
	8.33%	**4.17%**	**87.50%**
		B =	**0**

Questionnaire for factor D

D. External Awareness

D.a) Awareness within customers	**Yes**	**Partially**	**No**
Is the company measuring or doing something to understand the level of awareness of their customers?		1	

Is the company contributing to increase circular awareness among their customers?			1
Is the company contributing to increase circular awareness among the community?			1
D.b) Eco-labelling of products	**Yes**	**Partially**	**No**
Is the company sharing with the customers the environmental benefits in order to motivate the purchase of their products?			1
D.c) Awareness within suppliers	**Yes**	**Partially**	**No**
Is the company measuring or doing something to understand the level of awareness of their suppliers?			1
Is the company contributing to increase social awareness among their suppliers?			1
Total	**0**	**1**	**5**
	0.00%	**16.67%**	**83.33%**
		D =	**0**

Questionnaire for factor E

E. Value Chain Support

E.a) Selecting suppliers using environmental criteria	**Yes**	**Partially**	**No**
Is the company using sustainable/circular procurement to improve materials?	1		
Is the company using sustainable/circular procurement to secure future sustainable resources?		1	
Is the company using sustainable/circular procurement to find recycled or second hand materials if possible?	1		
Is the supply chain involved in circularity?	1		
Are suppliers required to provide environmental information on their activities and products?			1
Is the company using sustainable/ circular procurement to develop suppliers?		1	
Is the company using sustainable/circular procurement to assess suppliers' circularity?			1
Is the company basing their purchasing decision in a total cost assessment which considers transportation, use and waste management costs?			1
Is the company communicating the environmental purchasing criteria with all the stakeholders?			1
E.b) Cooperating with other firms to establish eco-industrial chains	**Yes**	**Partially**	**No**
Is the company working in partnerships with companies from the same sector?			1
Is the company working in partnerships with companies from different sector?	1		
Is the company working in partnerships with suppliers?		1	

Is the company working in partnerships with educational institutions?	1		
Has the company identified the amount of direct and indirect employments generated by the creation of partnership?	1		
E.c) Reusing energy and/or water across the value chain	**Yes**	**Partially**	**No**
Is the company sharing energy produced by their processes with another company for future utilisation?			1
Is the company sharing used water with another company for further utilisation?			N/A
Is the company utilising energy generated by another company?			1
Is the company utilising water generated by another company?			N/A
Total	**6**	**3**	**7**
	37.50%	**18.75%**	**43.75%**
		E =	**0.5**

Questionnaire for factor F

F. External practices for longevity

F.a) Taking back products from consumers after the end of their functional life	**Yes**	**Partially**	**No**
Is the company already taking back products from consumers at the end of their functional life?			N/A
Does the company work to avoid the misconception or misunderstanding of recovering at the end of their products functional life?			N/A
Is the company already implementing methods to avoid or reduce variability of conditions in waste recovery even if they were manufactured together?	1		
F.b) Taking back products from consumers after the end of their usage	**Yes**	**Partially**	**No**
Is the company already taking back products from consumers at the end of usage?			N/A
Does the company work to avoid the misconception or misunderstanding of recovering at the end of their product usage?			N/A
Is the company already implementing methods to avoid or reduce variability of conditions in waste recovery even if they were manufactured together?	1		
F.c) Reusing products	**Yes**	**Partially**	**No**

Is the company already implementing reusing as a business model?	1		
Does the company work to avoid the misconceptions or misunderstanding of reused products against second hand products?	1		
F.d) Refurbishing products (i.e. returning them to good working condition by replacing or repairing major faulty components)	**Yes**	**Partially**	**No**
Is the company already implementing refurbishing as a business model?	N/A		
Does the company work to avoid the misconception or misunderstanding of refurbishing against second hand products and obsolescence risk?	N/A		
Does the company work to avoid the lack of spare parts for refurbishing?	N/A		
F.e) Remanufacturing products	**Yes**	**Partially**	**No**
Is the company already implementing remanufacturing as a business model?	N/A		
Does the company work to avoid the misconception or misunderstanding of remanufacturing against second hand products?	N/A		
Does the company work to avoid the lack of spare parts for remanufacturing?	N/A		
F.f) Use of recycled materials	**Yes**	**Partially**	**No**
Is the company already using recycled materials for production?	1		
Does the company work to avoid the misconception or misunderstanding of recycling materials?	1		
F.g) Recycling of scrap	**Yes**	**Partially**	**No**
Is the company already recycling the scrap generated by production processes?	1		
F.h) Recycling of products recovered after the end of functional life	**Yes**	**Partially**	**No**
Is the company already recycling products recovered from the customers at the end of their functional life?	N/A		
F.i) Recycling of products recovered after usage	**Yes**	**Partially**	**No**
Is the company already recycling products recovered from the customers at the end of their usage?	N/A		
F.j) Adopting a leasing or service-based marketing strategy	**Yes**	**Partially**	**No**
Is the company already implementing leasing as a business model?	N/A		

Does the company work to avoid the misconception or misunderstanding of leasing?	N/A		
F.k) Adopting an updating market strategy?	**Yes**	**Partially**	**No**
Is the company already implementing updating as a business model?	1		
Does the company work to avoid the misconception or misunderstanding of updating?	1		
F.l) Cascading use (i.e. multiple usages/applications) of components and materials once its properties are lost and cannot be recycled anymore	**Yes**	**Partially**	**No**
Is the company already implementing cascading actions for the materials that are not adequate anymore or have lost their properties?	1		
Total	**10**	**0**	**0**
	100%	**0.00%**	**0.00%**
		F =	**1**

Questionnaire for factor G

G. Increasing green market

G.a) Targeting 'green' segments of the market	**Yes**	**Partially**	**No**
Does the company fully understand the needs of the green or environmentally aware market?			1
Is the company implementing actions to fully satisfy the needs of the green or environmentally aware market?			1
Does the company have an expansion plan or strategy for the green market?		1	
Does the company marketing strategy includes the environmental aspects of their products?			1
G.b) Incentives	**Yes**	**Partially**	**No**
Is the company offering price incentives in recovered, reused, refurbished, remanufactured, recycled, leased, and updated products to persuade the growth and development of circular economy?			1
Is the company offering incentives such as warranty services for reused, refurbished, remanufactured, recycled, leased and updated products to relieve obsolescence risk?	1		
Is the company offering incentive such as trial periods for reused, refurbished, remanufactured, recycled, leased and updated products to generate confidence?	N/A		
Is the company offering incentives within the organisation in order to persuade the growth and development of circular economy?			1
Is the company offering incentives within their suppliers to persuade the growth and development of circular economy?			1

Total	**1**	**1**	**6**
	12.50%	**12.50%**	**75.00%**
		G =	**0**

Questionnaire for factor H

H. Technological development

H.a) Cross-functional cooperation for environmental improvements	**Yes**	**Partially**	**No**
Is the company investing in infrastructure to support the circular economy?			1
Is the company following the environmental innovations and productivity improvements within their sector?		1	
Is the company evaluating the environmental costs of capital purchases and new technologies to be acquired?			1
Is the company making any research and development in circularity? For example, recycling processes.		1	
Is the company continuously looking for financing programs in order to create development programs?		N/A	
Is the company working in collaboration with other companies to develop useful technologies for circular economies?			1
Is the company working in collaboration with educational institutions to develop useful technologies for circular economies?			1
Total	**0**	**2**	**4**
	0.00%	**33.33%**	**66.67%**
		H =	**0**

Questionnaire for factor I

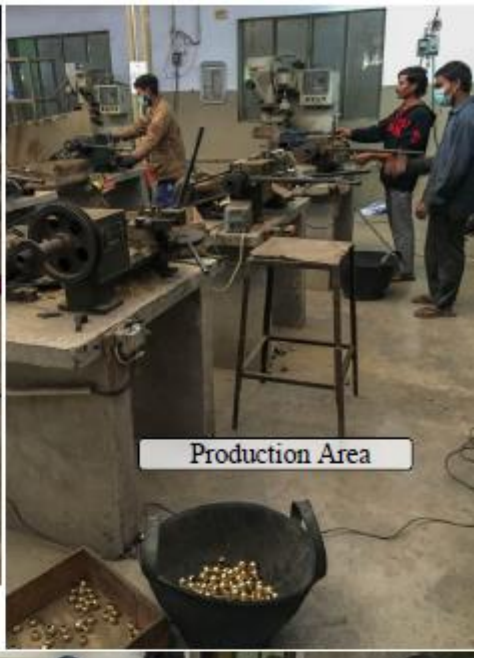
I. Legislation development

I.a) Legislation and policies	**Yes**	**Partially**	**No**
Is the company complying with the environmental legislation and policies according to the geographies of their operations?	1		
Is the company working with NGO's to improve the circular economies outside their value chain?			1
Is the company working with governmental agencies in the development of environmental legislation and policies such as taxation against non-renewable resources?			1
Is the company contributing to increase awareness in the government?			1
Total	**1**	**0**	**3**
	25.00%	**0.00%**	**75.00%**
		I =	**0**

Appendix H Pictures of Company B

Production Area and different equipment


Production Area


Production Area


Tools storage


Packaging


Finished goods storage area


Final Quality Check