Development of a Dedicated Framework for Deployment of Circular Economy Strategies in Manufacturing Organizations

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Abstract

In the current industrial scenario, manufacturing organizations are dealing with issues pertaining to lack of resources, higher environmental impacts and decreased value creation. To make the manufacturing process more efficient and to cope up with the volatile industrial market, manufacturing organizations have started to adopt sustainable strategies that focus on gradually decoupling economic activity from the consumption of finite resources, and designing waste out of the system. Circular Economy is one such strategy which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products. Deploying circular economy strategies would make the firm to strengthen its business model and also improves the overall value of the manufacturing process and as well as the product. A dedicated framework is required for deploying the circular economy concepts systematically. This research article proposes a dedicated framework for deploying circular economy concepts in manufacturing organizations. The developed framework consists of five phases namely Framing the factors, Production and Deployment, Collection and Reuse, Usage and Consumption and Measuring the performance. Each phase consists of a set of directives for deploying the concepts. The developed framework will be useful for implementation managers and manufacturing firms willing to deploy circular economy concepts in their organization.

Keywords

Lean Six Sigma, Sustainable Manufacturing, Structural Model, Enablers, MICMAC Analysis

1. Introduction

The structure of the supply chain has been largely untouched since people started to make and distribute products to each other (De Angelis et al., 2018). Raw materials flow in, are transformed into a product, and distributed and used until they are finally discarded. These discarded products have the potential of being raw materials or inputs for other process that are carried out worldwide (Tseng et al., 2020). This will most probably reduce the consumption of new raw materials and increase the profitability of the industry. Hence the after-market supply chain is gaining popularity over the custom linear supply chain, which is circular supply chain. The circular economy is a business concept that promotes application of reuse, remanufacturing, recycling methodologies on the discarded materials by product manufacturers and suppliers (Patwa et al., 2021). Industries are refurbishing discarded parts by melting down them to return them to their raw material form rather than developing a one-time-use products and transforming the model to "take, make, use, reuse".In industrial ecology and production economic literature the term circular economy is deep rooted, at present it is spreading in business and its practices too. It is also termed as a systemic approach

to economic development designed to benefit businesses, society, and the environment. In contrast to the 'take-make-waste' linear model, a circular economy is regenerative by design and aims to gradually decouple growth from the consumption of finite resources. Circular economy concerns not only the decrease of the use of the environment as a residual sink, but also the establishment of self-sufficient industrial systems for repeated use of materials and resources. Circular supply chains are more economical in long run for all the industries and once it has been implemented, enterprises spend less on raw materials, support the environment, are less vulnerable to price fluctuation and probably most importantly please their customers (Machado et al., 2020). In order to mitigate the possible environmental consequences, it is necessary to minimize the generation of waste and encourage the use of products, materials, and resources that will remain in the economy for as long as possible (Manavalan and Jaykrishna, 2019). These are the foundations of the so-called circular economy which seeks a new model of production and consumption of goods and services associated with sustainability. A framework is a step by step approach for deploying a certain concept. A dedicated framework would guide the implementation process properly and makes the process hassle free. For deployment of Circular Economy concepts, it requires a dedicated framework to systematically govern the implementation process. This work reports about the development of a dedicated framework for deployment of circular economy concepts in manufacturing organizations.

2. Literature Review

Circular Economy principles mainly focuses on three domains namely design out waste and pollution, keep products and materials in use and regenerate natural systems. Various research articles have briefly discussed about the core concept of Circular Economy and its link with sustainability. Since the present study focuses on development of a framework for deployment of CE concepts, literature was reviewed from the perspective of frameworks that are used for deploying circular economy concepts and principles. Table 1 depicts the major research findings obtained from the research studies that adhere to the research theme.

Table 1. Conducted Literature Review

Research Study	Findings
Lewandowski (2016)	Performed an extensive review to identify and classify the circular economy characteristics according to a business model structure. Based on the review , two new components namely the take-back system and adoption factors were identified to redefine the components of the business model canvas in the context of the circular economy
Pomponi, and Moncaster (2017)	Developed a research framework based on literature review to analyze the key roles of interdisciplinary research of both bottom-up and top-down initiatives in facilitating the transition to 'circular buildings'. The developed research framework is used to capture current discourse on the sustainability of the built environment and has proved to be a valuable tool to cluster existing initiatives and highlight missing links for interdisciplinary endeavors
Lieder and Rashid (2016)	Performed a comprehensive review of research efforts encompassing aspects of resources scarcity, waste generation and economic advantages to explore the CE initiatives. They also developed a framework that emphasizes on a combined view of three main aspects i.e. environment, resources and economic benefits. The study also found that joint support of all stakeholders is necessary in order to successfully implement the CE concept at large scale.
Prieto et al., (2018)	Performed a systematic literature review that resulted in four main outputs which includes a knowledge map of the circular economy, an analysis of the main notions of the concept, principles, and determinants of a circular economy. The work also cites few remarkable examples f eco-innovations developed for implementation in the circular economy
Van den Berg and Bakker (2015)	Designed a circular economy framework from a product design perspective with tools to aid product designers in applying circular product design in practice. The framework is an adapted circular economy model that comprises of the five most design-relevant topics namely future proof

	design, and design for disassembly, maintenance, remake and recycling. The model was also validated with a case study
Witjes, and Lozano (2016)	Proposed proposes a framework to include technical and non-technical specifications of product/service combinations that improve resource usage efficiency through recovery. The framework also considers socio-cultural specifications and physical and social proximity between the stakeholders in the procurement process. The developed framework is also based on collaboration, which is a vital link between the public procurement process and the development of more sustainable business models, where the experience gained in the collaboration process serves as the bases for suppliers and procurers in improving their contribution to CE
Moraga et al., (2019)	Framed a set of indicators for development of a framework for deploying CE concepts. The indicators were selected from literature and the European Union 'CE monitoring framework'. The study suggests that a set of indicators should be used to assess CE instead of a single indicator for successful deployment of CE
Bocken et al., (2016)	Developed a framework of strategies to guide designers and business strategists in the move from a linear to a circular economy. They also suggested a list of product design strategies, business model strategies, and examples for key decision-makers in businesses is introduced, to facilitate the move to a circular economy from a traditional linear one
Blomsma et al., (2019)	Proposed a strategic framework for the manufacturing organizations titled the Circular Strategies Scanner, which provides a comprehensive set of definitions of circular strategies and directly supports the early stages of CE oriented innovation. The framework introduces a taxonomy of circular strategies developed for use by manufacturing companies engaging in circular economy (CE) oriented innovation
Chen et al., (2020)	Conducted a detailed review about the Circular Economy Business Models and classified them under three topics namely CBM typologies and archetypes, transition guidelines, and major analytical tools for CBM research. The review also identifies the challenges and shortfalls in CBM deployment and these outcome will be useful while designing a dedicated framework for deployment of CBM

Based on this literature, we define Circular Supply Chain Management (CSCM) as the configuration and coordination of the organisational functions marketing, sales, R&D, production, logistics, IT, finance, and customer service within and across business units and organisations to close, slow, intensify, narrow, and dematerialise material and energy loops to minimise resource input into and waste and emission leakage out of the system, improve its operative effectiveness and efficiency and generate competitive advantages. Most of the available literature have systematically analyzed the literature and has proposed various indicators and outlines for development of frameworks for deploying Circular Economy. Following the importance of the value chain for the business model and the need for alignment of all the business model's elements for optimal sustainability performance, it can be argued that CE aims at fostering sustainable development should incorporate such characteristics. Few Authors have also proposed frameworks for deployment of CE concepts. To the best knowledge of the authors, no research article has proposed a concrete dedicated framework that provides a step by step approach for deployment of CE concepts in manufacturing organizations. Considering this gap, the current work focuses on development of a dedicated framework for deployment of CE concepts in a manufacturing domain perspective.

3. Framework Development

The developed framework consists of five phases. Each phase comprises of a predetermined set of activities that has to be elaborately performed for moving from one phase to another on completion. The five phases are Framing the factors, Production and Deployment, Collection and Reuse, Usage and Consumption and Measuring the performance. The developed framework is shown in Figure 1.

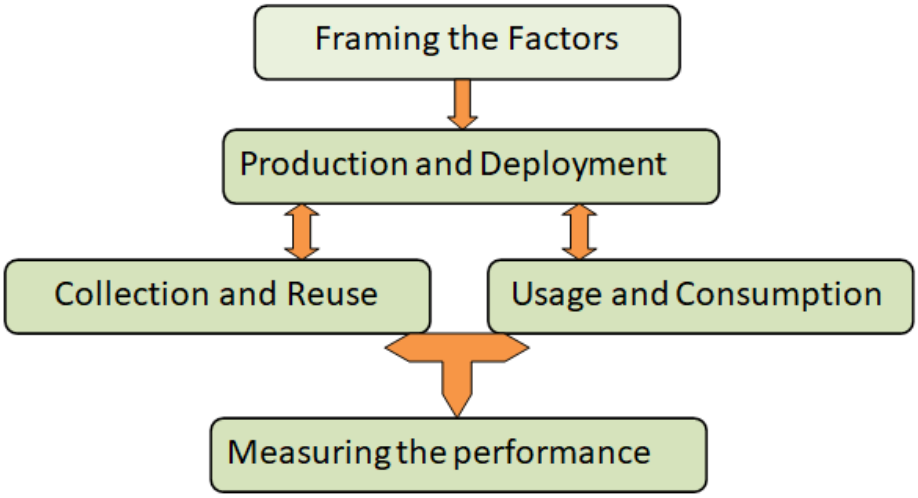

Figure 1. Developed ISM model

The developed framework is a step by step framework and during deployment, all subordinate components has to be systematically deployed for completion of each phase. Elaborate discussion of each phase and its sub components are discussed in the following sections.

3.1 Framing The Factors

Before starting the implementation, it is important for the firm to analyze its potential factors that both supports and hinders the implementation process. The factors could be either potential enablers or barriers. An enabler supports the implementation process and the barrier hinders the implementation process. Understanding about the factors would make the organization to prioritize the factors and will also help them to plan the deployment activities considering the firms resource availability and strengths. The steps to be followed in this phase are shown in Figure 2.

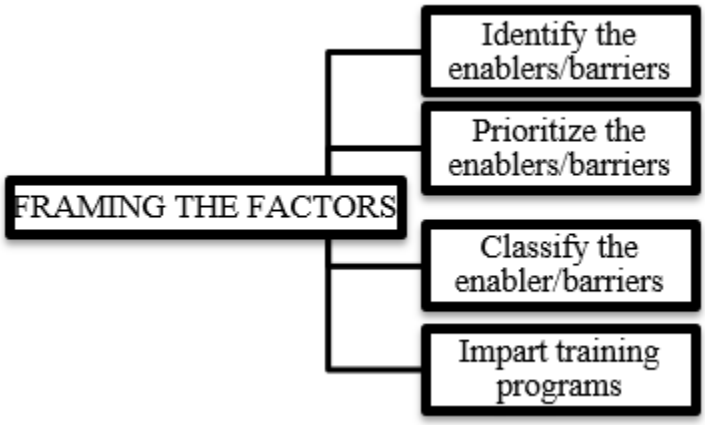

Figure 2. Steps in Framing the factors

Initially the firm has to decide whether it focuses on identifying the enablers or barriers. After deciding the factors to be collected, the firm gas to identify the factors. This could be based on the literature or based on a field study. After

identifying the factors, the firm could deploy a mathematical model for prioritizing it. After identifying such factors, the firm could focus on imparting training programs to improve the weaker area before actual deployment of the concepts.

3.2 Production and Deployment

Before deploying the circular economy techniques, it is necessary for the firm to enhance its value by minimizing the wasteful non value added activities. Performing this would improve both the product and process functions and would result in successful deployment. This could be performed by deploying the following steps as shown in Figure 3.

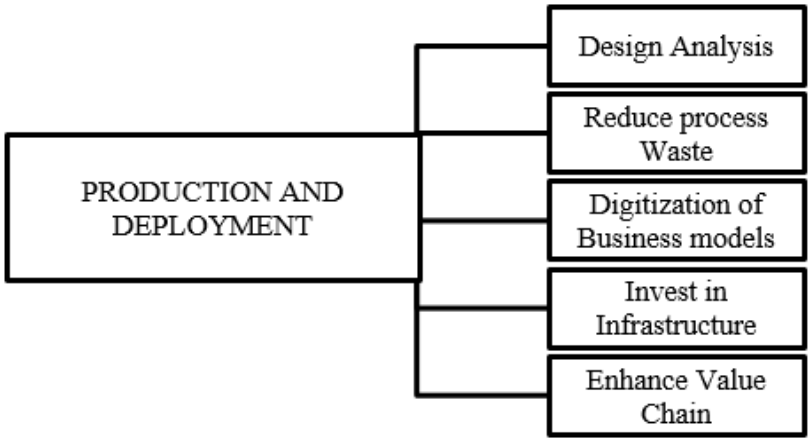

Figure 3. Steps in Production and Deployment

A complete design analysis has to be made to understand about design of the existing product. Deploying Concepts like Design for Environment, Design for Manufacture and Assembly and Alternate materials could be analyzed at this phase to reduce the case products environmental impacts. To reduce the process wastes, waste categorization must be performed first and deployment of lean principles could be done to reduce the non value added activities, After deploying the lean principles, the firm could focus on digitization of its business model by deploying Industry 4.0 technologies. At this point, the firm can review its infrastructural facilities and could invest in building its technological infrastructure if required. This would enhance the value chain of the case organization.

3.3a Collection and Reuse

During this phase, the firm must frame and design its collection policy to collect back the repaired product or product that is scheduled to be disposed by the customer. Within the manufacturing unit, the firm can consider setting up a recycling unit that extensively works on refurbishing the product that has reached its End of Life. A strong coordination must be made with the retailer in order to track the customer regarding collecting the products to be disposed. A communication model with high connectivity and a database management system must be maintained for better information flow. The facility that has to be made available in the recycling unit must be planned by the firm by consulting the production department. Once the case component comes out of the recycling unit, it should reach the manufacturing plant. The follow-up distribution activity must be done by the manufacturing plant as it is done for a new case product as shown in figure 4.

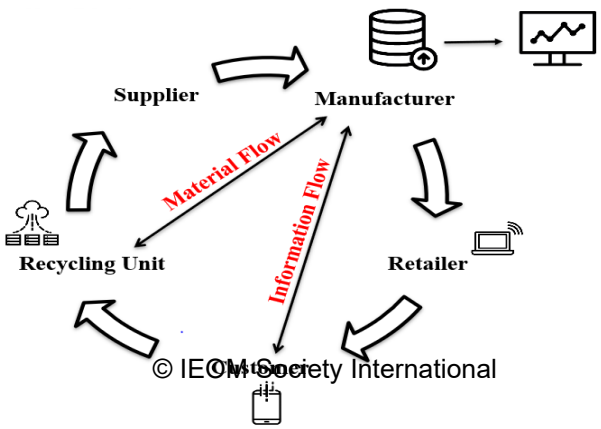

Figure 4. Collection and Reuse Cycle

3.3b Usage And Consumption

While deploying the activities in the recycling unit, it is necessary to perform the Life Cycle Assessment for the case product, to find its total impacts. This is performed after collecting the data pertaining to Inventory and manufacturing process. Also a database pertaining to the probable product failures, defects and repairs must be maintained by the recycling unit to plain for the refurbishing activities. After analyzing, if the product is found to be not in a condition to be reused, then a proper disposal scenario must be selected for disposing the parts. Based on the material and part complexity, either landfill or incineration may be used as the disposal techniques. The steps to be followed while deploying this phase is shown in figure 5.

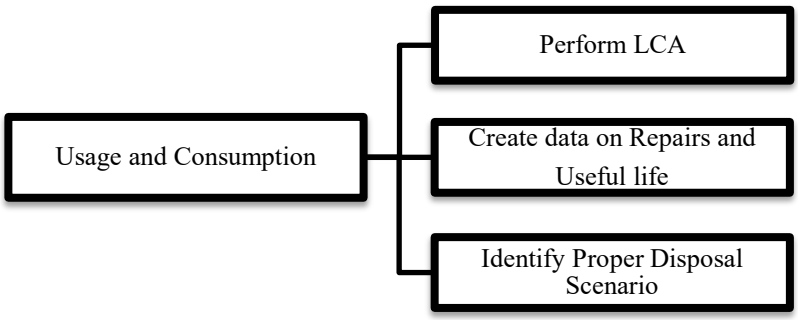

Figure 5. Steps in Usage and Consumption Phase

3.4 Measuring the performance

The firm must develop a performance evaluation model to evaluate its levelness of circularity. The model must consist of various performance measuring indicators that concisely measures the key metrics of Circular economy deployment. The firm can propose a numerical scale value based on fuzzy theory for the levelness and could self assess in which level the firm falls. Based on the results of the performance evaluation, weaker areas could also be identified and improvement actions for mitigating the weaker areas could be proposed and deployed. This phase helps the firm to evaluate the core deployment and helps in enhancing the firms overall performance. Further a performance evaluation model to evaluate the levelness of circularity was developed based on different metrics available from the literature. The model is a 3 leveled model consisting of enablers, criteria and attributes. The criteria and attributes were selected from the literature based on its frequency of citation and its relevance with the enabler. The evaluation system consists of three levels namely enabler, criteria and attributes. Each enabler has a direct relationship with its criteria and its associated attributes The first level consists of three enablers namely environment, economy and society. The second level consists of 6 criteria. The third level consists of 12 attributes. The an excerpt of the developed performance evaluation model is shown in Table 2.

Table 2. An excerpt of the developed performance evaluation model

Enabler	Criteria	Attributes
Environment	Green Purchasing and Logistics	1. Availability of ICT with suppliers 2. Accounting sustainability outcomes of suppliers

	Aligning with Environmental and Technological Concerns	1. Cooperation with customer for eco-design 2. Training and education to workers on eco friendly manufacturing and usage of CPS and IoT
Economy	Investment Recovery	1. Collection and recycle of end-of-life products and materials 2. Establish a recycling system using advanced technological tools for used and defective products
	Cost management	1. Costing system focusing on the investment on data management 2. Cost spent on disposal and remanufacturing
Society	Community and social cohesion	1. Product responsibility and population development 2. Community spending and charitable contributions
	Corporate social responsibility	1. Number of company-community partnerships 2. Upliftment of local community skills

Fuzzy logic mathematical tool could be deployed for performing the assessment. Fuzzy logic has the ability to deal with complex concepts, which are not responsive to a straightforward quantification and contain ambiguities. Further by applying fuzzy logic techniques, it is possible to identify the weak enablers and suitable improvement activities could be deployed for enhancing the performance of such enablers.

4. Conclusion

Circular Economy is an approach that is applied to eliminate waste and to maximize value by redesigning the manufacturing and distribution process. It concerns about making the production more sustainable by focusing on improving the indicators of Environment, Economy and Society. For deployment of Circular Economy concepts systematically, it requires a high level map or framework for guiding the implementation process. The present work describes about development of a dedicated framework for deployment of circular economy concepts for manufacturing organizations. The developed framework consists of five phases namely Framing the factors, Production and Deployment, Collection and Reuse, Usage and Consumption and Measuring the performance. Each phase consists of sub activities to be deployed and are designed to be implemented in a step by step manner. The developed framework allows the firm to assess its resources before implementation and makes the firm ready to the actual deployment. The developed framework provides a step by step procedure for deployment and also supports in enhancing the firm's efficiency post deployment of CE concepts. The developed framework will be useful for implementation managers, production managers and process engineers to systematically analyze their production and distribution system and allows them to plan their deployment activity during the framework deployment. In future, the developed framework can be validated with the case study and based on the implementation challenges, the framework can be further modified.

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