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An Analysis on Sustainable Supply Chain for Circular Economy

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Abstract

In recent years, organizations have started focusing on sustainable and green practices to address environmental, social, and economic concerns that form an approach which strives for the growth of an organization to encourage adapting the circular economy. The objective of circular economy is to extract the advantage of materials, energy and wastes of an industry. The circular economy associates the supply and demand of supply chain industries to improve resource efficiency. The research paper has analyzed a case example in a supply chain organization to meet industry 4.0 requirements and enable circular economy. An analysis on supply chain industry has been conducted with the focus on 6Rs such as Recover, Reuse, Remanufacture, Recycle, Redesign, Reduce. The article highlights the opportunities available in the transformation from linear economy to circular economy, which improves social, economic and environmental drivers of the organization. In addition, it also discusses the opportunities available in industry 4.0 for circular economy.

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Keywords: Circular Economy, Sustainable Supply Chain, Industry 4.0, Internet of Things

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1. Introduction

Circular economy stimulates a significant growth for supply chain organizations due to the consciousness on the environment, energy conservation and the global competitive atmosphere. Due to these factors, it is not only a single organization's responsibility but also the responsibility of all the stakeholders in the supply chain. Rapid change in climate, pollution and customer expectations sum up the performance of sustainability of an organization. Earlier, circular economy was represented as a theoretical approach but now industries have started looking at the opportunities of implementing it [1]. The focus is more on the positive implications of this concept in a supply chain where Corporate Social Responsibility (CSR) is key for the organization, which delivers environmental, social and economic benefits. In addition to global competition, insistence by government regulations on making environmentally friendly products stimulates the organizations to focus on sustainability in supply chain practices. Sustainable Supply Chain Management (SSCM) redefines the operational efficiency and can create a trend in the future strategic growth of the organization. Discovering new paths to support SSCM for circular economy becomes vital if the limits of sustainability are to be expanded. Circular economy primarily focuses on utilizing resources, conserving energy and managing physical flow of goods in supply chain systems effectively among the stakeholders [2].

A concept that helps supply chain in the path of circular economy is industrial symbiosis with an intention to abstract the maximum benefits of resources, products, energy consumption and synergize it to attain more sustainability across the supply chain [3, 4]. With the context of industrial symbiosis, a paper-manufacturing organization was studied with the focus on 6Rs, namely Reuse, Recycle, Reduce, Recover, Remanufacture, Redesign and discusses the opportunities that exists with cutting edge technologies such as Internet of Things (IoT), Artificial Intelligence (AI) in Industry 4.0 era [5]. Industry 4.0 brings the physical and digital world together to unleash the digitalization benefits to improve sustainability of the organization and in turn helps for the development of circular economy [6, 7]. The case study has been conducted by keeping the following key objectives into consideration.

- How circular economy can be influenced in supply chain by recycling the industrial scrap that can improve the sustainability of the organization?
- How to transform linear economy into circular economy to reduce the production wastages and reuse by-products as much as possible?
- How to recover the generated energy and optimize the utilization of available resources?
- How technology can help supply chain network to be more sustainable in terms of social accountability, environmental awareness and economic practices?

In order to attain the illustrated objectives, a case study has been performed. With the findings from circular economy perspective and Industry 4.0 tools, the recommendations have been provided to the management to improve sustainability across the organization.

Nomenclature

SSC	Sustainable Supply Chain
SSCM	Sustainable Supply Chain Management
CPS	Cyber Physical System(s)
IoT	Internet of Things
6Rs	Recover, Reuse, Remanufacture, Recycle, Redesign, Reduce
ERP	Enterprise Resource Planning
GPS	Global Positioning System
CSR	Corporate Social Responsibility
AI	Artificial Intelligence
hp	Horsepower
tph	Tonnes per hour
INR	Indian Rupee

2. Methodology

The process followed during the research work has been illustrated in Fig.1. The literature on circular economy, sustainable supply chain and industry 4.0 have been studied. Then, a case organization has been identified to study the sustainability of the organization. Entire supply chain process have been extensively studied on their linear economy. Later, the gaps in the linear supply chain practices from a circular economy perspective have been identified; wherever necessary, the 6R's have been proposed to make it more sustainable in a closed loop supply chain. In addition to that, a study on deploying new technologies have been investigated to make closed loop supply chain more sustainable [8]. Based on the assessment, recommendations have been discussed.

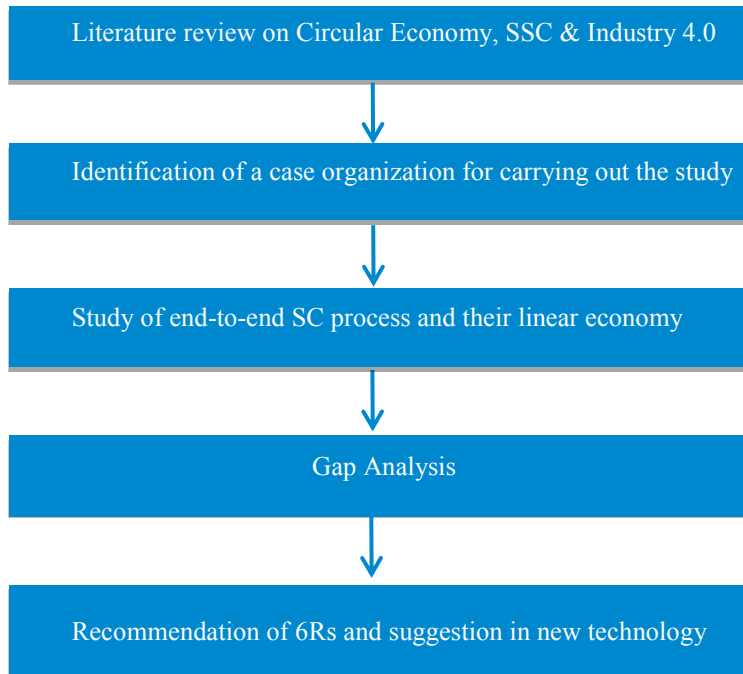


Fig. 1. Methodology on analysis of sustainable supply chain for circular economy

3. Case Study

3.1 About Case Organization

The study was performed in a paper manufacturing organization located in South India (hereafter stated as ABC). ABC manufactures writing paper and newsprint. ABC is an ISO 9001 - 2000 organization that distinguish themselves as quality organization and keen on implementing sustainable supply chain practices. The products produced are eco-friendly as some of the renewable raw materials are used. ABC is a right fit for this case study as the management is optimistic to develop a roadmap on applying circular economy as well as in deploying new technologies by leveraging industry 4.0.

3.2 Present System of Linear Supply Chain

The organization has taken few initiatives to go green in certain aspects, which indicates that they are in transition towards circular economy. Earlier, the supply chain economy of the organization had been linear which means that raw materials used to make the finished goods are under-utilized. A typical linear supply chain economy of that organization is illustrated in Fig. 2.

The supply chain of paper manufacturing is mostly straightforward and linear, but it uses renewal raw material. For example, one of the primary raw materials used for manufacturing paper is fibrous content ‘bagasse’. This raw material, bagasse is actually a byproduct of a sugar factory. Bagasse is loaded into truck and transported to the paper manufacturing plant, unloaded and stored in the yard. The raw materials are processed to make pulp. The pulp is fermented, boiled, bleached followed by calendering process. The outcome of the calendering process is the finished product. Based on the raw material used, the outcome can be writing paper, newsprint or cartons. The finished goods are transported to the distribution center through third party logistics. From the distribution center, finished goods are supplied to retailers based on the order received. Later, the retailers sell the writing paper, newsprint to consumers.



Fig. 2. Linear Supply Chain of present organization

3.3 Transformation of Supply Chain towards Circular Economy

The study has been conducted from cradle to cradle, including their supply chain partners to transform the present linear supply chain towards circular economy as illustrated Fig. 3. The article discusses the current industrial process and opportunities available with 6Rs to improve a synergetic network.

As illustrated in Fig. 4, a circular supply chain can be implemented in paper manufacturing organization. When the pulp is fermented, a residue is formed which is used as an ingredient in the spirit manufacturing process. Currently this residue is supplied to local spirit manufacturers. However, if the packing of the residue is done with high quality and supplied, then there is an opportunity to supply the residue at a relatively higher cost for a potential global spirit manufacturer. Subsequent to the fermentation process, the pulp is boiled at high temperature. The waste paper collected from waste paper recycle factory are used as raw material as well as during the boiling process. Coal is used for boiling the pulp. The outcome of boiling the pulp is semi-finished paper. During the boiling process, excessive steam is generated. The generated steam can be used to produce electricity, which can be utilized within plant for their power consumption as well as to cook food for employees. Large amount of coal used to boil the pulp results in a certain volume of fly ash. The fly ash can be supplied to cement industry, as there are many cement manufacturers located in the same region. Once the boiling of pulp is completed, bleaching is carried out to decide the color of the paper. During this process, a huge amount of water is used. The used water consists of sludge and waste materials. The wastewater can be treated which can be used for irrigation purposes for nearby farms. The semi-finished paper is further processed with the calendering process where size of the paper is decided as per demand.

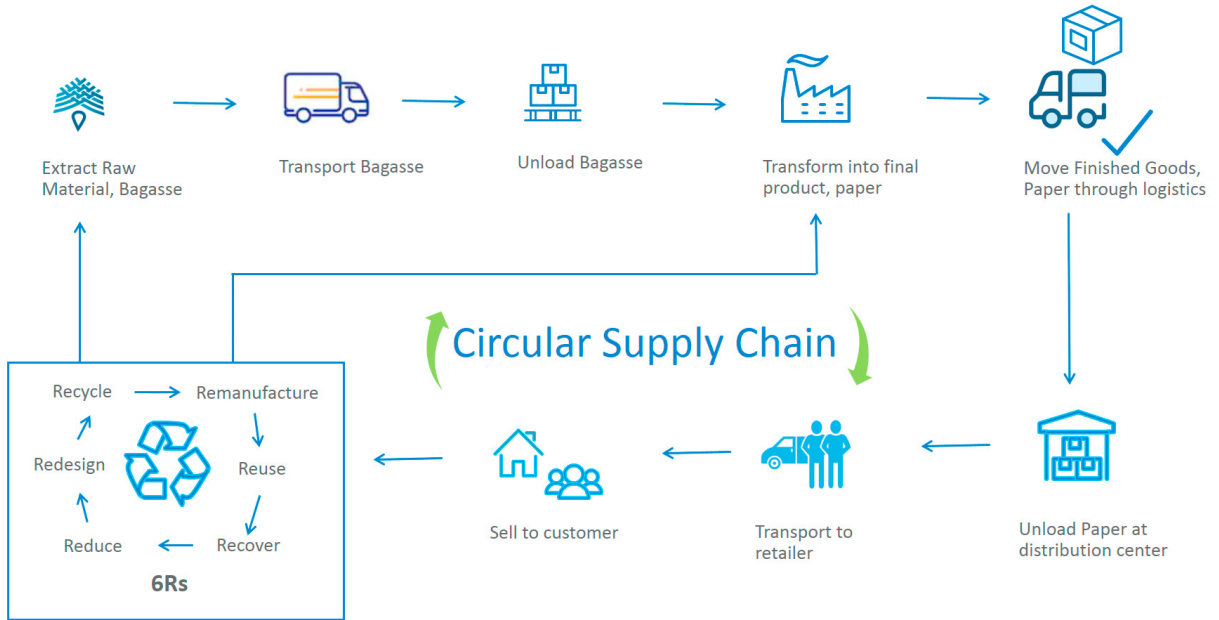


Fig. 3. Proposed Circular Supply Chain for the organization

The result of the calendering process is the final finished goods that are packed using automated packing machines. During inspection process, poor quality papers are scrapped. The scrapped paper can be classified based on the damage percentage and it can be re-sent to production for recycling, eventually fed in as raw material during the boiling process. The recommendations provided from the sustainable industrial perspective depicted in table 1, improve the operational efficiency resulting in circular economy.

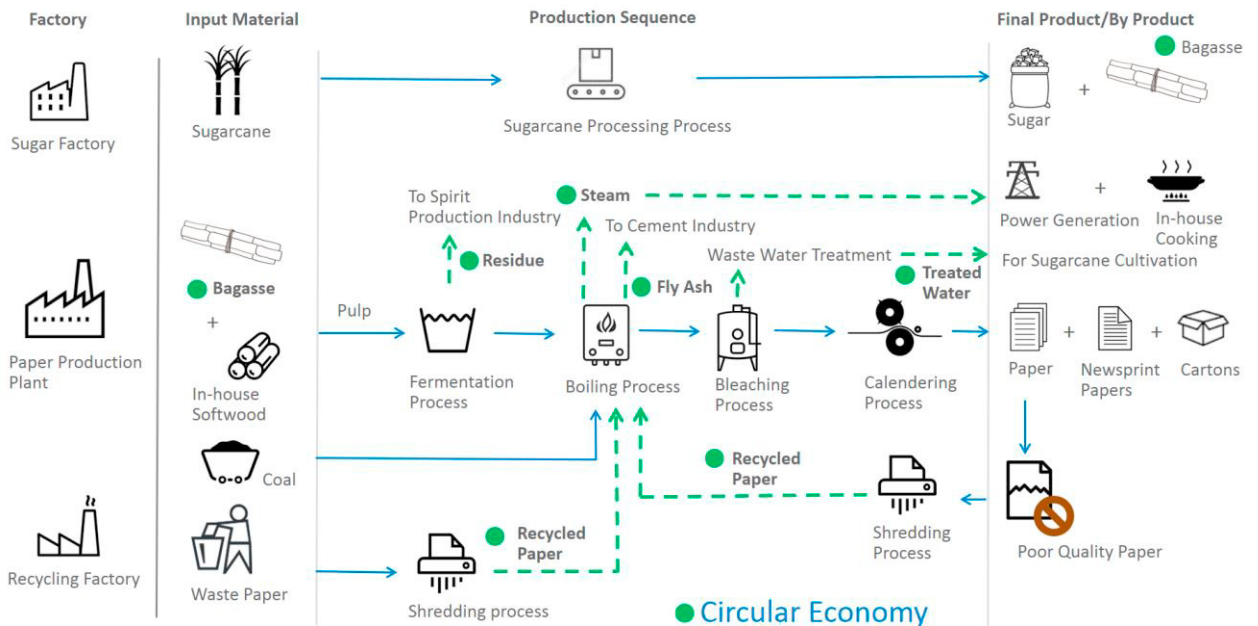


Fig. 4. Implementation of circular economy in sustainable supply chain

Table 1. 6R's of Sustainability and recommendation

6R's of Sustainability	Recommendation
Recover generated energy within the firm	Pumps are used to move water, pulp, etc. With the help of advanced technology such as IoT, the stakeholders are informed about worn impeller, mechanical seals on pumps. Replacing the items at right item improves the equipment efficiency and saves energy.
Reduce Production wastes	Felt Dryer Cylinder are used to press the sheets and remove the water content. It is observed that felt dryer cylinder are not insulated properly resulting in heat loss. Using IoT, the dryer cylinder can be monitored on real time and the loss can be avoided.

3.4 Study the energy and cost savings

During bleaching process, there are 6 pumps with 60 horsepower (hp) capacity are used. Thus, energy consumed by 6 pumps is 360 horsepower. Energy saved is 20 horsepower in each pump by better maintenance with the IoT to replace worn impellers, mechanical seals at right time.

Total energy saved by replaced components on pumps = $6 \times 20 = 120$ hp

Before calendaring process, the sheets are pressed using felt dryer cylinders and these felt dryer cylinders are not properly insulated. With the communication from IoT, if felt dryer cylinders are insulated properly there is a saving potential of 4%. Overall, Steam Utilization in the equipment is 18 tph, Steam Cost is INR 150 per ton and total operating hours per year is 10000 hrs.

Total savings per year = $18 \times 0.04 \times 10000 \times 150 = \text{INR } 10,80,000$

3.5 Opportunities with Industry 4.0 for Circular Economy

The study reveals that the supply of bagasse is depended on the supply of sugarcane to the sugar industry. The supply of sugarcane fluctuates based on seasonal demands and hence, the supply of bagasse fluctuates. This makes planning and seamless paper production difficult for the paper manufacturer. In that case, it is recommended to use alternate raw material like softwood. Big Data analytics will help the stakeholder to make right decisions with earlier supply pattern. The boiling process time depends on the grade of coal used. Based on the grade of coal, the lighting point varies. When the lighting point of coal increases, the result is improper burning and more fly ash. In other words, a lower lighting point results in a quick boil of pulp and less fly ash. Thus, it is important to know the coal quality and IoT can be used to classify the coal based on the moisture content in coal. In addition, the duration of fermentation varies based on the moisture content in bagasse. IoT can be used to monitor the moisture content in bagasse and alert the stakeholder when it reaches the threshold limit. This results in reduced fermentation duration and overall manufacturing lead-time.

IoT can be used to get the entire production visibility. In addition, production safety can be ensured using IoT by monitoring the key indicators remotely such as temperature variations, heavy vibrations, and unusual patterns of boilers in real time. Industry 4.0 guarantees detecting quality issues at the beginning, which improves the productivity and reduces the wastage cost drastically [9, 10]. Outside the production facility, IoT devices can be embedded at customer place to know 'in the field' usage and alerts product shortage in advance. Further, as illustrated in Fig. 5, introducing IoT enabled waste paper collection in bins at customer place helps organization to promptly collect the shredded papers and recycle it. IoT enabled system will monitor the bin capacity and alerts organization and any third-party organization can be arranged to collect the waste papers.

Fig. 5. Recycle paper in circular supply chain with the influence of IoT

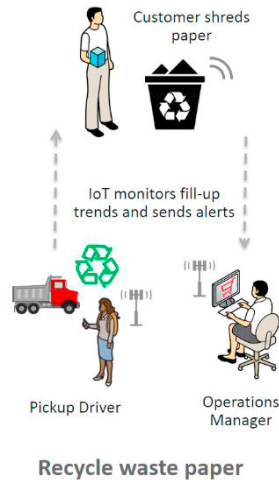


Fig. 5. Recycle paper in circular supply chain with the influence of IoT

IoT can be used to locate the exact material storage location in the warehouse and monitor the condition of the material from anywhere in the warehouse as illustrated in Fig.6. As the transport organization is a third-party organization, logistics manager finds it difficult to co-ordinate and spend several hours to manage transportation. With the help IoT and GPS, the vehicles can be tracked on real time and logistics manager can check the shipment status remotely [11].

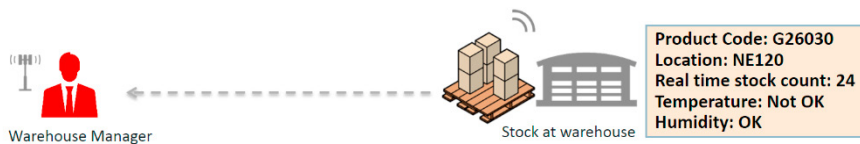


Fig. 6 Smart warehouse with IoT Devices

4. Organization Implications

With the result of the case study, the implications of sustainable supply chain for circular economy is described from three perspectives.

4.1 Economic perspective

Based on the recommendations, management is keen on deploying IoT tools considering the benefits of IoT where real-time information is shared—which allows them to make critical decisions on time. Furthermore, stakeholders also believe that resources can be managed more efficiently and remotely. They also believe that the investment in technology helps to improve their operational efficiency thereby increase the margins.

4.2 Environmental perspective

Management is motivated to make environmentally friendly products by using renewable raw materials, applying the 6R's wherever suggested and by utilizing the energy generated during the paper manufacturing process. Selection of raw materials is considered based on sustainability impacts and attention has been given to reduce the environmental effects.

4.3 Social perspective

The organization is trying to prove themselves as a CSR company. Stakeholders have agreed that workforce morale and safety are the important priorities. Few initiatives have been taken to recognize the employees' notable

performance with awards and appreciation every quarter, which will boost their morale. From the perspective of worker safety, the organization is exploring ways to enable IoT technology to get pre-detection of problems—particularly with the employees who works in boiler operations where extremely high temperatures are utilized.

5. Conclusion

In the recent years, the focus of SSC is to address sustainability issues by reducing negative processes in production, using non-toxic materials and recycling the used products. In addition to this, circular economy drives best environmental practices by producing sustainable products and re-using the materials, which helps in the economic growth of the country [12]. The outcome of industry 4.0 allows the supply chain partners to take wiser decisions in real time as the technology acts as a virtual assistant. With the help of industry 4.0, it is possible to interconnect the equipment, work center, materials and logistics. IoT plays a vital role in industry 4.0 as it facilitates making more decentralized decisions and real-time responses.

Within the context of circular economy, analysis has been conducted to study the sustainability of the Supply Chain; to transform the organization from linear economy to circular economy by implementing the 6R's; to leverage technology across supply chain so that the organization is more sustainable in terms of social accountability, environment awareness and economic practices. This study has emphasized that combining the concept of circular economy with sustainable supply chain can deliver strong benefits from an environmental perspective. Investment in technology helps organizations to improve operational efficiency, resulting in more proficient implementation of circular supply chain. With the in-depth case study, valuable insights on sustainability to the organization and its supply chain partners is provided. Furthermore, it is encouraging to realize that management considers the recommendations. When it comes to technology adoption, the investment is a major challenge in various industries at early stages, but in the long term, it allows the organization to become more sustainable. Further, support of government policies to strengthen sustainable practices and promotion of digital technologies encourages organizations to move forward with circular economy, which meets industry 4.0 requirements.

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