Evaluating and ranking the circular supply chain implementation enablers

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Swapnil Lahane*, Himanshu Prajapati, Ravi Kant

*Department of Mechanical Engineering, Sardar Vallabhbhai National Institute of Technology, Surat, India.

*Email: swapnillahane03@gmail.com; Corresponding Author.

ABSTRACT

This research aims to evaluate and rank the Circular Supply Chain (CSC) enablers for the effective implementation of CSC management. From the literature and input received from industrial experts, 30 CSC enablers are identified. Further, the selected CSC enablers are classified into seven main categories. This research employs the Pythagorean fuzzy analytic hierarchy process (PF-AHP) technique to prioritize the selected CSC enablers based on pairwise comparison of criteria and sub-criteria. The effectiveness of the proposed method is illustrated with the help of responses received from an Indian manufacturing industry. The result reveals that global climate pressure and ecological scarcity of resources is the most significant enabler and the environment management certifications and systems is the least important enabler. The result of the present study will assist the practitioners / decision makers in implementing CSC in manufacturing organizations by adopting the ranking obtained in a systematic way.

Keywords: Circular supply chain; Enablers; India; Pythagorean fuzzy AHP; Sustainability.

INTRODUCTION

In today's competitive business environment, manufacturing organizations seek to adopt more sustainable mode production and consumption into their supply chain practice (de Sousa et al., 2020). Also, they desire to have their supply chain more sustainable towards three dimensions of sustainability. The traditional production and consumption activities of business organizations are based on the linear supply chain, which generates massive waste and pollutes environment enormously (Batista et al., 2018). Thus, the circular supply chain (CSC) considered as alternative strategy to traditional supply chain business model.

The CSC philosophy combines the circular economy (CE) principles into supply chains of the business organization (Lahane et al., 2020). CSC is a waste management strategy and focuses on value gain approach of CE. The CE 6Rs principle includes recycling, remanufacturing, redesign, reuse, reduce, and repair. CSC emphases on product life cycle management and services through a product recovery mechanism. Some of the authors defined the term CSC. Batista et al. (2018) defined CSC as an industrial economic system developed for obtaining the sustainability in supply chain operations of manufacturing industries. CSC is an economic system design by restorative and regenerative principles of CE (Kirchherr et al., 2017). CSC is a waste management strategy and helps to improve the material and resource efficiency (Moktadir et al., 2018).

The manufacturing organizations can achieve several key benefits such as improved resource efficiency, reduced resource consumptions, reduced the resource scarceness issues, cost saving, reduced emissions, improved product design, improved economic efficiency, improved sustainability, improved social benefits, creates new business opportunities, improved corporate social responsibility, improved production strategies etc. by implementing CSC effectively (Guarnieri et al., 2020). Most of the developed nations had already started practicing such circular initiatives into their industrial supply chain. They have formulated stringent laws, regulations, and policies for effective CSC adoption (Ghisellini et al., 2018). However, developing economies are still lagging in adopting CSC initiatives into their businesses. It is a beginning stage in a most developing nation like India (Goyal et al., 2018). The India ranked second most populated country in the world and produces a tremendous amount of waste daily. Thus, it has a great potential to obtain sustainability by adopting CSC practice. Therefore, the Indian manufacturing sector needs to be mature towards adopting CSC with policy, skills, and infrastructure development (Mangla et al., 2018). Even though there are many advantages associated with CSC adoption, there is still uncertainty about its implementation in the emerging economy (Mishra et al., 2019). So it becomes essential to identify and prioritize the CSC enablers (CSCEs). This paper aims to identify and prioritize the CSC enablers using PF-AHP technique. PF-AHP utilizes the concept of Pythagorean fuzzy set theory. It handles the vagueness / uncertainty present in the given decision-making problems (Peng and Selvachandran, 2019).

LITERATURE REVIEW

The CSCEs help organizations to adopt CSC effectively and drive various circular activities in business organizations in a sustainable way. Table 1 illustrates the list of diverse CSCEs. These CSCEs were confirmed through extensive literature review on CSC and broad discussion with an industry expert of the relevant fields.

Table 1 List of CSCEs.

Main Enablers	Code	Sub Enablers	Literature Support
	ORGE1	Employee involvement	(Agyemang et al., 2019; Ansari et al., 2019)
	ORGE2	Training and education towards awareness and development programs for circular business model	(Hussain and Malik, 2020; Ansari et al., 2019)
	ORGE3	CSC supportive organizational culture	(Hussain and Malik, 2020; Salim et al., 2019)
	ORGE4	Providing proper incentives to end customers for products return	(Hussain and Malik, 2020; Agyemang et al., 2019)
	ORGE5	Strong coordination and collaboration among supply chain members	(Agyemang et al., 2019; Salim et al., 2019)
	OPE1	Product recovery mechanism for second-hand products	(Hussain and Malik, 2020; Salim et al., 2019)
	OPE2	Implement and monitor the product returns mechanism	(Salim et al., 2019; Ansari et al., 2019)
	OPE3	Circular supply and demand network design	(Agyemang et al., 2019; **Brown** and Bajada, 2018)
	OPE4	Design for circularity aspects	(Agyemang et al., 2019; Brown and Bajada, 2018)
	SE1	Top management support, commitment, and clear vision	(Hussain and Malik, 2020; Salim et al., 2019)
	SE2	Supplier, consumer, and organization strategic alliance	(Brown and Bajada, 2018)
	SE3	Cradle to cradle paradigm and circular public procurement	(Agyemang et al., 2019; Brown and Bajada, 2018)
	SE4	Warranties and standardization for recovered products	(Hussain and Malik, 2020; Salim et al., 2019)
	SE5	Industrial symbiosis enabled supply chain network	Experts Opinion
	ERE1	Government rules, legislation, and	(Hussain and Malik,

and Regulatory Enablers (ERE)		directives for CSC adoption	2020)
	ERE2	Global climate pressure and ecological scarcity of resources	(Salim et al., 2019)
	ERE3	Mandatory take-back policies for hazardous materials and products	(Salim et al., 2019)
	ERE4	Laws and regulations prohibiting informal waste handling sector	(Gunduz et al., 2020; Salim et al., 2019)
	ERE5	Environment management certifications and systems	(Agyemang et al., 2019)
	ECOE1	Government preferential tax policies and subsidies for circular business model	(Gunduz et al., 2020; Hussain and Malik, 2020)
	ECOE2	Separate fund allocation to develop a circular business model	(Salim et al., 2019)
	ECOE3	Fund for the acquisition of additional machinery equipment and tools	(Salim et al., 2019; Brown and Bajada, 2018)
	ECOE4	Understanding of organizational profitability from customer's return	(Hussain and Malik, 2020; Salim et al., 2019)
	SOCE1	Opportunities for employment generation	Expert Opinion
	SOCE2	Implementing the environmental consciousness health schemes programs for employees	(Ansari et al., 2019)
	SOCE3	Consumer attitude and ecological awareness towards eco-friendly products	(Salim et al., 2019; Batista et al., 2018)
	SOCE4	Corporate social responsibility and ethical standards	(Agyemang et al., 2019; Salim et al., 2019)
	TIE1	Up-gradation of existing information and communication technologies	(Hussain and Malik, 2020; Salim et al., 2019)
	TIE2	Process integration technology for cleaner production	Experts Opinion
	TIE3	Digital / Artificial intelligence transformation	(Gunduz et al., 2020; Agyemang et al., 2019)

METHODOLOGY

The analytic hierarchy process (AHP) is the most widely used decision-making technique. It solves complex decision-making problems (Ak and Gul, 2019). However, the classic AHP results are influenced by subjective opinion of experts. Thus, to deals with the uncertainty associated to CSC enablers, the integration of Pythagorean fuzzy set (PFS) in AHP technique has been used for this study. PF-AHP gives greater flexibility to decision-makers to communicate their idea in decision making problems (Lahane and Kant, 2021). Recently, PF-AHP has been used in many research areas, such as location selection problem (Kaya et al., 2020); evaluation of quality of hospital services (Yucesan and Gul, 2020); landfill site selection (Karasan et al., 2019); etc. The steps of PF-AHP are given below:

Step 1: Develop pair wise comparison matrix $A = (a_{ik})_{m\times m}$ based on experts' input using linguistic scale in table 2.

Table 2 Linguistic scale for PF-AHP.

Linguistic terms	Pythagorean fuzzy numbers			
	μ_L	μ_U	v_L	v_U
Certainly, Low Importance	0.00	0.00	0.90	1.00
Very Low Importance	0.10	0.20	0.80	0.90
Low Importance	0.20	0.35	0.65	0.80
Below Average Importance	0.35	0.45	0.55	0.65
Average Importance	0.45	0.55	0.45	0.55
Above Average Importance	0.55	0.65	0.35	0.45
High Importance	0.65	0.80	0.20	0.35
Very High Importance	0.80	0.90	0.10	0.20
Certainly, High Importance	0.90	1.00	0.00	0.00
Exactly Equal	0.1965	0.1965	0.1965	0.1965

Step 2: Compute the differences matrix $D = (d_{ik})_{m\times m}$ using (1) and (2):

$$d_{ik_L} = \mu^2_{ik_L} - v^2_{ik_U} \quad (1)$$

$$d_{ik_U} = \mu^2_{ik_U} - v^2_{ik_L} \quad (2)$$

Step 3: Compute the interval multiplicative matrix $S = (s_{ik})_{m\times m}$ using (3) and (4):

$$S_{ik_L} = \sqrt{1000^{d_{ik_L}}} \quad (3)$$

$$S_{ik_U} = \sqrt{1000^{d_{ik_L}}} \quad (4)$$

Step 4: Compute the determinacy value $\tau = (\tau_{ik})_{m\times m}$ using (5):

$$\tau_{ik} = 1 - \left(\mu^2_{ik_U} - \mu^2_{ik_L}\right) - (v^2_{ik_U} - v^2_{ik_L}) \quad (5)$$

Step 5: Construct the unnormalized weight matrix $T = (t_{ik})_{m\times m}$ using (6):

$$t_{ik} = (\frac{s_{ik_L} + s_{ik_U}}{2})\, \tau_{ik} \quad (6)$$

Step 6: Compute normalized priority weights w_i using (7):

$$w_i = \frac{\sum_{k=1}^{m} t_{ik}}{\sum_{i=1}^{m}\sum_{k=1}^{m} t_{ik}} \quad (7)$$

EMPIRICAL CASE EXAMPLE

This section presents the introduction of selected case company and its problem statement and application of PF-AHP technique for ranking of CSC enablers.

A. The case company and the problem statement

The case study is performed in an Indian automobile part manufacturing company for demonstration of proposed method applicability. The selected industry was established in the year 1996 and it has a turnover of about INR 1000 Crores and is situated in Aurangabad, Maharashtra. This organization manufactures sheet metal, tubular, fabricated, plastic molded components, and aggregates. The organization executives are attentive towards the concept of CSC management and its implementation. However, during the manufacturing of these automotive components, a tremendous amount of waste is generated that causes a negative environmental impact on supply chain operation and the surrounding environment. The selected company doesn't have an in-house recycling / remanufacturing facility to manage the generated waste. Thus, for effective handling of wastes, the selected company managers decide to develop and implement sustainable initiatives such as CSC into actual practice. Therefore, the case organization executives are fascinated in evaluating the selected CSCEs for effective adoption of CSC management.

B. Ranking the CSC enablers using PF-AHP technique

In this sub-section, the main enablers' relative importance weight and their sub-enablers are calculated using PF-AHP method. The aim is to prioritize these enablers based on their degree of importance. The input data required for pairwise comparison matrix was filled by decision making (DM) panel of selected case organization in the form of a questionnaire. The DM panel consists of five experts, namely head (production dept.), head (environmental dept.), lead (quality and maintenance dept.), head (waste management dept.), and senior manager (logistics dept.). Selected experts are highly qualified, and experienced. The DM experts used a relative scale of PF-AHP (Table 2). Afterward, some rounds of discussion concerning the weight allocation for pairwise comparison of main enablers and the sub enablers. The DM panel conversation continued till everyone had a similar opinion for the significant weight to be allocated during the pairwise comparison between main enablers and sub enablers. The equations (1) to (7) is used to calculate each CSC enabler's relative weights. After that, the global weight of each CSC enabler is obtained by multiplying relative weight of main enablers and local weight of sub enablers, and the final ranking of CSCEs is obtained based on global weight (Table 3).

Table 3 Final ranking of sub-enablers to CSC implementation.

Main Enablers	Relative weights	Sub-Enablers	Weight	Globalized weight	Global Rank
		ORGE1	0.2274	0.0286	12
		ORGE2	0.1506	0.0190	20
		ORGE3	0.3172	0.0399	8
		ORGE4	0.2097	0.0264	15
		ORGE5	0.0951	0.0120	27
		OPE1	0.1332	0.0192	19
		OPE2	0.1872	0.0270	14
		OPE3	0.2052	0.0296	11
		OPE4	0.1332	0.0192	18
		SE1	0.4646	0.0773	2
		SE2	0.1131	0.0188	21
		SE3	0.2701	0.0449	7
		SE4	0.1338	0.0223	17
		SE5	0.0184	0.0031	29
		ERE1	0.3480	0.0630	3
		ERE2	0.4679	0.0847	1
		ERE3	0.0875	0.0158	23
		ERE4	0.1774	0.0321	10
		ERE5	0.0105	0.0019	30
		ECOE1	0.1840	0.0223	16
		ECOE2	0.4589	0.0557	4
		ECOE3	0.2330	0.0283	13
		ECOE4	0.1241	0.0151	25
		SOCE1	0.1101	0.0151	24
		SOCE2	0.0985	0.0135	26
		SOCE3	0.2678	0.0368	9
		SOCE4	0.3553	0.0489	6
		TIE1	0.4435	0.0549	5
		TIE2	0.1483	0.0183	22
		TIE3	0.0806	0.0100	28

RESULTS, DISCUSSION, CONCLUSIONS AND FUTURE SCOPE

It is difficult to state beyond any doubt which CSC enablers are crucial, yet the positioning procedure by utilizing PF-AHP methodology made it extra extensive and organized. The Indian auto-part manufacturing industry is selected as a case study for demonstration of applicability of the proposed PF-AHP technique. A total of 30 CSCEs were identified and categorized under seven main criteria, namely organizational enablers (ORGE), operational enablers (OPE), strategic enablers (SE), environmental and regulatory enablers (ERE), economic enablers (ECOE), social enablers (SOCE), and technological and infrastructural enablers (TIE). The selected CSCEs have been prioritized based on the PF-AHP technique. This technique was employed to improve the uncertainty, impreciseness, and vagueness of a given decision-making problem. It has been observed that the main enabler as environmental and regulatory enablers (ERE) is found to be the most significant enabler among all the selected main criteria because it was having the highest weight of 0.1810. This indicates that nearly 18 % impact of this enabler's influence on the CSC implementation process. Hence, managers of the organization should give primary priority to focus on this enabler. The most significant CSCE found from the examination are the global climate pressure and ecological scarcity of resources (ERE2) from the category of environmental and regulatory enablers. This is followed by top management support, commitment, and clear vision (SE1) under the category of strategic enablers ranked second in the list. Government rules, legislation, and directives for CSC adoption (ERE2) under environmental and regulatory enablers have obtained the third most significant weight in the list. The enabler separate fund allocation to develop a circular business model (ECOE2) found to be the fourth most crucial enabler of CSC management under the category of economic enablers.

The research outputs of this study are significant and help the practitioners and decision makers to implement CSC effectively by managing the various CSCEs in a systematic manner. In the future, obtained result will assist the decision-makers of any manufacturing organization to recognize and evaluates the performance outcomes derived due to CSCEs implementation.

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