Exploring indicators of circular economy adoption framework through a hybrid decision support approach

Article *in* Journal of Cleaner Production · September 2020

DOI: 10.1016/j.jclepro.2020.124186

4 authors:

Gunjan Yadav
Prashanti Institute of Technology & Science

Sachin Kumar Mangla
O.P. Jindal Global University

Arijit Bhattacharya
University of East Anglia

Sunil Luthra
ALL INDIA COUNCIL FOR TECHNICAL EDUCATION

Exploring Indicators of Circular Economy Adoption Framework through A Hybrid Decision Support Approach

Gunjan Yadav

Department of Mechanical Engineering,

S.V. National Institute of Technology, Surat- 395007, Gujarat, India.

e-mail: gunjanyadav86@gmail.com

Sachin Kumar Mangla

Plymouth Business School, University of Plymouth

Plymouth PL4 8AA, United Kingdom.

Email: sachinmangl@gmail.com; Sachin.kumar@plymouth.ac.uk

Arijit Bhattacharya

Norwich Business School, University of East Anglia

Norwich Research Park, Norwich NR4 7TJ, United Kingdom.

e-mail: A.Bhattacharya@uea.ac.uk; arijit.bhattacharya2005@gmail.com

Telephone: +44 (0)1603 59 7520

Sunil Luthra

Assistant Professor, Department of Mechanical Engineering

Government Engineering College, Nilokheri-132117, Haryana, India.

e-mail: sunilluthra1977@gmail.com

Exploring indicators of circular economy adoption framework through a hybrid decision support approach

Abstract: Circular economy (CE) focuses on a circular approach to energy and material resources, which provides economic, environmental and social benefits for manufacturing organisations. CE adoption in emerging economies facilitates in substantial economic growth through appropriate utilisation of energy and material resources across manufacturing industries. This study identifies CE indicators in the context of an emerging economy. The study further develops a framework for the adoption of CE and tests it through a hybrid Best Worst Method and Decision-Making Trial and Evaluation Laboratory approach. The framework is validated through an Indian manufacturing case organisation. While Best Worst Method computes the CE related indicator weights, Decision-Making Trial and Evaluation Laboratory analyses the inter-relationship among indicators. Disparate CE related indicators, e.g. strategic, managerial, informational and technological, supply chain and organisational, influence the CE adoption in an emerging economy context. The findings reveal that the strategic and managerial indicators have the strongest influence on developing other indicators. The causal digraph and relationship diagram assist the practitioners in predicting the inter-relationship of indicators in CE adoption. The study outcomes will help the practitioners, policymakers and researchers to draw a framework for adoption of circular and green practices and usage of resources sustainably.

Keywords: Circular economy; Indicators; Decision-making; Sustainable operations; Emerging economies; India.

1. Introduction

Circular economy (CE) has emerged as one of the important aspects of a nation's economy (Mahpour, 2018). From various definitions of CE reported in the extant literature, it is difficult to have an in-depth understanding of CE (Kirchherr et al., 2017) as the definitions represent different perspectives (Sarkis and Zhu, 2017). Several studies have put an effort to link CE to different areas, such as industrial ecology, reverse logistics and waste reductions. However, CE is not limited to material and/or waste recovery as CE can be extended to energy utilisation, supply chain activities, production activities and sharing economy (Saidani et al., 2017). CE works in a closed or circular loop, but it can also be used in a forward loop (Korhonen et al., 2018a). Several frameworks, such as BECE (backcasting and eco-design for the circular economy) and ReSOLVE, are proposed for effective adoption of CE (Mendoza et al., 2017).

CE has a direct link to manufacturing organisations. CE adoption in manufacturing industries can be beneficial for nations' growth. Researchers argue that manufacturing organisations play a pivotal role, especially in developing nations such as China, India, Thailand etc., as they are outsourcing hubs to the developed economies (Fang et al., 2017; Lieder and Rashid, 2016). CE adoption in the manufacturing sector is a cumbersome process as it calls for an effective examination of some crucial factors before initiating the process. Some of these factors are CE adoption policies, its feasibility, effectiveness and adaptability to the sector. In literature, the factors are sometimes referred to as indicators, critical success factors, enablers, drivers and facilitators.

Driven by this concern, this study contributes to the literature by identifying the indicators that assist in the CE adoption process. The indicators are the factors that help in enhancing the CE adoption. Indicators possess the different intensity of influence (Govindan and Hasanagic, 2018). The intensity of influence refers to the weightage of each indicator during the CE adoption process. While, the study of Saidani et al. (2019) reports an exhaustive list of CE indicators, it fails to capture their intensity and does not highlight any information related to their inter-relationship. Therefore, another contribution of this study is to bridge this knowledge gap through identifying the intensity of influence of the indicators, the absence of which may hinder practitioners to implement an effective CE adoption process in manufacturing organisations. Further, the mere identification of the intensity of influence of the indicators is not adequate. Therefore, yet another contribution of the study is to analyse causal relationships of the indicators and explore their interaction possibilities in a whole system to facilitate the decision-making process of practitioners and policymakers for CE adoption.

A paradigm shift in the CE literature is reported in this study through the objectives of identifying the CE indicators, analysing their intensity of influence and examining their causal relationship. Here, the paradigm shift refers to explore different diversifying opportunities in CE literature. To address these objectives, a hybrid decision-support approach using the Best Worst Method (BWM) and Decision-Making Trial and Evaluation Laboratory (DEMATEL) methods is employed to analyse a case of an Indian manufacturing organisation. The exhaustive study identifies a set of CE indicators that affect the CE adoption process. These indicators are confirmed and validated through an expert panel. While the intensity of influence of the indicators is ascertained through the BWM approach, the DEMATEL approach explores the causal relationship of the indicators.

This article is organised as follows. Section 2 examines the theoretical foundation of the work through a thorough literature review. Section 3 describes the research methodology. Section 4 elucidates development and testing of the CE adoption framework through the considered case. Section 5 discusses the outcomes of the study. Section 6 provides an insight into the contributions and implications. Finally, in section 7, the article concludes with recommendations for future research.

2. Literature Review

To explore disparate CE indicators, a systematic literature review approach is conducted as set out in Tranfield et al. (2003). The articles considered in this literature review possess a strong focus on CE adoption and its indicators. The following keywords are framed and used in various combinations to identify the extant literature: 'circular economy indicators', 'circular economy enablers', 'circular economy critical success factors', 'circular economy drivers', 'circular economy and manufacturing', 'circular economy and developing economies' and 'circular economy facilitators'. The databases used include: "Web of Science", "Scopus" and "Google Scholar". The titles, abstracts and keywords of the identified articles are further scrutinised based on the following criteria: (a) inclusion of only journal articles which are peer-reviewed and excluding all the conference proceedings, and (b) inclusion of only English language articles. Although CE domain gained its momentum from 2010 (in terms publication of articles), few articles have been observed in the early 2000s. Therefore, the review time horizon is 2000 to 2019. The initial shortlisting left us with 231 articles. While the initial shortlisting of articles is performed according to the above procedure, the final scrutiny of the articles is conducted through forward snowball and backward snowball approach (Wohlin, 2014) which left us with 63 articles.

The articles that strictly focus on the indicators for developing economies and related to manufacturing concerns are though included. This approach assists to identify the articles strongly related to the present study. This review helps in developing a better understanding of CE and building a foundation to enhance various research threads in this domain.

2.1 Circular Economy related Indicators

Although the CE research is in a state of infancy, several publications (de Jesus and Mendonça, 2018; Lazarevic and Valve, 2017) report sets of indicators influencing the CE adoption process. These indicators influence the adoption process in a broader context (i.e. developed and developing nations' context). A study on CE (Mahpour, 2018) reports 'effective planning and management for CE adoption', 'allocation of financial budgets for CE', and 'top management commitment for CE adoption' as the most critical indicators influencing the CE adoption process. The strategic planning and budget allocation are directly linked to the top management (Bodar et al., 2018) to facilitate building effective strategies. Further, effective strategic planning assists in attaining sustainable resource management (Genovese et al., 2017). Sustainable resource utilisation can directly contribute to the CE adoption process thereby strengthening a nation's economy and future resource managing aspects (Parchomenko et al., 2019).

Govindan and Hasanagic (2018) argued that adoption of CE is a challenge until economic benefits are understood. Therefore, it is significant to have some strong strategies and policies for CE adoption (Kim and Lui, 2015). From this standpoint, the following indicators have emerged as prime importance: 'redesign based on customer feedback', 'effective lifecycle analysis', and 'rewards and incentives for greener activities' (Homrich et al., 2018).

Indicators relating to performance measures that aid in mapping CE performance are required to be considered (Wang and Li, 2006) in the CE adoption process. The indicators viz. 'effective facility layout decision making', 'effective information management system' (e.g. IoT), and 'adoption of innovative quality improvement practices' (Martins, 2018) are considered as key players in the CE adoption process. Adoption of CE requires indicators facilitating advanced technology transfer and constant monitoring on changing market needs (Anzola-román et al., 2018). In this regard, Saavedra et al. (2018) emphasise on the penetration of social media and big data analytics within an organisation. This helps to circulate the information within a correct loop. Availability of advanced technological setups will facilitate the practitioners to carry out their production activities and simultaneously help in providing high-quality products to the end-users (Urbinati et al., 2017).

CE possesses a strong linkage to the supply chain activities in manufacturing organisations (Batista et al., 2018b). Coordination and collaboration among the supply chain members is very essential for building the loop of CE (Geng et al., 2012). This leads to the emergence of the following indicators, viz. 'supplier commitment for recyclable materials' and 'CE education for suppliers'. Adopting reverse supply chain activities, e.g. includes Reverse Logistics (RL) and Extended Product Responsibility (EPR) etc., enhance the CE adoption process (Saridakis et al., 2019). Further, green practices and initiatives, such as green purchasing, green design and green packaging, strengthen the social and environmental dimensions of CE (Kirchherr et al., 2017). Such practices enhance supply chain performance and strengthen the closed-loop mapping procedures (Whicher et al., 2018). Linking CE to supply chain further assists in maintaining the product cost under control (Yadav et al., 2020).

Some highly impactful indicators for the CE adoption framework are 'adoption of 6R's', 'multi-stage quality check system', and 'reduction in carbon emission' (Heyes et al., 2018). The multi-stage quality check system helps to diagnose the defects at the production stage and recycle the same for corrective actions. Similarly, reduction in carbon emission and using it in other activities enhance the organisational productivity (Wang et al., 2018). The 6R's includes redesign, reduce, recycle, reuse, recover and remanufacturing which strongly correlate to CE (Kazancoglu et al., 2018). Hence, adoption of 6R's significantly improves the CE adoption possibility. Additionally, effective inventory management emerges as one of the key indicators in the CE adoption process (Ormazabal et al., 2018). Employee empowerment and motivation is a requirement for the successful implementation of these identified indicators (Ricciardi et al., 2016). Therefore, focussed training for the CE adoption process is needed. Table 1 identifies and collates the indicators essential for the CE adoption framework.

Table 1: Circular economy related indicators reported in the literature

Sl. No.	Circular economy related indicators	Description	Literature
1	Effective planning and management	Effective planning and management to align resources appropriately for CE adoption	Martins (2018); Homrich et al. (2018)
2	Top management commitment	Top management engagement and involvement enhance opportunities for CE adoption	Saavedra et al. (2018); Bodar et al. (2018)
3	Allocation of financial budgets	Separate budget allocation for the execution of CE practices is crucial	de Jesus and Mendonça (2018); Mahpour (2018)
4	Sustainable resource management	Appropriate usage of sustainable resources is required for CE adoption	Bodar et al. (2018); Genovese et al. (2017)
5	Supportive participation of stakeholders	Stakeholders' participation is essential for the adoption of CE framework	Fang et al. (2017); de Oliveira et al. (2017)
6	Building a brand image	Brand image in effective CE culture boosts the opportunities	Genovese et al. (2017); Lieder and Rashid (2016)
7	Understanding exact implications of CE (economic and social benefits)	Economic and social benefits are required to be understood explicitly for an effective CE adoption	de Oliveira et al. (2017); Wang and Li (2006)
8	Focussed training for CE adoption	Appropriate training sessions facilitate CE adoption process	Martins (2018); Lieder and Rashid (2016)

9	Employee empowerment and motivation	Motivating employees and transferring responsibilities to them to improve the productivity of an organisation	Zhu and Tian (2016); Kirchherr et al. (2017)
10	Multi-stage quality check system	Conducting quality checks for in-process products at checkpoints assist in diagnosing defects at an early stage for necessary rework	Sarkis and Zhu (2017); Urbinati et al. (2017)
11	Adoption of 6 R's	Adoption of 6 R's helps organisation to penetrate CE effectively	Korhonen et al. (2018a); Ghisellini, Cialani, and Ulgiati (2016)
12	Effective inventory management	Appropriate forecasting techniques aid practitioners to manage inventories	Tukker (2015); Zhu et al. (2010)
13	Reduction in carbon emission	Reducing carbon emission and using it further for any productive recycling process boosts the CE adoption process	Merli et al. (2018); Korhonen et al. (2018)
14	Coordination and collaboration among SC members	Effective collaboration and communication among the supply chain entities help to manage supply chain operations	Geng and Doberstein (2008); Heyes et al. (2018)
15	Supplier commitment for recyclable materials	Suppliers' commitment to recyclable materials promotes the CE adoption process	Zhu, Geng, and Lai (2010); Tseng et al. (2018)
16	Adopting reverse supply chain practices (e.g. EPR, reverse logistics)	Effective implementation of EPR and reverse logistic practices indirectly assist in the CE adoption process	Whicher et al. (2018); Kirchherr et al. (2017)
17	Adopting green practices (in purchasing, design and packaging)	Adoption of green purchasing, design and packaging develop a recyclable product	Korhonen et al. (2018b); Lazarevic and Valve (2017)
18	Educating customers for CE practices	The end-users are required to be educated regarding the benefits of CE	Bodar et al. (2018); Lacy and Rutqvist (2016)
19	Adopting innovative practices	Adoption of advanced quality improvement practices at different functional areas of supply chain help in the CE adoption process	Genovese et al. (2017); Fang et al. (2017)
20	Advanced technological transfer and applicability	Availability and applicability of advanced technology transfer help in mapping activities that improve inter-departmental communication within the organisation	van Loon and Van Wassenhove (2018); Lieder and Rashid (2016)
21	Penetrating social media and big data analytics in the organisation	Implementation of big data analytics and social media in the organisation facilitates understanding of customers' requirements to take effective measures	Govindan and Hasanagic (2018); Lazarevic and Valve (2017)

22	Effective facility layout decision making	Allocation of facilities in an optimised manner is extremely important that directly correlates to the product cost	Pomponi and Moncaster (2017); Homrich et al. (2018)
23	Constant monitoring of changing market needs	Observation on changing market needs helps effectively in modifying/developing products	Martins (2018); Fang et al. (2017)
24	Effective information management system (e.g. IoT)	Effective implementation of the internet of things (IoT) in the organisation facilitates in handling complex information management system	Saavedra et al. (2018); Pomponi and Moncaster (2017)
25	Adopting industrial ecology initiatives	Implementation of industrial ecology facilitates the assessment of the system's environmental impact	Geng et al. (2012); Genovese et al. (2017)
26	Availability of CE oriented framework (e.g. ReSOLVE)	Focussed CE framework facilitates its better penetration in the organisation	Martins (2018); Sarkis and Zhu (2017)
27	Redesign based on customer (internal and external) feedback	An effective closed-loop feedback system facilitates appropriate modification in design	Tseng et al. (2018); Geng and Doberstein (2008)
28	Effective life cycle analysis	Review and analysis of product life cycle and its effective implementation facilitates to adapt new products	Merli et al. (2018); Sarkis and Zhu (2017)
29	Rewards and incentives for greener activities	Rewards and incentives boost employee morale to facilitate the implementation of environmentally sustainable activities	Ormazabal et al. (2018); Zhu and Tian (2016)
30	Identifying performance measures for CE	Effective performance measures assist in analysing CE's benefits	van Loon et al. (2017); Urbinati et al. (2017)
31	Supportive government policies	Government regulations for promoting CE and subsequent subsidies and rebate in taxes can enhance the CE adoption process	Govindan and Hasanagic (2018); Lazarevic and Valve (2017)

2.2 Circular Economy in Developing Nations

Although the success stories of CE have broadly captured by the developed economies, the developing economies are struggling to adopt CE effectively across their manufacturing firms. Effective CE adoption is crucial in developing nations as their economies partly depend on outsourcing/off-shoring market and/or foreign direct investments (Saavedra et al., 2018). Developing nations provide cheap labour and deliver final products at low costs. China is considered as one of the largest exporters of electronic goods (Mangla et al., 2019). India and Thailand export electronics manufactured goods to all parts of the globe (Wang et al., 2018).

It becomes an extremely challenging task to adopt CE in these countries when they are compared to the developed nations (Ghisellini et al., 2016). These nations' struggle to meet the basic requirements along with their poor strategic infrastructure find CE implementation an extremely challenging task (Luthra et al., 2019). Adoption of CE in the developing nations will facilitate them to attain economic stability, economic perks (Tseng et al., 2018) and simultaneously set a roadmap for transition from developing to developed nations. Therefore, adoption of CE will help them to get rid of the problem.

Mere understanding of CE is not enough as identification of its indicators plays a pivotal role in its effective adoption (Sarkis and Zhu, 2017). Thus to facilitate the CE adoption process, it is necessary to identify the indicators influencing the CE adoption in the context of developing nations. It is pertinent to note that majority of the studies (Wang et al., 2018) consider cases from China. Literature is scant on the studies highlighting the CE indicators from other developing nations like India, Sri Lanka and Thailand etc.

2.3 Knowledge Gaps

An exhaustive examination of the extant literature identifies the following knowledge gaps:

- While the majority of research articles (Wang and Li, 2006; Homrich et al., 2018) discuss CE adoption benefits, the literature emphasising a framework facilitating the CE adoption process in manufacturing organisations is scant.
- Determination of the intensity of influence the CE indicators are extremely significant for the CE adoption process. The extant literature is unavailable on this aspect of the CE indicators.
- Existing CE adoption frameworks (Bodar et al., 2018; Genovese et al., 2017) do not rely on standard analytical validation treatments justifying the CE adoption process.
- Lack of adequate technological infrastructure and sustainable resources differentiate the nature of the CE indicators of the developing and developed nations because non-availability of these resources makes it extremely difficult for developing nations to adopt CE effectively. Little is known in this regard although a few studies (Lieder and Rashid, 2016; de Oliveira et al., 2017) report some of the key CE indicators. Therefore, indicators related to developing nations need to be identified.
- Literature is unavailable on the causal relationship of the CE indicators. It is important to examine the behavioural aspect of an indicator when it interacts with the others.

These knowledge gaps call for exploring the importance weights of the identified CE indicators in a decision-making context for examining their intensity of influence on the CE adoption process, which is elucidated in the next sections.

3. Research Methodology

Figure 1 illustrates the research methodology and describes the data collection in five phases. This collection procedure is conducted in the case organisation. The CE indicators derived from the extant literature are further verified through an expert panel (see section 4.1 for expert details). These experts are asked to categorise the shortlisted indicators into diverse groups for the development of the CE adoption framework. The hybrid BWM-DEMATEL approach examines disparate feasibility aspects of the developed framework and causal relationship of the indicators.

3.1 The Hybrid BWM-DEMATEL Approach

The hybrid BWM-DEMATEL approach is formulated to examine the feasibility of the developed CE adoption framework. This approach works in two stages. In the first stage, BWM computes the final shortlisted CE indicators and assesses the intensity of influence of each indicator. Researchers' prime choice (Yadav and Desai, 2017) is Analytic Hierarchy Process (AHP) among all other multi-criteria decision-making (MCDM) approaches. These decision-making approaches work on the principle of pair-wise comparison. Computation of weights in these approaches becomes complex when the number of considered criteria is large. Researchers (Gupta and Barua, 2017; Sadeghi et al., 2016) recommend BWM over other MCDM approaches where large numbers of criteria are dealt with. In this study, BWM has emerged as the best approach to compute the criteria weights as there are 31 CE indicators. BWM effectively deals with vagueness and bias within the experts' judgements.

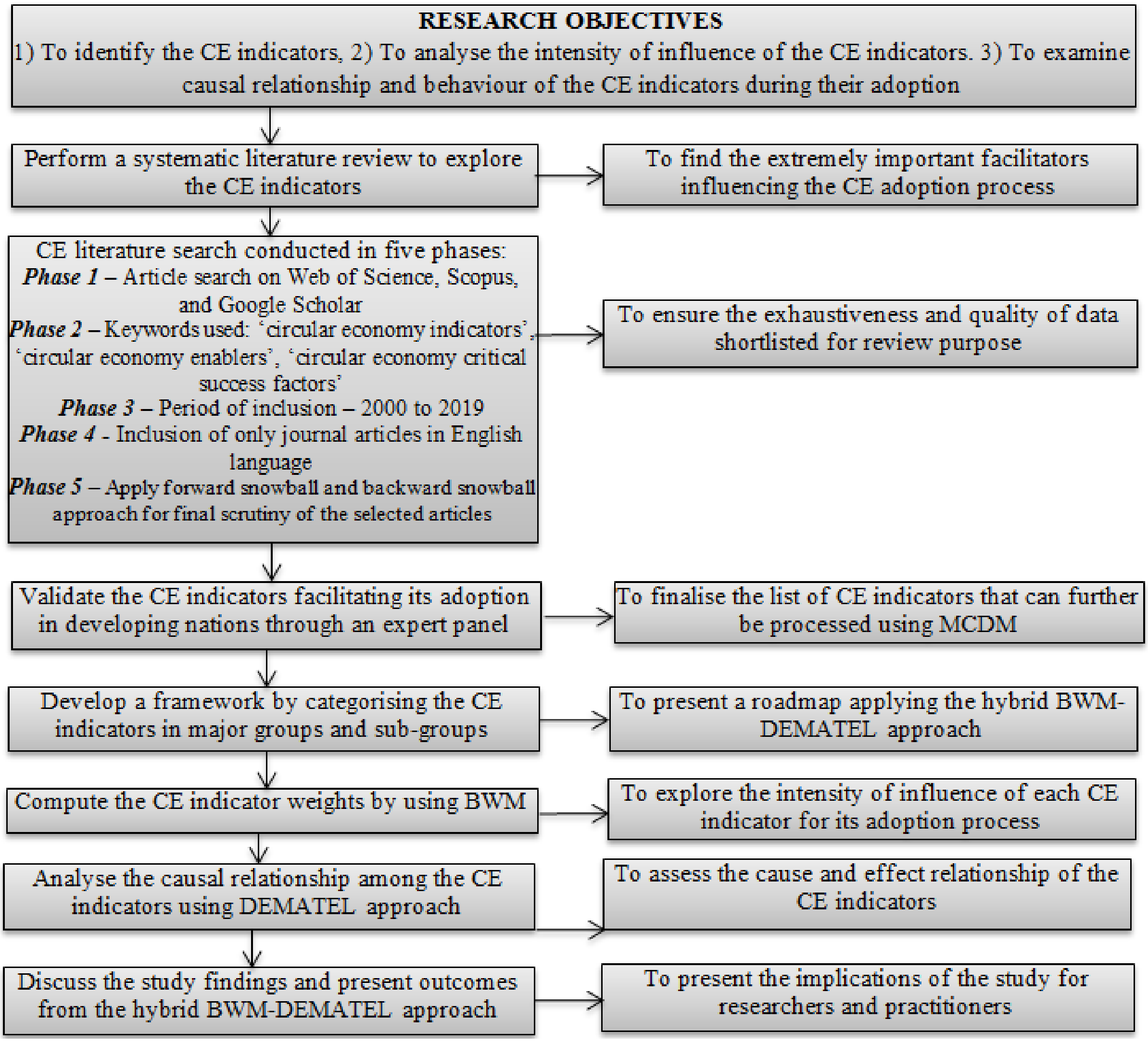


Figure 1: Research methodology

Note: CE- Circular Economy, BWM- Best Worst Method, DEMATEL- Decision Making Trial and Evaluation Laboratory, MCDM- Multi-Criteria Decision Making

The second stage of the two-stage hybrid BWM-DEMATEL approach analyses the causal relationship among the CE indicators. It is significant to assess how one indicator relates to the other. Several MCDM approaches may serve this purpose. Some of these are Analytical Network Process (ANP), Interpretive Structural Modelling (ISM), Fuzzy Cognitive Maps (FCM) and Decision Making Trial and Evaluation Laboratory (DEMATEL) etc. ISM and FCM are preferred in situations where structural hierarchy is required. However, in situations, where the causal relationships among the selected factors need to be examined, DEMATEL emerges as the prime choice. DEMATEL assists in examining the cause and effect factors, which facilitates the practitioners to effectively adopt CE.

4. Development and Testing of the Circular Economy Adoption Framework

4.1 Problem Description

In this study, a case study approach helps provide a theoretical background. The case of a heavy manufacturing company operating in western India is considered. The company is involved in manufacturing of a variety of products, such as motors and hydro turbines, industrial pumps, agriculture and household pumps etc. There are more than 1000 employees in the organisation. The organisation has a turnover of approximately US $10 billion.

The case company has a well-framed organisational mission with an objective of reducing its overall environmental impact and achieving sustainability in business. The company has adopted the CE initiatives, such as carbon neutrality, ISO 14001 and hierarchy of wastes (i.e. rethink and redesign, reduce, reuse, recycle, and dispose) in their business. The management of the company is committed to developing high-quality products and involved in a project titled "*circular economy and sustainability initiatives*". The management seeks to identify possible key indicators for CE implementation and subsequently aim to analyse the indicators for a successful CE adoption process. Additionally, the management is interested to analyse the cause and effect relations within the CE indicators.

To deal with the problem of the case company, an expert panel comprising six members is formed. The panel includes a production and planning manager, procurement manager, general manager, information technology engineer and environmental scientist. The literature reveals that the number of experts between five to eight is sufficient for the application of hybrid BWM-DEMATEL approach (Rezaei, 2016). Unlike other MCDM approaches the selected approach in this study requires less number of decision makers to arrive at the final judgement. Researchers (Ijadi Maghsoodi et al., 2019; Pourhejazy et al., 2019) have used an expert panel comprising four to six members to form case study judgements. Following the same analogy, in this study, a decision panel comprising six experts is formed. This research is employed to a limited setting steered with a case study approach of comparable sample size comprising six experts. However, it sets a ground for future study that could be extended to larger sample to test and validate the outcomes.

The selection of experts is decided based on certain criteria, such as the members' industrial and consultancy experience, decision-making competencies, respective designations and expertise in the domain etc. The experts are contacted for data collection. The framework of the CE indicators is analysed using the hybrid BWM-DEMATEL approach, details of which are provided in the following sections.

4.2 Determining the Circular Economy Indicators' Weights

The experts are initially asked to categorise the CE indicators identified from the literature. The indicators are categorised in five broad groups, viz. managerial indicators, organisational indicators, supply chain indicators, informational and technological indicators, and strategy and policy indicators. The framework developed for the CE adoption process is elucidated in Figure 2.

[Figure 2 about here]

The intensity of influence of the CE indicators is determined using the BWM approach. The steps adopted in BWM are as follows (Rezaei, 2016):

Step 1: Exploring the CE indicators – This step involves identification of the CE indicators influencing its adoption in developing nations. All the indicators are allotted criteria as i_1, i_2, $i_3 \ldots\ldots i_n$.

Step 2: Diagnosing the best and worst indicators – This step involves grouping of the CE indicators across diverse groups and then finding the best and worst indicators for the disparate major groups and each sub-group.

Step 3: Allotment of preference – In this step, a separate table for best and worst comparison is computed through the expert judgements by assigning numerals between 1 and 9. The assignments are performed separately for the main group indicators and sub-group indicators. The best and worst comparison of the major group indicators is illustrated in Tables 2 and 3 respectively. Equation (1) represents the comparison set of Best (A_B) and Worst (A_w) criteria.

$$A_B = (a_{1b}, a_{2b}, a_{3b} \ldots a_{nb}),\ A_w = (a_{1w}, a_{2w}, a_{3w} \ldots a_{nw}) \qquad (1)$$

Table 2: Best-to-Others (BO) comparisons for the main group indicators

Resp. No.	Best	MG	OG	SP	IT	SC
1	SP	6	3	1	5	2
2	MG	1	4	5	3	6
3	MG	1	4	6	2	5
4	OG	2	1	5	2	4
5	SC	4	5	4	2	1
6	SP	6	4	1	5	2

Note: MG- Managerial Indicators, OG- Organisational Indicators, SP- Strategy and Policy Indicators, IT- Informational and Technological Indicators, SC- Supply Chain Indicators

Table 3: Others-to-Worst (OW) comparisons for the main group indicators

Resp. No.	Worst	MG	OG	SP	IT	SC
1	MG	1	2	6	2	5
2	SC	6	3	2	4	1
3	SP	7	3	1	6	3
4	SP	4	5	1	4	2
5	OG	4	1	2	4	5
6	MG	1	3	6	2	5

Step 4: Computing the CE indicator weights – An objective function along with some constraints is formulated to compute the CE indicator weights,. Equation (2) represents a comparison of each constraint with the best criterion for all values of j. Similarly, equation (3) represents a comparison of each constraint with the worst criterion for all values of j. Equation (4) indicates that the sum of the weights of all the criteria should be equal to 1.

Min ξ

Subject to

$$\left| \frac{wB}{wj} - a_{Bj} \right| \leq \xi, \text{ for all values of j} \quad (2)$$

$$\left| \frac{wj}{ww} - a_{jw} \right| \leq \xi, \text{ for all values of j} \quad (3)$$

$$\sum_j wj = 1 \quad (4)$$

$w_j \geq 0$, for all values of j.

The linear programming model is used for computing weights of the CE indicators. The comparative judgements for the major group indicators are obtained computing the weights using the equations 2 to 4. The local weights obtained for the major group indicators are illustrated in Table 4.

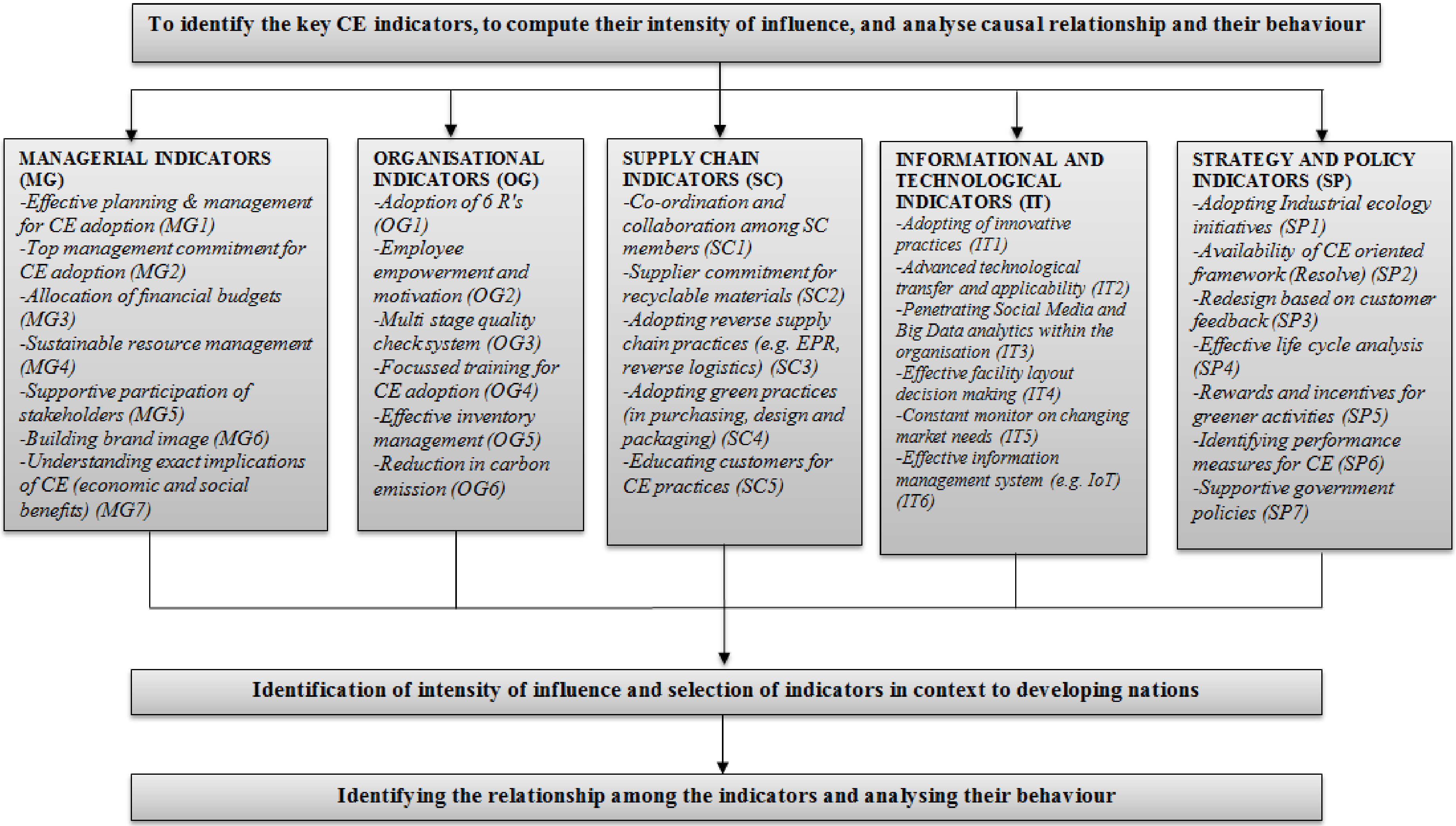


Figure 2: Framework for the CE adoption process

Table 4: Local weights obtained for the main group indicators

Expert number	MG	OG	SP	IT	SC	ξ
1	0.061475	0.163934	0.430328	0.098361	0.245902	0.061475
2	0.487145	0.142084	0.113667	0.189445	0.067659	0.081191
3	0.439883	0.131965	0.058651	0.26393	0.105572	0.087977
4	0.218487	0.386555	0.067227	0.218487	0.109244	0.05042
5	0.19245	0.074019	0.144338	0.473723	0.11547	0.103627
6	0.064103	0.128205	0.448718	0.102564	0.25641	0.064103
Criteria weight	**0.243924**	**0.171127**	**0.210488**	**0.224418**	**0.150043**	**0.074799**

A similar procedure is used while determining local weights of all the sub-group indicators. The values of ξ for all the group and sub-group comparisons are found to be consistent. The global weights are obtained (Table 5) after determining the local weights for all the sub-groups.

Table 5: Global weights of the CE indicators

Indicator	Major group	Sub-group code	Sub-group local weight	Global weight	Rank
Managerial indicators (MG)	0.244	MG 1	0.174	0.042	6
		MG 2	0.192	0.047	4
		MG 3	0.140	0.034	13
		MG 4	0.160	0.039	7
		MG 5	0.113	0.027	22
		MG 6	0.106	0.026	25
		MG 7	0.117	0.029	19
Organisational indicators (OG)	0.171	OG 1	0.265	0.045	5
		OG2	0.121	0.021	28
		OG 3	0.161	0.028	21
		OG 4	0.179	0.031	17
		OG 5	0.072	0.012	30
		OG 6	0.203	0.035	12
Supply chain indicators (SC)	0.150	SC 1	0.240	0.036	9
		SC 2	0.214	0.032	15
		SC 3	0.179	0.027	23
		SC 4	0.177	0.027	24
		SC 5	0.190	0.029	18

Information and technological indicators (IT)	0.224	IT 1	0.213	0.048	3
		IT 2	0.142	0.032	16
		IT 3	0.147	0.033	14
		IT 4	0.160	0.036	10
		IT 5	0.065	0.015	29
		IT 6	0.273	0.061	1
Strategy and policy indicators (SP)	0.210	SP 1	0.115	0.024	26
		SP 2	0.263	0.055	2
		SP 3	0.038	0.008	31
		SP 4	0.132	0.028	20
		SP 5	0.169	0.036	11
		SP 6	0.108	0.023	27
		SP 7	0.174	0.037	8

Note: For the abbreviation of all the subgroup code please refer to Figure 2

The global weights of all the sub-group indicators form a cluster diagram (Figure 3).

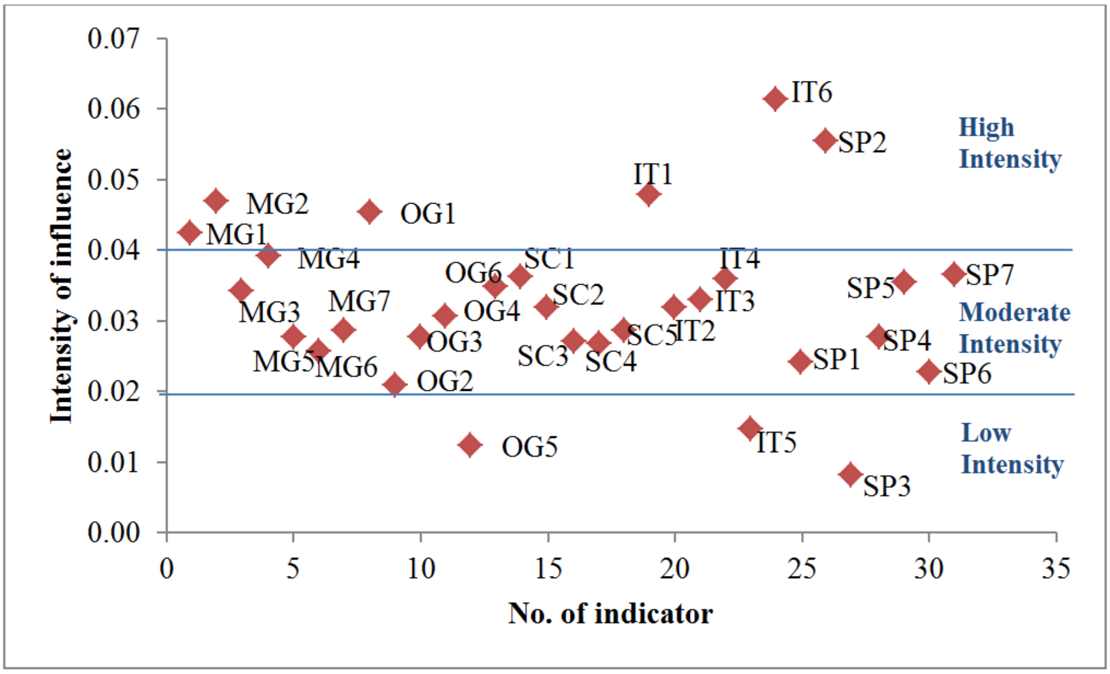


Figure 3: Cluster diagram for the CE indicators

Note: For the abbreviation of all the subgroup code please refer to Figure 2

The cluster diagram represents different intensities of the CE indicators falling in different clusters viz. high intensity, moderate intensity and low-intensity indicators. It is observed that six indicators fall in the high-intensity cluster, twenty-two indicators fall in the moderate-intensity cluster and three indicators fall under the low-intensity cluster. The low-intensity cluster indicators are ‘effective inventory management’ (OG5), ‘constant monitoring of changing market needs’ (IT5), and ‘redesign based on customer feedback’ (SP3). These results are discussed with the experts, and the indicators found under the low-intensity cluster are excluded for further processing. According to experts, CE concepts are in the very initial stage in developing nations such as India. Both the organisation and its customers are unsure about CE adoption. Hence, at this level, these low-intensity cluster indicators can be dropped from the framework development process.

4.3 Analysing the Causal Relationship of the Circular Economy Indicators

A total of 31 CE indicators are selected at the beginning, which is subsequently filtered to 28 indicators under the five major groups through the BWM approach in the previous stage. The main aim is to analyse the causal relationship among the available CE indicators through the cause and effect indicators. In this regard, the procedure adopted for executing the DEMATEL approach is explained below (Abdullah and Zulkifli, 2015):

Step 1: Defining the CE indicators – All the CE indicators including major and sub-group indicators from the output of the BWM approach are considered as input to this approach. However, the grouping of the indicators is retained as that of the previous stage. Only the indicators dropped in the previous stage are excluded while applying this approach.

Step 2: Development of indirect relation matrix and average matrix – The experts are asked to rate the indicators based on their relationship with the other indicators on a scale of 0 to 4, where, ‘0 – no influence’, ‘1 – weak influence’, ‘2 –moderate influence’, ‘3 – strong influence’, and ‘4 – extremely strong influence’. Hence, with the input of six available experts, six different matrices are formed for the major group indicators. An average of all these matrices for the major group indicators is determined (in Table 6). A similar procedure is followed for all the sub-group indicators.

Table 6: Average matrix of the major groups of the CE indicators

Major group	MG	OG	SP	IT	SC
MG	0	3.8	3.6	3.6	3.4
OG	2.8	0	3	3.2	2.6
SP	3.2	3.2	0	3.4	3
IT	2.8	3	3.2	0	3.4
SC	2.6	2.4	2.2	3	0

Step 3: Computing normalised direct relation matrix (D) – The average matrix determined in the last step is now converted into a normalised direct relation matrix by using the equation (5):

$$D = M \times S \quad (5)$$

Where, S is computed by using equation (6)

$$\min\left[\frac{1}{\max\sum_{j=1}^{n}|m_{ij}|}, \frac{1}{\max\sum_{i=1}^{n}|m_{ij}|}\right] \quad (6)$$

The normalised matrix found for the major group CE indicators is illustrated in Table 7.

Table 7: Normalised matrix of the major groups of the CE indicators

Major group	MG	OG	SP	IT	SC
MG	0.000	0.264	0.250	0.250	0.236
OG	0.194	0.000	0.208	0.222	0.181
SP	0.222	0.222	0.000	0.236	0.208
IT	0.194	0.208	0.222	0.000	0.236
SC	0.181	0.167	0.153	0.208	0.000

Similarly, this procedure is repeated for computing the normalised matrix for all other sub-group indicators.

Step 4: Development of total relation matrix – The total relation matrix for the CE indicators is found using equation (7).

$$T = D\,(I\text{-}D)^{-1} \quad \ldots (7)$$

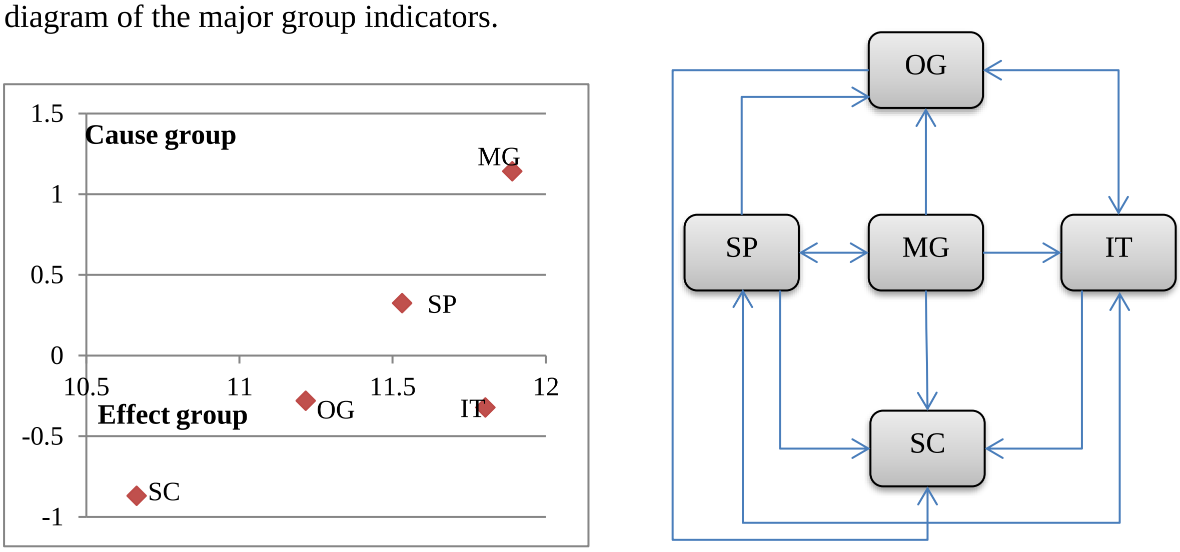
The total relation matrix for the major group indicators is illustrated in Table 8.

Table 8. Total relation matrix of the major groups of the CE indicators.

Major group	MG	OG	SP	IT	SC	ri	ri + cj	ri - cj
MG	1.076	*1.360*	*1.322*	*1.414*	*1.345*	6.517	11.891	1.143
OG	1.066	0.966	1.114	*1.200*	1.122	5.468	11.216	-0.280
SP	*1.161*	*1.229*	1.021	*1.295*	*1.223*	5.928	11.531	0.326
IT	1.111	*1.185*	*1.169*	1.069	*1.208*	5.741	11.803	-0.320
SC	0.961	1.008	0.977	1.084	0.868	4.898	10.664	-0.868
Sum cj	5.374	5.748	5.602	6.062	5.766	***Threshold value = 1.142***		

All the rows and column of the total relation matrix are added together. The row sum (r_i) represents the direct and indirect effect of r_i over other indicators. Similarly, the column sum (c_j) represents the direct and indirect effect experienced by indicator j from all other indicators. However, (r_i - c_j) can be defined as the net effect by which a particular indicator influences the entire system. The positive value of (r_i - c_j) is known as cause indicator while its negative value is termed as effect indicator.

Step 5: Identification of threshold measure – The threshold measure (Table 8) is identified to generate both causal digraph and relationship diagram. Considering all the values above the threshold measure the connections between the indicators are established for generating the relationship diagram. A similar procedure is carried out for computing the total relation matrix for the subgroup indicators. Based on the threshold values and ri, cj values, the causal digraph and relationship diagram are developed. Figure 4 presents the causal digraph and relationship diagram of the major group indicators.



(a) Causal digraph **(b) Relationship diagram**

Figure 4: Causal digraph and relationship diagram for the major group indicators

Figure 4(a) illustrates the causal digraph of major group indicators. It is found that ‘managerial indicators’ and ‘strategy and policy indicators’ exist in the cause group cluster. The effect group cluster includes ‘informational and technological indicators’, ‘organisational indicators’ and ‘supply chain indicators’. The relationship diagram in Figure 4(b) elucidates inter-relationships among other indicators. The managerial indicators and strategic and policy indicators strongly correlate to other major group indicators. The strategic indicators help in developing organisational and supply chain indicators. The strategic indicators are equally dependent on informational and technological indicators. Similarly, the causal digraph and relationship diagram for the sub-indicators are obtained (shown in Figures A1, A2, A3, A4 and A5 of Appendix A).

5. Results and Discussion

The outcomes from the BWM approach portray that 'informational and technological indicators' (0.244) and 'managerial indicators' (0.243) possess the extreme importance in the CE adoption followed by 'strategy and policy indicators' (0.210), 'organisational indicators' (0.171) and 'supply chain indicators' (0.150). This corroborates with the findings of Lazarevic and Valve (2017) and Lieder and Rashid (2016). Govindan and Hasanagic (2018) emphasised on strategy and policy-related indicators to adopt CE effectively. Among the sub-group indicators, 'effective information management system' (0.061), 'availability of CE oriented framework' (0.055) and 'adopting of innovative quality practices' (0.048) appear to be the most critical indicators strongly affecting CE adoption. However, 'top management commitment for CE adoption' (0.042) and 'adoption of 6R's' are strong facilitators for the CE adoption process. Korhonen et al. (2018b) reported that ignorance of management towards CE adoption and considering the adoption of 6R's on least priority may lead to failure of the CE adoption.

The CE indicators are plotted within clusters based on their calculated weights. Six indicators are found to be in a high-intensity cluster, twenty-two in the moderate-intensity cluster and three indicators in the low-intensity cluster. Based on the discussion with experts, 'effective inventory management' (OG5), 'constant monitoring of changing market needs' (IT5), and 'redesign based on customer feedback' (SP3) are dropped from further assessment. Experts suggest that although these indicators are related to the CE adoption process, in the developing nations' economy context they possess low influence. These indicators must be included after the appropriate assessment when considering CE adoption for the developed nations. Pomponi and Moncaster (2017) indicated that effective inventory management has an indirect effect on the CE adoption process. Therefore, a total of 28 CE indicators are finally considered for the CE adoption framework in the developing nations' economy context. These indicators are taken as input for the second stage of the hybrid approach.

The outputs from the BWM approach are considered as inputs in DEMATEL. DEMATEL generates causal digraphs and relationship diagram for the major group indicators and other sub-group indicators. Among all the major group indicators, managerial indicators and strategy and policy indicators are found to be the cause indicators. These indicators help in developing other indicators, viz. information and technology indicators, organisational indicators and supply chain indicators. Homrich et al. (2018) indicated that managerial indicators are strong driving factors that assist in developing other indicators for effective CE adoption. Mathur et al. (2012) explained the importance of managerial and strategic indicators considering the case of the Indian manufacturing organisation. They further suggest that by adopting the strategic indicators, the practitioners can execute the organisational indicators more easily. Geng et al. (2012) reported managerial indicators as the most significant indicators for the CE adoption while elucidating a case from China. The relationship diagram (Figure 4b) indicates the influence of managerial and strategic indicators in achieving all other major group indicators. The causal digraph in Figure 4a reveals that for effective implementation of the organisational indicators, it is required to have the strong support of managerial, strategic and informational and technological indicators.

Low penetration of the following indicators reduces the success possibility of the CE adoption, viz. 'effective planning and management for CE adoption', 'top management commitment for CE adoption' and 'supportive participation of stakeholders'. These indicators strongly drive the other indicators. Therefore, it is extremely difficult to adopt CE without the support of top management and stakeholders. This is corroborated in the study of Saavedra et al. (2018) and Whicher et al. (2018). Among the organisational indicators, 'adoption of 6R's' and 'reduction in carbon emission' strongly drive other indicators of its sub-group. This is corroborated in Sarkis and Zhu (2017) when they identify 6R's (i.e. redesign, reduce, recycle, reuse, recover and remanufacturing) as the most essential component for the CE adoption in manufacturing organisations. Within the supply chain indicators, 'co-ordination and collaboration among SC members', 'supplier commitment for recyclable materials', and 'educating customers for CE practices' possess a high impact on other supply chain indicators. Accordingly, suppliers' commitment to supply recyclable materials ensures green practices in purchasing, design and packaging (Zhu et al., 2010).

Among all the informational and technological indicators, 'adopting of innovative practices', 'effective facility layout decision making' and 'effective information management system (e.g. IoT)' possess a strong influence on other indicators in the same group. The results affirm that an effective information system holds a strong relation in achieving other informational indicators. The findings of Kirchherr et al. (2017) corroborate this as they report that poor information flow within an organisation can lead to a failure in the CE adoption process. The findings reveal that within the strategy and policy indicators, 'availability of CE oriented framework', 'rewards and incentives for greener activities', and 'supportive government policies' drive other strategic and policy indicators. Urbinati et al. (2017) reported that the CE oriented framework is responsible for its successful adoption. However, researchers

(Kirchherr et al. 2017; Geng et al. 2012) suggested various frameworks for the CE adoption process and subsequent improvement of the organisational performance.

6. Contributions and Implications

The findings from this study are equally beneficial for researchers, practitioners and policymakers. The findings contribute to theory and practice in the following ways:

- The extant literature on the CE adoption process does not shed any light on the manufacturing sector. This study guides the practitioners in the CE adoption process within the manufacturing organisation. As the study finding guides them to develop the roadmap that improves CE adoption.
- Several studies on CE indicators report a very limited set of indicators facilitating the CE adoption process. This study identifies 31 key indicators that influence the CE adoption process in the context of developing nations' economy. Further, this is a unique study that not only develops a framework for CE adoption but also justifies it through a hybrid BWM-DEMATEL approach. As observed in the literature, very few studies include multi-criteria decision-making treatment for obtaining the inter-relationship of the indicators.
- All the CE indicators cannot be implemented simultaneously. However, if the causal relationship among these indicators is obtained, it will facilitate practitioners and decision-makers of manufacturing companies to plan some effective CE adoption strategies. This study explicitly examines the causal relationship among each set of the major group indicators and sub-group indicators that will assist the practitioners and researchers to understand the behaviour of the indicators.
- The identified CE adoption framework and indicators are in the context of developing nations' economies. However, the same indicators can be employed to developed economies with appropriate modifications by consulting experts. Hence, this can be considered as a unique contribution in context to the developing nations.

6.1 Recommendations for the Developing Economy

Adoption of CE is comparatively easier in the developed nations than the developing nations. Many developing nations, such as China, India, Malaysia, Sri Lanka etc., are initiating various attempts for CE adoption, but could not achieve the success rate as expected. Unavailability of a robust CE oriented framework has been one of the prime reasons behind the CE adoption failures. Therefore, practitioners are recommended to obtain support from the government. These include the exemption in taxes, rebates and various other incentives to the organisations adopting CE. An effective CE adoption will enhance export possibilities thereby directly contributing to the nation's economy. It is further recommended to adopt industrial ecology initiatives as this will help in improving organisational performance and support sustainability initiatives. Adoption of CE directly relates to sustainability. Therefore, incentives for the adoption of green practices and usage of sustainable resources are recommended. Effective life cycle analysis will help in identifying the disposal period of products, which can support an effective CE adoption process.

7. Conclusions and Scope for Future Research

The manufacturing sector has a strong contribution to building nations' economy, especially in developing countries. This study conducts an exhaustive literature review to identify a unique set of 31 critical indicators facilitating the CE adoption process in the context of developing nations. Further, this study develops a framework for enhancing the CE adoption process through an exhaustive analysis of the indicators. A hybrid BWM-DEMATEL approach is applied to the developed framework to test its feasibility. BWM is adopted to compute the indicator weights. DEMATEL is used to analyse the causal relationship of the indicators through causal digraph and relationship diagram of the major group indicators and sub-group indicators. This study attempts to cover the CE indicators across five major groups among which managerial, informational and technological, and strategic indicators emerge as strongly influencing indicators for the CE adoption process. The results indicate that the managerial and strategic indicators fall in the cause group which facilitate the development of the effect group indicators, viz. information and technological, supply chain and organisational indicators. The case of an Indian manufacturing organisation elucidates in understanding the CE adoption framework, which is extremely useful for developing nations.

Although this study elucidates the CE adoption framework through a case of a manufacturing organisation, CE can be adopted across other industry sectors. Therefore, the same framework can be employed in other business sectors by appropriately tweaking the input indicators. Future research can be conducted through a large scale survey which will strengthen the validity of the CE indicator sets. Future research may adopt other decision-support methods to examine and analyse the CE indicators. Interpretive structural modelling (ISM), fuzzy cognitive map (FCM) and other structural approaches can be adopted to validate the CE indicators and its adoption framework.

Acknowledgements: We express our sincere thanks to the experts from the case organisation for providing the data to perform the case analysis.

References

Abdullah, L., Zulkifli, N., 2015. Integration of fuzzy AHP and interval type-2 fuzzy DEMATEL: An application to human resource management. Expert Syst. Appl. 42, 4397–4409. doi:10.1016/j.eswa.2015.01.021

Anzola-román, P., Bayona-sáez, C., García-marco, T., 2018. Organizational innovation, internal R & D and externally sourced innovation practices : Effects on technological innovation outcomes. J. Bus. Res. 91, 233–247. doi:10.1016/j.jbusres.2018.06.014

Bodar, C., Spijker, J., Lijzen, J., Waaijers-van der Loop, S., Luit, R., Heugens, E., Janssen, M., Wassenaar, P., Traas, T., 2018. Risk management of hazardous substances in a circular economy. J. Environ. Manage. 212, 108–114. doi:10.1016/j.jenvman.2018.02.014

de Jesus, A., Mendonça, S., 2018. Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy. Ecol. Econ. 145, 75–89. doi:10.1016/j.ecolecon.2017.08.001

de Oliveira, F.R. de, França, S.L.B., Rangel, L.A.D., 2017. Challenges and opportunities in a circular economy for a local productive arrangement of furniture in Brazil. Resour. Conserv. Recycl. 0–1. doi:10.1016/j.resconrec.2017.10.031

Fang, K., Dong, L., Ren, J., Zhang, Q., Han, L., Fu, H., 2017. Carbon footprints of urban transition: Tracking circular economy promotions in Guiyang, China. Ecol. Modell. 365, 30–44. doi:10.1016/j.ecolmodel.2017.09.024

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. doi:10.3843/SusDev.15.3

Geng, Y., Fu, J., Sarkis, J., Xue, B., 2012. Towards a national circular economy indicator system in China: An evaluation and critical analysis. J. Clean. Prod. 23, 216–224. doi:10.1016/j.jclepro.2011.07.005

Genovese, A., Acquaye, A.A., Figueroa, A., Koh, S.C.L., 2017. Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications. Omega 66, 344–357. doi:10.1016/j.omega.2015.05.015

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. doi:10.1016/j.jclepro.2015.09.007

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. doi:10.1080/00207543.2017.1402141

Gupta, H., Barua, M.K., 2017. Supplier selection among SMEs on the basis of their green innovation ability using BWM and fuzzy TOPSIS. J. Clean. Prod. 152, 242–258. doi:http://dx.doi.org/10.1016/j.jclepro.2017.03.125

Heyes, G., Sharmina, M., Mendoza, J.M.F., Gallego-Schmid, A., Azapagic, A., 2018. Developing and implementing circular economy business models in service-oriented technology companies. J. Clean. Prod. 177, 621–632. doi:10.1016/j.jclepro.2017.12.168

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. doi:10.1016/j.jclepro.2017.11.064

Ijadi Maghsoodi, A., Mosavat, M., Hafezalkotob, Ashkan, Hafezalkotob, Arian, 2019. Hybrid hierarchical fuzzy group decision-making based on information axioms and BWM: Prototype design selection. Comput. Ind. Eng. 127, 788–804. doi:10.1016/j.cie.2018.11.018

Kazancoglu, Y., Kazancoglu, I., Sagnak, M., 2018. A new holistic conceptual framework for green supply chain management performance assessment based on circular economy. J. Clean. Prod. 195, 1282–1299. doi:10.1016/j.jclepro.2018.06.015

Kim, Y., Lui, S.S., 2015. The impacts of external network and business group on innovation : Do the types of innovation matter ? J. Bus. Res. 68, 1964–1973. doi:10.1016/j.jbusres.2015.01.006

Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: An analysis of 114 definitions. Resour. Conserv. Recycl. 127, 221–232. doi:10.1016/j.resconrec.2017.09.005

Korhonen, J., Honkasalo, A., Seppälä, J., 2018a. Circular economy: The concept and its limitations. Ecol. Econ. 143, 37–46. doi:10.1016/j.ecolecon.2017.06.041

Korhonen, J., Nuur, C., Feldmann, A., Birkie, S.E., 2018b. Circular economy as an essentially contested concept. J. Clean. Prod. 175, 544–552. doi:10.1016/j.jclepro.2017.12.111

Lacy, P., Rutqvist, J., 2016. Waste to wealth: The circular economy advantage. Prod. Plan. Control 1–264. doi:10.1057/9781137530707

Lazarevic, D., Valve, H., 2017. Narrating expectations for the circular economy: Towards a common and contested European transition. Energy Res. Soc. Sci. 31, 60–69.

doi:10.1016/j.erss.2017.05.006

Lieder, M., Rashid, A., 2016. Towards circular economy implementation: A comprehensive review in context of manufacturing industry. J. Clean. Prod. 115, 36–51. doi:10.1016/j.jclepro.2015.12.042

Luthra, S., Mangla, S.K., Yadav, G., 2019. An analysis of causal relationships among challenges impeding redistributed manufacturing in emerging economies. J. Clean. Prod. 225, 949–962. doi:10.1016/j.jclepro.2019.04.011

Mahpour, A., 2018. Prioritizing barriers to adopt circular economy in construction and demolition waste management. Resour. Conserv. Recycl. 134, 216–227. doi:10.1016/j.resconrec.2018.01.026

Mangla, S.K., Sharma, Y.K., Patil, P.P., Yadav, G., Xu, J., 2019. Logistics and distribution challenges to managing operations for corporate sustainability: Study on leading Indian diary organizations. J. Clean. Prod. 117620. doi:10.1016/j.jclepro.2019.117620

Martins, N.O., 2018. The classical circular economy, Sraffian ecological economics and the capabilities approach. Ecol. Econ. 145, 38–45. doi:10.1016/j.ecolecon.2017.08.026

Mathur, A., Mittal, M.L., Dangayach, G.S., 2012. Improving productivity in Indian SMEs. Prod. Plan. Control 23, 754–758. doi:10.1080/09537287.2011.642150

Merli, R., Preziosi, M., Acampora, A., 2018. How do scholars approach the circular economy? A systematic literature review. J. Clean. Prod. 178, 703–722. doi:10.1016/j.jclepro.2017.12.112

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. doi:10.1016/j.jclepro.2018.03.031

Parchomenko, A., Nelen, D., Gillabel, J., Rechberger, H., 2019. Measuring the circular economy - A Multiple Correspondence Analysis of 63 metrics. J. Clean. Prod. 210, 200–216. doi:10.1016/j.jclepro.2018.10.357

Pomponi, F., Moncaster, A., 2017. Circular economy for the built environment: A research framework. J. Clean. Prod. 143, 710–718. doi:10.1016/j.jclepro.2016.12.055

Pourhejazy, P., Sarkis, J., Zhu, Q., 2019. A fuzzy-based decision aid method for product deletion of fast moving consumer goods. Expert Syst. Appl. 119, 272–288. doi:10.1016/j.eswa.2018.11.001

Prieto-Sandoval, V., Jaca, C., Ormazabal, M., 2018. Towards a consensus on the circular economy. J. Clean. Prod. 179, 605–615. doi:10.1016/j.jclepro.2017.12.224

Rezaei, J., 2016. Best-worst multi-criteria decision-making method: Some properties and a linear model. Omega. 64, 126–130. doi:10.1016/j.omega.2015.12.001

Ricciardi, F., Zardini, A., Rossignoli, C., 2016. Organizational dynamism and adaptive business model innovation : The triple paradox con figuration. J. Bus. Res. 69, 5487–5493. doi:10.1016/j.jbusres.2016.04.154

Saavedra, Y.M.B., Iritani, D.R., Pavan, A.L.R., Ometto, A.R., 2018. Theoretical contribution of industrial ecology to circular economy. J. Clean. Prod. 170, 1514–1522. doi:10.1016/j.jclepro.2017.09.260

Sadeghi, S., Rasouli, N., Jandaghi, G., 2016. Identifying and prioritizing contributing factors in supply chain competitiveness by using PLS-BWM techniques (case study: Payam shoes company). World Sci. News 49, 117.

Saidani, M., Yannou, B., Leroy, Y., Cluzel, F., 2017. How to assess product performance in the circular economy? Proposed requirements for the design of a circularity measurement framework. Recycling 2, 1–18. doi:10.3390/recycling2010006

Saidani, M., Yannou, B., Leroy, Y., Cluzel, F., Kendall, A., 2019. A taxonomy of circular economy indicators. J. Clean. Prod. 207, 542–559. doi:10.1016/j.jclepro.2018.10.014

Salimi, N., 2017. Quality assessment of scientific outputs using the BWM. Scientometrics 112, 195–213. doi:10.1007/s11192-017-2284-3

Saridakis, G., Idris, B., Hansen, J.M., Dana, L.P., 2019. SMEs' internationalisation : When does innovation matter ? J. Bus. Res. 96, 250–263. doi:10.1016/j.jbusres.2018.11.001

Sarkis, J., Zhu, Q., 2017. Environmental sustainability and production: taking the road less travelled. Int. J. Prod. Res. 56, 743–759. doi:10.1080/00207543.2017.1365182

Tranfield, D., Denyer, D., Smart, P., 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. Br. J. Manag. 14, 207–222. doi:10.1111/1467-8551.00375

Tseng, M.L., Tan, R.R., Chiu, A.S.F., Chien, C.F., Kuo, T.C., 2018. Circular economy meets industry 4.0: Can big data drive industrial symbiosis? Resour. Conserv. Recycl. 131, 146–147. doi:10.1016/j.resconrec.2017.12.028

Tukker, A., 2015. Product services for a resource-efficient and circular economy - A review. J. Clean. Prod. 97, 76–91. doi:10.1016/j.jclepro.2013.11.049

Urbinati, A., Chiaroni, D., Chiesa, V., 2017. Towards a new taxonomy of circular economy business models. J. Clean. Prod. 168, 487–498. doi:10.1016/j.jclepro.2017.09.047

Uygun, Ö., Kaçamak, H., Kahraman, Ü.A., 2014. An integrated DEMATEL and fuzzy ANP techniques for evaluation and selection of outsourcing provider for a telecommunication company. Comput. Ind. Eng. 86, 137–146. doi:10.1016/j.cie.2014.09.014

van Loon, P., 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. doi:10.1080/00207543.2017.1398429

van Loon, P., Van Wassenhove, L.N., 2018. Assessing the economic and environmental impact of remanufacturing: a decision support tool for OEM suppliers. Int. J. Prod. Res. 56(4), 1662–1674. doi:10.1080/00207543.2017.1367107

Wang, J.F., Li, H.M., 2006. The development of circular economy in China. Aquat. Ecosyst. Health Manag. 9, 99–103. doi:10.1080/14634980500536162

Wang, N., Lee, J.C.K., Zhang, J., Chen, H., Li, H., 2018. Evaluation of urban circular economy development: An empirical research of 40 cities in China. J. Clean. Prod. 180, 876–887. doi:10.1016/j.jclepro.2018.01.089

Whicher, A., Harris, C., Beverley, K., Swiatek, P., 2018. Design for circular economy: Developing an action plan for Scotland. J. Clean. Prod. 172, 3237–3248. doi:10.1016/j.jclepro.2017.11.009

Wohlin, C., 2014. Guidelines for snowballing in systematic literature studies and a replication in software engineering. Proc. 18th Int. Conf. Eval. Assess. Softw. Eng. - EASE ’14 1–10. doi:10.1145/2601248.2601268

Yadav, G., Desai, T.N., 2017. A fuzzy AHP approach to prioritize the barriers of integrated Lean Six Sigma. Int. J. Qual. Reliab. Manag. 34. doi:10.1108/IJQRM-01-2016-0010

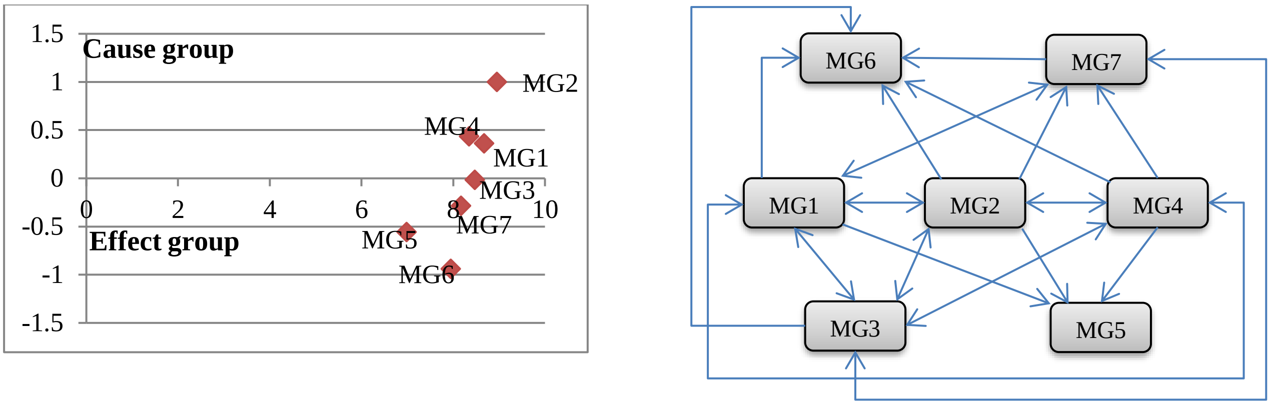
Yadav, G., Luthra, S., Jakhar, S.K., Mangla, S.K., Rai, D.P., 2020. A framework to overcome sustainable supply chain challenges through solution measures of industry 4.0 and circular economy: An automotive case. J. Clean. Prod. 254, 120112. doi:10.1016/j.jclepro.2020.120112

Zhu, Q., Geng, Y., Lai, K. hung, 2010. Circular economy practices among Chinese manufacturers varying in environmental-oriented supply chain cooperation and the performance implications. J. Environ. Manage. 91, 1324–1331. doi:10.1016/j.jenvman.2010.02.013

Zhu, Q., Tian, Y., 2016. Developing a remanufacturing supply chain management system: a case of a successful truck engine remanufacturer in China. Prod. Plan. Control 27, 708–716. doi:10.1080/09537287.2016.1166282

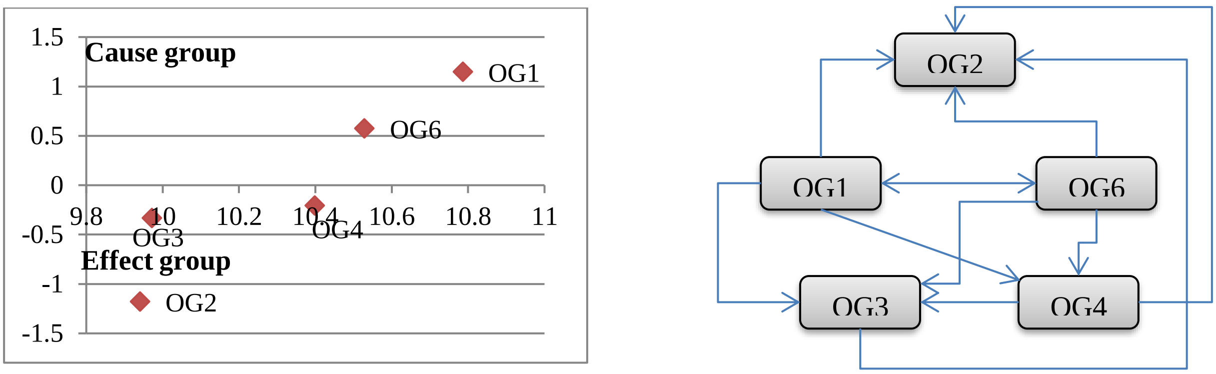
APPENDIX – A

Note: For the abbreviation of all the sub group code in all the figures of appendix please refer Figure 2.



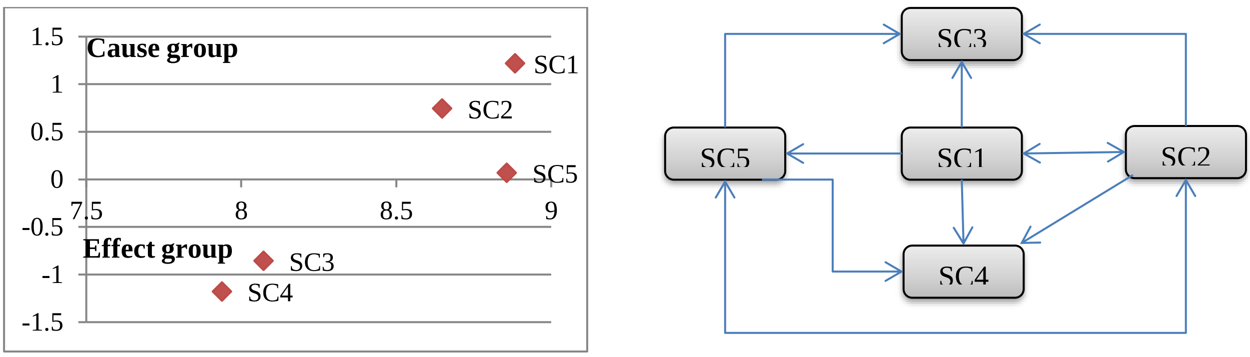
(i) **Causal digraph** (ii) **Relationship diagram**

Figure A1: Causal digraph and relationship diagram of managerial indicators



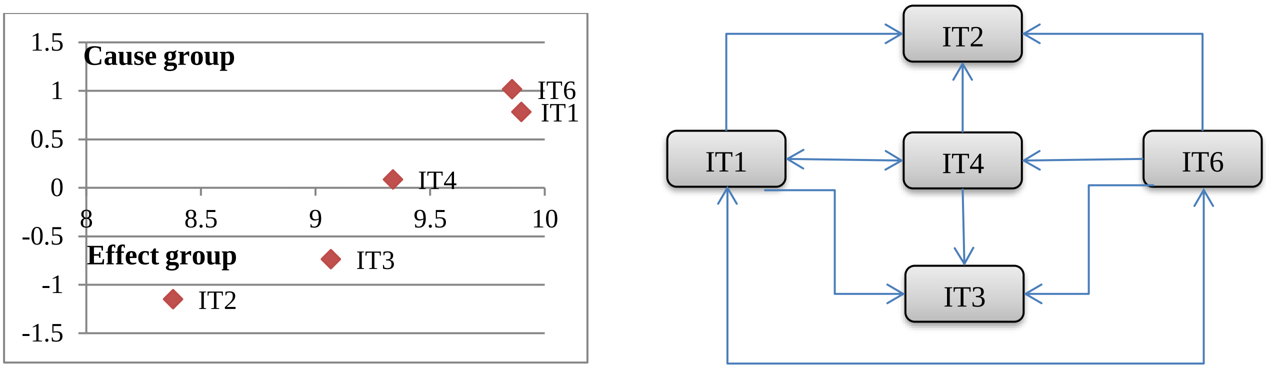
(i) **Causal digraph** (ii) **Relationship diagram**

Figure A2: Causal digraph and relationship diagram of organisational indicators



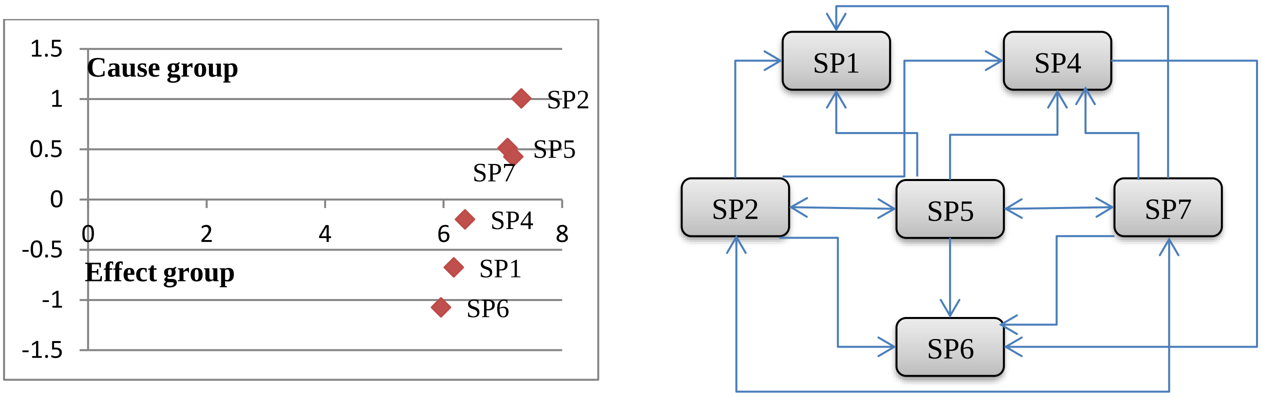
(i) **Causal digraph** (ii) **Relationship diagram**

Figure A3: Causal digraph and relationship diagram of supply chain indicators



(i) Causal digraph **(ii) Relationship diagram**

Figure A4: Causal digraph and relationship diagram of informational and technological indicators



(i) Causal digraph **(ii) Relationship diagram**

Figure A5: Causal digraph and relationship diagram of strategy and policy indicators