SUSTAINABLE METAL RECYCLING SUPPLY CHAINS: PRIORITIZING SUCCESS FACTORS APPLYING COMBINED AHP & PCA TECHNIQUES

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ABSTRACT

Triple Bottom Line (3 BL) Sustainability has been expressed as a tool in the hands of policy makers to achieve competitive advantage. Closed-Loop Supply Chain (CLSC) conceptualizes the design, control, and operation of the supply chain systems to recover the value from the product even after their useful life through the processes of reuse and recycle. Efficient management of CLSC operations in metal recycling industry will enhance 3BL sustainability. The present study investigates and shortlists critical sustainability factors in metal recycling CLSC operations. The study applies Analytic Hierarchy Process (AHP) to identify the most important factors and Principal Component Analysis (PCA) techniques to check the reliability and validity of these factors through statistical analysis. The study identifies five most important factors to achieve sustainability in metal recycling CLSC. Although the article is focused on the Indian metal recycling industry but factors can be relevant for researchers in other developing countries, where similar economic, social and environmental conditions exist.

KEYWORD

Analytic Hierarchy Process, Closed Loop Supply Chain, Principal Component Analysis, Triple Bottom Line, Sustainability

1. INTRODUCTION

During the first industrial revolution period (176-1820) and subsequent industrial revolutions traditional unit production methods were replaced by the mass production methods and manual operations were substituted with machines. These changes in production methods have lead to increasing growth in resource consumption all over the World. The large scale industrialization in the expanding global markets, coupled with increasing population, has created imbalance between the availability and consumption of natural resources. The simultaneous increase in demand and reduction in metallic resource reserves, the degradation of existing reserves, the up-rooting of inhabitants associated with mining operations, the deteriorating natural environment, and rising awareness among public has compelled business, policy makers and governments to begin thinking in terms of *sustainability*. Sustainability is considered to consist of three components: the conservation of natural environment, benefits of the local communities and society at large and economic growth. Researchers argue assimilation of these three concepts into business policies and practices are of paramount importance for sustainable development (SD) [1], [2], [3]. Closed-Loop Supply Chain (CLSC) is one such practice adopted by businesses and it targets recovering the left over values from the product after it has served the intended

DOI: 10.5121/ijmvsc.2015.6303

purpose [4]. Researchers have highlighted the importance of identifying important factors which can contribute to 3-BL sustainability in metal recycling industry in order to achieve sustainable metal supply for future generations [5].

This current study investigates the most critical factors responsible for 3-BL sustainability in Indian metal recycling industry through application of Analytic Hierarchy Process (AHP) and Principal Component Analysis (PCA) methodology.

2. LITERATURE REVIEW

2.1. Triple Bottom Line (3-BL) Sustainability

In order to address the new challenges on natural resources; both perishable as well as non-perishable, by growing industrialization, businesses needs to ensure that their activities eliminate waste and become sustainable [6], [7]. Sustainability or Sustainable Development (SD) has been proposed as a tool for decision-makers to repay their due towards society by taking into account the balanced economic, environmental, and societal growth. After a thorough study of the consumption pattern of natural resources over a period of 30 years, in their famous book, Limits to Growth", researchers [8] warn that the world might collapse one day as it greatly relies on diminishing global resources and produces excessive emissions. The European Union (EU), considering the importance of sustainability, has urged member countries that current and future legislation must integrate sustainability into implementation orders. Many other countries are also introducing regulations that address sustainability issues [9]. In general terms, sustainability is expressed as a concept that enables the current generation meeting their requirements without harming the ability of future generations through thoughtful exploitation of resources [1] (WCED, 1987). Researchers suggest that by adopting simultaneous economic, ecological and societal factors of sustainability (3 BL) into business objectives, we can ensure future of next generations [3] [5] [10] [11]. While the economic aspect of the 3BL is widely understood and used in business and industry and its measurement criteria are also well defined, the environmental and social concepts are far less understood and practiced. However, most corporate are preparing to include societal and environmental objectives into their policies due to increased internal and external pressures [12].

2.2. Closed-Loop Supply Chain and Triple Bottom Line Sustainability.

Since the sub-processes of supply chain process involve the initial processing of raw material through final production and up to delivery of the product or services to potential customers, supply chain sustainability is considered as the single most important contributor towards business sustainability. Growing number of researchers and policy makers have started realizing that supply chain sustainability has the latent potential to realize 3-BL business objectives [13], [14]. Hence Sustainable Supply Chain Management (SSCM) has been defined as a strategic management function that incorporates societal and environmental objectives along with economic objectives for the successful long term successful performances of the organizations [15]. Successful SSCM demands the effective synchronization of available resources, business processes and stakeholders' needs into organization's vision for generating healthy returns on assets. Researchers and policy makers [16], [17] now agree that closing the loops are a prerequisite for supply chain sustainability whether it is measured in terms of economic, environment or societal context; and hence the concept of CLSC was introduced. CLSC operations are designed to recover efficiently the remaining values of the used products in the forward supply chains through reuse or recycling thus providing additional sustainability to supply chains [17] [18].

2.2.1. Achieving Triple Bottom Line Sustainability through Closing Metal Supply Loop

Researchers have identified major wastes and concerns that emerge in the metal forward supply chains, including supply chain disruption and discontinuity, inadequate or inconsistent product quality, unpredictable delivery times and substantial, unanticipated additional costs, including premium freights [19], [20], and [21]. On the other hand, closing the loop activities are mainly concerned with waste reduction through efficient collection, recycling and integration of the recyclable material/ products back into the manufacturing stream. Metal recycling advances the necessary conditions for promoting triple bottom line sustainability by conserving perishable virgin metal resources, reducing mineral processing energy consumption, reducing landfill requirements, and protecting natural environment and creating job opportunities [22], [23] [24]. The same researchers highlight the need for identifying important CLSC factors and addressing them to exploit the maximum latent potential for achieving sustainability.

2.3. Review of Previous Research for Sustainability Studies in Supply chain.

Research methodology is the research approach followed by the researcher from theoretical considerations to data collection and analysis [25], [26]. The intent of this section is twofold: First to review the literature on the sustainable supply chain operation and important factors identified and investigated previously by researchers. The second objective is to review research methodologies commonly used and also the less common methodologies with high potential research opportunities to investigate the triple bottom line sustainability in supply chains.

Conceptual /theory and case studies have been the most common methodological approaches to sustainability and supply chain relations study till date [27] [28]. Some authors specifically developed concepts and proposed frameworks in order to classify and deal with strategic issues in SCM and sustainability [29], [30], and CLSC uncertainties and sustainability relation[31], [32], [33] and in development of algorithm for simultaneous study of economic and environmental impacts of CLSC operations [34]. The other commonly used method for sustainability research in supply chain is the case study methodology since this methodology is most suitable for understanding the issues in a new research domain [35]. Researchers have applied this methodology to study different aspects of CLSC across various industry sectors [36], [37], and [38]. Another less common method used by researchers is analytical models for studying the supply chain and sustainability relationships. Literature points out a lack of multi-criteria decision making (MCDM) approaches for green logistics and supply chain sustainability study [39], [14]. However quantitative studies have been done using different approaches for the study of sustainability phenomena in supply chain. This includes use of optimization concepts [40], Analytic Hierarchy Process (AHP) [41] [42], Fuzzy decision making [43]. Another less applied but promising research method suggested in literature is mixed method research [44], [45]. In the present study, researchers applied multi-methods approach or method triangulation in his study. This entailed the use of a combination of research instruments that includes interviews schedules, questionnaires guides, non-participant observation, and secondary data analysis.

2.3.1 AHP Method

The AHP is a multi-criteria decision making (MCDM) methodology, developed by T.L. Saaty [46] in 1980. Owing to its easy to understand and simple to apply methodology [47], [48], researchers have applied AHP methodology across a number of situations for studying sustainability and supply chain issues including sustainable supply chain technology evaluation and selection, performance measurement system development and prioritization of environmental factors [24], [47], [48], [49], [50].

This multi-criteria methodology disintegrates a complex decision-making issue into sub-problems/ sub-sub problems, which are easy to understand and diagnose. The subjective choices of experts are assigned numerical values through ranking on a scale developed by Saaty [46]. The pair-wise comparisons of various criteria generated at previous step are organized into a square matrix. The diagonal elements of matrix are 1. In order to assign relative values to various factors under consideration, Principal Eigen values and maximum Eigen values (λ_{max}), are calculated. Consistencies in the diagnosis of the experts are verified through calculating Consistency Index (CI) and Consistency Ratio (CR) values, applying following steps [46]

$$CI = (\lambda_{max} - n) / (n - 1) \qquad (1)$$

Where, λ_{max} is the maximum Eigen value of judgment matrix and n is number of evaluated criteria. Consistency Ratio (CR) is calculated as:

$$CR = CI / RI \qquad (2)$$

RI value is fixed for a given sample size. In general, a CR up to 0.10 is regarded to be acceptable value [24], [46].

2.3.2. Principal Component Analysis Method

Principal component analysis (PCA), a multivariate methodology, is applied when researcher needs to contract numbers of observed variables into comparatively fewer factors contributing towards appreciable amount of data variability [51]. This methodology compiles changes in the observed data, to a group of unrelated factors each of which is an aggregate of original variables and are known as principal components (PC). Researchers have applied multivariate techniques for study of supply chain sustainability [52], [53] in electronic industry.

3. RESEARCH DESIGN

Our research methodology is adapted from the work of Kim et al. [54], who studied most important factors for growth of retail sector supply chain in Korea by applying multi-criteria analysis technique.

This study consisted of two surveys: First an AHP survey and then a general survey. The first survey was aimed at prioritizing and assigning quantitative values to the sustainability factors in CLSC operations identified from the literature and the field work. A conceptual CLSC sustainability model was developed. A general survey was undertaken to statistically check the validity and reliability of the previously prioritized factors. Principal Component Analysis (PCA) methodology was employed to extract the most common factors. The commonality of the factors in the two methods validates the conceptual model developed through AHP technique. Prior to large scale survey of CLSC practices and sustainability performances, a pilot study was first conducted to test the suitability of proposed survey instrument prior to sending it out. The procedural steps are explained in Fig. 1.

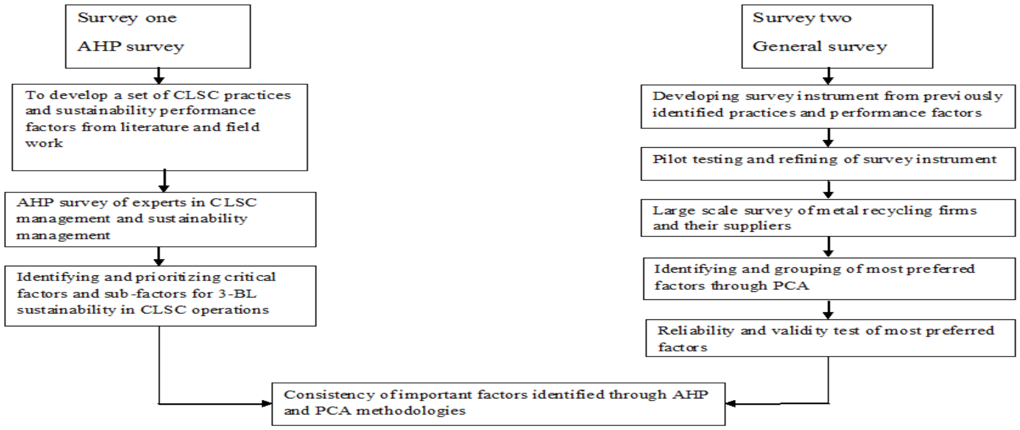

Figure1. Research Design

3.1. The AHP survey: Prioritizing and assigning ranks to critical factors
3.1.1. Data Collection

A questionnaire was prepared to evaluate and prioritize the factors identified previously and were arranged in accordance with the matrix as suggested by Saaty [46]. The questionnaire was developed based on four dimensions of operations management and two dimensions of performances related to CLSC. The management dimensions include: (1) Strategy, (2) Operations, (3) People, and (4) Structure and Infrastructure, while performance dimensions included (5) Business performance and (6) 3-BL Sustainability performances, as identified in the literature review. A total of 25 experts, having relevant experience were selected for AHP survey and they all agreed to respond. The respondents included top industry leaders (6 nos.), academics (4 nos.), and managers (15 nos.) from metal recycling supply chains and sustainability fields. A limited number of people, possessing thorough knowledge of the subject matter are required for evaluating identified factors and it is not necessary to involve many respondents [55].

3.1.2. Findings and discussions of AHP Survey

The hierarchy levels of AHP survey factors are shown in Figure 2. The commercial software packages (i.e., Expert Choice TM) was used for making computations. The local weights of all the main criteria and sub-criteria were first calculated. The global priority vector was then calculated combining all successive hierarchical levels in each matrix, as per standard AHP method.

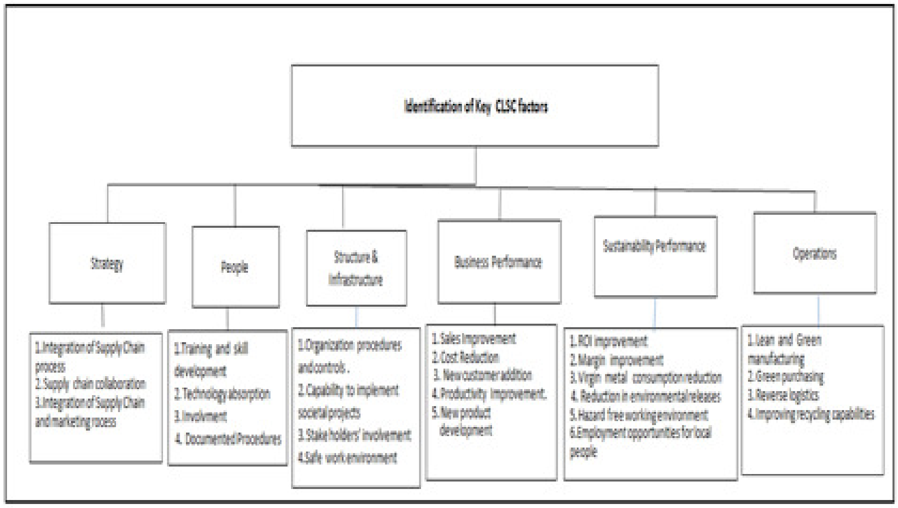

Figure 2 Key factors identified in AHP survey

The evaluation began by determining the relative weight of the six dimensions of CLSC selected for the study. A matrix was prepared to explain and assign comparative importance to each factor, as suggested in literature [46], [47], [48] and results are summarized (Table 1).

Table 1: Prioritization of 3- BL dimensions

	People (P)	Sustainability Performance (SP)	Structure & Infra (SI)	Business Performance (BP)	Strategy (S)	Operations (O)	Eigenvector
P	1	1	2	0.25	0.25	0.5	.09
SP	1	1	2	0.2	0.2	0.5	.09
SI	0.5	0.5	1	0.2	0.5	0.5	.06
BP	4	5	5	1	0.5	4	.32
S	4	5	2	2	1	1	.26
O	2	2	2	0.25	1	1	.17
CR	**.09**						

The experts' opinions suggest that Business Performance dimension is the highest priority followed by Strategic factors and Operational factors. People factor and 3-BL sustainability performances have been equally rated. Similarly, Table 2 to Table 7 show the factors under each dimension of People, Operations, Structure and Infrastructure, Strategy, Sustainability Performance and Business Performances, and their evaluation results by experts, respectively.

Table 2: Prioritization of sub-factors under People Dimension

	HR1	HR2	HR3	HR4	**Eigenvector**	
Training and skill development	1	1	2	0.25	0.25	
Involvement	1	1	2	0.2	0.2	
Technology absorption capability	0.5	0.5	1	0.2	0.5	
Documented procedures	4	5	5	1	0.5	
CI	4	5	2	2		1
RI	2	2	2	0.25		1
CR			**.09**			

Table 3: Prioritization of sub-factors under Operations Dimension

	OM1	OM2	OM3	OM4	**Eigenvector**
Lean and green manufacturing	1	1	2	0.25	0.25
Green purchasing	1	1	2	0.2	0.2
Reverse Logistics	0.5	0.5	1	0.2	0.5
Improving recycling capabilities	4	5	5	1	0.5
CI	4	5	2	2	1
RI	2	2	2	0.25	1
CR	**.09**				

Table 4: Prioritization of sub-factors under Structure and Infrastructure Dimension

	SI 1	**SI 2**	**SI 3**	**SI 4**	**Eigenvector**	
Organizational procedures and controls	1	.5	5	5	.33	
Stakeholders' involvement		1	8	5	.52	
Capability to implement societal projects			1	1	.07	
safe work environment				1	.08	
CI						.02
RI						.90
CR	.02					

Table 5: Prioritization of sub-factors under Strategy Dimension

	ST1	**ST2**	**ST3**	**Eigenvector**	
Integration of supply chain processes (ST1)	1	1	.5	.23	
Supply chain collaborations (ST2)		1	.25	.19	
Integration of marketing & supply chain processes (ST3)			1	.58	
CI					.02
RI					.58
CR	.03				

Table 6: Prioritization of sub-factors under Strategy Dimension

	ROI	**MI**	**VM**	**ER**	**HF**	**EO**	**Eigenvector**	
ROI improvement (ROI)	1	1	2	.33	.4	1	.11	
Margin Improvement(MI**)**		1	2	.2	.2	.5	.08	
virgin metal consumption (VM)			1	.2	.125	.5.	.05	
Reduction in environment release (ER)				1	.5	2	.28	
Hazard free working environment (HF)					1	2	.36	
Employment opportunities for local communities (EO)						1	.12	
CI								.025
RI								1.24
CR	.02							

Table 7: Prioritization of sub-factors under Business Performance Dimension

	SIM	CR	NCA	PI	NPD	Eigenvector	
Sales Improvement (SIM)	1	.2	.1	10	10	.3	
Cost reduction (CR)		1	2	.5	2	.19	
New customer addition (NCA)			1	1	.25	.19	
Employees' productivity improvement (PI)				1	3	.17	
New Product Development (NPD)					1	.14	
CI							.02
RI							1.12
CR	.02						

The local and global ratings of CLSC factors important for sustainable value creations are presented in Table 8. The calculations highlight that Integration of marketing and supply chain functions (0.151), Sales improvement (.097), Green Purchasing (.09) and Cost reduction (.061) are considered highest rating factors. The analysis also highlights that sale improvement is approximately as important as green purchasing while it is 1.59 times more important than cost reduction. Experts also considered ROI improvement as important as creating job opportunities for the local communities (.01 and .011 respectively).

Table 8: Local and Global rating summary of CLSC sustainability factors

Factor		**Sub-Factors**	**Local value**	**Global value**
People (P)	**0.09**	Training & skill development	0.409	0.037
		Involvement	0.193	0.017
		Technology absorption capability	0.294	0.026
		Documented procedures	0.104	0.009
Sustainability Performance(SP)	**0.09**	ROI improvement (SP1)	0.109	0.010
		Margin Improvement(SP2)	0.080	0.007
		Virgin metal consumption(SP3)	0.051	0.005
		Reduction in environmental releases(SP4)	0.276	0.025
		Hazardous free working environment(SP5)	0.361	0.032
		Employment opportunities for local communities (SP6)	0.124	0.011
Structure and Infrastructure(SI)	**0.06**	Organizational procedures and controls	0.330	0.020
		Stakeholders' involvement	0.522	0.031
		Capability to implement societal projects	0.069	0.004
		safe work environment	0.080	0.005
Business Performance (BP)	**0.32**	Sales Improvement	0.303	0.097
		Cost reduction	0.191	0.061
		New customer addition	0.191	0.061
		Employees' productivity improvement	0.174	0.056
		New Product Development	0.141	0.045
Strategy (S)	**0.26**	Integration of supply chain processes(ST1)	0.230	0.060
		Supply chain collaborations(ST2)	0.187	0.048
		Integration of marketing & supply chain processes(ST3)	0.579	0.151
Operations (O)	**0.18**	Lean and Green manufacturing(OM1)	0.288	0.052
		Green purchasing (OM2)	0.501	0.090
		Reverse logistics (OM3)	0.054	0.010
		Improving recycling capabilities(OM4)	0.146	0.026
				0.997

The second survey aimed at investigating the CLSC operations management practices at strategic and operational levels was conducted on the secondary metal manufacturing firms, their raw material suppliers, and reverse logistics (RL) providers. The respondent list was prepared from the data-base of professional bodies representing metal recyclers in India (ALUCAST, INLZDA and ISRI). Raw material suppliers and RL providers were chosen based on their linkages with India metal recycling industry; either through their offices in India or abroad.

Content validation technique was applied to ensure that chosen factors adequately address the research issue under investigation. In this phase, the questionnaires were mailed to a total of 225 secondary metal manufacturing (such as raw material ingots, billets), units performing additional processing of the secondary metal manufactured in the first phase (such as wire drawing, rolling into channels and sections etc.), 15 raw material supplying firms, and 10 RL service providers, into engineering and automotive components, who are part of automotive and construction industry closed-loop supply chains. For the first survey, out of 250 postal surveys to manufacturing companies, 134 valid responses (54%) were received,15 questionnaires were returned as the recipients were no longer at that address(i.e. 6%), 10 surveys were not completely filled (4%). The surveys were administered between January 2013 and October 2013 and professional software SPSS was used for data analysis. In order to identify fewer factors that are able to account for the observed relationship, exploratory factor analysis (EFA) technique was employed on the 42 CLSC operations and sustainability practices identified in the previous research stages [56]. Principal components having Eigen values more than one were for deriving factors. Orthogonal rotation method (Varimax) with Kaiser Normalization was applied for deriving factor loading due to its simplicity [60]. Only absolute values over 0.4 were considered.

From the original 42 variables which were used in the questionnaires, only 16 were related to each other in order to form dimensions. All variables in this research, based on their mean scores are valued high by the participants. Verification on the majority of survey results for reliability and validity through statistical method is necessary to minimize the potential distortion in accordance with the propensity of the responder [54]. Cronbach's alpha test was performed to gauge the internal consistency of the applied instrument and the resultant value of 0.71 validates the instrument [57], [58]. Measurement validity indicates how closely an instrument measures the constructs it is designed to measure and Kaiser-Meyer-Olkin (KMO) and Bartlett Test of Sphericity are performed to test the validity in PCA methodology. The test results (table 9) suggest that factor analysis was appropriate for these data sets. Factor loadings values were satisfactory as suggested in literature [59].

Table 9: KMO and Bartlett's test

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.589
Bartlett's Test of Sphericity	Approx. Chi-Square	1420.659
	df	861
	Sig.	.000

3.1.3. Findings and discussions of General Survey

SPSS presents the Eigen values related with each PC (factor) were determined by applying standard methodology through SPSS software. Before extraction, 16 linear components were identified within the data set. Table 10 depicts the list of factors with coding.

Table 10: Factors and coding

Factor	Coding
Margin Improvement	VAR00001
Integrating CLSC and other business processes	VAR00002
Flexible manufacturing	VAR00003
Employment opportunities for local communities	VAR00004
Reduction in release of pollutants	VAR00005
Sustainable supplier development	VAR00006
Collaboration with competitors	VAR00007
Human resource development	VAR00008
Lean and Green Manufacturing	VAR00009
Technology absorption capability	VAR00010
Establishing joint environmental objectives with suppliers	VAR00011
Avoidance of virgin metals	VAR00012
Organizational procedures & controls	VAR00013
Cost reduction	VAR00014
Efficient Reverse Logistics (RL)	VAR00015
CLSC risk identification and mitigation capability	VAR00016

Table 11: Descriptive Statistics for important variables.

	N	Mean	Std. Deviation	Variance
VAR00001	146	1.8836	.83468	.697
VAR00002	146	2.0822	.72879	.531
VAR00003	146	2.6164	1.03231	1.066
VAR00004	146	1.7877	.60125	.362
VAR00005	146	1.8904	.66564	.443
VAR00006	146	2.1575	.83615	.699
VAR00007	146	2.8425	1.27408	1.623
VAR00008	146	2.5411	1.17518	1.381
VAR00009	146	2.4178	.64066	.410
VAR00010	146	2.2740	.77478	.600
VAR00011	146	2.2534	.89297	.797
VAR00012	146	2.3562	.65115	.424
VAR00013	146	2.5411	.78016	.609
VAR00014	146	1.9589	.83770	.702
VAR00015	146	1.9041	.74583	.556
VAR00016	146	2.2055	.76038	.578
Valid N (list wise)	146			

The 16 variables identified in Table 10 are described in Table 11. The Eigen value of a particular factor is indicative of the variability caused by that particular factor in the data. For example the first factor (table 12), having maximum Eigen value indicates that maximum data discrepancy is due the first factor. Similarly, second factor having the second highest value causes second most discrepancy in the data and so on. In the present study, as presented (table 12), the first seven components are strongly associated with discovered factors and account for 60.850 percent variability in the data. After rotation, the sum total of variability due to first seven components remains same (i.e. 60. 850 percent). However, the variability due to individual component has changed. For example, the data variability due to first component, which was 13.106 percent, has changed to 9.34 percent after rotation.

Through of factor analysis, the initial 42 CLSC sustainability practices (independent variables) and performances (dependable variables) have reduced to seven factors. The factors were assigned nomenclature pertaining to individual's distinguishing features as suggested by Kim & Mueller [60]. In this study, the following seven factors were extracted (Table 12):

'Structure and infrastructure', 'Business performance', 'Sustainable manufacturing', 'Green purchasing and distribution', 'Resource redundancy','3 –BL Sustainability performance', and 'Business process integration& collaboration'

Table 12: Total Variance Explained (after Varimax rotation)

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.097	13.106	13.106	2.097	13.106	13.106	1.492	9.324	9.324
2	1.683	10.521	23.627	1.683	10.521	23.627	1.448	9.048	18.372
3	1.319	8.244	31.871	1.319	8.244	31.871	1.425	8.907	27.280
4	1.295	8.091	39.962	1.295	8.091	39.962	1.415	8.841	36.121
5	1.238	7.740	47.702	1.238	7.740	47.702	1.393	8.709	44.829
6	1.079	6.745	54.447	1.079	6.745	54.447	1.320	8.251	53.080
7	1.024	6.403	60.850	1.024	6.403	60.850	1.243	7.770	60.850
8	.994	6.214	67.065						
9	.929	5.809	72.873						
10	.816	5.101	77.974						
11	.759	4.741	82.715						
12	.663	4.145	86.861						
13	.611	3.819	90.680						
14	.586	3.665	94.344						
15	.460	2.878	97.222						
16	.444	2.778	100.000						

Extraction Method: Principal Component Analysis.

The first factor, ‘Structure and infrastructure’, accounted for 9.32 per cent of the variance in the data. The second factor ‘Business performance’ accounted for 9.04 per cent, the third factor ‘Sustainable manufacturing’ accounted for 8.90 per cent, the fourth factor ‘Green purchasing and distribution’, accounted for 8.84 per cent, the fifth factor ‘resource redundancy’, accounted for 8.70 per cent, the sixth factor ‘3- BL Sustainability performance’, accounted for 8.25 percent of the variance, and the seventh factor ‘Business process integration & collaboration’ accounted for 7.77 percent of the variance. These seven factors together accounted for 60.85 per cent of the total variance in the data.

Table 12 presents the exact criteria that were grouped under each factor. The first factor, ‘Structure and Infrastructure’ consisted of two variables: Organizational procedures & controls and CLSC risk identification and mitigation capability. The second factor, “Business Performance” consisted of one variable: margin improvement. The third factor, “Sustainable Manufacturing” consisted of two variables: Green and Lean manufacturing and Avoidance of virgin metals. Similarly, “Green Purchasing and Distribution” factor consisted of four variables: Sustainable supplier development, establishing joint environmental objectives with suppliers, Material Cost reduction and Efficient Reverse Logistics (RL). Factor “Resource Redundancy”, consisted of two variables: Human resource development and Flexible manufacturing. Factor “3-BL sustainability performance” consisted of three variables: Employment opportunities for local communities, Reduction in release of pollutants, and Technology absorption capability, and factor “Business Process Integration and Collaboration” consisted of two variables: Integrating CLSC and other business processes and Collaboration with competitors.

CONCLUSION AND DISCUSSION

This study identified the most critical CLSC factors contributing to metal recycling 3- BL sustainability. Important conclusions can be summarized as follows. Although the most important business category for achieving sustainability was the business performance (0.32); strategy (0.26) and operations management (0.26) were two other important categories. The five most important factors, in order of highest Global Values were integration of supply chain and marketing processes (0.151), sales improvement (.097), green purchasing (0.90), cost reduction (0.061) and integration of supply chain processes (0.060).

The results of the study were reconfirmed using statistical analysis. Selection of important factors by bundling the factors extracted through PCA and factors within the AHP priority ranking group, the results were statistically analyzed. The results obtained by applying PCA methodology confirmed the results obtained through AHP method, thus statistically validating the most important factors contributing to CLSC sustainability.

Since this study was primarily done considering CLSC practices in Indian metal recycling industry, the results are most suitable for addressing the sustainability issues in Indian metal CLSC. The ranking of factors or even few factors may be different in developed countries, and hence the results may be applicable partially. But as the researchers suggest that [61], sustainability issues in emerging markets are very similar, results concluded from the present research can be applied to countries such as Pakistan, Bangladesh, and Sri Lanka where similar societal, economic and environmental concerns exist.

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