Development of Green Supply Chain for Plastic Films Manufacturing Industries in India: Ranking of Challenges using Analytic Hierarchy Process

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Abstract: Green supply chain shall reduce environmental burdens of plastic films. However, literatures do not report plastic film green supply chain developmental efforts. Authors have identified and confirmed (in a separate study) challenges using literature data whilst developing green supply chain for plastic films. This paper ranked these identified and classified challenges using "analytic hierarchy process". This study developed comparison matrices for challenges using calculated challenge strength. The research calculated challenge strengths using Equation (1). Authors used five point "comparison scale" to develop comparison matrices for criteria and sub-criteria. The present research validated data for internal consistency and goodness of fit using chi-square tests. To validate deduced challenge priorities, authors calculated consistency index. The study refers data sources from 1990 to 2010. Development of solutions for the green supply chain for plastic films is the future work.

Keywords: Analytic hierarchy process, ranking of challenges, challenge strengths, green supply chain, plastic films

1 INTRODUCTION

Experts opine that green supply chain (GrSC) alleviates environmental burdens of plastic films [1, 2]. Adopting "green manufacturing" reduces environmental burden at plastic film manufacturing and recycling. "Reverse logistics" plays a vigorous role in plastic film waste management. "Reuse/reduce" strategies preserves nonrenewable energy and material sources. Integrated supply chain planning using "material flow analysis" (MFA), "life cycle analysis" (LCA) and "design for environment" optimizes environmental burdens over plastic film life cycle. GrSC practice adaptation accrues environmental related profits. It reduces product cost and improves the image of plastic film manufacturing units. Firms practice GrSC as a tool to divulge product differentiation. Finally, it aids in framing better environmental laws allied to plastic film waste.

The advocated GrSC for plastic film will result into better practices, if practitioners use environmental tools in synchronized manner. It requires simple and customized framework. In addition, it needs strategies for GrSC practices implementations [3]. Simplification and customization for GrSC practices implementation needs assessment of various hurdles or challenges. Identification and removal of these obstacles is inevitable to develop GrSC [4, 5]. So, first step towards developing the GrSC for plastic is to identify the challenges/obstacles and prioritize them.

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Researchers used survey/case study/factor confirmation analysis method to identify and confirm challenges/obstacles. But, in India, about 80% are informal plastic film manufacturing/recycling units. So, there is trifling response towards such studies [6, 7]. Large uncertainty in data and uncontrolled experimentation may drift results in case of plastic films GrSC. So, literature is good source of data relevance to exhume obstacles in developing GrSC for plastic films. Literature reconnoiters range of obstacles while succinctly reviewing arm's length approaches. However, it is difficult to correlate problems in developing GrSC [4, 5]. Authors had undertaken a separate study to report and confirm the challenges in development of plastic film GrSC.

These identified challenges needs prioritizing. It results into methodical studies for remedies by individual supply chain partner or cumulative efforts by supply chain partners. It optimizes the efforts for this microenterprise. With this objective, authors have undertaken this work to rank challenges in the development of GrSC for plastic films. Next section reviewed literature for GrSC obstacle prioritizing efforts. It follows method to prioritize challenges in the development of GrSC for plastic films. The paper presents results and conclusions at the end.

2 LITERATURE REVIEW

Ranking/weighting of variables in multi-criteria decision-making (MCDM) extensively uses 'analytic hierarchy process' (AHP) approach [8, 9, 10, 11]. Saaty [12] being the primary source, Toke et al. [13] and Hofmann [14] used AHP for selecting the appropriate green supply chain (GrSC) practices for implementation. Toke et al. [13] combined AHP with interview and survey method to ascertain the relative priority of 19 variables with 113 underlying dimensions. Peng [15], Lin and Juang [16], Dai and Blackhurst [17] and Genovese et al. [18] suggested methods for green supplier selection using AHP. Peng [15] used AHP and 'grey relational analysis (GRA)' to select green supplier. Lin and Juang [16] adopted interviewing methodology and AHP for biotechnology industry supplier evaluation and selection. Awasthi et al. [19] and Noci [20] measured the supplier environmental performance. To compute variable weights in the measurement process, researchers used AHP approach. Yang et al. [21] and Lun [22] used AHP for GrSC performance measurement. Choudhary [23] suggested GrSC inter-organizational comparison using AHP. The study was aimed at the automobile industry. The paper described five criteria and 18 sub-criteria for performance measurement to evaluate and rank inter-organizational GrSC performance. The five performance measures of GrSC management included 'internal environmental management', 'green purchasing', 'customer cooperation', 'investment recovery', and 'eco-design'. The study computed weights of 18 sub-criteria and five criteria using AHP approach. Murlidhar et al. [24] and Verma and Gangele [25] used AHP along with fuzzy concepts in GrSC for evaluation of GrSC performance and supplier environmental performance. Sarmiento and Thomas [5] analyzed the problems that firms face while implementing green initiatives. They used 'multi-tier' AHP approach to benchmark issues and prioritize them.

Literature corroborated the fact that, researchers magnificently employed AHP to rank / weight variables. Using literature data, studies ranked challenges faced by firms whistle implementing green initiatives [5]. In literature, research studies also identified barriers to implement GrSC management for automobile industry [23]. But, weights/ranks vary with supply chain framework. The efforts for ranking challenges for plastic film GrSC developmental efforts are absent in the literature. Thus, next section reconnoiters the methodology for ranking challenges for the development of GrSC for plastic films.

3 METHODOLOGY

Methodology used to rank challenges in the development of GrSC for plastic films is AHP. Following steps sub-divides the methodology.

a) Identify and classify challenges in the development of GrSC for plastic films.

b) Identification of attributes of literature data sources and development of measurement scales to quantify challenges based on attributes of literature data sources.

c) Development of AHP model for ranking of challenges.

d) Computation of challenge strength.

e) Development of comparison matrices for criteria, sub-criteria and challenges.

Table 1. Literature profile of challenges in the development of green supply chain

Source	Challenges	Country Specific	Type of Literature	Literature Quality
[6]	C6, C7, C8, C9, C11, C12, C13, C15	India	Case study analysis	Semi-reviewed
[7]	C1, C6, C7, C9	South Africa	Survey	Un-reviewed
[26]	C7	Greece	Experiment	Reviewed
[27]	C6, C8, C9, C12, C13, C14, C15	Europe	Report	Un-reviewed
[28]	C6, C7, C8, C13	UK, but problems to Asia	Review	Reviewed
[29]	C6, C10	UK	Review	Reviewed
[30]	C1, C6, C13	America	Survey cases,	Un-reviewed
[31]	C1, C2, C6, C10	USA	Review	Un-reviewed
[32]	C6, C8, C13	South Africa	Case Study	Un-reviewed
[33]	C1, C12, C13	USA	Analysis survey	Reviewed
[34]	C7, C9	Germany	Experiment on films	Reviewed
[35]	C4	UK	Guidebook	Un-reviewed
[36]	C5, C7, C9, C12, C15	Europe	SC Analysis	Semi-reviewed
[37]	C6, C8	India	Analysis	Un-reviewed
[38]	C6, C7, C8, C9, C12, C13, C14, C15,	UK	Book	Semi-reviewed
[39]	C4	Vietnam	Case review	Un-reviewed
[40]	C1, C2, C3, C5	Malaysia	Analysis	Un-reviewed
[41]	C6, C7, C8, C12, C13	Europe/Australia	Review of Case studies	Reviewed
[42]	C1, C2, C3	USA	Analysis	Reviewed
[43]	C5, C12, C13, C14,	India	Analysis	Un-reviewed
[44]	C6, C9, C13	India	Analysis	Un-reviewed
[45]	C1, C2, C3, C14	Japan	Review of case studies	Reviewed
[46]	C2, C5	USA	LCA Analysis	Un-reviewed
[47]	C1, C2	Sweden	LCA Analysis	Semi-reviewed
[48]	C1, C6, C10,	India	Analysis	Reviewed
[49]	C1, C6, C7, C9, C12, C13, C14, C15	India	Report	Un-reviewed
[50]	C6, C7, C9	India	Case study	Semi-reviewed
[51]	C8	India	Review analysis	Semi-reviewed
[52]	C6	Australia	Survey	Un-reviewed
[53]	C1	UK	Case Analysis	Un-reviewed
[54]	C6, C8	Europe	Case Analysis	Un-reviewed
[55]	C4	New Zealand	EMS – Case Studies	Un-reviewed
[56]	C2, C6	Thailand	Case study	Semi-reviewed
[57]	C1, C2	Australia	Case study	Reviewed
[58]	C11	Brazil	Experiment	Reviewed
[59]	C5, C13	India	Case study	Un-reviewed
[60]	C6, C7, C9	USA, Germany and Japan	Review	Reviewed
[61]	C7	India	Experiment	Reviewed
[62]	C1	Scotland/EU	Assessment	Un-reviewed
[63]	C5, C6, C7, C9, C13, C15	Belgium / Europe	Review	Un-reviewed
[64]	C12, C14	Australia	Analysis	Semi-reviewed
[65]	C6, C7, C8, C9, C13, C15	India	Analysis	Reviewed
[66]	C6, C7, C8, C11, C13	India	Case Studies	Un-reviewed
[67]	C6, C8, C9, C13, C15	India	Report – Case studies	Un-reviewed
[68]	C9 , C13	India	Study	Un-reviewed

Challenges: C1- Incomplete plastic film material flow analysis(MFA), **C2**- Absence of fate analysis of plastic films in open dumping, land filling and litter, **C3**- Absence of comprehensive and reliable performance measurement tool, **C4**- Absence of customized environmental management system and its implementation, **C5**- Lack of appropriate process technology to reduce material and energy consumption , **C6**- Poor reverse logistics, **C7**- Old recycling technology, **C8**- Absence of waste management facilities, **C9**- Lack of appropriate technology in recovery and disposal, **C10**- Longevity of plastic film waste, **C11**- Higher Cost of effluent treatment / waste disposal facilities, **C12**- Ineffective reuse and reduce strategies, **C13**- Lack of finance/higher cost of implementation, **C14**- Ineffective use of design for environment tool, **C15**- Lack of experience manpower

f) Calculation of priorities for challenges.

It justifies the use of AHP for ranking the identified challenges, since, the relationship between the criteria and sub-criteria and challenges is of hierarchical in nature. Below steps elaborates the methodology.

3.1 Identification and Classification of Challenges in the Development of GrSC for Plastic Films

Table1 depicts the succinct review of literature from year 1990 to 2012, undertaken to identify challenges in the development of GrSC for plastic films. Literature gaps are challenges in the developing the GrSC for plastic films. Table1 depicts the broad classification of challenges found in these literature sources. Authors classified challenges into fifteen major categories. The premise of this categorization is the GrSC practices implementation and GrSC developmental efforts/literature gaps throughout the life cycle of plastic films. The present work reviews literature for literature gaps pertaining to plastic film GrSC in plan, source, make, deliver and return phase.

3.2 Identification of Attributes of Literature Data Sources and Measurement Scales

The identified and classified challenges need quantification for ranking. Challenges in the development of GrSC for plastic films are literature gaps from literature data sources. The literature acts as a data source. So, a literature data source requires quantification. For this purpose, authors have identified measurable attributes of literature data sources to quantify the magnitude of literature data source. The table2 shows identified attributes and sub-attributes for literature data sources. It also depicts measurement scales.

The identified attributes and sub-attributes have theoretical footing. For instance, literature attributes viz. literature quality (LQ), literature year (LY), literature type (LT), literature country (LC) and literature frequency (LF) compares relative weights of criteria on measurement scale. Authors assigned 5, 4, 3, 2 and 1 scale value on comparison scale for LQ, LY, LF, LC and LT, respectively. LQ stresses the acceptance of work and its universal confirmation and hence assigned with highest priority. LY is second in importance for accordance of development in literature on time scale. The current literature means a step ahead of previous content of literature. LF is third to emphasis the density of literature. LC is second last to rationalize the study pertaining to India. The scales though have theoretical proofs for formation; academic experts in the area have also validated the scales.

Review process judges literature quality. Thus, reviewed (RW), semi-reviewed (SRW) and un-reviewed (URW) are three sub-criteria selected for literature quality judgments. Similarly, literature type (LT) acts as evidence to confirmation of work claimed. So, 'analysis (AN)', 'case study (CS)', and 'review/report (RW/RP)' are three sub-criteria selected for LT. Literature frequency (LF) is the frequency of challenge in the literature data sources. Table2 shows comparison scales to quantify sub-criteria magnitudes.

3.3 Development of AHP Model

Figure 1 shows the hierarchical model developed for AHP analysis to rank challenges. Since, methodology used literature data sources, criteria and sub-criteria are literature attributes and sub-attributes, respectively. So, AHP model have five criteria viz. LQ, LT, LY, LC and LF and 3, 3, 5, 2, 3 sub-criteria, respectively.

Table 2. Identified criteria and sub-criteria with measurement scale.

Criteria	Sub-criteria	Measurement Scale	
Literature quality (LQ)	Reviewed (RWD)	5	5
	Semi-reviewed (SRWD)	3	
	Non-reviewed (NRWD)	1	
Literature type (LT)	Analysis (AN)	5	1
	Case study (CS)	3	
	Review/Report (RW/RP)	1	
Literature source year (LY)	2008 - 2012 (Y1)	5	4
	2004 - 2007 (Y2)	4	
	2001 - 2003 (Y3)	3	
	1996 - 2000 (Y4)	2	
	1990 - 1995 (Y5)	1	
Literature country (LC)	Developing (DP)	5	2
	Developed (DD)	3	
Literature frequency (LF)	9 - 16% (F1)	5	3
	5- 8.99 % (F2)	3	
	0 - 4.99% (F3)	1	

3.4 Computation of Challenge Strength

Construction of comparison matrices for challenges needs computation of challenge strength. The present study used Equation (1) and literature data sources from table1 to compute challenge strengths. The Equation (1) normalizes the challenge over its attributes and thus justifies its use.

$$\left(\mathbf{C}_j\right)_{kStrength} = \left[1/n\Sigma\left(LT_{ij} + LQ_{ij} + LC_{ij} + LF_{ij} + LY_{ij}\right]\right] - STDER \quad (1)$$

Where, $\mathbf{C}_j$ - Challenge j,

LQ_{ij} - Literature quality scale value for j challenge and i source

LT_{ij} - Literature type scale value for challenge and i source

LC_{ij} - Literature country scale value for j challenge and i source

LF_{ij} - Literature frequency scale value for j challenge and i source

LY_{ij} - Literature year scale value for j challenge and i source

$i = 1, 2, \ldots, n$ are variable in our model

$j = 1, 2, \ldots, 15$ are Challenges

k - sub-variable

STDER = stand error = $(STDEV)_p$ - $(STDEV)_s$

$(STDEV)_p$ - Population standard deviation_ Computed as 2.8886

$(STDEV)_s$ – Sample standeard deviation

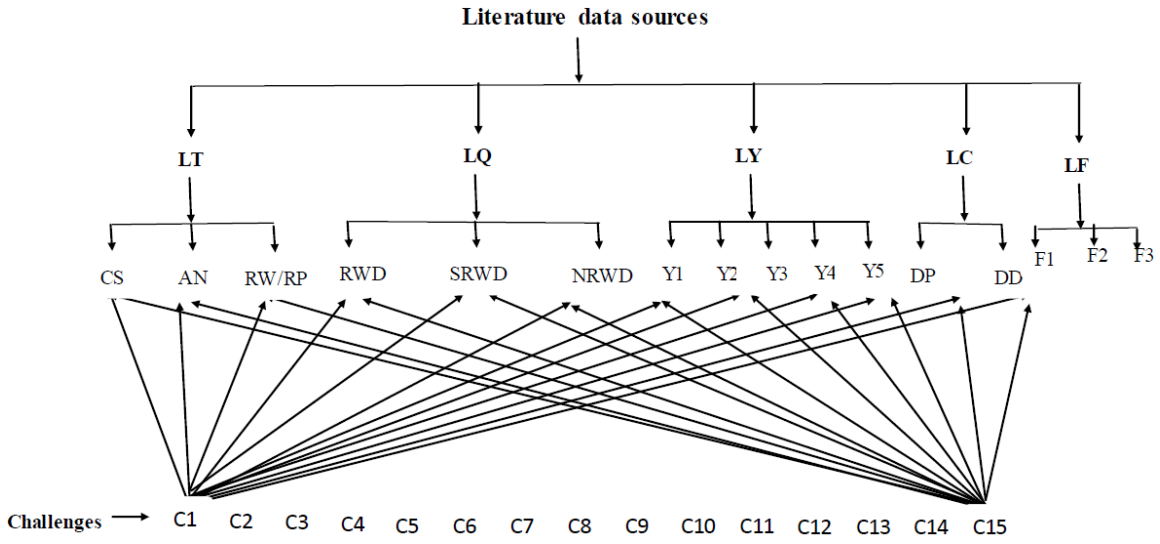

Fig. 1. Hierarchy model

Table 3 (a). Literature data pertaining to RWD sub-variable referred from table 1.

Source with year	Challenges Reported	Country Specific	Type of Literature	Literature Quality
[26]	C7	Greece	Experiment	Reviewed
[28]	C6, C7, C8, C13	UK, but problems to Asia	Review	Reviewed
[29]	C6, C10	UK	Review	Reviewed
[33]	C1, C12, C13	USA	Analysis survey	Reviewed
[34]	C7, C9	Germany	Experiment on films	Reviewed
[41]	C6, C7, C8, C12, C13	Europe/Australia	Review	Reviewed
[42]	C1, C2, C3	USA	Analysis	Reviewed
[45]	C1, C2, C3, C14	Japan	Review	Reviewed
[48]	C1, C6, C10,	India	Analysis	Reviewed
[57]	C1, C2	Australia	Case study	Reviewed
[58]	C11	Brazil	Experiment	Reviewed
[60]	C6, C7, C9	USA, Germany and Japan	Review	Reviewed
[61]	C7	India	Experiment	Reviewed
[65]	C6, C7, C8, C9, C13, C15	India	Analysis	Reviewed

Table 3 (b). Literature data pertaining to RWD sub-variable and challenge C1.

Source with year	Challenge	Country Specific	Type of Literature	Literature Quality
[33]	C1	DD	AN	RWD
[42]	C1	DD	AN	RWD
[45]	C1	DD	RW/RP	RWD
[48]	C1	DP	AN	RWD
[57]	C1	DD	CS	RWD

Table 3 (c). Computation of challenge strength pertaining to sub-variable RWD and Challenge C1

Source	LY	LC	LT	LQ	LF	Total
[33]	2	3	5	5	3	18
[42]	1	3	5	5	3	17
[45]	4	3	1	5	3	16
[48]	4	5	5	5	3	22
[57]	3	3	3	5	3	17
					Total	90
					Mean	18
					STDEV	2.345208
					STDER	0.543392
					Challenge Strength	17.45661

The process for computing challenge strength for sub-criteria RWD and challenge C1 is as shown in table 3 (a to c). The calculation of challenge strengths incorporates standard error as difference between standard deviation of population and standard deviation of sample. It is a measure of shifting of mean. Similarly, computation of challenges strengths for all challenges pertaining to sub-criteria are undertaken. Construction of comparison matrices for challenges pertaining to sub-criteria uses these deduced challenge strengths.

To validate the uses of data, authors computed internal consistency using chi-square test.

3.5 Development of Comparison Matrices

The methodology uses measurement scales to construct comparison matrices for criteria and sub-criteria. For instance, LQ prefers by 5 points, 5/2 points, 5/3 points and 5/4 points compared to LT, LC, LF and LY, respectively. Similarly, develop comparison matrices for sub-criteria using its respective developed scale. For example, sub-criteria in LQ i.e. RWD prefers by 5 points and 5/3 points compared to NRWD and SRWD, respectively. The comparison matrices for challenges with respect to sub-criteria uses computed challenge strengths.

3.6 AHP Analysis

The process of computation of overall priorities for challenges uses Equation (2). Authors used MS Excel for computation and analysis.

$$(C_T)_j = \sum (P_F)_j x (P_{cr})_j x (P_{ch})_j \quad (2)$$

Where, $(C_T)_j$ - Final priority score for the challenge,
P_F - Priority for the criteria
P_{cr} - Priority for the sub-criteria
P_{ch} - Priority for the challenge
$j = 1, 2, 3, \ldots, 15$

Lastly, to validate the resulted priorities, authors calculated consistency ratio. Next section elaborates the AHP analysis and results.

4 AHP ANALYSIS AND RESULTS

The AHP analysis consists of following steps.

a) Construct comparison matrix for criteria and compute priorities for criteria.

b) Construct comparison matrices for sub-criteria and compute priorities for sub-criteria.

c) Construct comparison matrices for challenges pertaining to sub-criteria and compute priorities.

d) Calculate overall priority and validate it.

4.1 Construction of Comparison Matrices for Criteria / Sub-criteria and Computation of Criteria / Sub-criteria Priorities

Construct comparison matrix for criteria using weights assigned on comparison scale to criteria as shown in table 2. For instance, LQ weighs 5 and LY weighs 4, resulted in 1.25 weight for LQ compared with LY and vice-versa. Compute priorities for criteria as shown in table 4 (a, b). Table 4 (a, b) shows that, first, normalize columns of comparison matrix. Row average is priority for that row element. Similarly, compute priorities for sub-criteria.

Table4. (a) Comparison of criteria

Factors	LQ	LY	LF	LC	LT
LQ	1	1.3	1.67	2.5	5
LY	0.8	1	1.33	2	4
LF	0.6	0.8	1	1.5	3
LC	0.4	0.5	0.67	1	2
LT	0.2	0.3	0.33	0.5	1
Total	3	3.8	5	7.5	15

Table4. (b) Priority calculation for criteria

Priorities	LQ	LY	LF	LC	LT	Priority
LQ	0.33333	0.33333	0.33333	0.33333	0.33333	0.33333
LY	0.26667	0.26667	0.26667	0.26667	0.26667	0.26667
LF	0.2	0.2	0.2	0.2	0.2	0.2
LC	0.13333	0.13333	0.13333	0.13333	0.13333	0.13333
LT	0.06667	0.06667	0.06667	0.06667	0.06667	0.06667
	1	1	1	1	1	1

Normalized columns = cell value / column total and Priority as row average of normalized matrix

4.2 Construction of Comparison Matrices for Challenges Pertaining to Sub-criteria

Using challenge strengths, construct comparison matrices for challenges with respect to sub-criteria. Authors have computed challenge strengths as depicted in table 5 (a) using procedure described in section 3.4. The uses of data need validation. 'Significance of population variance' and 'goodness of fit' is best fit statistical methods for the confirmation of uses of data reported. Compute 'significance of population variance' and 'goodness of fit' using chi-square test. All chi-square calculated values are less than tabulated values. The test results as depicted in Table 5 (b) validate use of data.

The deduced challenge strengths for individual sub-criteria become the basis for construction of comparison matrix for that challenge with respect to sub-criteria. The challenge having 'zero' challenge strength, will result into infinity at reciprocal comparison. It is address by ideal condition. The ideal challenge strength, model permits is 25 as maximum and 1 as minimum, considering large population. If it uses, maximum challenge strength, then comparison over challenges is constant. Thus, minimum challenge strength as 1 is used instead of 'zero' challenge strength to simplify AHP calculations while comparing challenges for sub-criteria. For instance, whistle comparing challenges for sub-criteria 'RW', challenge C1 prefers by 16.81/13.97, 16.81/12.31, 16.81/1, 16.81/1, 16.81/19.46, 16.81/17.97, 16.81/16.66 16.81/17.11, 16.81/18.15, 16.81/20, 16.81/13.31, 1681/16.75, 16.81/14 and 16.81/20 compared to challenge C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, C15, respectively. Likewise, all the comparison matrices had built. The comparison matrix for RWD sub-criteria is shown in table 6 as a sample.

Computing challenges priorities pertaining to sub-criteria first normalize comparison matrix. Then, compute row average to ascertain the priority for that row element. Likewise, compute priorities for all challenges pertaining to sub-criteria.

4.3 Calculation of Overall Priority for Dhallenges and Validating the Computed Priorities

Use Equation (2) to compute overall priority for challenges. Assign ranks to challenges using computed priorities. The calculated priorities and assigned ranks are as depicted in table 7.

Consistency ratio is a measure of consistency in assigning comparison values in comparison matrices. This is a ratio of consistency index (CI) to random consistency index (RI). Use eigen vectors to compute consistency index. Thus, to ensure that the assigned priorities are consistent, authors have computed consistency ratio for all comparison matrices pertaining to criteria, sub-criteria and challenges as depicted in table 8. The consistency ratio is less than 0.1. This ensures the consistency in assigning priorities to criteria, sub-criteria and challenges.

4.4 AHP Results

The AHP analysis resulted in priorities for challenges in the development of GrSC for plastic films. The priorities for challenges are as depicted in table8. The challenges priorities with assigned ranks are as shown in table9. Priorities become the basis for ranking of challenges. The highest priority challenge is first and lowest priority challenge is las

Table5 (a). Challenge strength.

Challenge strength	RWD	SRWD	NRWD	AN	CS	RW/RP	Y1	Y2	Y3	Y4	Y5	DP	DD	F1	F2	F3
C1	17.45	16	13.84	18.3	13.29	12.62	13.52	15.44	8.11	16.76	14.11	17.39	15.78	17.87	1	1
C2	13.97	13.32	13.36	14.82	12.11	11.73	13.94	12.61	8.11	1	14.11	1	15.21	1	15.08	1
C3	12.31	1	14	12.32	1	11.11	1	11.11	1	1	14.11	1	13.11	1	1	12.02
C4	1	1	10.52	1	9.31	5.11	1	9.11	8.11	5.11	1	1	9.52	1	1	9.52
C5	1	15	16.14	14.82	9.11	4.11	1	12.93	12.11	9.11	10.11	13.94	14.31	1	1	12.78
C6	19.46	15.69	14.86	20.33	16.11	15.22	17.1	18.16	15.08	14.11	10.11	18.51	15.7	17.26	1	1
C7	17.97	14.52	13.34	20.66	13.02	15.92	19.57	16.28	13.11	16.11	10.11	19.18	16.23	19.12	1	1
C8	16.66	15.29	13.27	20	13.85	15.58	13.11	14.94	16.49	1	1	17.74	13.48	1	15.17	1
C9	17.11	14.52	14.76	17.99	14.19	14.02	12.11	14.63	14.11	16.11	10.11	17.15	13.39	17.68	1	1
C10	18.15	1	11	20	1	12.94	13.94	17.11	1	1	1	17.11	12.94	1	1	18.14
C11	20	15	14	20	12.32	1	1	18.35	12.11	1	1	17.66	1	1	1	14.85
C12	13.31	15.52	13.83	15.36	15	13.42	12.11	13.99	13.11	14.11	1	14.52	14.56	1	15.42	1
C13	16.75	1	15.03	18.07	16.12	16.2	14.11	15.17	13.11	15.83	10.11	17.95	13.59	17.58	1	1
C14	14	16	16	13.11	1	12.74	1	13.86	1	1	1	13.94	13.69	1	1	12.86
C15	20	14.84	11.72	18.14	12.32	12.9	1	15.21	13.11	1	10.11	17.63	12.47	1	15.85	1

Table 5(b) Chi-square test for significance of population variance at 5% level of confidence

Challenges	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
Calculated $\chi 2$	10.15	11.65	13.11	6.29	11.6	11.3	11.8	15.75	9.28	21.59	22.44	10.36	13.01	16.22	15.05
Tabulated $\chi 2$	24.96	24.96	24.96	24.96	24.96	24.96	24.96	24.96	25	24.96	24.96	24.96	24.96	24.96	24.96

Table 6. Comparison Matrix of challenges pertaining to RWD sub-variable.

RWD	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
C1	1	1.249	1.418	17.45	17.45	0.897	0.971	1.047	1.02	0.961	0.873	1.311	1.042	1.246	0.873
C2	0.801	1	1.135	13.97	13.97	0.718	0.777	0.839	0.816	0.77	0.699	1.05	0.834	0.998	0.699
C3	0.705	0.881	1	12.31	12.31	0.633	0.685	0.739	0.719	0.678	0.616	0.925	0.735	0.879	0.616
C4	0.057	0.072	0.081	1	1	0.051	0.056	0.06	0.058	0.055	0.05	0.075	0.06	0.071	0.05
C5	0.057	0.072	0.081	1	1	0.051	0.056	0.06	0.058	0.055	0.05	0.075	0.06	0.071	0.05
C6	1.115	1.393	1.581	19.46	19.46	1	1.083	1.168	1.137	1.072	0.973	1.462	1.162	1.39	0.973
C7	1.03	1.286	1.46	17.97	17.97	0.923	1	1.079	1.05	0.99	0.899	1.35	1.073	1.284	0.899
C8	0.955	1.193	1.353	16.66	16.66	0.856	0.927	1	0.974	0.918	0.833	1.252	0.995	1.19	0.833
C9	0.981	1.225	1.39	17.11	17.11	0.879	0.952	1.027	1	0.943	0.856	1.285	1.021	1.222	0.856
C10	1.04	1.299	1.474	18.15	18.15	0.933	1.01	1.089	1.061	1	0.908	1.364	1.084	1.296	0.908
C11	1.146	1.432	1.625	20	20	1.028	1.113	1.2	1.169	1.102	1	1.503	1.194	1.429	1
C12	0.763	0.953	1.081	13.31	13.31	0.684	0.741	0.799	0.778	0.733	0.666	1	0.795	0.951	0.666
C13	0.96	1.199	1.361	16.75	16.75	0.861	0.932	1.005	0.979	0.923	0.838	1.258	1	1.196	0.838
C14	0.802	1.002	1.137	14	14	0.719	0.779	0.84	0.818	0.771	0.7	1.052	0.836	1	0.7
C15	1.146	1.432	1.625	20	20	1.028	1.113	1.2	1.169	1.102	1	1.503	1.194	1.429	1

Table 7. Calculation of overall priority for challenges.

Factor	Priority	Criteria	Priority	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
Literature Quality (LQ)	0.3333	Reviewed (RWD)	0.5556	0.0776	0.0645	0.0568	0.0003	0.0003	0.0898	0.083	0.0769	0.079	0.0838	0.0923	0.0614	0.0773	0.0646	0.0923
		Semi-reviewed (SRWD)	0.3333	0.0966	0.0804	0.0004	0.0004	0.0904	0.0945	0.0875	0.0921	0.0875	0.0004	0.0904	0.0935	0.0004	0.0964	0.0894
		Non-reviewed (NRWD)	0.1111	0.0673	0.065	0.0681	0.0511	0.0785	0.0723	0.0649	0.0645	0.0718	0.0535	0.081	0.0672	0.0731	0.0778	0.057
Literature Type (LT)	0.0667	Analysis (AN)	0.5556	0.075	0.0607	0.0505	0.0003	0.0607	0.0833	0.0847	0.082	0.0737	0.082	0.082	0.063	0.0741	0.0537	0.0743
		Case study (CS)	0.3333	0.0845	0.077	0.0013	0.0592	0.0579	0.1024	0.0828	0.088	0.0902	0.0013	0.0783	0.0953	0.1025	0.0013	0.0783
		Review/Report (RW/RP)	0.1111	0.0727	0.0675	0.064	0.0294	0.0237	0.0876	0.0917	0.0897	0.0807	0.0745	0.0004	0.0773	0.0933	0.0734	0.0743
Literature Source Year (LY)	0.2667	2008 - 2012 (Y1)	0.3333	0.1025	0.1025	0.003	0.003	0.003	0.1297	0.1484	0.0994	0.0919	0.1057	0.003	0.0919	0.107	0.003	0.003
		2004 - 2007 (Y2)	0.2667	0.0705	0.0576	0.0508	0.0416	0.0591	0.083	0.0744	0.0683	0.0668	0.0782	0.0838	0.0639	0.0693	0.0633	0.0695
		2001 - 2003 (Y3)	0.2	0.0551	0.0551	0.0013	0.0551	0.0822	0.1024	0.089	0.112	0.0958	0.0013	0.0822	0.089	0.089	0.0013	0.089
		1996 - 2000 (Y4)	0.1333	0.1518	0.0041	0.0041	0.0463	0.0825	0.1278	0.1459	0.0041	0.1459	0.0041	0.0041	0.1278	0.1434	0.0041	0.0041
		1990 - 1995 (Y5)	0.0667	0.1341	0.1341	0.1341	0.0037	0.0961	0.0961	0.0961	0.0037	0.0961	0.0037	0.0031	0.0037	0.0961	0.0037	0.0961
Literature Country (LC)	0.1333	Developing (DP)	0.625	0.0855	0.001	0.001	0.001	0.0686	0.091	0.0943	0.0873	0.0844	0.0842	0.0869	0.0714	0.0883	0.0686	0.0867
		Developed (DD)	0.375	0.0813	0.0784	0.0676	0.0491	0.0737	0.0809	0.0836	0.0695	0.069	0.0667	0.0003	0.075	0.07	0.0706	0.0643
Literature Frequency (LF)	0.2	9 - 16% (F1)	0.5556	0.1863	0.0067	0.0067	0.0067	0.0067	0.1799	0.1993	0.0067	0.1843	0.0067	0.0067	0.0067	0.1832	0.0067	0.0067
		5- 8.99 % (F2)	0.3333	0.0101	0.2179	0.0101	0.0101	0.0101	0.0101	0.0101	0.2192	0.0101	0.0101	0.0101	0.2228	0.0101	0.0101	0.229
		0 - 4.99% (F3)	0.1111	0.0067	0.0067	0.1409	0.1116	0.1498	0.0067	0.0067	0.0067	0.0067	0.2126	0.174	0.0067	0.0067	0.1507	0.0067
		Overall priorities		0.0893	0.0655	0.0326	0.0211	0.0454	0.0958	0.0965	0.0777	0.0875	0.054	0.059	0.0756	0.0802	0.0481	0.0722

Table 8. Consistency ratio for developed comparison matrices.

Entities	Variables	Sub-variables					LQ		LT				LY					LC		LF		
		LQ	LT	LF	LC	LY	RWD	SRWD	NRWD	AN	CS	RW/RP	Y1	Y2	Y3	Y4	Y5	DP	DD	F1	F2	F3
λ_{max}	5	3	3	3	2	5	15	16.62	15	15	15	15	15	15	15	15	15	15.205	15	15	15	15
n	5	3	3	3	2	5	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
CI=(λ_{max}-n)/(n-1)	0	0	0	0	0	0	0	0.116	0	0	0	0	0	0	0	0	0	0.0146	0	0	0	0
RI	1.12		0.58		0	1.12									1.58							
CR= CI/RI	0	0	0	0	0	0	0	0.073	0	0	0	0	0	0	0	0	0	0.009	0	0	0	0

AHP results as depicted in table9, reveals that, researchers stresses more on challenge 'C6 and C7' i.e. poor reverse logistics and old recycling technology. Plastic film litter and illicit dumping are the most environmentally decried problems in India which relates to reverse logistics. Further, best environmental solution to the plastic film waste is recycling and thus it ranked first. In India, plastic manufacturing industry is small scale/micro-enterprise and MFA is absent (C1). Thus, C1 ranked third, followed by C9, C13, C8, C12, C15, C2, C11, C10, C14, C5, C3, and C4. Except recycling technology, other process technologies and related environmental analysis like LCA had not been taken up in the literature on priority basis. The reasons could be accrued for sustainability of these processes compared to alternative flexible packaging materials. 'C1' challenge ranked 'third' in reporting because of developed countries research contribution in this area.

5 CONCLUSIONS

Following conclusions are drawn from the present study.

a) The results of the AHP analysis matches with environmental decry i.e. for plastic films litter and illicit dumping is the major problem in India. Hence, 'C6' and 'C7' needs addressing on top priority to mitigate the environmental burdens because of plastic films.

b) Challenge 'C6 and C7', weighs almost equal i. e. '0.0982 and 0.0973'. This signifies the requirement of efforts to tackle these challenges.

c) Challenge 'C8', 'C11' and 'C13', needs addressing by proper provisioning of finance for implications of GrSC. But, in India, plastic film manufacturing industry operates at small/micro scale. Thus, to resolve challenge 'C8', 'C11' and 'C13', it needs cumulative efforts from supply chain partners.

d) Challenges 'C1, C2, C3' are pertinent environmental planning tools. The rank '9' and '14' for 'C2' and 'C3' implies that the researchers in the literature did not address the problem adequately and necessitates future research for the development of GrSC for plastic films. The challenge 'C3' is important challenge, since, measurement tool decides the performance of GrSC for plastic films. The performance measurement tool aids in planning, controlling and managing GrSC activities for better environment.

This study directs the GrSC solutions in more comprehensive manner. For instance, the basic problem in case of plastic film is that, it mixed with other MSW content at 'end-of-life'. Thus, it requires segregation of plastic films at source. GrSC solution is development of instrument which will avoid plastic film mixing in MSW at source. But, it requires MFA and environmental performance measurement models to study feasibility. This work uses literature data spanning for more than 20 years and becomes scope of the work. Further, the AHP use in our study requires large population to avoid 'zero' challenge strength. Integrated solutions like GrSC practices implementation based on challenges ranking is future work.

Table 9. Ranks for challenges in the development of GrSC for plastic films

Challenge	Challenge code	Priority computed	Rank
Incomplete plastic film material flow analysis (MFA)	C1	0.0893	3
Absence of fate analysis of plastic films in open dumping, land filling and litter	C2	0.0655	9
Absence of comprehensive and reliable environmental performance measurement tool	C3	0.0326	14
Absence of customized environmental management system and its implementation	C4	0.0211	15
Lack of appropriate process technology to reduce material and energy consumption	C5	0.0454	13
Poor reverse logistics	C6	0.0958	2
Old recycling technology	C7	0.0965	1
Absence of waste management facilities	C8	0.0777	6
Lack of appropriate technology in recovery and disposal	C9	0.0875	4
Longevity of plastic film waste	C10	0.054	11
Higher Cost of effluent treatment / waste disposal facilities	C11	0.059	10
Ineffective reuse and reduce strategies	C12	0.0756	7
Lack of finance/higher cost of implementation	C13	0.0802	5
Ineffective use of design for environment tool	C14	0.0481	12
Lack of experience manpower	C15	0.0722	8

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