Int J Syst Assur Eng Manag (December 2016) 7(4):480–487
DOI 10.1007/s13198-016-0486-3

ORIGINAL ARTICLE

An optimization model for sustainable solutions towards implementation of reverse logistics under collaborative framework

Vernika Agarwal[1] · **Kannan Govindan**[2] · **Jyoti Dhingra Darbari**[1] · **P. C. Jha**[1]

Received: 19 March 2016 / Revised: 9 May 2016 / Published online: 23 May 2016

Abstract Enforced Legislations, social image, corporate citizenship and market competence are forcing manufacturing enterprises (MEs) to incorporate reverse logistics (RL) into their supply chains. RL can be used as a strategic tool to gain customer loyalty and reduce operational costs by maximizing recovery from used products. MEs face many issues which hinder successful implementation of RL such as lack of government support, financial limitations, capabilities and facilities, and market constraints. The situation is worse in case of MEs in developing countries and hence the collaboration of all its stakeholders is essential for handling the issue. Some earlier studies focused on investigating these issues and their solutions from company's perspective without considering the role of the channel partners . To overcome this gap, this study proposes a collaborative framework for MEs which includes identifying the sustainable solutions for implementation of RL, prioritizing the solutions as per their importance and designing and optimizing a RL network based on the most important solutions identified. Decision Making Trial and Evaluation Laboratory (DEMATEL) approach is employed to understand the mutual relationships among the solutions and extract the most imperative solutions. The paper presents a linear programming problem for the RL network developed under a collaborative framework which aims to maximize the total sustainable impact in the planning horizon. The focus of the study is to optimally utilize the profit accrued from the returned products to generate funds for the NGO and company employees. A numerical illustration of the Indian electronic and electrical industry is presented to validate the proposed study.

Keywords Reverse logistics · Sustainable · DEMATEL · Collaborative partners

✉ Vernika Agarwal
vernika.agarwal@gmail.com

[1] Department of Operational Research, University of Delhi, Delhi, India

[2] Department of Technology and Innovation, University of Southern Denmark, Odense, Denmark

1 Introduction

Reverse Logistics (RL) as defined by many authors over the years refer to the processes of collection, inspection, sorting, repairing, refurbishing, remanufacturing, recycling and disposal so as to take control of the products back from the original source of consumption to the original source (Rogers and Tibben-Lembke 1999; Thierry et al. 1995; Fleischmann et al. 2001; Srivastava and Srivastava 2006; Mutha and Pokharel 2009). RL can be used as a strategic tool by original equipment manufacturers to gain sustainable image, customer loyalty and significant improvement in their market presence. Companies in India have yet not paid much attention to RL even though they are legally bound by the legislative policy to take care of product returns. Policies have been introduced owing to rising environmental and sustainable concerns, but in reality not many manufacturing enterprises (MEs) have developed a systematic recovery system which can yield rewarding results. The implementation and integration of RL with the existing forward supply chain (SC) system encounter many barriers which may include lack of government support, financial limitations, capabilities and facilities, and market constraints. There is lack of awareness among the consumers as well as manufacturers regarding the potential advantages of engaging in RL (Ravi and Shankar 2015). Most of the recovery activities are predominantly taken over by an informal sector in India and therefore MEs find it even tougher to crack through and make way for a formal recovery structure (Manomaivibool 2009; Wath et al. 2010; Dwivedy and Mittal 2012). Even though there are numerous benefits associated with RL, there is still lack of academic research aimed at addressing these issues and the strategies adopted towards the practical implementation of RL. Some earlier studies have focused on investigating these issues and their solutions from company's perspective without considering the role of the supply chain (SC) partners. Understanding and analyzing the strategies that can be adopted within a collaborative framework can guide companies in finding sustainable solutions for incorporating RL as an integral part of their supply chain. Multi-stakeholder's initiatives are a major requirement in a collaborative framework. Collective methods of all the stakeholders facilitate dynamic interactions to produce significant and long-term improvements towards achieving sustainability. Substantial support of its stakeholders, contribution of the government and commitment of top management can help deal with a large proportion of the problems faced. Collaboration between companies, customers, governments and others are a requisite for economic viability and attaining sustainability oriented RL model (Lozano 2008; Nagarajan et al. 2013). To overcome this gap, this study proposes a RL network model for MEs which includes identifying and prioritizing the strategies (solutions) and examining the feasibility of executing them with support of all its partners. A thorough investigation of the strategies is done to provide a suitable framework to the decision makers (DMs) for guiding them on how RL can be sustainably managed. The key research question therefore addressed in the paper is to find the key strategies and how they can be implemented by a ME for attaining a sustainable RL system with the involvement of its stakeholders. In view of above, the aim of the present work is encapsulated as follows:

1. To identify strategies (solutions) for sustainable implementation of RL in a collaborative framework.
2. To identify the most imperative strategies and their influence on the other strategies.
3. To propose a mathematical model addressing the most imperative strategies to attain a sustainable RL system.

The solutions are identified from an extensive literature survey and interaction with DMs. Based on several evaluation factors, these solutions then need to be prioritized as per the stakeholders' perspectives. A systemic methodology is required to reflect upon the most imperative solutions in presence of the interdependent relationships existing between the derived solutions. Among the various MCDM techniques, we have utilized Decision Making Trial and Evaluation Laboratory (DEMATEL) which is based on structural modeling approach for identification of most important solutions (elements) for resolving the complex problem (Fontela and Gabus 1976). In contrast to AHP which requires the elements to be independent, DEMATEL analyses the interdependence and interrelationships among those elements. In addition, DEMATEL can determine the intensity of the direct and indirect relationships (Kiakojuri et al. 2015) existing between the elements, a property not exhibited by other MCDM techniques such as ISM. The proposed technique helps to recognize the most central solutions to the problem and construct the cause and effect groups. Hence, the use of DEMATEL in the present study is justified as it facilitates the decision making process by providing the DMs with a comprehensible structural model which highlights the most important long-term decision strategies and their impact on other flexible decision strategies. As a result the DMs can focus on the solutions in the order of their relative priorities which can significantly ease the process aimed at attaining a sustainable RL network within a collaborative framework.

The implications derived using DEMATEL can be used by the company to construct a framework for promoting the positive impact of RL on the environment and society with the help of the government, NGO, channel partners and its own employees. The proposed mathematical model hence explores the feasibility of government support in form of subsidies, collaboration with 3PRL (third party reverse logistic) providers under a profit sharing alliance, collaboration with the NGO for promoting awareness, and providing monetary benefits to employees for their efforts towards RL promotion. To encourage the staff, financial incentives are given based on the number of returns collected. A NGO fund is established as a move towards jointly taking up projects aiming towards social development. A linear programming problem is formulated which aims to maximize the sustainable impact of the proposed RL network (in terms of allocation of NGO and employee funds). The key decisions taken are determining the fund allocated to NGO in each time period, the profit sharing percentage between the ME and 3PRL based on the number of returns, the total employee fund generated for each collection center and the fund allocation per employee in each time period. The profit accrued from the returns is optimally utilized for raising the funds.

In continuation of the above, the rest of the paper focuses on the following: Sect. 2 elaborates the DEMATEL approach for prioritizing the strategies; Sect. 3 discusses the problem definition; Sect. 4 shows the mathematical modeling; Sect. 5 discusses the numerical illustration; Sect. 6 summarizes the conclusion and future enhancement for the proposed model.

2 DEMATEL approach

Increasing government legislations are putting pressure on MEs to redesign their traditional supply chain networks into contemporary supply chains which incorporates RL. In developing countries, an essential tool towards implementation of a sustainable RL is collaboration among the stakeholders and therefore their role in choosing the strategies for engaging RL is extremely important. In relation to our study, 12 strategies were identified (as shown in Table 1) which included a detailed literature survey, interactions with the DMs which summarizes all the possible short term as well as long term strategies which can be adopted by the company to achieve the desired RL framework.

Analyzing these RL adoption strategies is a complex process because of their interrelationships and hence in such situation DEMATEL can be ideally used. DEMATEL methodology is utilized for the purpose of understanding the mutual relationships between the strategies to extract the most imperative ones. The DEMATEL approach derives the priorities for the strategies for achieving a feasible partnership among the stakeholders, so that the desired RL network represents the voice and opinion of every SC member involved. The result of DEMATEL methodology is a visual representation in form of impact-relations map (IRM) which can provide more clarity of the existing interdependence between various criteria to the DMs. Following are the major steps of DEMATEL (Tzeng 2007; Wu 2008; Shieh et al. 2010; Govindan and Chaudhuri 2016):

Step 1: *Construct the Direct relation matrix (DRM)*. The direct relationship among a pair of criteria is evaluated using the numerical scale 0–3 (where 0, 1, 2, 3 represent existence of no, low, medium, high level of influence among the criteria respectively). The data obtained from K DMs is represented by an *nxn* pairwise comparison matrix X^k where x_{ij}^k is the level of influence among the pair of

Table 1 Strategies (solutions) for sustainable implementation of RL in a collaborative framework

Strategies	Description	References
Cross-functional collaboration (S1)	Company should persuade collaboration between various departments	Hung Lau and Wang (2009), PWC report (2008), Prakash and Barua (2015)
Strategic collaboration with reverse chain partners (S2)	Company should engage with reverse chain partners for planning and improvement	Hung Lau and Wang (2009), PWC report (2008), Prakash and Barua (2015)
Perceive returns as perishable goods (S3)	Companies should consider returns as deteriorating products to ensure quick recovery process	PWC report (2008), Prakash and Barua (2015)
Training and development programs for staff (S4)	Company should offer training and development programs on regular basis for the employees to enhance their skills	OWN
Reclaiming value from returns (S5)	Company should reclaim maximum value from returns as it will lead to significant cost savings	PWC report (2008), Srivastava (2008), Prakash and Barua (2015)
Create public awareness on environmental issues and conservation (S6)	Company must promote initiatives for enhancing public awareness about the benefits of RL practices	Hung Lau and Wang (2009), PWC report (2008), Prakash and Barua 2015)
Enforce environmental legislation, regulations, and directives (S7)	Company must ensure that all SC partners adhere to the environmental guidelines and directives issued by government	Hung Lau and Wang (2009), Prakash and Barua (2015)
Develop RL as part of sustainability program (S8)	The focus on RL should not be merely for financial gains and legislative obligations but should be implemented to enhance the overall sustainable performance of the SC	Hung Lau and Wang (2009), Prakash and Barua (2015), Gunasekaran and Spalanzani (2012)
Implement green practices for electronic products (S9)	Production design should facilitate easy recovery, reuse and recycling of products	Hung Lau and Wang (2009), Prakash and Barua (2015), Gunasekaran and Spalanzani (2012)
Create, develop and invest in RL technology (S10)	Create active recycling network and system for WEEE returns to safeguard smooth and easy RL flows and effective recycling operation	Hung Lau and Wang (2009), Prakash and Barua (2015)
Develop closed loop supply chain by integrating RL (S11)	Efficiently integrating forward and reverse SCs for managing product, finance and information flow in both directions	Hung Lau and Wang (2009), Prakash and Barua (2015)
Develop outsourcing strategy for recovery and collection of end of life products (S12)	To utilize the expertise of the third party providers and to focus on their core competency, outsourcing reverse logistics must be seen as a effective strategy for a fast and efficient recovery of the products	Dat et al. (2012), Efendigil et al. (2008), Senthil et al. (2014), Prakash and Barua (2015)

Table 2 Initial influence matrix A

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1	0	3	0	2	0	0	1	3	3	2	2	3
C2	2	0	1	3	3	2	0	1	2	2	2	3
C3	0	3	0	0	3	0	0	2	1	2	2	1
C4	2	3	2	0	3	2	2	2	3	3	3	2
C5	0	2	3	2	0	2	1	2	2	2	2	3
C6	1	2	1	2	3	0	0	2	3	3	3	1
C7	2	3	0	3	2	3	0	2	3	2	3	2
C8	2	3	2	3	2	3	2	0	2	2	2	1
C9	1	2	2	3	2	3	0	2	0	2	3	1
C10	0	3	0	3	2	3	0	3	3	0	3	3
C11	3	3	1	3	2	0	0	2	3	3	0	2
C12	0	2	2	3	1	1	0	0	0	1	2	0

Table 3 Total influence matrix for criteria with threshold values

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
S1	0.10	*0.29*	0.11	*0.26*	0.17	0.14	0.08	*0.24*	*0.27*	*0.23*	*0.25*	*0.25*
S2	0.16	0.21	0.15	*0.30*	*0.27*	0.21	0.05	0.19	*0.25*	*0.25*	*0.26*	*0.27*
S3	0.07	*0.24*	0.08	0.14	*0.22*	0.10	0.03	0.17	0.16	0.19	0.20	0.15
S4	0.20	*0.37*	*0.22*	*0.27*	*0.32*	*0.25*	0.12	*0.26*	*0.33*	*0.33*	*0.35*	*0.28*
S5	0.10	*0.27*	0.21	*0.26*	0.18	0.21	0.08	0.21	*0.24*	*0.24*	*0.26*	*0.26*
S6	0.14	*0.28*	0.16	*0.28*	*0.28*	0.15	0.05	*0.23*	*0.29*	*0.28*	*0.30*	0.21
S7	0.20	*0.35*	0.15	*0.35*	*0.28*	*0.28*	0.06	*0.25*	*0.33*	*0.29*	*0.34*	*0.27*
S8	0.19	*0.34*	0.20	*0.33*	*0.28*	*0.27*	0.12	0.18	*0.29*	*0.28*	*0.30*	*0.23*
S9	0.14	*0.28*	0.19	*0.30*	*0.25*	*0.24*	0.05	*0.22*	0.19	*0.26*	*0.30*	0.20
S10	0.12	*0.33*	0.14	*0.33*	*0.27*	*0.26*	0.05	*0.26*	*0.30*	0.21	*0.32*	*0.28*
S11	0.20	*0.32*	0.16	*0.32*	*0.25*	0.16	0.05	*0.23*	*0.29*	*0.29*	0.21	*0.25*
S12	0.06	0.19	0.14	0.21	0.14	0.11	0.03	0.09	0.11	0.14	0.18	0.10

Threshold limit values above 0.22 are in italics

Table 4 Values of $R_i + C_i$ and $R_i - C_i$

Strategy	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
R_i	2.38	2.56	1.75	3.31	2.53	2.64	3.15	3.01	2.63	2.87	2.73	1.52
C_i	1.67	3.47	1.91	3.36	2.91	2.39	0.77	2.54	3.04	2.98	3.28	2.75
$R_i + C_i$	4.06	6.04	3.65	6.67	5.44	5.03	3.92	5.55	5.67	5.85	6.01	4.27
$R_i - C_i$	0.71	−0.91	−0.16	−0.05	−0.38	0.26	2.37	0.46	−0.41	−0.11	−0.55	−1.23

criteria (i, j) for *k*th DM. To incorporate the opinions of all DMs, an average matrix A is constructed from these initial matrices (Table 2).

Step 2: *Obtain the Normalized direct relation matrix*. The DRM is normalized as:

$$D = [d_{ij}] = \frac{A}{s}, \quad s = \max\left(\max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}, \max_{1 \le j \le n} \sum_{i=1}^{n} a_{ij}\right)$$

Step 3: *Calculate the Total relation matrix* T. (Table 3) .

$$T = [t_{ij}]_{nxn} = \lim_{m \to \infty} \left(D + D^2 + D^3 \ldots + D^m\right) = D(I - D)^{-1}$$

Let R_i and C_j be n × 1 and 1 × n matrices showing the row-sum and column-sum of the T. R_i represents the total effect exerted by criterion *i* on other criteria while C_j represents the total effect received by criterion *j*. Thus, $(R_i + C_i)$ indicates the level of significance of *i*th criterion in the decision making process. On the other hand, $(R_i - C_i)$ indicates the resultant effect of *i*th criterion. $R_i - C_i$ greater than zero implies that criterion *i* falls in the dispatcher group as it is a net cause. $R_i - C_i$ less than zero implies then the criterion *i* being a net receiver is part of the receiver group (Table 4).

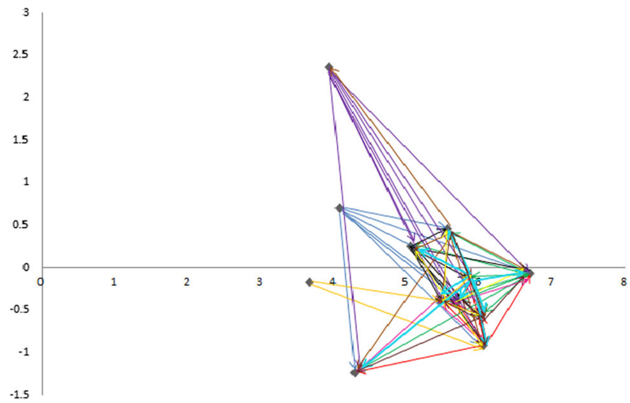

Fig. 1 IRM diagram

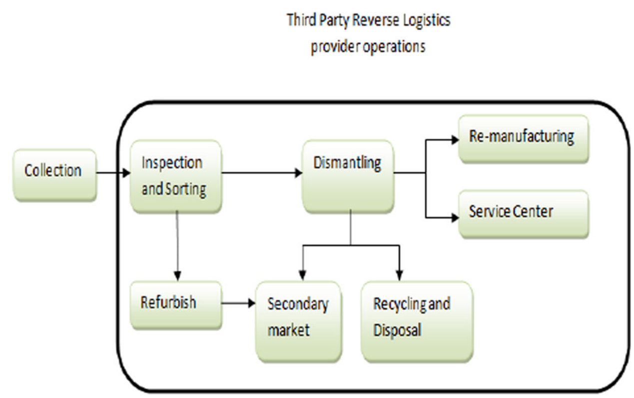

Fig. 2 Reverse Logistics Network

Step 4: *Construct the IRM diagram.* To filter the criteria that have negligible effect on others, the DMs may fix a threshold limit. The criteria having value greater than threshold limit will be chosen to map in the dataset ($R_i + C_i$, $R_i - C_i$) in the form of impact- relations map (IRM) as shown in Fig. 1.

The results of DEMTEL give four major solutions for successful implementation of RL under collaborative framework. The solutions are Cross-functional collaboration (S1), Create public awareness on environmental issues and conservation (S6), Enforce environmental legislation, regulations, and Directives (S7) and Develop Reverse Logistics as part of sustainability program (S8).

3 Problem definition

The paper addresses the issue of sustainable implementation of RL for MEs with the help of other SC members. The DEMATEL approach was utilized to understand the important strategies to be adopted by the ME for successfully executing its RL operations in a collaborative framework. The implications derived from the DEMATEL solution highlights the importance of compliance to environment regulations, cross functional collaborations between stakeholders, adopting initiatives for creating environmental awareness and most importantly development of sustainability oriented RL. In view of this, ME must focus on the above strategies (solutions) while planning their RL network. The network so designed must also ensure the following:

1. Amount of returns is substantial enough for a viable RL network
2. The RL network generates long-term sustainable results.

To begin with, the ME intends to collaborate with a 3PRL provider for the RL activities. The ME plans to allocate a part of its available budget for creating positive environmental and social impact. To initiate the process, it plans to work along with NGO who are involved in creating public awareness about the harmful effects of e-waste. The ME hopes to receive government subsidy for collection of returns. To encourage the staff, financial incentives are given based on the number of returns collected. As a consequence, it will also help in an increase in the number of returns.

To implement the above, the RL network proposed for the ME is as follows (Fig. 2): the ME collects the end of life (EOL)/end of use (EOU) at it collection centers. Once the returned products are collected, 3PRL provider picks these products from the collection points and carries out the product recovery operations which include inspection, sorting, refurbishing, dismantling, recycling and disposal. Though, the 3PRL benefits from the revenue generated from reselling the products at secondary markets, the company benefits from using the refurbished components at their service center and remanufacturing center. The company is majorly concerned with the collection, while outsourcing the remaining RL activities to 3PRL shifts the responsibility from the MEs. The 3PRL is under revenue sharing contract and thus pays a certain percentage of is profit to the company based on the number of returns. For sustaining the awareness program (with NGO) and employee benefit plan, a substantial amount from the available budget is allocated for NGO fund and employee funds in each time period. The employee funds are monetary incentives given to the employees based on their performance.

4 Mathematical model

To satisfy the above requirements as desired by the MEs, following linear mathematical model is proposed which maximizes the total sustainable impact in terms of employee fund and NGO fund of RL network in the planning horizon. The proposed model will help the DMs in determining the fund allocation to NGO in each time period, the profit sharing percentage between the ME and 3PRL based on the number of returns, the total employee fund generation for each distribution cum collection center and the fund allocation per employee in each time period.

Sets

t Time periods, t = 1,2…T
r Collection centers/retail points

Parameters

α	Rate of increase in returns in each time period
$G^{Subsidy}$	Government subsidy per unit returned product collected (in Rs.)
C^{SP}	Per unit selling price of returned products (in Rs.)
C^{CI}	Per unit buyback cost per unit returned product from customer (in Rs.)
E_r	Total number of employees at rth distribution center
ϕ_{rt}	Allowable difference in employee fund to reduce disparity at rth distribution center in tth time period
$\gamma_{\max}$	Maximum profit sharing percentage between the ME and 3PRL
G_{rt}	Fund allocation per each unit of return collected at rth distribution center in tth time period (in Rs.)
$X_{\min}$	Minimum number of returns collected to activate maximum profit sharing percentage ($\gamma_{\max}$) with 3PRL
X_{r0}	Quantity of returned products at rth distribution center in initial time period
$B_{\min}$	Minimum budget sanctioned by the company in each time period (in Rs.)

Decision variables

X_{rt}	Quantity of returned products at rth distribution center in tth time period
B_t	Total budget available in each time period (in Rs.)
P_t	Profit incurred in each time period (in Rs.)
C_t^{NGO}	NGO fund allocation in each time period (in Rs.)
γ_t	Profit sharing percentage between the ME and 3PRL in time period
U_{rt}	Total employee fund generated at rth distribution center in each time period (in Rs.)
F_{rt}^e	Fund allocation per employee at rth distribution center in each time period (in Rs.)

Objective

The objective is to maximize the total sustainable impact in terms of employee fund and NGO fund in the planning horizon for the proposed RL network in a collaborative framework.

$$Max \sum_t \sum_r \left(E_r F_{rt}^e + C_t^{NGO}\right)$$

Subject to

$$X_{rt} = X_{ro} \quad \forall r, t = 1 \tag{1}$$

$$X_{rt} \leq X_{rt-1} + \alpha X_{rt-1} \quad \forall r, t = 2, .., T \tag{2}$$

$$\gamma_t = \min\left(\sum_r \frac{X_{rt}}{X_{\min}} \gamma_{\max}, \gamma_{\max}\right) \quad \forall t \tag{3}$$

$$P_t = \sum_r X_{rt}\gamma_t\left(C^{SP} - C^{CI}\right) + \sum_r G^{Subsidy} X_{rt} \quad \forall t \tag{4}$$

$$B_t = P_t + B_{\min} \quad \forall t \tag{5}$$

$$B_t \geq \sum_r E_r F_{rt}^e + C_t^{NGO} \quad \forall t \tag{6}$$

$$\sum_r G_{rt} X_{rt} = \sum_r U_{rt} \quad \forall t \tag{7}$$

$$U_{rt} = E_r F_{rt}^e \quad \forall r, t \tag{8}$$

$$U_{rt} - \phi_{rt} \leq G_{rt} X_{rt} \leq U_{rt} + \phi_{rt} \quad \forall r, t \tag{9}$$

$$X_{rt}, C_t, U_{rt}, F_{rt}^e, C_t^{NGO}, \gamma_t, B_t \geq 0 \text{ and integers} \quad \forall r, t \tag{10}$$

Constraint (1)–(2) determines the initial amount of return and the amount of return in each subsequent period. Constraint (3) determines the profit sharing percentage between ME and 3PRL in each time period (maximum percentage $\gamma_{\max}$ will be activated only if the number of returns sent by ME to 3PRL is more than a minimum threshold). Constraint (4) calculates the profit incurred in each time period due to government subsidy and profit accrued from 3PRL. Constraint (5) determines the total budget for funds in each time period is the sum of profit and the minimum allocated budget. Constraint (6) ensures that the funds raised for NGO and employees do not exceed the available budget in each time period. Constraint (7) is a flow balancing constraint which ensures that for each time period, total employee fund generated from all the DCs is distributed among all the DCs. Constraint (8) calculates the allocation of employee fund (incentive) for each time period to each distribution center. Constraint (9) ensures reduction in the disparity between the employee fund generated by each DC and allocated to each DC in each period. The non negativity restriction for the decision variables is enforced by constraint (10).

5 Numerical illustration

The company, in the case study, is an electric and electronic appliances manufacturer which manufacturers small and medium home appliances in Delhi NCR region. For the

Table 5 Quantity of returned products at *r*th collection center at *t*th time period

Time period	Collection Centers									
	1	2	3	4	5	6	7	8	9	10
T1	140	150	160	130	140	160	160	140	130	160
T2	168	180	192	156	168	192	192	168	156	192
T3	201	216	230	187	201	230	230	201	187	230
T4	241	259	276	224	242	276	276	242	225	276

Table 6 Total employee fund generated at *r*th collection center at *t*th time period

Time period	Collection centers									
	1	2	3	4	5	6	7	8	9	10
T1	27,911	29,911	32,800	25,911	27,911	31,911	31,911	27,911	25,911	31,911
T2	33,511	35,911	39,200	31,111	33,511	38,311	38,311	33,511	31,111	38,311
T3	40,231	43,111	46,880	37,351	40,231	45,991	45,991	40,231	37,351	4599
T4	47,939	51,395	59,296	44,483	47,939	54,851	54,851	47,939	44,483	54,851

Table 7 Fund allocation per employee at *r*th collection center at *t*th time period

Time period	Collection centers									
	1	2	3	4	5	6	7	8	9	10
T1	1395	997	1025	1727	1496	1276	1329	1395	1439	1450
T2	1675	1197	1225	2074	1763	1532	1596	1675	1728	1741
T3	2011	1437	1465	2490	2117	1839	1916	2011	2075	2090
T4	2396	1713	1853	2965	2523	2194	2285	2386	2471	2493

proposed study, as the intensity of returns is generally low, we have considered 4 planning horizons each of 6 month duration. The company has 10 major collection centers located in and around Delhi. It is estimated that there will be 20 % increase in returns due to promotion of RL through various means undertaken by the company. A minimum budget of Rs. 200,000 is allocated by the company for carrying out RL activities in each time period. Government subsidy per unit returned product collected is Rs. 300. The selling price of returned products to 3PRL is Rs. 1500 while the buyback cost per unit returned product from customer is Rs. 700. The total number of employees at each distribution center are 20, 30, 32, 15, 19, 25, 24, 20, 18 and 22. Allowable difference in incentives to reduce disparity at collection center in each time period is Rs. 4000. Maximum percentage of the total profit allocated to the ME under collaboration with 3PRL is 50 %. Per unit incentive offered to employees for collection of returns at each time period is Rs. 200. Predefined number of returns by 3PRL for revenue sharing contract is 2100.

6 Result

The mathematical model is solved using LINGO 11.0 using the above data. A total of Rs. 6,034,376 is generated by the model for carrying out social activities in terms of employee fund and NGO fund for the proposed RL network, with Rs. 1,052,600, Rs. 1,321,904, Rs. 1,681,760 and Rs. 1,978,112 as total budget allocated in each time period. The budget allocated to NGO are Rs. 75,860, Rs 96,910, Rs. 125,840 and Rs. 147,008 in each time period. A profit of Rs. 852,600, Rs. 1,121,904, Rs. 1,481,760, Rs. 1,778,112 is generated through government subsidy and selling the returns to 3PRL provider. Percentage of the total profit earned by the ME under collaboration with 3PRL is 0.35, 0.42, 0.5 and 0.5 % for each time period. A total of 1470, 1764, 2116 and 2540 returns are collected from the ten distribution centers in the each planning horizon. Tables 5, 6 and 7 gives the quantity of the returned products, the total employee fund generated and the total employee fund allocated at each collection center in each time period.

7 Conclusion

The MEs are shifting towards incorporation of sustainability into their traditional supply chain because of the pressure from government and stakeholders. In order to move towards sustainability, one of the key factors is the inclusion of reverse logistics. This paper addresses the issue of successful implementation of RL in Indian context by understanding the mutual relationships between various solutions that a company can implement for economically, environmentally and socially viable RL. Collaboration between the various stakeholders is an imperative tool for the successful RL undertaking. The contribution of the paper to the literature is to integrate an economically viable RL network with the help of collaborative partners. The study uses DEMATEL technique to identify the cause and effect groups among the various strategies and to provide a visual representation in form of IRM for successful RL implementation to the DMs. The results show that the collaboration among various stakeholders and creating more awareness about RL are among the major factors that the MEs should focus on. Further, enforcement of legislations and development of a comprehensive RL network are also seen as the influencing factors from the IRM. A mathematical model is proposed which can help the MEs to incorporate these measures for RL activities in a collaborative framework. The model aims to generate a positive sustainable impact by utilizing the profit earned from the returns in raising funds for promotion of RL. The model is transformed into a linear programming problem which maximizes the total sustainable impact in terms of generating employee fund and NGO fund. Results of this modeling can be further used with various other decision making methods for a deeper understanding of the problem. Further uncertainty can be incorporated to capture the subjectivity in DM preferences.

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