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A Performance Model for Designing Network in Reverse Logistic

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***Abstract*—**In this paper, a reverse supply chain network is investigated for a decision making. This decision is surrounded by complex flows of returned products, due to the increasing quantity, the type of returned products and the variety of recovery option products (reuse, recycling, and refurbishment). The most important problem in the reverse logistic network (RLN) is to orient returned products to the suitable type of recovery option. However, returned products orientations from collect sources to the recovery disposition have not well considered in performance model. In this study, we propose a performance model for designing a network configuration on reverse logistics. Conceptual and analytical models are developed with taking into account operational, economic and environmental factors on designing network.

***Keywords*—**Reverse logistics, Network design, Performance model, Open loop configuration.

I. Introduction

THE rapid changes, competition and technical innovation in market have increased the variety of used products [1]. Used products have received attention, in part, by legislation such as the end of life vehicle directive (WEEE). An environmentally friendly firm is merged to improve the environmental image by removing the growing waste [2]. Indeed, complexity of reverse logistics process has increased the opportunity for saving cost and improves competiveness. The design of reverse logistic network requires an economical and environmental quantification. It concerns, for example, the choice of deposit locations, their capacities, quantity of returned product, etc.

In recent years, reverse network configuration has seen an increased research due to the competitiveness customers' varied expectation [3]. The majority of researches use the linear programming formulation to develop a network configuration problem. It can determine an optimal number of these manufacturing centers, suppliers, transshipments, productions, and the stocking of the optimal quantities of remanufactured Thus, the network design is being important not only for creating value associated to the returned products, but also by examining the impact of appropriateness of network designs [9] on management orientation of returned products. The network design is considered as complex decision due to the growth of type and number of returned products. It refers to the distribution activities involved in products returns, source reduction conservation recycling, substitution, reuse, disposal refurbishment, repair and remanufacturing [10] products and used parts [4], [5]. Despite it optimality, these models are not considering the various characterizations of the reverse logistics. Researchers are looking for efficient ways in order to meet decision making, related to the selection of alternatives reverse network [6]-[8].

The concept of performance model can allow decision maker to an effective and efficient decision on different recovery alternatives. For this purpose, integrated logistics network design is critical to avoid a successful managing. Thus, several researches consider this problem as an optimizing problem [11]-[14].

Measuring the performance of supply chain is a merge of many ways: analyzing the external changes, improving performance, achieving a better satisfaction and choosing the right decision of the objectives. Moreover, the concept of measuring performance may involve the best decision in various contexts characterizing different alternatives. It offers to the decision maker to analyze the impact of changing, in order to adjust decision to the fixed objective.

Performance measurement is defined as “the process of quantifying the effectiveness and efficiency of action. Effectiveness is the extent to which customer’s requirements are met and efficiency measures. How economically a firm’s resources are utilized when providing a pre-specified level of customer satisfaction” [15] Performance model appears to offer practitioners and researchers to get solutions on managing and improving effectiveness and efficiency of the variety of measures and metrics supply chain. The excellent overview of performance models provides by [16], highlight their specific characteristics and applicability in different contexts, while providing decision assistance framework that will allow managers to choose the model that offers a kind of analysis they need. This study is needed to generate a new model capable of integrating new ways of creating value for the whole supply chain. The scope of this paper presents a performance model for network decision in reverse logistics field. The proposed performance model is used to investigate the impact of economic and environmental factor to choose an appropriate orientation of recovery products under variation of capacity, quantity and quality of products.

Our contribution is twofold: first original is to develop a new model for assessing a reverse logistics chain for multi-recovery alternatives and multi-type of products applied in open loop configuration. This model allows the decision maker to achieve the optimality, presented by linear

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programming model mainly for reducing cost and satisfying footprint emission. Second, this model allows decision maker to follow the suitable network design of the reverse supply chain. The paper is divided into five sections as follows: Section II presents a relevant literature review on the main performance models. Section III describes both proposed conceptual and analytical models. Section IV provides a numerical example following by a comparison between two cases: considering environmental factor or without taking into account environmental factor. Section V concludes by suggesting directions for future research.

II. Literature Review

A lot of previous researches on performance model are concentrated on managing supply chain practices, improving the performance of each system such as Supply Chain Operation Reference (SCOR), Quality Management Excellence Model (EFQM), BSC (Balanced Scored Card) and GSCF (Global supply chain framework). SCOR Model presents an important issue to measure four dimensions: reliability of commercial performance, flexibility/ responsiveness, cost of supply chain and turnover of committed capital [17]. Moreover, many measures emphasize customer relationship, customer relationship management, customer service management and customer internal such as EFQM, BSC and GSCF. EFQM is oriented to determine efficiency, relating to product, services, and personnel management. However, BSC is permitted to analyzed strategy, organization and logistic competence by combining non-financial indicators such as service quality, employee morale and customer satisfaction. Using links between supply chain and process, GSCF can be practice to provide coordination between activities and processes within and between organizations in the supply chain. Several measuring performance tools are based on economic performance to minimize cost due to financial piloting indicators. An important issue in evaluating performance seeks to improve economic factors with implementation of measure performance. Activity-Based Costing (ABC) can reduce costs and improves the resource allocation, which contribute managing various operations management decisions. In other hand, economic factors are not considered on certain performance models such as (APICS) association for Operations Management Model, Global EVALOG, SASC (Strategic Audit Supply Chain), ASLOG audit can evaluating process and procedures in supply chain. Aims to implement a good practice, ASLOG audit provide to analyze strengths and weakness of logistics procedures. In the same way, SASC model is applied at organizational level to link competencies to information technology and organization of chain. Both of ASLOG audit and Global EVALOG are used in specific industry. To structure our literature review of performance measurement system, we are based on different supply chain performance evaluation models to investigate what are the kind of systems should be evaluated? What types of performance analysis models are permitted? Table I shows various performance evaluation models involved in several literature reviews. A comparison of performance model summarizes different particularities of well-known performance evaluation, organized by main objectives and limits as shown in Table I. This table reveals models related to measure performance. However, the majority of performance models were general and oriented towards systems, organization and process. In this paper, we suggest a performance model principally adapted to reverse supply chain in order to provide suitable network design under some criteria.

III. Methodology

A reverse logistics has been extensively tackled for decades due to the shipment of the returned flows of product. It is used to manage product taken back from the costumer and shipped to manufacturers via collection centers in order to be managing in efficient manner. In broader sense, environmental degradation and increased opportunity for saving cost, prompted some researchers to improve the performance of reverse configuration network at different scales. By measuring the factors influencing the effectiveness and the efficiency of the reverse configuration network, decision makers can suggest appropriate policies to improve the performance of reverse logistic configuration. In fact, according to literature ([19]-[21], [23]) a reverse supply chain performance has a huge variety of measurement systems which are extensively related to cost and profit. Many of them are implemented to the environmental concern and to economic benefit to make performance measurement model more significant and real. Thus, introduction of the ecological and environmental performance measurement can provide ecological outcomes and an effective management. Differentiation measurement is useful to indicate the ability to cover all changes. The purpose of design reverse logistic network is to get managing used products and convoyed to the different location or called recovery center (collection center, reprocessing center, remanufacturing centers, recycling center, disposal center and redistribution center). Fig. 2 shows the basic flows diagram of reverse logistics activities.

Supply chain performance measurement is well reflected by the large and growing literature on problem. Thus, in the context of reverse flow, performance measures have found practical difficulties. This difficulty is caused by complexities of processes and the variety of activities of recovery product. This complexity stems from a high degree of uncertainty due to the quantity and quality of the products [19] and the variety of disposition options (reprocessing, repair, recycle). Moreover, uncertainty is one of the most challenging in configuration problem to determine the number, location, capacity, level and technology of facilities to be considered [20]. Even though, uncertainties in delivery and in return of product which are two majors sources of vagueness in open loop configuration, some researches investigate uncertainty in reverse logistic by developing mathematical model to solve this problem [21]-[23]. There are relatively a few attempts of measurement performance model, to address the realistic problem of reverse logistics, taking into account uncertainty in reverse network configuration.

For the proposed model, three stages are developed. Initially, a conceptual model represents the relationship between reverse logistic network and the different factors: operational, economic and environmental factors. Then, a linear programming model is applied to quantify the relation among Reverse Logistic Network (RLN) and considered factors. Finally, the result of the model is used to evaluate the systematic supply chain.

TABLE I
PERFORMANCE MEASURING MODELS

	Topic	Approach	Contributions
[2]	Recovery end of life vehicles in Mexico	Scenario Analysis.	Determine the minimum number of collection centers Minimize the transport distance of vehicles with a maximum coverage of areas served.
[22]	Problem of location of sites and allocation of material flows in RL network	Genetic algorithm	Minimize the cost of installation of collection points, considering the maximum revenue products returned
[14]	Localization problem in two main centers of the network	Genetic algorithm	Reduce the negative impacts on the environment in process center.
[8]	Network design	Linear programming.	Consider the capacity of treatment facilities.
[23]	Processing and recycling of waste phones battery	fuzzy logic Lagrangian relaxation	Locate the problem of processing center
[9]	Recovery of municipal solid waste.	Genetic algorithm	Locate the problem of processing center.
[18]	Recovery industrial waste of the aluminum	Genetic algorithm	Minimize operational and environmental cost
[12]	Operation level of handling process of multi products in a deterministic and dynamic approach.	Optimization tool: OPL studio.	Minimize the total operational cost of each chain partner and the whole supply chain.
[15]	Network configuration and design.	Optimization tool: Lingo 08.	Minimize cost of the network Considering the relationship between the scope of electronic waste recycling network and quantities.
[23]	Recovery computer in city of Tai'an in Shandong China.	Method of Lagrangian relaxation.	Minimize the total costs, fixed and variable.
[24]	Problem-localization-allocation in strategic situation	The software MILP-solver Lingo 8.0.	Minimize the number of installation center of forward chain (factories and distribution centers)

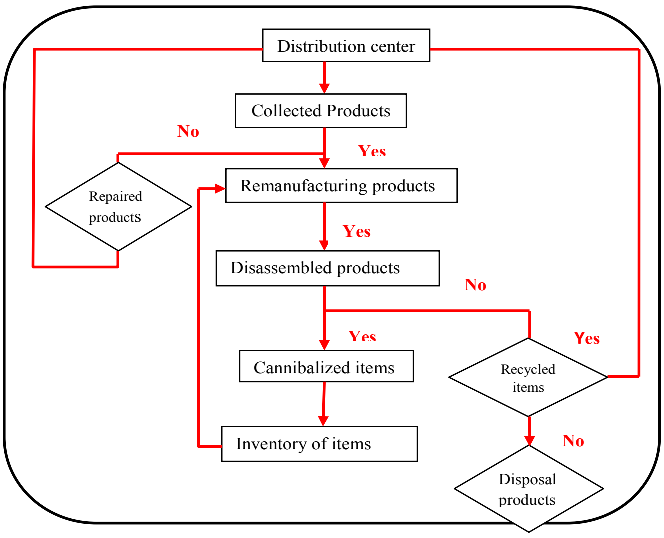

Fig. 1 Flow diagram of reverse logistics in open loop

A. Conceptual Model

The proposed performance model is developed to analyze the impact of economic, environmental and operational factors for achieving a successful reverse supply chain based on different characterization of network. As shown in Table II, a reverse logistics network differs from other configuration by the type of returned products, layers of network and type of activities. In the design of reverse network, it may occur in one of two contexts: closed-loop or open loop system. In a closed loop system, sources and sinks coincide so that flows cycle in the system. In open loop system flows enter at the one point of logistics system and leave at other The focus on all aspects of open-loop system, an important feature of returned flows provides such recovery options, reverse logistic network structure and facility, type of returned products…

Although, in open loop configuration valorized products are not returned to the original chain, so many stockholders are willing to use the recovered products or materials. Even Though, open loop chain includes multi-centers are decentralized different activities of valorization. Considering, the ambiguity of returns, open loop structure very complex according to managing volume of returns in different ways. The concept of open-loop supply chains is now widely garnering attention. It can manage all type of returned products on different states (warranty returns, core returns, damaged goods, seasonal items, hazardous materials). All this type of returns growing complexity in open loop configuration, the decision makers take in account to these features for evaluation sensitivity analysis in different alternatives and due to the lack of certainty of the quantity and quality of returned product to determine optimal flows between facilities. We develop a new evaluating performance model to select the appropriate system. In this paper, we propose an open loop configuration (Fig. 2), which considers collect center, reprocessing center, recycling center, remanufacturing center, redistribution center and disposal center. The management of recovery flow can be operating by one recovery option or strategy. It depends on the state of returned products and their economic value.

Based on the performance factors such environmental and operational criteria, a suitable decision may take from different alternatives generated to provide an exciting system. For this purpose, a conceptual model can be proposed to allow decision maker to focus on their future decision and different possible scenario. The conceptual model is useful to identify causal link between stockholders and to explain their relationship.

An appropriate conceptual model is shown in Fig. 3, by which we can describe the network structure in the case of reverse logistics. There are many factors in the design of logistics network as well as characteristics of the material flow, product characteristics, reverse logistics activities and the recovery options. The first step is used to formulate the problem under constraint and based on collected data for an optimal solution. In our conceptual model, we address to the various goals (financial, environmental…) to generate alternatives of strategy, regarding mainly reverse logistics network characteristics. We can vary some of the issues of reverse logistic network (capacity of center, quantity of products…) by implementing and converting data for assessing information. The significant results will be used to improve design.

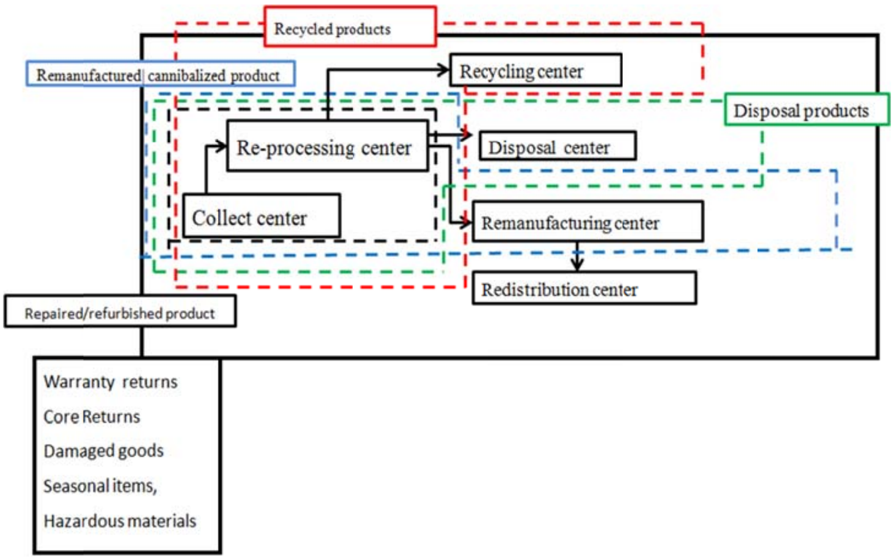

Fig. 2 Open-loop supply chain

TABLE II
FEATURE CLASSIFICATION IN RLN

Features of RL		Details
Type of returned products	-Warranty returns -Core returns -Damaged goods -Seasonal items	Goods a store/distributor knows are in need of warranty Reusable goods, those items that can be remanufactured Goods are damaged in shipment or damaged on site Items are returned due to the end of a season, which causes no retail value in the next season (s).
	-Hazardous materials	Items considered hazardous and yet must be returned.
Layers of Network [11], [6]	-Collection Center - Reprocessing Center -Remanufacturing Centers	Returned products are collected from customer returned product undergoing some change by different levels of activities in material, component, product, selective part, module, and energy. It consists of recycle, Center responsible for the process of remanufacturing by inspection and replacement of broken/outdated parts
	-Recycling Center	Centers responsible in recovering materials and reintroduce as secondary materials into the economy
	-Disposal Center	It concerns products need to be sent to a landfill
	-Redistribution Center	Center refers to directing re-usable products to a potential market and to physically moving them to future users
Type of Activities	- Repair and reuse	It concerns a product in operating condition
	- Refurbishing	It's a product operating condition with fixed quality
	-Remanufacturing	Bring used products up to quality standards as new product
	-Cannibalization	Recovery of certain parts of the product needs repair to valorized used product
	- recycling	Reuse the materials constituting the used product
	-Landfill	Required for unused products for technical or economical reasons

TABLE III
SYMBOLS USED IN MODEL FORMULATION: DECISION VARIABLES AND PARAMETERS

Notations	Descriptions
I	Index of scenario
T	Index of type of products
N	Index of number of products
Cc	Index of collect center
Tr	Index of recovery center
Decision variables	
$S_{i,t,n} = \begin{cases} 1 & \text{product nwith type t over scenario i} \\ 0 & \text{otherwise} \end{cases}$	
$X_{tr,t,n} = \begin{cases} 1 & \text{product n of type t are affected to terminal tr} \\ 0 & \text{otherwise} \end{cases}$	
$y_{cc,t,n} = \begin{cases} 1 & \text{product n of type t is assigned to center cc} \\ 0 & \text{otherwise} \end{cases}$	
Parameters	
$d_{1o,cc}$	Distance between different locating of used product and collect center
$d_{2,cc,i}$	Distance between different locating of collect center in different scenario
$d_{3,i,tr}$	Distance between different locating of terminal center in different scenario
$M_{t,n}$	Weight of product number 'n' type 't'
$P_{t,n}$	Quantity of product type 't' numbered 'n'
$Q_{cc,t}$	capacity of the collect center
$Q_{i,t}$	capacity of all center of each scenarios
$C_{1,o,cc}$	transport cost between different locating of used product and collect center
$C_{2,cc,i}$	transport cost between different collect center in different scenario
$C_{3,i,tr}$	transport cost between different locating of terminal center "tr" in different scenario "i"

B. Analytical Model

The purpose of this paper is to evaluate the performance of the reverse logistic system that will aid decision makers to determine returned products orientation. The reverse logistics network problem is multi product, multi-recovery option applied in open loop configuration. We assumed that:

Reverse logistics network system is composed of "t" types of recovery products.

The proposed network considers collect center for control and inspection. Controlling and testing returned product, that can identify the type of activities are considered.

Repaired and refurbished products are treated in collection center. The returned product needs to be remanufactured or cannibalized in remanufactured center.

Recycling centers are reserved to damaged goods.

The hazardous material or disposal products are transferred to disposal center.

Returned products are oriented to one recovery strategy.

They are three possible recovery strategies: remanufacture, recycle or disposal.

Mathematical Formulation

$$\text{Min } \sum_{t=1}^{T}\sum_{n=1}^{N}\sum_{cc=1}^{CC}\sum_{o=1}^{O} d_{1,o,cc}\, C_{1,o,cc} M_{t,n} Y_{cc,t,n} + \sum_{t=1}^{T}\sum_{cc=1}^{CC}\sum_{n=1}^{N} CT_{t,n}\ P_{t,n} Y_{cc,t,n}) + \sum_{t=1}^{T}\sum_{n=1}^{N}\sum_{i=1}^{3} S_{i,t,n} CT_{i,t} + \sum_{cc=1}^{CC} d_{2,o,cc} C_{2,cc,i} CT_{i,t} + \sum_{tr=1}^{TR} d_{3,i,tr} C_{3,tr,i} X_{tr,t,n}\ M_{t,n} \quad (1)$$

Subject to

$$\sum_{n=1}^{N} P_{t,n} \leq Q_{cc,t} \forall\ t \epsilon \{1,\dots,T\} \quad (2)$$

$$\sum_{n=1}^{N} S_{i,t,n} \leq\ Q_{i,t,}\ \ \forall i \in \{1,\dots 4\} \quad (3)$$

$$\sum_{n=1}^{N} S_{i,t,n} =\ 1\ \forall t \in \{1,\dots T\}, n \in \{1,\dots N\} \quad (4)$$

$$\sum_{tr=1}^{TR} X_{\ tr,t,n} = 1 \quad (5)$$

$$\sum_{cc=1}^{CC} Y_{cc,t,n}\ = 1\ \forall\ t,n \quad (6)$$

$$\sum_{t=1}^{T}\sum_{n=1}^{N} E_{tn}\ \times (d_{1,o,cc} \times M_{t,n} \times Y_{cc,t,n} + d_{2,cc,i} \times P_{t,n} \times S_{i,t,n} + d_{3,i,tr} \times P_{t,n} \times X_{tr,t,n}) \leq ET \quad (7)$$

Constraints (2) ensure that the capacity of collect center, the quantity of returned product for all type of product should not exceed the capacity of the collect center. Constraints (3) show that the sum of the quantity of all type of product is less than capacity of all centers of each scenario. Constraints (4) insure that each product must follow one scenario. Constraints (5) show that each product should be directed to a single center collect. Constraints (6) assure that all returned products should be assigned to the different recovery centers. Constraints (7) aimed to reduce carbon emissions from transport. The sum of carbon emission from each vehicle with an average weight Pt,n of transported products should not exceed total emission (ET) (Environment Agency and Energy Management report (ADME)).

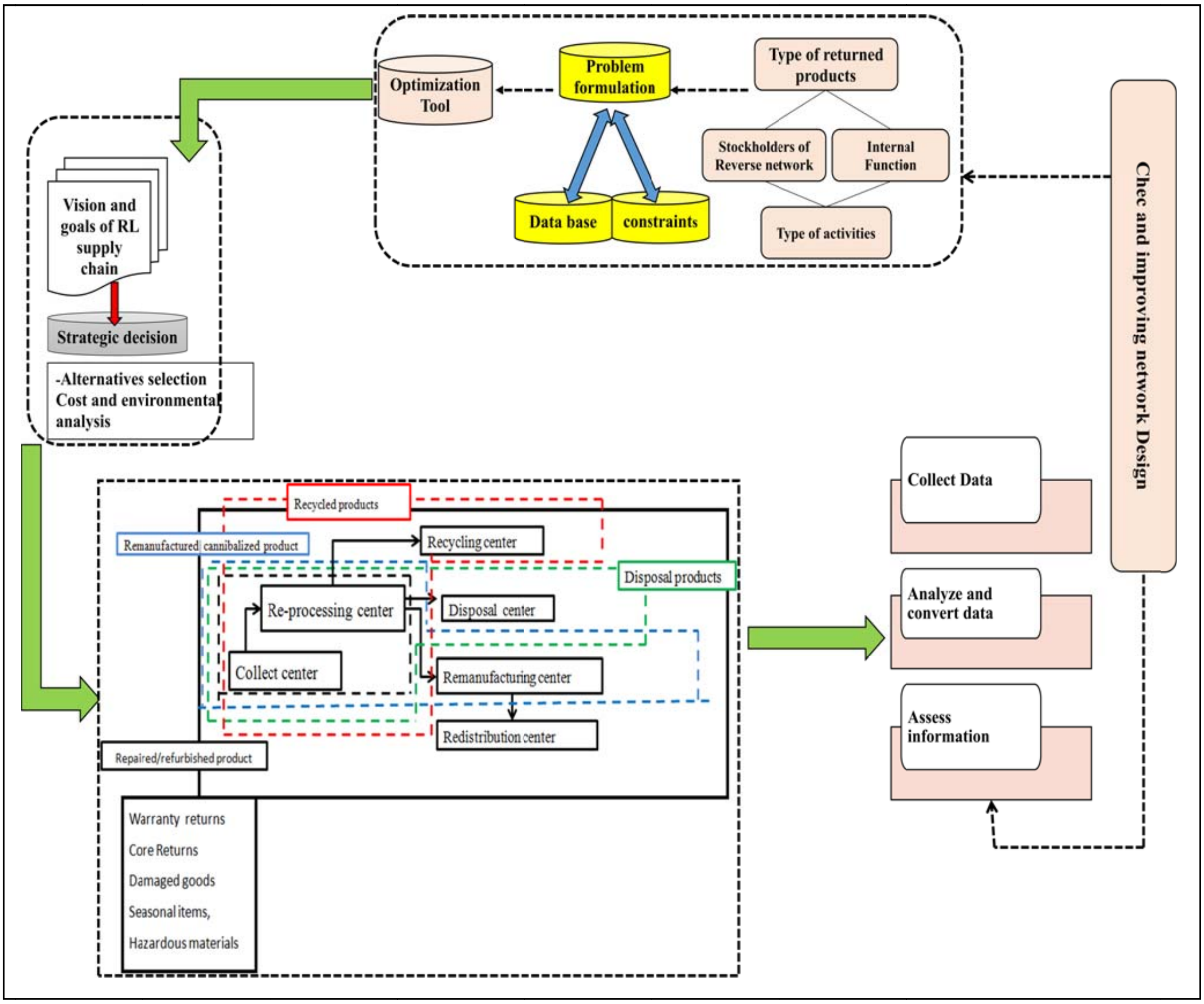

Fig. 3 Conceptual model for assigning reverse supply chain

IV. Illustrative Example

In order to validate the proposed model, a numerical example is used. Let's consider a network configuration of open loop applied in automobile industries. For simple illustration of the model, we suggest three types of returned products: Warranty products (W), Damaged product (D) and Obsolescent product (O). The valorization options in our model refer to recycling (Rec), remanufacturing (Rem), distribution (Dis) and clean disposal (Cle) activities. We restrict the number of different center respectively by:

- Four collect centers: Cc1, Cc2, Cc3, Cc4,
- Three re-processing centers: S1, S2, S3
- Four terminal centers: tr1, tr 2, tr3, tr4
- Numbers of returned products doesn't exceed 90 units for each product.
- All costs related to transportation and recovery activities are fixed.
- The application of the proposed model has been carried out in two different analyses:
- First is without taking into account environmental constraints
- Second by considering the environmental constraints

A. The Proposed Model without Environmental Constraints

In order to create an optimal connection between different center without take into account to the environmental constraints, decision maker will have to determine an effective direction of returned flows in different location. By oriented returned products to the suitable center, an optimal connection is the major objective of our model respecting the economic interest. It's involves an economic evaluation to get an optimal reconfiguration. We solve this problem using OPL12.5 Solver, running windows XP Professional. The resultant solution of an optimal network is shown in Fig. 3 and Table III. The total cost for this solution amount to 1.3923349500e+007.

The colored arrows in the Fig. 3 show the orientations of each type products to the different centers (red- type 1, green and blue type 2, black type). We can find four strategies of recovery, for example: warranty products are assigned as follow: Cc1-S3-tr4. Whereas, damaged products direction is divided into two ways, depending on the quantity. So, we can find the impact of various parameters such as: quantity, type of products, capacity on the on the value and the design of network.

TABLE IV
RESULTS OF THE PROPOSED MODEL WITHOUT ENVIRONMENTAL CONSTRAINTS

Constraint	Decision Variables	Runtime	Number of constraints	Objective value
105	325	2,11	105	1.3923349500e+007

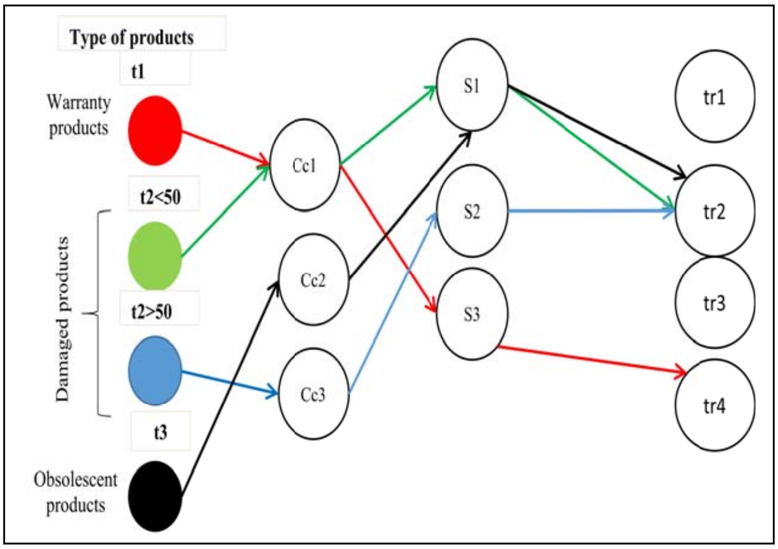

Fig. 4 Optimal network structure without environmental constraints

Considering the variation of quantity of recovery products, we will analyze their effect on total cost and the number of strategy. Quantity of returned products is assumed N_1, N_2 and N_3. Table IV presents the results of considered case keep constant value of other parameter. We see that total cost increase progressively from 164 in the base case to around 240 MU in case 2 and 390 MU when a quantity is increased N1<N2<N3. A significant result is illustrated in Fig. 4 that shows the impact of variation quantity on the total cost and strategy number for the various cases given in Table IV. The analysis showed that if quantity of recovery product exceeds the main quantity the number of strategy are decreased from 4 to 3 strategies for the second case (N1<N2). Strategy number is constant regardless of the quantity returns. As compared to the total cost and number of strategy the total cost is more affected than the network design in the different cases.

We take into account the variation of capacity of different location and we assume that there is no inventory at the recovery centers (collect center, re-processing centers and terminal centers), the other parameters are kept constant. From Table V, we can see that cost value is high for less capacity of all facility ($Q_{1cc,t}<Q_{2cc,t}$) from 164 in the base case to around 201 MU in case 2. Whereas, it's became high for a minimum capacity around 154 MU. However, as compared to the base case, the numbers of strategy are higher from 4 to 5 strategies, and it is similar for other scenario of variation of facility capacity (Table V). In Fig. 5, capacity variation has a significant effect on the total cost for all scenarios. Although, the number of recovery strategy is increases for the first scenario $Q_{1,cc,t}<Q_{2,cc,t}$ and its remain constant for scenario number3 ($Q_{2cc,t}<Q_{3cc,t}$). Based on precedent experiences, quantity and facility capacity have not a considerable impact on structure of network (strategy number). Further, we conclude that total cost is affected by facility capacity and quantity of returned products.

TABLE V
RESULTS OF VARIATION QUANTITY OF RETURNED PRODUCTS WITHOUT CONSIDERING ENVIRONMENTAL CONSTRAINTS

$Q_{cc,t}$	$Q_{1cc,t}$ (Base case)	$Q_{1cc,t}<Q_{2cc,t}$	$Q_{2cc,t}<Q_{3cc,t}$
Total cost	164	201	154
Number of strategy	4	5	5

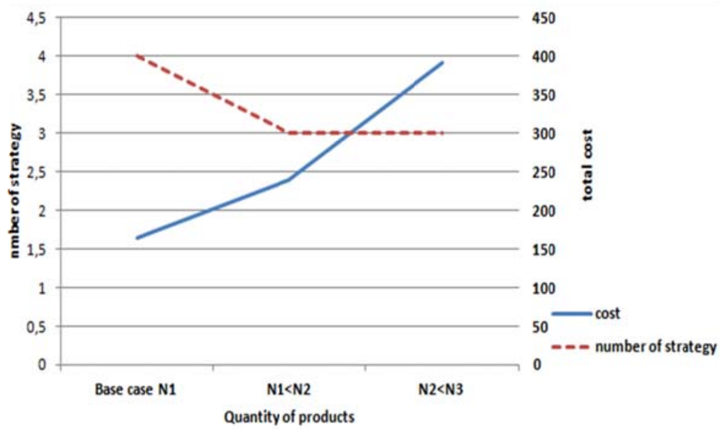

Fig. 5 Effect of quantity variation on the strategy number and total cost

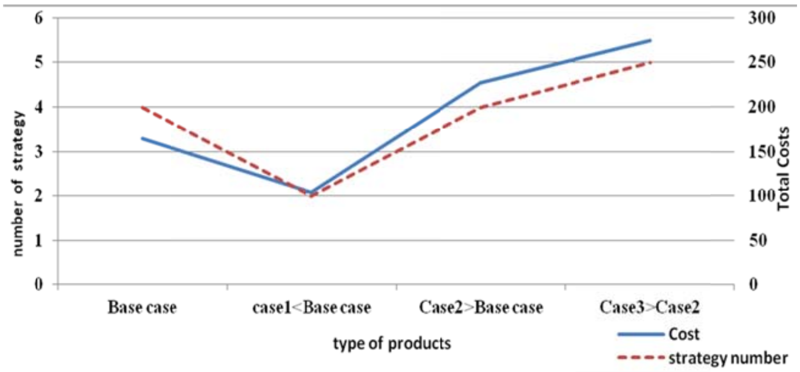

Fig. 6 Effect of products type variation on the strategy number and total cost

TABLE VI
RESULTS OF VARIATION CAPACITY OF RETURNED PRODUCTS WITHOUT CONSIDERING ENVIRONMENTAL CONSTRAINTS

Quantity of returned products	Base case N1	N1<N2	N2<N3
Total cost	164	240	392
Number of strategy	4	3	3

B. Proposed Model with Environmental Constraints

For a comparison purpose, we propose to analyze the effect of environmental constraint on the total cost and the structure network. In fact, environmental criterion is important for the reverse network study due to the responsibility of manufacturer to reduce the negative impacts of used products. The emission factor of CO2, from transport in supply chain, can have impact mainly on vehicle energy efficiency and on environmental performance. Many stakeholders can take measures to reduce CO2 emissions from freight transport in the supply chain. With this goal, we consider the environmental constraints to analyze the impact of reducing CO2 on design reverse supply chain. The result obtained is shown in Table VII. Due to the impact of environmental factor on the configuration of the network, the orientation products become more complex to find the ways that have emitted a minimum quantity of carbon. So, strategy number is automatically increases to 6 as shown in Fig. 7. In fact, warranty and obsolescence products are oriented to distinct directions. For example, warranty products are oriented to the collect center number 2, next, reprocessing centers 3 and finally recycling center. This way is guided if the quantity of products is less than 60 units. This type of returned product changes its direction where the quantity of returned products is equal or exceeds 60 units.

As a compared to warranty and obsolescent products, only damaged product direction is not oriented to different ways. We believe that when environmental factor is considered decision maker focuses on the short distance. Consequently, recovery strategy numbers are raises.

TABLE VI
RESULTS OF PROPOSED MODEL WITHOUT ENVIRONMENTAL CONSTRAINTS

Constraint	decision Variables	Runtime	Number of constraints	Objective value
297	325	1,08	105	2.0855001634e+003

Be aware of the different meanings of the homophones “a

TABLE V II
RESULTS OF VARIATION QUANTITY OF RETURNED PRODUCTS CONSIDERING ENVIRONMENTAL CONSTRAINTS

Quantity of returned products	Base case N1	N1<N2	N2<N3
Total cost	238	396	515
Number of strategy	6	5	6

Compared with the first analysis, environmental criteria have a significant impact on the total cost and strategy number, which means that transport factor, has an important effect in the design of reverse network. Quality of returned products brings out a significant change to design reverse network in both cases: considering or not the environmental constraints.

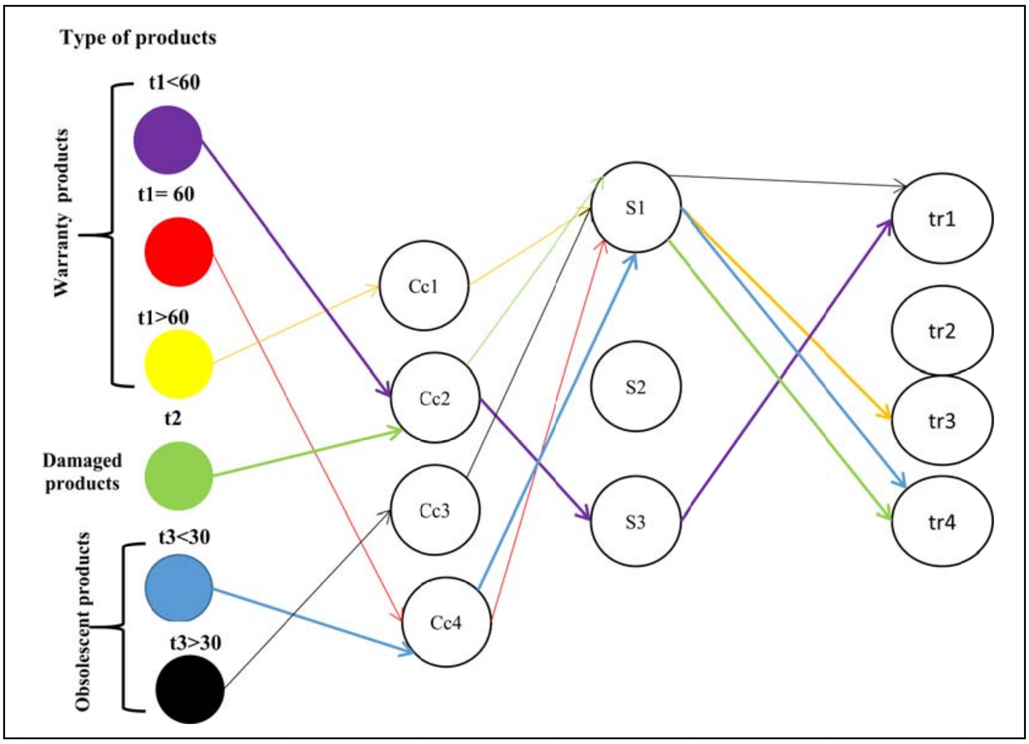

Fig. 7 Optimal Network structure considering environmental constraint

TABLE VII
RESULTS OF VARIATION CAPACITY OF RETURNED PRODUCTS CONSIDERING ENVIRONMENTAL CONSTRAINTS

$Q_{cc,t}$	$Q_{1cc,t}$ (Base case)	$Q_{1cc,t}$<$Q_{2cc,t}$	$Q_{2cc,t}$<$Q_{3cc,t}$
Total cost	238	144	104
Number of strategy	6	5	3

TABLE X
RESULTS OF VARIATION TYPE OF RETURNED PRODUCTS CONSIDERING ENVIRONMENTAL CONSTRAINTS

Type of products	Base case	case1<Base case	Case2>Base Case	Case3>Case2
Total Cost	238	152	317	407
Number of strategy	6	3	5	6

V. CONCLUSION

In this paper, we provide a new model for evaluating RLN performance considering multi-recovery alternatives and multi-type of products applied in open loop configuration. This configuration has complex flow to manage returned product to different ways. The major contribution is fourfold: (1) developing conceptual model, which describes the network structure of reverse logistics considering the characteristics of the real problem; (2) formulating a linear programming model to determine the recovery disposition of each product in minimum cost. We use CPLEX 7.5 solver which provide an optimal reverse configuration with minimum value; (3) identifying the most influential factor on the network design and cost value generated by the variation of capacity, quantity and state of returns; (4) analyzing the environmental impacts regarding the carbon emission constraint on the structure of network and total cost. The application of our performance model shows that the variation of product type is the most important factor in the network design decision and total cost. Also, transport carbon emission has a remarkable effect in the economic factor and on the returned products orientation. In our model, we do not consider the confecting objectives of different stockholders in reverse supply chain such as: customer satisfaction, quality of products, cost of recovery products, energy consumption cost … for recovery strategy decision. In a further work, we may extend our performance model to cover these aspects using real data.

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