A Goal Programming Approach for the Retrofit of Supply Chain Networks

Tânia Pinto-Varela[a,b], Ana Paula F. D. Barbosa-Póvoa[b] and Augusto Q. Novais[a]*

[a]UMOSE, LNEG-INETI, Lisboa, Portugal

(tania.pinto@lneg.pt; augusto.novais@lneg.pt)

[b]Centro de Estudos de Gestão, IST, Lisboa, Portugal

(apovoa@ist.utl.pt)

**Corresponding Author*

Abstract

In order to achieve sustainability, the design and planning of a supply chain has to fulfil economic, social and environmental objectives. Traditionally the design of supply chains has been based on economic objectives. As societal environment concerns grow, environmental aspects are also emerging, not only at the industry level, but also within the context of supply chain management. The investment towards logistics structures that consider both economic and environmental performance is nowadays an important research topic. However, much is still to be done.

This paper, addresses the retrofit of supply chain networks where planning aspects are also considered. The supply chain network design and planning is modeled through a Resource-Task-Network (RTN) methodology. A mixed integer linear programming (MILP) multi-objective approach is developed, which attempts to simultaneously maximize the annual profit of the supply chain, taking into account the network retrofit, while environmental impacts are minimized. The environmental impacts are accounted for through the Eco-indicator 99 methodology. Profit and environmental impacts are balanced through the use of goal programming. The model applicability is illustrated through the solution of an example.

Keywords: Planning, Design, Supply Chain, Environment, RTN.

1- Introduction

Sustainable Supply Chains can be seen as logistic structures that guarantee the production and distribution of products globally in an environmental friendly manner (Barbosa-Póvoa 2009). To achieve such goal, companies must invest on the design and planning optimization of their logistic structures, while accounting for the trade-off between profits and environment impacts. In spite of a considerable amount of research that has already been carried out on supply chain management, a new area exploring environmental aspects is now emerging.

In recent years there has been a growing awareness for the importance of incorporating environmental aspects along with the traditional economic indicators. This trend has been motivated by several issues, a major one being tighter governments regulations and customers' perception towards more environmentally conscious systems, which may eventually lead to higher product sales (Guillen-Gosalbez et al. 2009).

The simultaneous annual profit maximization and environmental impacts minimization requires a multi-objective approach. A way to deal with such problem is through the use of a goal programming (GP) approach, which can combine the optimization with the decision maker desire to satisfy several goals. Pati et al (2008) applied GP to a recycled paper distribution network. Three goals were pursued: reduction in reverse logistics cost; product quality improvement through increased segregation at the source; and environmental benefits through increased wastepaper recovery. In the following year, Melo et al. (2009) presented a survey, where the majority of cited works feature a cost minimization objective and noticed that very few refer to models using multiple and conflicting objectives, covering both profit and environmental aspects. More recently, the design of a sustainable supply chain network was studied by Chaabane et al. (2010). A multi-objective approach is used that denotes an emission trading scheme to achieve sustainability objectives in a cost-effective manner.

In this work the simultaneous optimal design and planning of a supply chain is investigated. A generic and uniform mathematical framework is developed which accounts for the design and retrofit (of the supply chain, while considering profit maximization together with minimization of environmental impacts. A GP formulation is used to deal with the multiple objectives involved.

The paper is structured along five sections. Section 1, the current one, gives a brief introduction to the work. In section 2 the model framework is characterized. Section 3 presents the problem characterization followed by section 4, which illustrates the model applicability. This paper concludes with final remarks and lines for future work.

2- Modelling framework

As stated above, the current problem uses three main methodologies, the Resource-Task-Network (RTN), the Life Cycle Analysis (LCA) and the Goal Programming (GP) Approach. Briefly the main concepts of these methodologies are described below.

a. Resource-Task-Network Methodology

RTN, presented by Pantelides (1994), is a general and conceptually simple representation methodology. Its main characteristics lie in the uniform description and characterization of the available resources, with no distinction between them, and on the

definition of tasks. A Task is an abstract operation that consumes and/or produces a specific set of Resources. Resources can be classified in: non renewable, which represents raw materials, utilities, manpower, etc., and renewable, which represents all types of equipment associated to the supply chain network (manufacturing, warehouse, distribution centre, transportation, technology, etc). Each task *k* has a fixed duration τ_k and the execution of task *k* starting at time *t* is characterized by the pair of variables (N_{kt}, ξ_{kt}). N_{kt} is an integer variable while ξ_{kt} is continuous. These variables define respectively the number of instances of task *k* starting simultaneously at time *t*, and the total amount of resource being processed by all these instances. The amount of resource type *r* produced at time θ relative to the start of task *k* at time *t* is given by:

$$\mu_{kr\theta} N_{k,t-\theta} + \nu_{kr\theta} \xi_{k,t-\theta} \tag{1}$$

where $\mu_{kr\theta}$ and $\nu_{kr\theta}$, θ = 0,..., τ_k are known constants. Negative values for the latter indicate consumption of the resource, while positive values denote production. These coefficients allow the modeling of different type of tasks such as those with time-dependent manpower or utility requirements, as well as those that involve transformations from raw materials to products using a process facility. In terms of resources, changes on their utilization can only occur at interval boundaries. The variable R_{rt} denotes the amount of excess resource *r* over time interval *t* (e.g. the amount that is not involved in the tasks that are active over this time interval). The change in the excess resource level for each resource type from one time interval to the next is given by excess resource balance constraints that will be defined later on.

b. Life Cycle Analysis

LCA can be described as a quantitative framework for considering the environmental impacts associated with every stage in the life cycle of a product, from raw materials production to final disposal. Based on this, the Eco-indicator methodology appears as a powerful tool for designers to aggregate LCA results into easily understandable and user-friendly quantitative units (Ministry of Housing et al. 2000). The Eco-indicator 99 introduces a damage function approach that represents the relation between the impact and the damage to human health, resource and ecosystem. Such methodology involves three main steps: (1) inventory of all relevant emissions, resource extractions and land-use in all processes that form the life cycle of a product, (2) calculation of the damages that these emissions flow cause on the Human Health, Ecosystem Quality and Resources and (3) weighting these damage categories. The set of weights used, noted by Pt (it reads Points), results from the contributions of all types of damage. Those weights

were defined using a social study (PRéConsultants 2001) measuring the social sensibility to each type of damage for population samples representative of three cultural perspectives: equalitarian, hierarchical and individualistic. Furthermore, due to the small dimension of the social panel used in that particular study, all subsequent work uses a set of mean weights, which are: 40% for both Human Health and Ecosystem, with the remaining 20% assigned to Resources.

c. Multi-Objective Optimization

The design and planning of a supply chain taking into account environmental impacts is obtained through the solution of a deterministic MILP formulation (Pinto-Varela et al. 2011), which is extended in this paper with the application of a GP approach.

The model developed considers the following sets, parameters and variables:

Sets:

C= {r: set of all non-renewable resources}
C_r={r: set of material resources storable in dedicated warehouse/distribution centers}
C_p / C_f = {r: set of final products /raw materials}
D={d :set of damages}
E={p:set of pollutants emitted}
F ={f:set of facilities}
L={p:set of pollutants from land use}
N={p:set of pollutants from natural resources extraction}
T_P={k: set of technological processes(tasks) in an resource technology, r}
T_v={k: set of technological processes(tasks) in an dedicated warehouse and distribution centers }

T_T ={k: set of all technological processes associated to connection between two entities}
T_r^f ={r: set of all resources technologies that may be installed in facility f}
U={u: set of utilities}
W_r={r: set of all resources renewable}
W_{fp}/W_{rm}={r $\in$ W: set of dedicated warehouse and distribution centers for final products/raw materials}
W_v={r $\in$ W: set of dedicated warehouse and distribution centers}
W_c ={r $\in$ W: set of all connections between entities}
W_p={r $\in$ W: set of resource technologies}

Parameters:

CC_r^0 *-fixed cost associated to the supply chain resources*
CC_r^1*- variable cost associated to the supply chain resource*
CC_r^s *- variable cost of material storage*
CCF - capital charge factor
F^f - maximum amount of resource technologies available in facility f
H - planning horizon per year
HourYr – number of hours per
$NormF_g$ *- weighted value of the damages g*
$Q_r^{\min}/Q_r^{\max}$*- min/max capacity available for resource r*
$R_r^{\min}/R_r^{\max}$ *- the minimum/maximum demand of the resource at H*
Km_r- distance between two entities
v_r */p_r - price of resource (raw material / product)*
α_k^0/α_k^1 *- fixed and variable cost coefficients for techonogical processes*

$\alpha_{ur}^{WD}/\beta_{ur}^{WD}$*- fixed and variable utility cost coefficients for dedicated warehouse and distribution center*
$\mu_{kr\theta}/\nu_{kr\theta}$ *- consumption /production of a renewable(-1,1)/non-renewable(-1,0) resource r, at the start/end of θ*
$\phi_r^{\max}$ *- resource techonogy size factor*
$\phi_r^{\min}$ *- resource techonogy size factor*
$\Omega_{u,p}$*- quantity of pollutant emitted to generate an unit of utility u consumed*
η_u *- amount of diesel consumed* m^3/km
ς_{dp} *- impact factor coeficient*
λ_{pr} *- defines the quantity of pollutants p, emitted per unit mass of resource r used*
λ_{pf} *- defines the quantity of pollutants p, emitted to soil occupation/transformation*
λ_{pu} *- defines the quantity of pollutant p, emitted per unit of utility u consumed*

$\alpha_{uk}^{F} / \beta_{uk}^{F}$ *- fixed and variable utility coefficients for the techonological process*

Variables:

DR^u- direct costs associated to the utilities consumption

Dam_d^{SC} - set of damages

Eco99- environmental indicator

P_{rt} - amount of material delivered from the resource technology r in instant t

Q_r - capacity of resource technology r

QR_p=quantity of pollutant emitted from natural resources

QL_p-quantity of pollutants emitted from the land use

QE_p- quantity of pollutants emitted from the emissions

DR- direct costs

Q_p^{Utotal} - total amount of pollutants emitted

R_{rt} - excess of resource at t

R_{r0} - level of resource provisions necessary

UT_u- total amount of utility consumed

ξ_{kt} - production/storage size of technological process k at time t

N_{kt} – technological process selection k at instant t

y_r -1 if resource technology r is used; 0 otherwise

y^f - 1 if the facility is opened; 0 otherwise

PR-operational revenues

OCI-Indirect cost

The model evaluates two criteria, the environmental impact defined in equation (2) and annual profit in equation (3), followed by a sets of constraints from equation (4) to (25), showed below:

$$Eco99 = \sum_g NormF_g Dam_g^{SC} \tag{2}$$

$$Profit = (PR - DR) \times \frac{HourYr}{H} - OCI \times CCF \tag{3}$$

The Design and planning model of supply chain:

Excess resource technology balance: the mass balance for each resource technology must be satisfied at every instant *t*.

$$R_{rt} = R_{r_0|t=1} + R_{r,t-1|t\geq 2} + \sum_k \sum_{\theta=0}^{\tau_k} (\mu_{kr\theta} N_{k,t-\theta} + \upsilon_{kr\theta} \xi_{k,t-\theta}) + P_{rt} \quad \forall r \in W_p \; t = 1...H+1 \tag{4}$$

Operational Constraints are based on the following rules: at any one time each resource technology is either idle or being used by a technological process (task) that cannot be pre-empted once started. This can be modelled by:

$$\sum_{t'=t-\tau_k+1}^{H} \sum_{k \in T_r} N_{kt'} \leq y_r \qquad \forall\, r \in W_p \tag{5}$$

The amount of material being processed through a technological process, *k*, in resource *r* must always be within the maximum and minimum capacity available of the resource technology:

$$\phi_{kr}^{\min} Q_r N_{kt} \leq \xi_{kt} \leq \phi_{kr}^{\max} Q_r N_{kt} \qquad \forall\, k \in T_p,\, r \in C,\, t = 1...H \tag{6}$$

The previous equation is replaced by the equation (8) after the linearization.

$$\phi_{kr}^{\min} \sum_{j=1}^{N_k^{\max}} j\, \tilde{Q}_{rjkt} \leq \xi_{kt} \leq \phi_{kr}^{\max} \sum_{j=1}^{N_k^{\max}} j\, \tilde{Q}_{rjkt} \qquad \forall\, k \in T_p,\, r \in W_p,\, t=1...H \tag{7}$$

For simplicity, a detailed explanation of the linearization is omitted, but the equations are showed. A more detailed information is presented in Pinto-Varela et al. (2011).

$$N_{kt} = \sum_{j=1}^{N_k^{\max}} j\,\tilde{N}_{jkt} \qquad \forall\ k \in T_p,\ t=1...H \qquad (8)$$

$$\sum_{j=0}^{N_k^{\max}} \tilde{N}_{jkt} \le 1 \qquad \forall\ k \in T_p,\ t=1...H \qquad (9)$$

$$Q_r^{\min}\tilde{N}_{jkt} \le \tilde{Q}_{rjkt} \le Q_r^{\max}\tilde{N}_{jkt} \qquad \forall\ k \in T_p,\ r \in W_p,\ j=1...N_k^{max},\ t=1...H \qquad (10)$$

$$\sum_{j=0}^{N_k^{\max}} \tilde{Q}_{rjkt} = Q_r \qquad \forall\ k \in T_p,\ r \in W_p,\ t=1...H \qquad (11)$$

Resource technology capacity and design constraints:

$$Q_r^{\min} y_r \le Q_r \le Q_r^{\max} y_r \qquad \forall\ r \in W_p \qquad (12)$$

Dedicated warehouse/distribution centre capacity and design constraints:

$$R_{rt} \le \phi_r^{\max} Q_r \qquad \forall\ r \in W_v,\ k \in T_V,\ t=1...H+1 \qquad (13)$$

$$Q_r^{\min} y_r \le Q_r \le Q_r^{\max} y_r \qquad \forall\ r \in W_v \qquad (14)$$

Transport constraints:

$$\xi_{kt} \le \phi_{kr}^{\max} Q_r \qquad \forall\ k \in T_T,\ r \in W_c \qquad (15)$$

$$Q_r^{\min} y_r \le Q_r \le Q_r^{\max} y_r \qquad \forall\ r \in W_c \qquad (16)$$

Market demand constraints: the model allows the possibility, as part of the supply chain design problem, of optimizing its design taking into account the trade-off between its total cost and the added value of satisfying demand over the planning horizon *H*, together with the global environmental impact.

$$R_r^{\min} \le R_{rt} \le R_r^{\max} \qquad \forall\ r \in C_p,\ t=1,...,H+1 \qquad (17)$$

Supply Chain Facilities Design: The choice of a certain facility is defined by the choice of any of the technological resources associated to it:

$$y^f \ge \sum_{r \in T_r^f} y_r \qquad \forall\ f \in F \qquad (18)$$

Life Cycle Analysis constraints:

The utilities consumptions are defined by equation (20), which is used to obtain the emission inventory (equation (21)), followed by land and resource inventory in equation (22) and (23), respectively.

$$UT_u = \sum_t \sum_{k\in T_p} \sum_{\theta}^{\tau_k} \left(\alpha^F_{uk} N_{kt-\theta} + \beta^F_{uk}\xi_{kt-\theta}\right) + \sum_{r\in W_v} \alpha^{WD}_{ur} y_r + \sum_t \sum_{r\in W_v} \beta^{WD}_{ur} R_{rt} \qquad \forall\ u \in U \qquad (19)$$

$$QE_p = \sum_u \Omega_{u\,p} \left(UT_u + \eta_u \sum_{r\in W_c} Km_r y_r \right) \qquad \forall\ p \in E \qquad (20)$$

$$QL_p = \sum_f \lambda_{pf} y^f \qquad \forall\ p \in L \qquad (21)$$

$$QR_p = \sum_{r\in C_f} \lambda_{pr} \left(R_{r_0} - R_{rt|t=1+H} \right) + \sum_u \lambda_{pu} UT_u \qquad \forall\ p \in N \qquad (22)$$

The total pollutant inventory and the environmental impact are expressed by the equation (24) and equation (25) respectively:

$$Q_p^{Utotal} = QE_p + QL_p + QR_p \qquad \forall\ p \qquad (23)$$

$$Dam_d^{SC} = \sum_p \varsigma_{dp} Q_p^{Utotal} \qquad \forall\ d \in D \qquad (24)$$

Taking into account the previous constraints, the objective functions ((2) and (3)) become soft constraints specifying the requirements that are desirable to verify. The deviational variables d_i are added to the model, because there may be no solution that simultaneously achieves the desire levels of all soft constraints. The model presented can be stated for the GP approach as:

$$\begin{aligned}
&Min \quad d_1 + d_2 \\
&s.t. \\
&\qquad Profit + d_1 \ge t_1 \quad (z_1 \succ t_1) \\
&\qquad Eco - d_2 \le t_2 \quad (z_2 \prec t_2) \\
&\qquad g_j(x) \le 0 \qquad j = 1, 2, ...J; \\
&\qquad h_k(x) = 0 \qquad k = 1, 2, ..., K; \\
&\qquad x_i^{(L)} \le x_i \le x_i^{(U)} \ \ i = 1, 2, ..., n.
\end{aligned} \qquad (25)$$

Since the two objectives are defined in different units with different magnitude, the equalization of the criterion value over the efficient set is used. Each objective function is then multiplied by its representative *range equalization factor*.

$$\pi_i = \left(\frac{1}{Z_i}\right)\left[\sum_{j=1}^{k} \frac{1}{Z_j}\right]^{-1} \qquad (26)$$

where Z_i is the range width of the *i th* criterion value over the efficient set.

3- Problem statement

Summarising and assuming a uniform discretization of time, the problem in study can be stated as follows. *Given*: a fixed time horizon, set of products, markets in which products are available to customers and their nominal demand; a set of geographical sites for locating facilities, warehouse and distribution centres; a set of technologies for product manufacturing; the lower and upper bounds for the capacity of facilities, warehouse and distribution centres; the RTN representation for the product recipes; the suppliers capacity; the fixed and variable costs associated to the setting up of facilities, warehouse, distribution centres, the materials transportation and operational costs; price for every product in each market and raw-material costs; diesel and electricity consumptions; all the necessary environmental specifications and parameters.

Determine: the facilities to be opened; the technologies to be selected at each production facility; warehouse and distribution centres capacity; the amount of final products to be sold in different markets and the flow of materials to be transported.

So as to balance the maximization of the supply chain profit, while simultaneously considering the environmental impact minimization.

4- Illustrative Example

An illustrative example based on a real case from a pulp and paper industry is studied. All the presented data were modified due to confidentiality reasons.

Two cases are used to show the applicability of the proposed model. Case a) that corresponds to the optimization of the operating conditions of the current supply chain, where the maximization of the profit is obtained for the available facilities, not taking into account environmental aspects. Case b) employs the GP approach to investigate alternative strategic targets, taking case a) as a reference.

Both cases were solved for an optimality margin of 5%. A Pentium Intel Core 2 Quad, 3.0 GHz and 3.5 GB RAM, and the GAMS 21.3 software package with the CPLEX (v 11.0) solver was employed.

The current supply chain operates with two production sites (A and B). Based on their technological characteristics, a prospective acquisition of more modern multipurpose technologies is to be analysed for site B, aiming at the reduction of the associated environmental impact. However, since new investment is required, a set of conditions were predefined namely, site A facility must produce at least 10 tonnes of each final product per year, maintaining the characteristics already defined related with the

technological resource suitability, variable not only production capacity but also annual production in the facility and two new targets must be evaluated (1) an increase around 20% of profit and (2) a decrease of 10% in the environmental impact. Based on these conditions a viability study analysis was made.

Sites' Facilities characteristics

The paper industry has two facilities respectively installed in Site A and Site B. Each one of these production sites has three parallel multipurpose technological resources (MP1, MP2 and MP3) available to produce 12 types of different products. MP1 produces six final products (P1 to P6) and MP2 and MP3 three final products each (P7 to P9 and P10 to P12, respectively). All the production is exported to the international market, mainly in Central Europe. The technological resources suitability remains unchanged, as well as the annual production range of site A. Site B may install a new technology that is able to increase 50 % of its annual production.

In Table 1 the capacity associated to the facilities technologies is characterized and it is showed that the maximum capacity available in site A remains constant from case a) to case b). In Table 2 is showed the demand for each market, where there is a dedicated distribution centre (DC).

Table 1– Facilities suitability technological resources and capacities.

		Capacity (min:max Tonnes)	
Facilities	Technological Process	Case (a)	Case (b)
Site A	MP1	0:85	0:85
	MP2	0:45	0:45
	MP3	0:25	0:25
Site B	MP1	0:65	0:130
	MP2	0:25	0:50
	MP3	0:25	0:50

Table 2 – Product annual demand by each market.

		Demand for each product (min :max Tonnes)	
Product	Market	Case (a)	Case (b)
P1-P6	M1	0:200	10:300
	M2	0:260	10:390
P7-P9	M3	0:200	10:300
	M4	0:140	10:210
P10-P12	M5	0:100	10:150
	M6	0:80	10:120

In terms of environment, not only the electricity consumption associated to the technological resource (MPi) is quantified, but also the material transportation

environmental impact, namely in terms of CO2, NOx and SOx emissions. The corresponding emitted values per utility consumption (equations 20-24) are given in Table 3.

Table 3- Pollutants emitted per utility consumption (Duque et al. 2010).

Utility	CO	CO2	NOx	SOx	Units
Diesel	14.828	2609.5	34.6	-	Kg/m3
Electricity	4.151e-3	7.306e-1	1.941e-3	3.872e-3	Kg/kwh

The transportation costs are dependent on the geographical distance between the locations involved and quantities transported. It was assumed full truck load freights and an average speed of 80 km/h.

In this work the environmental analysis is focused on the Human Health (HH) damage and Table 4 presents it reflecting the respiratory effects of the inorganic substances emitted by the utilities consumption (equation 25).

Table 4- Damage to Human Health (Geodkoop et al. 2001).

Damage	CO	CO2	NOx	SOx
Human Health (DALYs/kg emission)	-	7.5e-4	8.74e-5	5.35e-5

The results from the two cases are showed in Table 5. In case (a) the site A facility presents a higher production than site B, providing all products for central European markets, while site B does not supply markets M2 and M4. In case (b) and site B, where retrofit is possible, the use of better performing technologies leads to an increase in production, leaving the production for some products at site A, at the level imposed by the board. In both facilities all the technological resources are used. The retrofit of site B allows an increase in production around 36 %.

Table 6 shows the values of profit and environmental impact for each case. Case (b), due to the retrofit in site B, allows an increase of 42% in profit when compared to case (a) and exceeds by 28.9% the board target. On the other hand, it presents a reduction of 21.4% in the environmental impact when compared with case (a). While this represents a 9.3% drop, it is slightly below the board target of 10%. An adjustment to the latter target could be sought, but it is considered satisfactory in terms of the broad goals set by the board.

In case (a) the solution was reached in 1.8 s, with 9784 constraints and 2 679 binary variables in a total of 7 660. Case (b) is characterised by 9787 constraints, 2 679 discrete variables in a total of 7 663 and solution reached in 1.3 s.

Table 5–Warehouse/DC sites, products produced in each facility and respective flows.

		Case a (Tonnes)			Case b (Tonnes)		
	Products	Site A	Site B	Total	Site A	Site B	Total
DC-M1	P1	85	100	185	75	195	270
	P2	85	65	150	75	200	275
	P3	85	100	185	75	185	260
	P4	85	100	185	75	195	270
	P5	85	100	185	75	195	270
	P6	85	100	185	85	195	280
DC-M2	P1	-	-	-	10	190	200
	P2	85	-	85	10	190	200
	P3	85	-	85	10	10	20
	P4	85	-	85	10	190	200
	P5	130	-	130	10	190	200
	P6	-	-	-	10	190	200
DC-M3	P7	100	100	200	10	160	170
	P8	90	75	165	45	160	205
	P9	90	100	190	10	85	95
DC-M4	P7	70	-	70	35	140	175
	P8	70	-	70	45	140	185
	P9	45	-	45	35	140	175
DC-M5	P10	50	50	100	15	100	115
	P11	50	50	100	15	100	115
	P12	50	50	100	15	100	115
DC-M6	P10	25	40	65	10	75	85
	P11	40	20	60	10	75	85
	P12	40	40	80	10	75	85

Table 6- Profit and environmental results.

	Case a)	Target	Case b)	Units
Profit	4e9	4.9e9	6.9 e9	m.u.
Eco 99	86055	77452	70847	mPt

The warehouse and distribution centres design for both networks are showed in Table 7.

Table 7- Warehouse and distribution centre design.

	Warehouse/DC design (Tonnes)	
	Case a	Case b
DC_M1	1075	1625
DC_M2	385	1020
DC_M3	555	470
DC_M4	185	535
DC_M5	300	345
DC_M6	205	255

5- Conclusions

In this paper the design and retrofit of supply chains is studied while accounting simultaneously for profit maximization and environmental impacts minimization. The mathematical formulation incorporates three methodologies, Resource-Task-Network used to define the supply chain characteristics with no ambiguity, Eco-indicator 99,

which quantifies the environmental aspects and Goal Programming approach that deals with the multi-objective characteristics of the problem.

The goal programming approach allows a multi-objective problem to be represented in a very simple way, which is an approach that might be expected to become more attractive as the number of targets increases.

An illustrative example based on a real case study was presented where the retrofit of an existing supply chain is optimized taken into account not only economic and environmental aspects, but also administration board's strategies. These consist of two defined targets employed when analysing the retrofit of the existing supply chain.

As future work a more detailed analysis of the quantification of the environmental impacts will be considered, as well as other methods to deal with the multi-objective characteristics of the problem.

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