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ORIGINAL RESEARCH PAPER

Optimization of goods relocation in urban store networks with an incentive strategy

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Abstract

Nowadays, goods are relocated daily among urban fashion stores by van or truck. This relocation activity generates externalities in urban areas that cause deterioration in the quality of life of their citizens. Innovative strategies based on a sharing approach promise solutions to reduce the use of heavy, polluting vehicles and therefore the related externalities in urban areas. The authors aim to optimise the relocation activity of city fashion stores through a customer-involved incentive mechanism. The method provides store shopping vouchers to loyal customers as a reward for package delivery from one shop to another. If no customers agree to participate in the delivery game, company relocation staff will perform the delivery service. The benefit of the proposed delivery game is twofold—it increases customer loyalty and reduces the externalities produced by heavy vehicles moving through the city. To this end, two integer linear programming problems are formalised to optimise goods relocation activity with package deliveries (1) by company staff only and (2) by loyal customers in an incentive game. A simulation case study is presented to show the application of the methodology in fashion stores.

1 | INTRODUCTION

Globalisation and online markets have generated increased logistics activities, especially freight transport in urban areas [1]. Some sectors, and the fashion sector in particular, have experienced increased sales revenue as a result of the reduced production costs of manufacturing their products in developing countries and the evolution of more efficient logistics services.

Human activities generate positive and negative impacts [2]; these negative impacts are also defined as externalities. The transport sector is one of the main industries responsible for externalities [3], especially in urban areas where there are large numbers of citizens and vehicles [4].

The European Union's definition of an external cost, also known as an externality, is a cost arising 'when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group' [5]. The main externalities caused by the transport sector can be classified as follows: (a) air pollution, (b) congestion, (c) accidents, (d) noise pollution, (e) land use, and (f) oil dependence [6–9]. The European Commission has underlined the need to charge logistics operators for the external costs they generate (internalisation of external costs) since 1999 [10], and various internalisation strategies have been proposed in [11]. Nowadays, however, the responses to address logistic externalities are often limited to extra-urban transport.

In addition, crowdsourcing is an open IT-enabled innovation. Open innovation is considered by [12,13] as a paradigm in which organisations systematically look for outside ideas relevant to their internal problems or external ways to market their own ideas. According to [14,15], crowdsourcing is defined as a process in which an organization outsources tasks to a crowd of external individuals that have traditionally been performed by the organization's members. Another crowdsourcing definition, by [16], is based on a review of over 200 definitions and proposes a type of participative online activity in which an individual, an institution, a non-profit organization or a company proposes the voluntary undertaking of a task via a flexible open call to a group of individuals of varying knowledge, heterogeneity and number.

In recent years, networks of stores selling the same brands have opened in many cities, providing their customers with the same items—for instance, within the fashion sector [17]. Very often in the same city, the same brand will have multiple shops,

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with some of them too small to stock all the items that can be found in the brand's larger stores. Fashion companies normally use their larger stores as hubs to supply other stores with missing items.

When some stores lack certain products, some goods must be moved from one store to another; this relocation activity can be performed as a daily activity. In this way it is possible to improve customer satisfaction by providing an additional service. Therefore, company vans and trucks are often used to carry out the logistics service for goods relocation.

Goods relocation among city stores can generate several transport externalities in urban areas.

The literature proposes several solutions to reduce such externalities [18], mainly related to the use of more ecological vehicles, such as electric vehicles, hybrid electric vehicles, fuel cell electric vehicles [19–24], or to innovative methods and strategies, both in warehouse activities [25,26] and in freight transport [27–29] as well as in last-mile delivery, such as collaborative and cooperative urban logistics [30,31], optimization of transport management and routing [32,33], and proximity stations [34,35], with the common aim of achieving a smart city vision [36–38]. Few works regarding goods relocation involving users are present in literature and most of the works focus on personal mobility. In this context, the proposed approaches can be categorised as exact approaches and heuristic approaches. In the first case, the main advantage is related to the quality of the optimal solution, while the disadvantage is the numerical complexity, which can become very large depending on the number of variables and parameters of the problem. In the second case, the advantage is in the simplification of the problem and the speed of calculation, yet this allows only for a suboptimal rather than optimal solution. Among the heuristics, the agent-based approach [39] is quite interesting because it allows evaluation of the interactions among agents in order to model agent behaviour in the context of decisions, especially in the case of high-dimension problems with a large number of interactions. The specific approach used here is based on integer linear programming (ILP) because the number of variables and parameters is not so high.

In particular, the proposed approach presented here is based on a crowdsourcing paradigm that involves loyal customers in a delivery game through rewards [40] in the form of a discount to purchase goods within a store network.

The aim is to model an innovative relocation method based on an incentive system implemented with an interactive assignment algorithm that allows customers to play the delivery game. The proposed approach can be implemented through an IT application available to customers that provides information about relocation needs as well as the prizes to be awarded when the relocation game is played correctly. The process of goods relocation is modelled by two ILP problems to minimise relocation costs: the first ILP performs relocation activity by using the company staff; the second ILP performs relocation activity with the involvement of loyal customers.

Furthermore, to demonstrate the applicability and effectiveness of the proposed approach, a simulation case study about fashion stores is presented.

The paper is organised in five sections. The problem of goods relocation for city stores is presented in Section 2. Section 3 describes an optimization approach to solve the goods relocation problem. Section 4 proposes a simulation case study and the potential benefits of the proposed approach to the goods relocation in city fashion stores with incentive for loyal customers. Finally, conclusions and future works are discussed in Section 5.

2 | GOODS RELOCATION PROBLEM FOR A NETWORK OF STORES WITHIN AN URBAN AREA

The existence of networks of stores selling the same brands in an urban context allows for the quick movement of goods when needed, even within a short period. Relocation requests can occur for several reasons, such as the need for missing items, sizes, and colours as well as limited-edition goods only available in some stores.

In this context, an additional and efficient sales service has been provided to customers to increase their satisfaction and ensure greater and faster availability of products. Therefore, the management of goods relocation is an important daily activity for stores. Companies use vans and trucks to relocate goods from one shop to another, and in many cases, the vehicles used are heavy and generate pollution.

New concepts of transport have been proposed in the literature [41,42]. In urban mobility, the Mobility as a Service vision has been proposed, while in freight transport, the concept of Logistics as a Service is spreading, especially for delivery activities in urban areas.

Additionally, the incentive system approach to engage customers in wasteful activities is used in different fields including the mobility sector [43–46].

In this context, an innovative method is modelled for relocating goods among stores in the same retail network within a city by involving loyal customers through an incentive mechanism.

The method's goal is to reduce the externalities caused by relocation transport activity in urban areas, the costs for the company and the involvement and engagement of customers in the delivery game through an incentive system. In this case, loyal customers of a brand share their resources (time, vehicle etc.) in the relocation process with benefits accruing to both the company and its customers.

Loyal customers are recruited by offering prizes in the form of vouchers to buy items in stores as a reward for delivering packages from one store to another.

The idea to involve only loyal customers in goods relocation activity is based on the need to avoid delivery problems and preserve product integrity. This choice to involve only loyal customers better meets that need because the company already has extensive information about such customers. If problems arise during a relocation activity performed by a customer, such as lost or damaged packages, the value of the goods can be charged directly to the customer involved, and

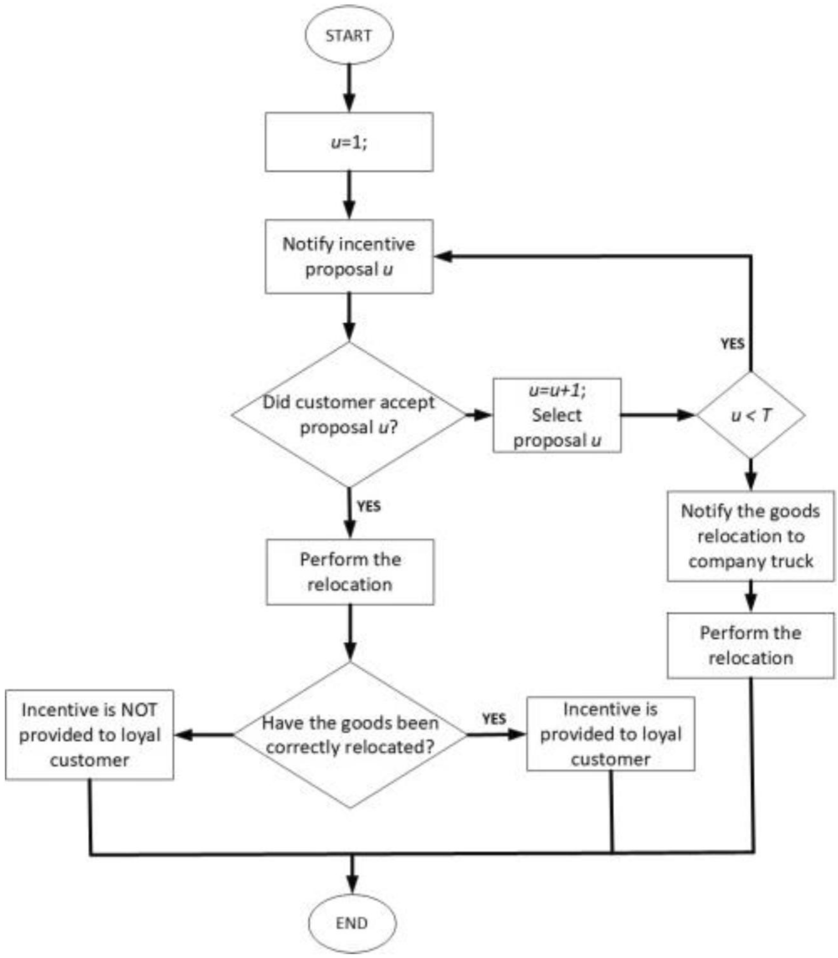

FIGURE 1 Incentive strategy algorithm

that customer can be removed from the list of loyal customers.

The goods relocation procedure is shown in Figure 1. First, an incentive bid is made to all loyal customers who want to take part in goods relocation activities. At this stage, two options are available: (1) at least one loyal customer accepts the incentive proposal, picking up goods from one store, delivering them to another and receiving a reward when the relocation activity is completed (the reward can be uploaded to the customer's online account in the form of a voucher to buy goods in stores); if more than one loyal customer accepts the proposal, the algorithm will choose the first one who has accepted); (2) no user accepts to take part in the delivery game with the proposed incentive, and a new notification is broadcast to all users with an increased incentive bid. Step 2 can be repeated several times based on the incentive levels designed by the company (e.g. the company proposes two incentive levels, so step 2 can be performed two times at most). After that, if no loyal customer accepts the incentive proposal, the company will have its relocation staff use vans and trucks to carry out the relocation service.

The proposed incentive mechanism allows for a reduction in goods relocation costs. The set of incentive proposals (levels) is $\mathscr{U} \in \mathbb{Z}^+$, with cardinality $|\mathscr{U}|$. The incentive levels designed by the company are $u \in \mathscr{U}$, $u = 1, \ldots, |\mathscr{U}| - 1$. In addition, the last element of $\mathscr{U}$ does not represent an incentive proposal for customers but instead indicates that company staff carry out the relocation activity with vans or trucks.

3 | OPTIMIZATION APPROACH FOR GOODS RELOCATION

This section presents the optimization approach to solving the goods relocation problem for a store network in an urban area. In the proposed framework, two optimization models are designed to minimise relocation costs for the case in which relocation is performed solely by company staff and the case in which loyal customers are involved. The optimization models are formulated under the following assumptions:

- The relocation cost for company staff is variable only and not fixed, and it is proportional to the distance between stores based on a predefined destination–source matrix.
- External costs are related to air pollution, accidents, congestion, climate change and noise pollution as reported in [2]. The values considered are those for a light commercial vehicle (LCV) in the case of company staff and a car in the case of a loyal customer.

- Company staff have enough vehicles available to perform relocation between the stores.
- The number of daily relocations does not change regardless of whether they are performed by company staff or by loyal customers.
- The relocation process between stores uses the shortest route, and therefore relocation cost, which is linked to distance travelled, is calculated based on the length of the trips between the different stores.
- The load-capacity constraint is the number of goods a vehicle can load. Load capacity is in terms of a van or truck for company staff vehicles and a car for loyal customers. The relocation is allowed if the vehicle has a load factor equal to or greater than the sum of the goods to be picked up at that store. The load capacities of the cars of loyal customers are categorized by incentive level.
- All goods have the same dimensions when calculating the load-capacity constraint.

Note that no distance constraint is considered because the customer knows the locations of the departure and arrival stores in advance and can decide whether relocation can be performed based on distance.

3.1 | Goods relocation problem for company staff

In this section, the goods relocation problem is formulated as an ILP problem that aims to minimise the cost of relocations performed by company staff.

Let us define the following sets: $\mathscr{I} \in \mathbb{Z}^+$, set of stores with cardinality $|\mathscr{I}|$; $\mathscr{T} \in \mathbb{Z}^+$, set of types of goods in the store, with cardinality $|\mathscr{T}|$, $\mathscr{K} \in \mathbb{Z}^+$, set of goods in the store of each type, with cardinality $|\mathscr{K}|$, and $\mathscr{V} \in \mathbb{Z}^+$, set of vehicles with a defined goods load capacity, with cardinality $|\mathscr{V}|$. In addition, the goods relocation cost is known thanks to past trips performed by company staff and the calculated distances between stores.

Therefore, the following parameters are introduced to describe the model:

- $I = \{i,j = 1,\ldots,S\}$, set of S stores
- $T = \{k = 1,\ldots,T\}$, set of the available types of goods
- $K = \{k = 1,\ldots,K\}$, set of K goods of each type
- $V = \{v = 1,\ldots,V\}$, set of V vehicles
- $D_{i,j}$ is the distance between store i and store j [km].
- c is the cost per kilometre for the relocation activity [€/km].
- e is the external cost per kilometre for the relocation task [€/km].
- $\hat{s}_j^t$ is the number of goods of the *k-th* type in store j before the relocation process.
- s_j^t is the number of goods of the *k-th* type in store j after the relocation process.
- $N_{min}^t \in \mathbb{Z}^+$ is the minimum number of goods of the *k-th* type in each store required by the company.
- $N_i^t \in \mathbb{Z}^+$ is the number of goods of the *k-th* type required by store j [unit].
- LF_v is the load factor of company staff vehicles v [unit].

The binary decision variables are $x^t_{i,j,k,v}$, $\forall\, i,j \in \mathscr{I}$, $\forall\, k \in \mathscr{K}, \forall\, t \in \mathscr{T}, \forall\, v \in \mathscr{V}$, where the pick-up store is labelled i, the receiving store is labelled j and the vehicle is labelled v. If $x^t_{i,j,k,v} = 1$, then the relocation of goods k of type t is performed from store i to store j by vehicle v; otherwise, $x^t_{i,j,k,v} = 0$. Moreover, $Y_{i,j,v}$, $\forall\, i,j \in \mathscr{I}$, $\forall\, v \in \mathscr{V}$ represents the package of goods for type $x^t_{i,j,k,v}$ to be relocated from store i to store j by vehicle v. $Y_{i,j,v} = 1$ means that the goods package is relocated from store i to store j; otherwise, $Y_{i,j,v} = 0$. The introduction of $Y_{i,j,v}$ is necessary to linearise the problem.

The integer variables are s_j, $\forall\, j \in \mathscr{I}$, representing the number of goods that have been relocated to each store when the relocation process has been completed.

Moreover, the objective of the optimization problem is the total relocation cost (TRC) as follows:

$$TRC = (c+e) \cdot \sum_{i=1}^{|I|} \sum_{j=1, i\neq j}^{|I|} \sum_{v=1}^{|V|} D_{i,j} \cdot Y_{i,j,v} \tag{1}$$

ILP1, which formalises the described problem, is formulated as follows:

$$\min TRC$$

s.t.

$$t \cdot k \cdot Y_{i,j,v} \geq \sum_{t=1}^{|T|} \sum_{k=1}^{|K|} x^t_{i,j,k,v}, \forall i,j \in I, \forall v \in V \tag{2}$$

$$s^t{}_j = \hat{s}^t{}_j + \sum_{i=1}^{|I|} \sum_{v=1}^{|V|} \sum_{k=1}^{|K|} x^t_{i,j,k,v} - \sum_{i=1}^{|I|} \sum_{v=1}^{|V|} \sum_{k=1}^{|K|} x^t_{j,i,k,v}, \forall j \in I, \forall t \in T \tag{3}$$

$$s^t{}_j \geq N^t{}_{\min}, \forall j \in I, \forall t \in T \tag{4}$$

$$t \cdot k \cdot Y_{i,j,v} \leq LF_v, \forall i,j \in I, \forall v \in V \tag{5}$$

$$x^t_{i,j,k,v} \in \{0,1\} \tag{6}$$

$$Y_{i,j,v} \in \{0,1\} \tag{7}$$

$$i,j \in I$$

$$k \in K$$

$$v \in V$$

$$t \in T$$

Objective function (1) is the TRC of the relocation process when performed by company staff, including the external costs caused by the transport activity.

Constraint (2) is introduced to link the binary decision variable $Y_{i,j,v}$ to the binary decision variable $x^t_{i,j,k,v}$, and constraint (3) is used to achieve the same number of goods before and after the relocation process in all stores. Constraint (4) imposes a minimum number of goods for each store after the relocation process, and constraint (5) considers the load factors of the vehicles.

Note that a feasible solution is obtained for the proposed problem so long as company staff vehicles have a load capacity greater than or equal to the number of goods to be relocated. In addition, ILP1 exhibits exponential numerical complexity.

3.2 | Goods relocation problem with involvement by loyal customers

The introduction of loyal customers to the relocation process requires a new mathematical formulation of the optimization problem formulated by (1)–(7). Let us recall the set $\mathscr{U} \epsilon \mathbb{Z}^+$of incentive proposal levels as defined in Section 2. In addition, $N_{lc} \in \mathbb{N}$ is the number of loyal customers available for relocation activities. They are also classified by incentive level based on the load capacities of their cars. Acceptance of the task by loyal customers is based on the proposed incentive levels. In particular, loyal customer acceptance rate $r_u \in \mathbb{R}^+$ is considered for each incentive level. Therefore, the number of loyal customers involved in goods relocation is given by the following formulation:

$$LC_u = \sum_{u=1}^{|U-1|} N_{lc_u} \cdot r_u \tag{8}$$

In the proposed approach, both loyal customers and company staff are available to perform the goods relocation process. Bids are first made to loyal customers, and if those customers are unavailable or unwilling to perform the task, company staff are available to ensure that the relocation task is completed.

Moreover, incentive rate in_u for incentive level u [€] is introduced to describe the new model.

The incentive mechanism is based on the principle that the prizes proposed to loyal customers at the different incentive levels are always a percentage of the relocation cost faced by company staff. In this view, the following formulation describes the incentive proposed for different levels with parameters $h, ..., m$, included in the range between 0 and 1.

$$in_{u,v} = \begin{cases} c \cdot D_{i,j} \cdot h \\ ... \\ c \cdot D_{i,j} \cdot m \end{cases} \tag{8a}$$

In addition, in the goods relocation problem involving loyal customers, the load factor is related to company staff vehicles and loyal customer vehicles. Therefore, a new load factor parameter is defined, LF_w, that joins set $\mathscr{V}$ of company staff vehicles and the set of loyal customer vehicles. The load factors of the loyal customer cars are classified in categories equal to $u = 1, \ldots, |\mathscr{U}| - 1$ to provide an incentive that is also based on loading capacity. The newly formed set is named ? and is used for all the other parameters and decision variables.

The binary decision variables that represent the goods to be relocated between stores are $x^t_{i,j,k,w,u}$, $\forall\, i,j \in \mathscr{I}$, $\forall\, k \in \mathscr{K}$, $\forall\ w \in \mathscr{W}$, $\forall\, u \in \mathscr{U}$, where the pick-up store is labelled i, the receiving store is labelled j, the vehicle with a defined capacity is labelled v and the incentive level is labelled u. If $x^t_{i,j,k,w,u} = 1$, then relocation of goods k of type t, is performed from store i to store j by vehicle v under incentive level u; otherwise, $x^t_{i,j,k,w,u} = 0$. Moreover, $Y_{i,j,w,u}$, $\forall\, i,j \in \mathscr{I}$, $\forall\, w \in \mathscr{W}$, $u \in \mathscr{U}$, represents the package of goods for different type $x^t_{i,j,k,w,u}$ to be relocated from i to store j, by vehicle v under incentive level u. $Y_{i,j,w,u} = 1$, means that the goods package is relocated from store i to store j; otherwise, $Y_{i,j,w,u} = 0$.

The objective of the optimization problem is TRC′, as follows:

$$TRC' = \sum_{i=1}^{|I|} \sum_{j=1, i\neq j}^{|I|} \sum_{w=1}^{|W|} \sum_{u=1}^{|U|} \left(in_u \cdot D_{i,j} \cdot Y_{i,j,w,u}\right) \cdot (c + e_u) \tag{9}$$

ILP2, which formalises the described problem of TRC′ including incentives, is formulated as follows:

$$\min TRC'$$

s.t.

$$t \cdot k \cdot Y_{i,j,w,u} \geq \sum_{t=1}^{|T|} \sum_{k=1}^{|K|} x^t_{i,j,k,w,u}, \forall i,j \in I, \forall w \in W, \forall u \in U \tag{10}$$

$$s^t{}_j = \hat{s}^t{}_j + \sum_{i=1}^{|I|} \sum_{w=1}^{|W|} \sum_{k=1}^{|K|} \sum_{u=1}^{|U|} x^t_{i,j,k,w,u} - \sum_{i=1}^{|I|} \sum_{w=1}^{|W|} \sum_{k=1}^{|K|} \times \sum_{u=1}^{|U|} x^t_{j,i,k,w,u}, \forall j \in I, \forall t \in T \tag{11}$$

$$s^t_j \geq N^t_{\min}, \forall j \in I, \forall t \in T \tag{12}$$

$$t \cdot k \cdot Y_{i,j,w,u} \leq LF_w, \forall i,j \in I, \forall w \in W \tag{13}$$

$$\sum_{i=1}^{|I|} \sum_{j=1}^{|I|} \sum_{k=1}^{|K|} \sum_{w=1}^{|W|} \sum_{t=1}^{|T|} x^t_{i,j,k,w,u} \leq LC_u, \forall u \in U \tag{14}$$

$$x^t_{i,j,k,w,u} \in \{0,1\} \tag{15}$$

$$Y_{i,j,w,u} \in \{0,1\} \tag{16}$$

TABLE 1 Distance between stores in urban areas (km)

	S1	S2	S3	S4	S5	S6	S7
S1	-	3	10	6	12	18	21
S2	3	-	7	4	15	19	22
S3	10	7	-	11	24	18	12
S4	6	4	11	-	14	15	20
S5	15	15	24	14	-	8	11
S6	18	19	18	15	8	-	7
S7	21	22	12	20	11	7	-

TABLE 2 Number of goods by store and type before relocation

Store	Goods type 1	Goods type 2	Goods type 3	Goods type 4
S1	1	4	2	5
S2	7	5	10	0
S3	0	15	2	15
S4	14	10	1	15
S5	15	8	15	0
S6	1	2	10	15
S7	12	6	10	0

$$i, j \in I$$

$$k \in K$$

$$v \in V$$

$$t \in T$$

$$u \in U$$

TABLE 3 Incentive levels

Incentive levels	Value of incentive relative to company cost (%)
1	50
2	70
3	90

The objective function (9) is a new, updated TRC (TRC′) that includes the incentives to involve loyal customers in the relocation process.

Constraints (2), (3), (4) and (5) of ILP1, are equivalent to constraints (10), (11), (12) and (13) of ILP2. Constraint (14) limits the number of goods to be relocated by loyal customers in relation to the acceptance rate based on the proposed incentive values.

It is remarked that the ILP2 problem always obtains feasible solutions if the company staff vehicles have a capacity greater than or equal to the number of goods to be relocated. The numerical complexity of ILP2 is exponential.

It is expected that the TRC updated by solving ILP2 is less than or at most equal (in case no loyal customer is available for relocation) to the TRC obtained by solving ILP1.

The proposed optimization approach can be applied to real cases for the relocation of goods in urban store networks.

4 | CASE STUDY

This section shows a simulated case study to demonstrate the benefits of the proposed methodology to solve the goods relocation problem with an incentive strategy in the urban fashion store networks. In the proposed case study, simulations are performed to solve the ILP1 and ILP2 problems, that is, to solve the problem of goods relocation by, respectively, company staff or loyal customers.

The case study considers the followings parameters to formulate the ILP1 and ILP2 problems: $|\mathscr{I}| = 7$; $|\mathscr{K}| = 50$; $|\mathscr{T}| = 4$; $N_{min} = 6$; c = 1 [€/km]; the destination-source matrix are reported in Table 1. In addition, the number of goods in the stores before relocation, $\hat{s}_j^k$, $\forall j \in \mathscr{I}, \forall k \in \mathscr{K}$ are reported in Table 2. The incentive strategy is designed with three incentive levels, $in_{1,2,3}$, as defined in the Table 3; the number of loyal customers available in relocation activities related to the incentive level, N_{lcu}, is defined in Table 4 and the acceptance rates of loyal customers, r_u, for the three incentive levels, u = 1, 2, 3, are detailed in Table 5.

The external costs values are related to data proposed by [2], considering the following vehicles used in urban area: diesel Euro 3 LCVs for the relocation process performed by company staff and diesel Euro 3 car for the activities performed by loyal customers. In Table 6, the values of the external costs related to the two types of vehicles are reported. Finally, the values of LF_v with $|\mathscr{V}| = 10$, for different kind of vehicles of company staff and of loyal customers are respectively detailed in Table 7.

The formulated ILP problems are solved by a standard solver, that is, MatLab (LinProg), on an Intel-Core i5, 2.7 GHz CPU with 8 GB RAM. All the performed tests are solved in less than 2 s.

The TRC obtained by solving ILP1, which considers relocation performed only by company staff, is equal to 850.87 €. The cost includes operating costs faced by the company and external costs as social cost (not paid by the company).

The simulation results are reported in Table 8, with the number of goods classified per type of goods. In Figure 2 are the results: the red lines show the goods relocation performed by the company staff from one store to another. Note that because a minimum number of goods is required in each store, in some cases it does not allow them to move all goods from a single store.

Solving ILP2, TRC′ equals 658.10 €, which includes operating and external costs. In addition, the loyal customers receive incentives in the form of vouchers to purchase goods in the stores of the company. The value of the provided incentives is 213.50 €.

TABLE 4 Loyal customers available in relocation process

Incentive levels	Number of loyal customers available for the relocation process
1	500
2	600
3	300

TABLE 5 Acceptance rate of incentive strategy and number of loyal customers involved in relocation process

Incentive levels	Acceptance rate (%)	Loyal customers involved in relocation (LC_u)
1	0.2	1
2	0.5	3
3	1	3

TABLE 6 External costs of relocation process

	Company staff [€/km]	Loyal customer [€/km]
Accidents (table 8 in [2])	0.041	0.072
Air pollution (table 16 in [2])	0.034	0.019
Climate change (table 25 in [2])	0.028	0.018
Noise pollution (table 35 in [2])	0.011	0.009
Congestion (table 48 in [2])	0.708	0.472
Total external costs	0.822	0.59

TABLE 7 Vehicle load factors by number of goods

	LF_v	LF_w
Company V1	5	5
Company V2	5	5
Company V3	5	5
Company V4	5	5
Company V5	5	5
Company V6	7	7
Company V7	7	7
Company V8	7	7
Company V9	7	7
Company V10	7	7
Company V11	10	10
Company V12	10	10
Company V13	10	10
Company V14	10	10
Company V15	10	10
User L1		2
User L2		3
User L3		4

TABLE 8 Goods relocation within fashion store network

Type of goods	Departure store	Receiver store	Number of goods
1	4	1	5
1	2	3	1
1	4	3	3
1	7	3	2
1	7	6	5
2	5	6	2
2	4	6	2
2	3	2	1
2	4	1	2
3	2	4	4
3	5	4	1
3	5	1	4
3	7	3	4
4	4	1	1
4	4	2	6
4	6	5	6
4	6	7	3
4	3	7	3

The simulation results of the ILP2 solution are shown in Figure 3; the green lines show relocations performed by loyal customers, while the red line shows relocations performed by company staff. The lines describe the number of goods relocated and the stores that supply and receive goods.

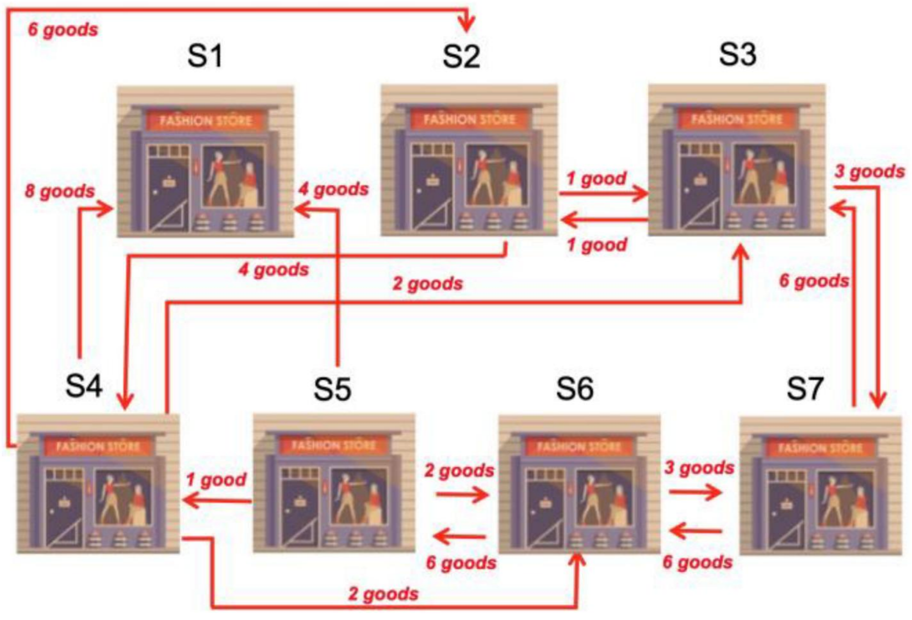

FIGURE 2 Relocation of fashion goods in urban areas by company staff only

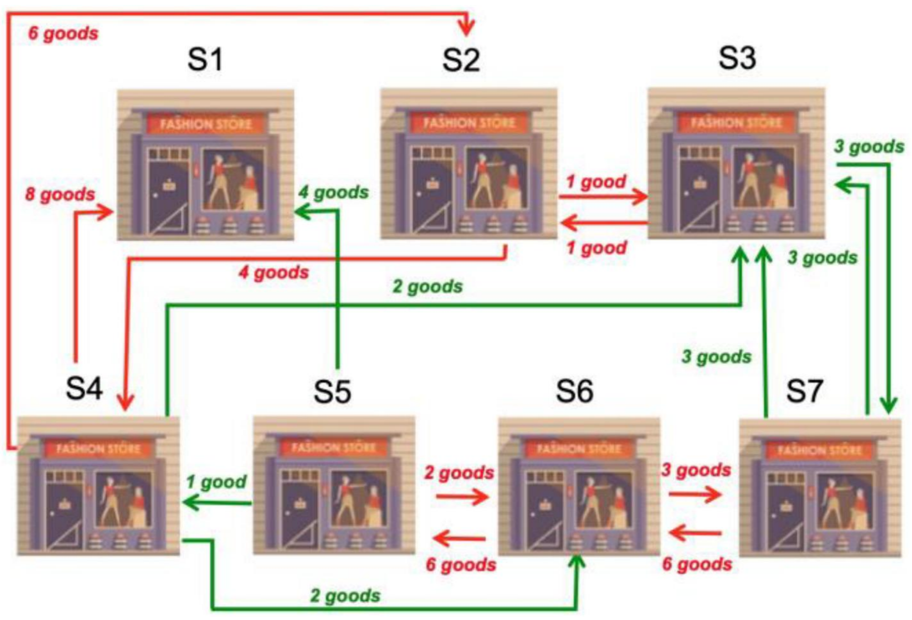

FIGURE 3 Relocation of fashion goods in urban areas with involvement by loyal customers

The results obtained by ILP2 are also shown in Table 9, describing the stores involved in relocation, the number of goods and the relocation method.

Table 10 allows comparison of the results obtained by the ILP1 and ILP2 problem solutions. The results of the simulations show a significant reduction in TRC. In particular, TRC′ is more than 45% lower than TRC. External costs are decreased by about 50% due to the limited use of vans and trucks by company staff; external costs related to vans and trucks have a greater impact than those related to cars, especially for small deliveries and lightly loaded vehicles.

In summary, the reduction in TRC obtained with the incentive strategy generates several benefits for the company. There is not only a significant reduction in operating costs but also an indirect advantage related to the greater promotion of environmentally sustainable initiatives with an associated reduction in external costs. Moreover, customer loyalty is increased thanks to a marketing strategy based on incentives in the form of voucher discounts for the purchase of goods.

TABLE 9 Goods relocation within fashion store network involving loyal customers

Type of goods	Departure store	Receiver store	Number of goods	Relocation method
1	4	1	5	Company
1	2	3	1	Company
1	4	3	3	LC
1	7	3	2	LC
1	7	6	5	Company
2	5	6	2	Company
2	4	6	2	LC
2	3	2	1	Company
2	4	1	2	Company
3	2	4	4	Company
3	5	4	1	LC
3	5	1	4	LC
3	7	3	4	LC
4	4	1	1	Company
4	4	2	6	Company
4	6	5	6	Company
4	6	7	3	Company
4	3	7	3	LC

Abbreviation: LC, loyal customer.

TABLE 10 Integer linear programming results for ILP1 and ILP2

	ILP1 [€]	ILP2 [€]
Total relocation cost	850.87	658.10
Relocation operating cost	467.00	413.90
External cost	383.87	244.20
Incentive value	-	213.50

5 | CONCLUSIONS

This paper presents an innovative goods relocation strategy to minimise TRC for an urban stores network. The proposed approach is based on an incentive strategy able to engage loyal customers in the goods relocation process among stores. The rewards are provided in the form of vouchers to buy goods in the company's stores to those are provided only if goods relocation activity is correctly performed.

With this aim in mind, two integer linear programming problems are formulated (ILP1 and ILP2) to respectively represent the goods relocation problem in two ways, delivery of goods (1) by company staff only and (2) by involved customers. The loyal customers willing to participate in the relocation game among the network of stores receive a notification on their smartphone indicating how to deliver goods from the supplier store to the receiver store under a defined incentive value. They can accept and perform the relocation to receive a reward, or they can decline the invitation. In cases of customer unavailability, relocation is ensured by company staff.

The proposed approach allows for a reduction in a company's TRC in the case where loyal customers participate in the relocation game. The TRC includes operating costs directly charged to corporate financial statements and external costs charged only in corporate sustainability reports without being a true cost to the company. In addition to the direct benefit generated on total costs, the strategy increases the profit of the store network in a second step: the rewards generated by the incentives are in the form of vouchers to purchase additional goods from the same store network, so the incentives can be seen as a marketing strategy that increases sales.

A case study simulation in the fashion brand sector shows the effectiveness of the proposed approach. The incentive strategy based on rewards results shows the fundamentality of involving loyal customers in the goods relocation process.

In future works, a decentralised optimization approach will be developed to solve the goods relocation problem in urban store networks.

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