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Evaluating the impact of new trends in urban freight transportation attending the triple bottom line: A case study

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ABSTRACT

Urban freight transportation is considered one of the activities that has the greatest impact on urban areas in terms of sustainability and livability, therefore, new trends are emerging to reduce its impacts. However, there is a lack of methodologies to evaluate and validate the implementation of these trends. In this context, the proposed methodology presents the implementation of three KPIs attending the triple bottom line approach, which look at impacts from the social, environmental, and economic perspectives. This methodology is tested on a case study and the results conclude that the implementation of new trends in UFT can reduce its impact in urban areas.

1. Introduction

In the new global economy, the challenges associated with the urban freight transportation (UFT) of products have become a central issue for the on-line market increase (Janjevic & Winkenbach, 2020). Gonzalez-Feliu et al. (2012) and Taniguchi et al. (2016) identify the following constraints of last mile deliveries as the most important: the strict regulation, a lack of dedicated logistics infrastructure and the high levels of congestion. Comi (2020) point out their impact on terms related to city sustainability and liveability.

New trends on UFT are emerging to avoid its impacts in urban areas. They are focused on the improvement of UFT through the three issues of the triple bottom line (TBL): economy, sustainability and society (Reyes-Rubiano et al., 2021). The Urban Consolidate Centers (UCC) defined by the University of Westminster Report as "a logistics facility that is situated in relatively close proximity to the geographic area that it serves be that a city centre, an entire town or a specific site (e.g. shopping centre), from which consolidated deliveries are carried out within that area. A range of other value-added logistics and retail services can also be provided at the UCC. Logistics companies with deliveries scheduled for the urban area or site are able to transfer their loads at the UCC and thereby avoid entering the congested area. The UCC operator sorts and consolidates the loads from a number of logistics companies, if necessary, stores them, and delivers them, often on environmentally friendly vehicles, to an agreed delivery pattern" (Marcucci & Danielis, 2008). The use of environmentally friendly vehicles attends to the sustanible issue, furthermore, the UCC increase the load average and decrease the number of necessary journeys (Gogas & Nathanail, 2017), therefore the economic and social issues are also covered by the UCC. However, the benefits of these new trends, such as UCC and environmentally friendly vehicles, must be evaluated by measurable indicators that nowadays are not standardized (Morana & Gonzalez-Feliu, 2015).

This paper proposes a new methodology for measuring and evaluating the implementation of new UFT's trends to address this gap. The performance of new trends is measured by 3 KPIs developed according to the TBL philosophy, thus there is an environmental, a social and an economic indicator. This methodology is applied to a case study in which the UFT's new trends are implemented in a city.

The paper is structured as follows. Section 2 presents a review on the UFT concept and its relationship with the TBL, its new trends and the current studies on KPIs for UFT. Section 3 presents the proposed methodology and the development of KPIs, that are applied to a case study in Section 4. Finally, the conclusions are summarized in section 5.

2. Literature review

In this section, we first characterize the UFT and its impacts in urban areas. Then we present the triple bottom line (TBL), which is used to group all these impacts. And finally, we show the lack of standardization of the existing Key Performance Indicators (KPIs) for measuring the TBL

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in UFT.

2.1. Urban freight transportation (UFT)

UFT may be defined as the distribution of goods from producers to consumers on time and in the right way, trying to achieve low costs and guaranteeing good customer service (Viu-Roig & Alvarez-Palau, 2020). UFT involves different actors (stakeholders), that Comi et al. (2018) classified into good receivers, end-consumers, transport, and logistics operators and public administration. All the objectives and perspectives of the stakeholders must be considered to develop a more sustainable UFT and therefore, a more liveable urban area (Taniguchi, 2014).

According to Muñoz-Villamizar et al. (2020) research on UFT started in 1970s but it was not until 1990s when researchers started to conduct serious studies on this area. In recent years, the boom in e-commerce involves a growth in delivery numbers and hence in the impact of UFT (Viu-Roig & Alvarez-Palau, 2020). This situation has attracted the interest of researchers in evaluating this impact (Bektaş et al., 2019) and the society's awareness of health and quality life (Kiba-Janiak, 2017).

UFT is considered one of the greatest environmental impacts in urban areas. Its movements represent between 20 % and 30 % of vehicle kilometres and between 16 and 50 % of the air pollution by transport activities in a city (Albergel et al., 2006). Moreover, Eurostat (2020) demonstrated that UFT activities in 2017 constituted for almost 15 % of the greenhouse gas (GHG) emissions and 24 % of the emissions of ozone precursors, regarding all the economic activities. Lindholm (2013) divided the impacts into three affected elements: impacts on the planet (e.g., pollutant emissions), on people (e.g., public health injuries) and on profit (e.g., congestion). However, Bektaş et al. (2019) asserted that the UFT negative impacts could fit one of these categories: emissions, noise, land use or safety hazards.

According to (Viu-Roig & Alvarez-Palau, 2020) the combination of different pick-up and transportation scenarios is beneficial to reduce the UFT's impacts. It considers strategies such as the use of pickup systems (lockers), nighttime deliveries, cargo bikes or electric vehicles (EV) (Bjerkan et al., 2014). Pickup systems can solve the "not at home problem" of deliveries and reduce the additional costs due to failed deliveries. This system sends the parcels to lockers (delivery points) and the clients collect them, instead of receiving them at home (Morganti et al., 2014). Cargo bikes enable the reduction of environmental impact. They reduce the car traffic delivering parcels on bike routes (Arnold et al., 2018). Another problem derived from UFT's impacts is the strong limitation on vehicle access (Russo & Comi, 2020). Urban consolidation centres (UCC) located in city boundary where parcels can be loaded onto EV and cargo bikes can solve this limitation (Zhang et al., 2019). UCC consolidates the shipments from suppliers to clients (Gómez-Marín et al., 2020), therefore it decouples the freight transportation outside the city and the UFT (Quak & Tavasszy, 2011).

2.2. TBL in UFT

The sustainability concept applied into UFT is considered the solution to its negative impacts (Reyes-Rubiano et al., 2021). Sustainability reaches a balance between environmental, economic, and social dimensions (Ulmer et al., 2020), which are embedded in the triple bottom line (TBL) term (Buldeo Rai et al., 2017). The TBL enables the classification of UFT's impacts into three dimensions (Elkington, 1999), as can be seen in Comi and Savchenko (2021). Environmental impacts, such as, air pollution and GHG emissions are gaining importance in transportation processes (İmre et al., 2021). The quality service and costs generated by congestion are considered as economic impacts (Halldórsson & Wehner, 2020). Finally, social impacts mainly related to safety and security (McDonald et al., 2019).

Based on this classification, cities must be sustainable in these three dimensions: environmental economic and, social (Lyons, 2018). However, there is not a consensus about attending these three dimensions together. According to (Olsson et al., 2019; Russo & Comi, 2020) the most covered issue is the economic sustainability. Whereas other authors maintain that environmental sustainability is the research priority, since reducing GHG is a primary issue of international agreements (Bektaş et al., 2019).

2.3. Key performance indicators in UFT

KPIs enhances the identification of UFT's problems (Shah & El-Geneidy, 2012). Monitoring and performance measurement enable the evaluation and validation of projects on UFT (Kaparias et al., 2011). These KPIs are based on the acquisition of data from mobility systems to describe the status of UFT in different segments, such as transport, economy, or environment (Vidović et al., 2019).

A considerable amount of literature has been published on this topic. National Research Council (2002) provided several KPIs to be used within every assessment (travel time, lost time, reliability of the system, the status of the transport system and travel costs) and added optional indicators (congestion-related, quantity of trips, modal split, transit time required and transit efficiency). These KPIs cover the economic and social dimensions of TBL but not the environmental one. Other authors classified the KPIs corresponding to the TBL. For example, Barker (2005) defined social indicators (congestion and traffic accidents), economic indicators (transport-generated expenditure) and environmental indicators (energy consumption and polluting emissions). In the same way, Litman (2003, 2012) proposed for environmental KPIs: the energy consumption per ton kilometre, the land occupancy per capita, the energy consumption per capita per transport mode, the air pollution per capita, the air and noise pollution, the meteoric water drainage system coverage among others. As economic indicators: the costs of pollution per capita, the modal split, the mobility per capita, the average duration of traveling to work, the average speed of freight transportation, and the total transportation-related expenditures per capita. Litman suggested also social indicators such as the overall satisfaction with the transport system, the number of accidents and fatalities per capita, financial availability and the adjustment to the needs of the users with disabilities. Imran & Low (2003) added a fourth category: transport. They suggested as transport indicators the non-motorised transport, car ownership, average travel time, traffic volume, and vehicle status. They related social indicators to urban density, space consumption, public transport availability, traffic related injuries, and fatalities. The economic indicators involved the fuel price, GDP per capita, and space consumption in terms of the transport infrastructure. Finally, they defined as environmental indicators the GHG emissions, CO2 and CH4, NO2 and noise emissions. Other authors proposed multidimensional indicators that involved the three TBL's dimensions to succeed against the challenges of UFT, preserving economic growth and quality life while implementing environmental strategies (Kiba-Janiak, 2016).

Regarding case studies related with this topic, Musolino (2019) proposed an analysis to obtain the relationships between transport costs and land prices in urban areas to support the decision of locating freight transport facilities. However, this study did not take into account the social and environmental dimension in this decision-making. Other studies mentioned the concept of TBL (for example (Russo et al., 2013)), although there are not suggestions about KPIs in those three issues (social, environment and cost). The deepest study was conducted by Musolino et al. (2019), who proposed a case study with KPIs for the three issues of TBL. This case study is similar to the one presented in this research, but our study shows a very detailed cost KPI with a large number of well-defined sub-costs that can help obtain accurate transportation costs. Moreover, do our research not only talk about the benefits of UDC, but also about the implementation of other trends, for example, lockers and cargo bikes.

Most of those KPIs are limited by their replicability. They have been developed for specific locations, so they are not applicable in other cities (Vidović et al., 2019). Moreover, the KPIs are not standardized and they are based on different meanings of sustainability (Gonzalez-Feliu, 2018).

Based on the above, there is a lack of standard KPIs for measuring the UFT considering all the stakeholder's needs (Anand et al., 2015; Buldeo Rai et al., 2017). The following section presents a methodology for developing three KPIs based on the TBL's dimensions that can fulfil the lack of standardization and replicability of the existing KPIs of UFT.

3. Methodology

This paper proposes a new methodology for measuring and evaluating the UFT performance attending to the three dimensions of TBL. This methodology considers the accessibility to the variables and parameters to enable the replicability of the KPIs' calculus in any city. Three KPIs were developed, one per TBL's dimension:

- Environmental dimension: the reduction of GHG is a primary issue for all the stakeholders (Bektaş et al., 2019). For that reason, we chose the carbon footprint emitted per parcel as the environmental KPI.
- Economic dimension: costs per parcel are the economic KPI. It is an easy way to evaluate how affects a change in UFT economically.
- Social dimension: there are a lot of KPIs for measuring the social dimensions. However, we considered that congestion groups all of them, since it is related to other indicators, such as accidents, overall satisfaction, or delivery time.

3.1. Kpis definition

This section defines the KPIs proposed in this paper, their equations and the variables needed.

The environmental indicator (EI) is defined as the GHG emitted per parcel. It considers the distance of the route per day (km), the CO_2 equivalent emission (CO_2 eq) of each type of vehicle and the average of parcels delivered per day in the city (see equation (1)).

$$EI = \sum_{i=1}^{N}\left(S_i \bullet DT_i \bullet EF_i \bullet \frac{1}{Nd_i}\right)\ (\text{kg}\,CO_2\,\text{eq/parcel}) \quad (1)$$

where.

- i is the type of delivery modes (e.g., trucks, cargo-bikes, e-bikes, on-foot).
- S_i is the percentage of shipments with vehicle i.
- DT_i is the distance traveled with vehicle i per day (km/day).
- EF_i is the emission factor of CO_2 eq per km that the vehicle i emits (kg CO_2 eq/km)
- Nd_i is the number of delivered parcels per vehicle type i (parcels/day).

The social KPI, congestion, is defined as the quantity of UFT moving vehicles that there are in the analyzed city. It is calculated as follows (equation (2)):

$$Congestion = \frac{\sum N_{vi}}{C_s}\ (\text{number of vehicles/km}^2) \quad (2)$$

where.

- N_v: number of vehicles that increase the congestion.
- C_s: city surface (km^2).
- *i* i is the type of delivery modes (e.g., trucks, cargo-bikes, e-bikes, on-foot).

Finally, the economic KPI considers the delivery costs from the UCC or the supplier center, not the logistic costs inside it. Equation (3) shows the calculus of the delivery cost indicator (DCI) that is divided into the cost of parcel's delivery with UFT vehicles (€/delivery) (C_{Fleet}) and the locker's cost (€/delivery) ($C_{Lockers}$).

$$DCI = C_{Fleet} + C_{Lockers}\ (\text{€/delivery}) \quad (3)$$

These costs appear in detail below:

C_{Fleet} (equation (4)) are the annual costs of all the vehicle types per delivery. This equation has two terms, one represents the home-delivery costs and the other the lockers-delivery costs.

$$C_{Fleet} = H_d\left(\frac{1+df(1+df_{overcosts})}{wd \bullet (1+df)} \bullet \sum_{i=1}^{N}(S_i \bullet \frac{cv_i}{Nd_i})\right)_{Hd} + L_d\left(\sum_{i=1}^{N} S_i \bullet \frac{cv_i}{Nd_i}\right)_{Ld}\ (\text{€/delivery}) \quad (4)$$

where.

- H_d is the percentage of home-deliveries (%).
- L_d is the percentage of lockers-deliveries (%).
- cv_i is the annual cost of vehicle *i* (€).
- wd is the working days per year (days).
- df is the percentage of delivery failures (%).
- $df_{over\ costs}$ is the percentage of over costs due to delivery failures (%).

The annual cost of vehicles is divided into direct (C_{Di}) and indirect costs (C_{Ii}) (see equation (5)). Fig. 1 presents the components of each cost.

$$cv_i = C_{Di} + C_{Ii}(\text{€}) \quad (5)$$

The components of each cost are defined below.

Depreciation (D) is presented in equation (6). Being C the acquisition cost of the vehicle (€), R the residual value (€), N the tyres' cost (€).

$$D = \frac{C - R - N}{lifetimeofvehiclei}\ (\text{€}) \quad (6)$$

Finance (F) is composed by L (the loan finance (€)), i (interest rate (%)), n (finance period (years)) and $j = (1+i)^n$.

$$F = \frac{\left(n \bullet \frac{L \bullet i \bullet j}{j-1}\right) - L}{lifetimeofvehicle}\ (\text{€}) \quad (7)$$

The salary considers gross salary and social quotation.

Insurances are the annual insurance costs involved on a vehicle.

Tax costs include the fiscal costs of vehicles.

Consumables costs (CC) refer to the fuel or energy costs depending on the type of vehicles. Costs of internal combustion engine (ICE) are calculated by equation (8) and electric vehicles (EV) by equation (9).

$$CC_{ICE} = \frac{fap \bullet fc \bullet k}{100}\ (\text{€}) \quad (8)$$

Where:

- *fap* is the prize of fuel acquisition taking into account the discount due to the professional use of fuel (€/liter).
- *fc* is the average of fuel consumption of this vehicle (liter/100 km).

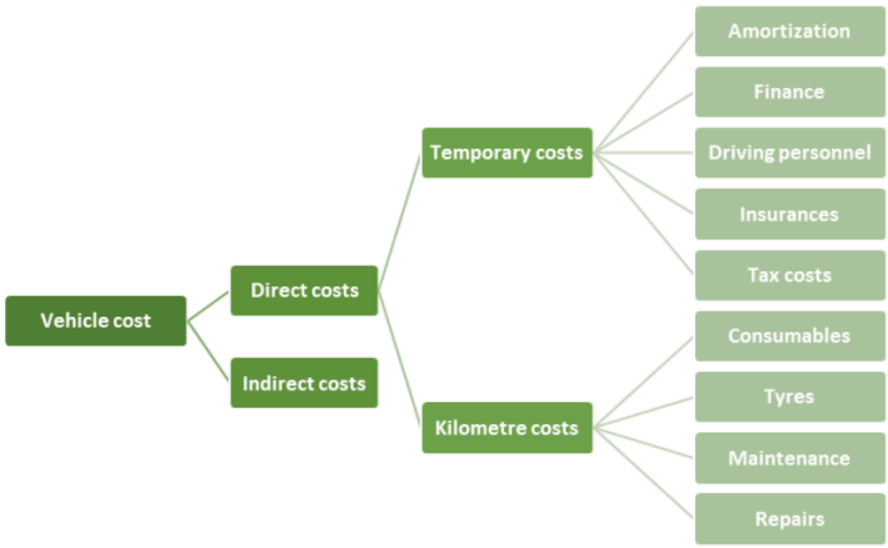

Fig. 1. Vehicle cost scheme.

- k is the annual distance travelled per vehicle (km).

$$CC_{EV} = \frac{eap \bullet ec \bullet k}{100}\,(€) \tag{9}$$

eap: electric acquisition prize (€/kW).

ec: average of electric consumption of this vehicle (kW/100 km).

Tyres cost (TC) is presented in equation (10). Being p_t the prize of tyres change (€) and n_t the number of tyres per vehicle.

$$TC = \frac{p_t \bullet n_t \bullet k}{lifetimeoftyres(km)}\,(€) \tag{10}$$

Maintenance considers a ratio of maintenance cost per km (m) in €/km (see equation (11)).

$$M = m \bullet k\,(€) \tag{11}$$

Repairs also considers a ratio of repairs per km (r) in €/km (see equation (12)).

$$R = r \bullet k\,(€) \tag{12}$$

Finally, the indirect costs (C_i) are calculated as a percentage of the direct costs (C_d), being q a factor introduced by the user (see equation (13)).

$$C_i = C_d \bullet q\,(€) \tag{13}$$

The other part of UFT costs is related to lockers, whose costs are presented in Fig. 2 and calculated with equation (14).

$$LC = ac_{lockers} * (1 + q_{lockers})(€) \tag{14}$$

Lockers costs (LC) contains the cost of lockers acquisition (calculated with equations (6) and (7)) and the maintenance and renting cost calculated as a percentage of their acquisition costs introduced by the users through the $q_{lockers}$ parameter.

4. Case study

In this section we apply the proposed methodology to a case study in a city. That city is considering the implementation of traffic restrictions in the city center. These restrictions together with the UFT impacts encourage the idea of establishing an UCC combined with more environmental-friendly vehicles to improve the UFT. The project is in an early step, so the city name is confidential. It has a population of more than 700,000 inhabitants and a land area of 973,78 km^2. The current UFT's situation represents a chaotic parcels delivery distribution, in which logistic operators distribute independently the parcels by ICE. The future scenario (S1) will place a UCC in the limits of the city center, then the parcels will be distributed from the UCC to home or lockers by EV or cargo-bikes (see Fig. 3). This study aims to use the proposed KPIs to evaluate the improvements when the future scenario (S1) is established.

4.1. Calculus of KPIs

This section calculates the KPIs in both situations and compares the results. There are parameters, known as global parameters, that are characteristic from the city, so they are independent of the scenario (Table 1). However, other parameters depend on the scenario and the vehicle type (Table 2).

The three KPIs have been calculated using the equations presented in Section 2, the global parameters of Table 1 and other specific parameters for each KPI.

The EF_i is necessary to calculate the environmental KPI (equation (1)) and depends on the type of vehicle. In S0 all the vehicles are ECI

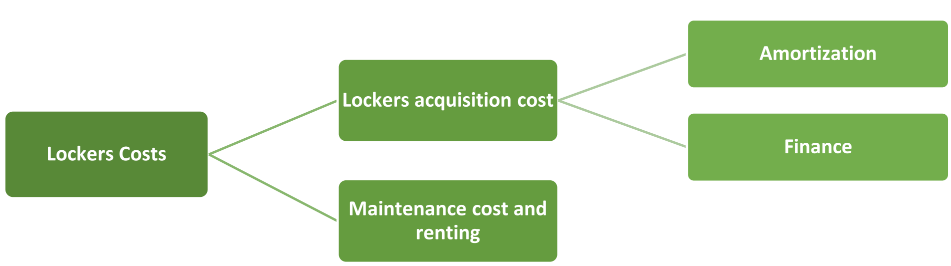

Fig. 2. Lockers cost scheme.

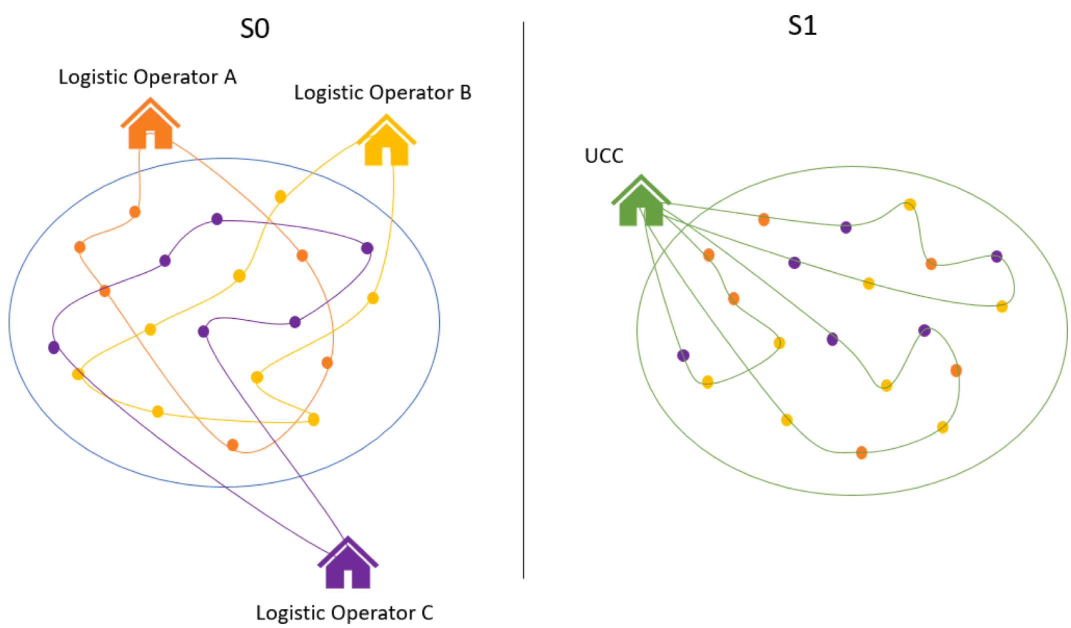

Fig. 3. Description of S0 and S1.

Table 1
Common parameters for KPIs development.

Parameter	Value	Units	Reference
City Surface (C_S)	973.78	km^2	*
Working days/year (Wd)	225	days/year	*
working hours	8	hours/day	*
Parcels delivered per day	30,275	parcels/day	*

* These values are acquired from confidential referees involved in city project.

whereas in the S1 there are EV and cargo bikes. Table 3 shows the value of EF_i for each vehicle and the EI in S0 and S1.

The CI is a more complex calculus which requires more parameters presented in Table 4 (cost of vehicles) and Table 5 (cost of lockers).

Once the costs of vehicles and lockers are calculated. The CI is obtained as these costs per parcel delivered per day (Table 6).

Finally, congestion is calculated by equation (2) and the results obtained can be seen in Table 7. It must be considered that cargo bikes do not affect the congestion of the city, so in S1 only the EV are considered.

Table 8 presents the KPI results for both situations.

The three KPIs show an improvement achieved with the S1. These results support the idea that the combination of new UFT models (UCC, lockers or more environmental-friendly vehicles) reduce the UFT's impacts (Viu-Roig & Alvarez-Palau, 2020). The GHG emissions decrease more than 80 % since the ICE are changed into EV and cargo bikes. Regarding congestion, the use of lockers and cargo-bikes help eliminate traffic in the city. In this case it decreases a 50 %. Finally, the delivery cost is halved with the S1. Table 3 shows that EV and cargo bikes are cheaper than ICE and lockers reduce the delivery failures which increase the delivery cost too. Moreover, the establishment of a UCC enable the optimization of UFT's routes, since in S0 logistic operators could duplicate routes and had fewer load average than in S1 where the UCC can group all the parcels of a city zone in one route.

5. Conclusions

This research presents a methodology to evaluate the new trends in UFT attending to the three issues of the TBL. The methodology develops three KPIs, one for each TBL issue. Moreover, this methodology has been tested in a real scenario through the case study.

Regarding the development of KPIs in UFT, this research overcomes

Table 2
Specific parameters for KPIs development.

Parameter	S0	S1			Units	Reference
	ICE	EV	Cargo bike	Locker		
Shipments (S)	100	96	4	–	%	*
Distance traveled (DT)	60	60	18	–	km/day	*
Delivered parcels (Nd)	75**	125	45	–	parcels/vehicle travel	(Segura et al., 2020)
No. of lockers	–	–	–	535 (34 gaps/locker)***	No. of lockers	(ZHILAI, 2021)
Lockers deliveries (L_d)	0	0		30	% total parcels	*
Home deliveries (H_d)	100	70		0	% total parcels	*
Delivery failures (df)	15	15		0	% of home deliveries	(Segura et al., 2020)
Delivery failures overcost ($df_{overcosts}$)	20	20		0	% of parcels cost	*

* These values are acquired from confidential referees involved in city project.
** In S0 it is considered that the ICE vehicles have a lower average load (60%) because there is not an UCC in which the load would be consolidated, and the routes would be optimized.
*** It is considered that the parcels can stay 2 days in lockers, therefore the number of lockers' gaps are the double of parcels delivered per day.

Table 3
EI calculus.

Scenario	EF_{ICE} (kg CO_2 $_{eq}$/km)	EF_{EV} (kg CO_2 $_{eq}$/km)	$EF_{Cargo\ bike}$ (kg CO_2 $_{eq}$/km)	EI (kg CO_2 $_{eq}$/ parcel)
S0	0.18	×	×	0.12
S1	×	0.06	0.0066	0.02

× represents that this parameter is not considered in this scenario.

Table 4
Parameters for CI calculation.

Annual Costs	ICE	EV	Cargo bikes
A	2,433.44 € (10 years of useful life) (Volkswagen, 2021a)	2,374.64 € (10 years of useful life) (Volkswagen, 2021b)	1,298.20 € (5 years of useful life) (Yokler, 2021)
F	333.56 € (Ministerio de Transportes, 2021)	336.11 € (Ministerio de Transportes, 2021)	57,49 € (Ministerio de Transportes, 2021)
Salary	27,927.96 € (BOE, 2021; Seguridad Social, 2021)	27,927.96 € (BOE, 2021; Seguridad Social, 2021)	27,927.96 € (BOE, 2021; Seguridad Social, 2021)
Insurances	4,797.61 € (Ministerio de Transportes, 2021)	4,797.61 € (Ministerio de Transportes, 2021)	1,062.99 € (Ministerio de Transportes, 2021)
Tax costs	583.74 € (Ministerio de Transportes, 2021)	583.74 € (Ministerio de Transportes, 2021)	315,28 € (Ministerio de Transportes, 2021)
Consumables	1.704,73 € (Ministerio de Transportes, 2021)	617.89 € (Ministerio de Transportes, 2021)	13,05 € (Ministerio de Transportes, 2021)
Tyres	238,90 € (Roncero, 2018; Volkswagen, 2021a)	238,90 € (Roncero, 2018; Volkswagen, 2021a)	121,50 € (Decathlon, 2021; Yokler, 2021)
Maintenance	553,50 € (Volkswagen, 2014)	553,50 € (Volkswagen, 2014)	2,250.00 € (Schliwa et al., 2015)
Repairs	691,88 € (Volkswagen, 2014)	691,88 € (Volkswagen, 2014)	2,812.50 € (Schliwa et al., 2015)
Indirect costs*	2,536.05 €	2,483.05 €	2,265.02 €
Total costs	41,817.55 €	40.896,00 €	38.189.81 €

* Considered as the 6.5% of DC.

Table 5
Costs of lockers.

Annual Cost	Lockers
A	506.516.40 € (ZHILAI, 2021)
F	67,348.20 €
Total Cost*	573,864.60 €

* The maintenance cost is included in the acquisition cost of lockers.

Table 6
CI indicator.

Scenario	CI
DCI_{S0} (€/parcel)	2.53
DCI_{S1}(€/parcel)	1.20

Table 7
Congestion calculus.

Scenario	Congestion
$Congestion_{S0}$ (Vehicles/km^2)	0.4132
$Congestion_{S1}$ (Vehicles/km^2)	0.0585

Table 8
Results of KPIs in S0.

KPI	S0	S1
EI (kg CO_2/parcel)	0.12	0.02
Congestion (vehicles/km^2)	0.41	0.21
DCI (€/delivery)	2.53	1.20

the gaps identified in the literature review. The KPIs developed according to the TBL enables to attend the three dimensions together (Lyons, 2018; Olsson et al., 2019; Russo & Comi, 2020). Our methodology can solve the problems of standardization and replicability (Anand et al., 2015; Buldeo Rai et al., 2017), since the KPIs attend to the TBL and the data for their calculus can be easily obtained by any city.

Our conclusion about the new trends are in line with that of Viu-Roig & Alvarez-Palau (2020) and our case study supports it. The combination of new UFT's trends contributes to reduce the impacts of UFT. The establishment of UCC enables the route improvement, and therefore the congestion and GHG emissions are lower. The use of more environmentally friendly vehicles contributes to the sustainability improvement and cargo-bikes also reduce the congestion in urban areas. Furthermore, lockers reduce the delivery failures, that implies that delivery costs are fewer, and the number of home deliveries, and therefore the congestion.

Finally, we aim to develop a software tool for future research, that allows to calculate these KPIs in real time acquiring data from different stakeholders, such as the UCC, suppliers, logistic operators, or receivers.

CRediT authorship contribution statement

Paula Morella: Conceptualization, Investigation, Methodology, Validation, Writing – review & editing, Supervision. **María Pilar Lambán:** Conceptualization, Investigation, Methodology, Writing – original draft. **Jesús Royo:** Project administration, Supervision. **Juan Carlos Sánchez:** Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Glossary

AcLockers: acquisition costs
CC: Consumable Costs
CDi: direct costs (€)
CFleet: cost of parcels delivered by UFT vehicles (€/delivery)
CIi: indirect costs (€)
CLockers: cost of parcels delivered by lockers (€/delivery)
C_s: city surface (km2)
cvi: annual cost of vehicle i (€)
D: depreciation
DCI: delivery cost indicator (€/parcel)
Df: percentage of delivery failures (%).
dfover costs: percentage of over costs due to delivery failures (%).
DTi: distance traveled with vehicle i per day (km/day)
eap: electric acquisition prize (€/kW)
ec: average of electric consumption of this vehicle (kW/100 km)
EFi: is the emission factor of CO2 eq per km that the vehicle i emits (kg CO2 eq/km)
EI: Environmental Indicator
EV: electric vehicles
F: Finance
fap: is the prize of fuel acquisition taking into account the payback of the professional use of fuel (€/liter).
fc: is the average of fuel consumption of this vehicle (liter/100 km).
GHG: Green House Gas Emissions
Hd: percentage of home-deliveries (%).
I: type of delivery modes (e.g., trucks, cargo-bikes, e-bikes, on-foot)
ICE: Internal Combustion Engine
k: is the annual distance travelled per vehicle (km)
KPIS: Key Performance Indicators
LC: lockers costs
Ld: percentage of lockers-deliveries (%).
M: maintenance
m: ratio of maintenance cost per km (€/km)
ndi: number of delivered parcels per vehicle type i (parcels/day)
nt: the number of tyres per vehicle.
N_v: number of vehicles that increase the congestion
pt: the prize of tyres change (€)
q: factor of indirect costs
qlockers: ratio of maintenance costs of lockers
R: repairs
r: ratio of repairs per km (€/km)
Si: percentage of shipments with vehicle i
TBL: Triple Bottom Line
TC: Tyres Cost
UCC: Urban Consolidate Centers
UFT: Urban Freight Transportation
Wd: working days per year (days)