Assessing the Environmental Impacts of Different IPSS Deployment Scenarios for the Light Commercial Vehicle Industry

Dina Andriankaja, Natacha Gondran, Jesus Gonzalez-Feliu

Assessing the environmental impacts of different IPSS deployment scenarios for the light commercial vehicle industry

Dina Andriankaja, Natacha Gondran, Jesus Gonzalez-Feliu

EVS-PIESO, Institut Henri Fayol, Mines Saint Etienne, 158 cours Fauriel, 42023 Saint Etienne Cedex 2

Abstract

IPSS are popular in different fields of transport, mainly for personal use (car-sharing, bike-sharing). Their usage in urban goods transport is not still generalized but those systems present a good potential. This paper proposed to assess and analyze four different scenarios for urban goods transport to compare IPSS configurations to a business as usual situation, in terms of environmental impacts. Those impacts will be estimated via a life cycle analysis (LCA) method. First, the four scenarios are presented. The first scenario is the reference one, i.e. the business as usual situation. The other three scenarios represent possible IPSS configuration, i.e. a vehicle leasing system, a vehicle sharing system and an urban consolidation system. Second, the methodology for scenario assessment using LCA is described, and the main proposed indicators defined. Third, the main results of the scenario assessment are presented, analyzed and discussed. Finally, future researches are proposed.

Keywords: Urban logistics; collaborative transport; life-cycle analysis; Industrial Product-Service Systems; scenario assessment

1. Introduction

Urban logistics is a popular subject in both research and practice and, since 1995, different works show the interest of different logistics solutions or stakeholders' (both public and private) actions to improve urban goods transport and make it more sustainable ([1][2]). One of the most popular themes of research in city logistics is that of evaluating the environmental impacts of urban goods transport ([3][4]). However, most works related to evaluating sustainability of urban goods transport are based on only Greenhouse gas (GHG) rates and other direct polluting emissions (the operational phase of transport, [5]) and on questions related either to engine (only product manufacturing) or to organization (service vision). In this context, the deployment of IPSS seems to have a potential, as already shown for people transport (car-sharing and bike-sharing systems, public-private partnerships in the deployment of rail-based public transport lines, etc.)

PSS is defined as "*a system of products, services, networks of players and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have lower environmental impact than traditional business models*" ([6]). And we can use the term of "servizisation" when a company creates value by adding services to products and provides value in use to the customer ([7]). For the industry, a product can be dematerialized by including services that reduce the quantity of materials consumed in the life cycle of a product i.e. the production, the use, the reuse and the recycling ([8]). thus, companies that implement PSS may help to minimize the environmental impacts of their activities. However, this reduction of environmental impacts needs to be verified.

But implementing PSS is not as easy as it seems; the barriers to the adoption of PSS are multiple: it calls for changes in behavior and organization of all stakeholders ([7]), it can generate high financial risks and new responsibilities ([8]). So, generally, a company does not offer a PSS on its own but often involves other companies because the key success of PSS is the relationship between companies, by sharing information, and consumers, by meeting their satisfaction.

The aim of this paper is twofold. First, we aim to explore the potential and impacts of IPSS by assessing three scenarios of different IPSS configurations for urban goods transport and compare them to a reference situation. Second, we aim to estimate the environmental impacts not only by GHG in direct emissions, but by a more general framework based on life cycle analysis (LCA), which takes into account all phases of the vehicle's life, from manufacturing to its end-of-life, including also (but not only) the operational phase of use of the vehicle. The paper is organized as follows. First, the fours proposed scenarios (the reference plus the three IPSS configurations' scenarios) are presented and their hypotheses explained. Then, the methodology for scenario assessment using LCA is described. After that, the main results of the scenario assessment are presented, analysed and discussed. Finally, general conclusions to this work are presented.

2. Proposed scenarios and assessment framework

To assess the environmental impact of different IPSS alternatives, we propose to analyze four scenarios related to the deployment of light goods vehicles for urban goods distribution. The four proposed scenarios are the following:

- S0: Reference scenario. Each company owns its vehicle fleet.
- S1: Internal reorganization. Vehicles are proposed in an IPSS configuration: they do not belong to companies but are rented, and the owner remains the vehicle manufacturer. This scenario aims to simulate a leasing system in which carriers re-organize their flows. Due to the usage of vehicles in leasing, each company makes a re-optimization of its routes in order to reduce the number of vehicles. Each company uses its own vehicle fleet which is not shared with the others.
- S2: Vehicle sharing system. The vehicle manufacturer proposes a logistics sharing system were vehicles are common to all users (carriers) in order to reduce the total number of vehicles. Companies use their vehicles for their own needs then they bring them to common parking spaces where other companies can take them for different uses.
- S3: Logistics pooling system. Manufacturer does not propose only the vehicles but also the organization of transport to city centre, in order to drastically reduce the number of vehicles and increase their performance. An urban distribution center (in the sense of [9]) is used to consolidate goods and prepare routes going to city center. Opposing to most literature works in urban consolidation, both inbound flows to the consolidation center and outbound flows from that platform to the city are considered.

The proposed framework is organized as follows:

1. Reference scenario definition.
2. Deployment scenarios construction.
3. Environmental assessment of each scenario
4. Results analysis and discussion

2.1. Scenario construction and assessment

In order to build the different scenarios, we need to start from a solid base that represents a reality then to do the same for the other scenarios in a way to ensure comparability among them. The scenario assessment and comparison is close to that of a before-after assessment ([10]), so the precision of reference data is less important that the robustness of the assessment method. In other words, the aim of the scenario assessment is to compare different situations and to analyze their gap in terms of environmental performance, not to make an accurate diagnosis of the current situation, so if the assessment method estimates impacts on the same basis to all scenarios, this comparison is possible.

The scenarios are related to different usages of vehicles for urban delivery purposes by carriers, and this on an IPSS viewpoint. Consequently, the proposed scenarios need to be based on carrier behavior data, and not on aggregated databases often used for public transport planning ([11]). To build the scenarios, we use data from the urban goods database proposed in [5]. Then, from this database, a set of 100 representative routes is obtained using a probabilistic random generation procedure that respects the statistical distribution of each route category. In this study, we focus only on third-party transport, so own account routes are not considered. Moreover, not all goods can be transported by light commercial vehicles. For this reason, only routes made with vehicles with 3.5T of full loaded weight are considered. For more information on the database and the route categories, see [5].

Three main types of carriers are defined, related to the weight of goods transported (and indirectly, to the type of packaging moved, i.e., small and medium weights are supposed to be parcel deliveries and big weights pallet deliveries)..

2.1.1. Reference scenario construction

To build the reference scenario, the 100 routes (which characteristics are generated but are not still spatialized, i.e. related to a territory) are grouped into 31 carriers. This is done via an analysis of French urban goods surveys ([11]) and the results of previous researches on the organization of such routes ([5][12]). Carriers are assumed to have its own platforms located inside a 14 km x 14 km zone in the Eastern part of a city (which centroid is assumed to be situated at 12 km from the city center). In this study, and to simplify estimations, we assume this zone to be a square and the 31 carriers to be uniformly distributed in that zone.

From those assumptions, and assuming that the context takes place on a conurbation with similar characteristics to those of Lyon, France (about 1.9 million inhabitants, platform location in a zone at East of the city, good access conditions to the city and a congested city center, among others), we estimate the approach trip length (from the platforms to the main zone of delivery) and the inter-customer trip distance, in order to spatialize routes. Then, the main spatial characteristics of a route (traveled distances) as well as routes' travel and stop times are estimated.

The proposed set of 100 routes respects also the French regulation related to driving time, as the total working time of each driver is always lower than 8h (including loading and unloading operations and contractual breaks). Each vehicle is then assumed to be used by only one driver but the route can include more than one passage to the depot then different delivery rounds (for example, one vehicle can make two rounds with 6 deliveries each).

2.1.2. S1: Vehicles in leasing, own reconfigurations for each carrier

The first scenario aims to represent an IPSS configuration where vehicles are not sold but rented, like in vehicle leasing systems. In this configuration, we suppose that carriers would reorganize internally their transport to city in order to individually reduce their number of vehicles. However, routes being quite well optimized with respect to practice criteria, so the number of vehicles is similar to that of scenario 0 (100 vehicles in scenario 0 and 96 in scenario 1). Indeed, although real routes are far from theoretical optima, we observe that urban distribution constraints make the optimization difficult so those routes are robust and a further work of optimization produces small (although non-negligible) savings.

The re-optimization is made following the procedure for generating routes described in [5]. Indeed, all customers of a carrier are grouped, then new averages of weights and traveled distances are re-calculated, redesigning routes that respect the urban distribution constraints. Because of this re-organization, the composition of routes and the traveled distance change.

2.1.3. S2: Vehicle sharing system

The second scenario represents the usage of a vehicle sharing system, but without internal reorganization. Indeed, this IPSS configuration considers that all companies keep their route organization unchanged but vehicles can be shared. Consequently, to estimate the total number of vehicles, we analyze each carrier’s set of routes and select routes which total time (considering travel time, loading time, delivery time and eventual contractual beaks) is lower than 5h. Then, we match routes in sets of two, having as constraint that the total vehicle usage time is lower than 10h. This is made considering that vehicles are used by different carriers (and then by different drivers) and that current delivery hours in France (for proximity retailers) are inside a range that goes from 8 a.m. to 6 p.m. ([13]), which makes a total time window length of 10h. Note that this measure may appear as contradictory with the current incentive of cities to prevent goods delivery on certain time periods.

After that, the new number of vehicles is calculated. It is important to recall that in this configuration, the total traveled distance does not change with respect to S0; the only change is the total number of vehicles needed that is lower. Indeed, in S0 it is assumed a total number of vehicles of 100, whereas in S2, the total number of vehicles is 85

2.1.4. S3: Urban consolidation center system

A third possibility would be that of offering vehicles in a sharing configuration but in addition to propose a consolidation center based delivery service to city center. In this configuration, we assume carriers will bring goods to urban consolidation center the evening, using the 3.5 ton vehicles, and making TL transport (Truckload, i.e. a direct transport form the origin, i.e. the carrier’s depot, to the destination, i.e. the consolidation center). Then, the morning after that, the same vehicles are used to deliver goods of all carriers, previously rearranged into almost full-loaded vehicles that deliver the city. To assess the impacts of an IPSS configuration based on an urban consolidation center, we propose an empirical route construction procedure that calculated both flows (inbound transport from carriers’ depots to the consolidation center and outbound transport from the consolidation center to the city destinations. Opposing to many works in literature on urban consolidation simulation ([14][15]), we consider both inbound and outbound flows because to evaluate the impact of this configuration both flows are contributing to environmental impacts and need then to be considered in a systemic viewpoint ([16]).

We assume the consolidation center is located in the centroid of the industrial zone where carriers are located (i.e. in the center of the 14 km x 14 km square where we assume the carriers' depots located). Then, from that location, both distances to city gates (i.e. the points that represent the entrance in the urban zone where final destinations are located) and distances to carriers' depots locations are estimated. The proposed assessment method works as follows. To estimate the inbound routes, we calculate the distance travelled from each carrier's depot to the consolidation center is estimated considering that each carrier bring to the consolidation center a number of vehicles that allow to transport all demand.

Then, for each type, routes are re-constructed using the route construction procedure as for scenario 0, considering that customers in average are nearer between them (the average distance between two destinations is re-calculated from the total number of customers and the entire area to be delivered). Then, total traveled distances, total travel times and total number of vehicles needed for this configuration are estimated.

2.2. Environmental assessment using life cycle analysis

The environmental assessment of the proposed scenarios will be made via a Life Cycle Analysis to take into account all different stages of the product's life (in this case, the vehicle) and not only direct emissions related to its utilization (for delivery purposes). Indeed, the aim of this research is to compare the environmental impacts of the four product systems that we consider. For an equitable comparison, it is essential that the systems, which are compared, actually provide the same function to the user.

The main motivation of using LCA arises on the fact that this method participates especially in identifying opportunities to improve the environmental performance of products and services at different stages of their life cycle; and information to industry decision makers and public authorities in their strategy or planning. More precisely, we propose a method based on the standardized LCA methodology ([17][18]). LCA was developed as an analytical tool to assess the environmental impacts from products or services. In our case, we will consider the impact of the entire life cycle of the vehicles. This includes production, operation, maintenance and disposal.

In order to show the total environmental impacts caused by the product or the service, the analysis must focus on the product systems (four scenarios corresponding to four product systems), we then consider nine indicators. These indicators have been validated in a recent work on the environmental assessment of urban mobility ([19]). These indicators describe the greenhouse gases (GHG) emission, the energy requirements (fossil and renewable energy), the resources used and the local air pollution. There are four phases in an LCA standard framework:

1) Goal and scope definition
2) Life cycle inventory
3) Life cycle impact assessment (LCIA)
4) Interpretation

2.2.1. Goal and scope definition

In this first phase, we define the goal and the intended use of the LCA and describe the function to be provided by the system in qualitative terms and quantified in the functional unit. The functional unit defines the number of product units for which the collection of data is done. In our case, the functional unit is to realize the delivery activities of seventy tons of goods in one day, from thirty-one expeditor clients to the urban center.

2.2.2. Life cycle inventory

In this second phase, the aim is to collect information on the input and output for all processes within the boundaries of the product system ([20]). In our case, we use 2010 inventories from Ecoinvent database ([21]). The impacts per vh.km were obtained by modifying Ecoinvent data to better represent the description of the actual vehicle (light commercial vehicle 3,5t) used in the scenarios. In terms of processes, we consider four processes corresponding to the entire transport life cycle of the vehicle: production, operation, maintenance and disposal processes for van.

2.2.3. Life cycle impact assessment (LCIA)

LCIA's purpose is to assess a product system life cycle inventory analysis results to better understand its environmental significance ([22]). It models selected environmental issues called impact categories (nine in our case).

Table 1. Assessed impact categories

Impact categories	Units	Substances
Global warming potential (100 years)	kg CO_2 eq	all greenhouse gases
Terrestrial acidification potential (100 years)	kg SO_2 eq	NH_3, SO_2, NO_x
Photochemical oxidant formation	kg NMVOC eq	NMVOC * and other photochemical oxidants
Particulate matter formation	kg PM10 eq	PM, SO_2, NO_x, NH_3
Fossil depletion potential	kg oil eq	coal, gas, oil
Metal depletion potential	kg Fe eq	all metals
Urban land occupation	m²*a	
Fossil energy	MJ eq	coal, gas, oil, peat, uranium, primary forest
Renewable energy	MJ eq	hydro, wind, geo, solar, biomass energies

We use ReCiPe midpoint method to normalize these impacts because it evaluates most of the chosen midpoint indicators with a standard method ([23]). The energy indicators were obtained by cumulative energy demand operations.

2.2.4. Interpretation

Interpretation is the phase of the LCA where the results are analyzed and interpreted according to the goal of the study. The outcome of the interpretation may be a conclusion serving as a recommendation to the decision makers, who will normally consider the

* Non-Methane Volatile Organic Compounds

environmental and resource impacts together with other decision criteria (like economic and social aspects).

2.2.5. Limits of LCA

LCA is a mature tool with a well-established set of methods and data that enables a direct comparison of alternatives associated with the analyzed product ([24]). However, LCA is still subject to limitations that should be considered within the sustainability context. LCA usually models “average” systems, and may not capture the impacts of policies that cause indirect changes or significant (non-marginal) changes in the market. For example, a shift in energy supply may affect power plant operations, and a new technology may create new demand (or eliminate demand) for other technologies (diesel vs electric vehicle for instance). Another barrier is the gaps in the availability of inventory data, data have not yet been assembled for some products, systems, and emissions. Filling data gaps requires significant effort, causing typical LCA studies to require many months to complete.

3. Results and discussion

After assessing the four scenarios and estimating its environmental impacts with the proposed LCIA method, we synthesize the results as presented in Table 2. To represent the results per day, we considered a lifetime of ten years for the vehicles ([25]). We observe that all IPSS configurations have lower environmental impacts (both direct and indirect impacts) that the reference situation, which shows the interest of deploying IPSS strategies for urban goods transport, but the impacts are different for each scenario. Indeed, scenarios 1 and 2 (those without real collaboration among carriers) remain lower but close to the reference scenario, whereas scenario 3 (which implies a strong collaboration among carriers) reduces the total traveled distances drastically (about 35% of reduction of total number of km), which is directly translated into strong environmental gains.

However, we observe environmental gains in all scenarios with respect to S0 which is mainly due to the reduction of the number of vehicles and then to the construction and end-of-life phases of the life cycle. Note that all indicators are estimated with relation of day-type utilization, then adjusted to be related to the total daily traveled distances.

Regarding S1, we estimate an average impact reduction of about 3.3% with respect to S0. We observe that the total number of kilometers is close to that of S0, which shows that routes are nowadays (in the initial scenario) well-optimized with respect to the goals and constraints related to urban distribution. Moreover, the number of vehicles is very close to that of S0. However, this small reduction allows already an interesting reduction, mainly in energy consumption (routes are higher but customers are closer).

For S2, we can see that the impact reduction with respect to S0 is lightly higher than that of S1. Indeed, the overall impact reduction is estimated to about 5.9% with respect to S0. However, the travelled distances are equal to those of S0 –the distances directly related to deliveries are the same than S0 because we consider only a mutual usage of vehicles, not a re-configuration of delivery organizations). The reduction in the number of vehicles is about 15%, which clearly shows that the contribution to impact reduction is mainly due to the usage of less vehicles in a more rational way.

Table 2. Assessed impact results for the delivery of 70t of goods, per day

Impact categories	S0	S1	S2	S3
Nb. of vehicles	100	96	85	56
Number of routes	123	96	123	187
Total daily distance (km)	5513	5355	5513	3610
Direct emissions				
GHG (kg CO_2 eq)	3636	3532	3636	2381
Land acidification (kg SO_2 eq)	12.9	12.5	12.9	8.4
Oxidants (kg NMVOC)	23.3	22.7	23.3	15.3
Particulates (kg PM10 eq)	6.2	6.0	6.2	4.1
Fossil depletion (kg oil eq)	1246	1211	1246	816
Metal depletion (kg Fe eq)	13.9	13.5	13.9	9.1
Urban land occupation (m^2*a)	3.2	3.1	3.2	2.1
Fossil energy (GJ)	52.4	50.9	52.4	34.3
Renewable energy (MJ)	132	128	132	87
Indirect emissions				
GHG (kg CO_2 eq)	815	782	693	456
Land acidification (kg SO_2 eq)	4.0	3.8	3.4	2.2
Oxidants (kg NMVOC)	2.7	2.6	2.3	1.5
Particulates (kg PM10 eq)	1.7	1.6	1.5	1.0
Fossil depletion (kg oil eq)	281	270	239	157
Metal depletion (kg Fe eq)	454	436	386	254
Urban land occupation (m^2*a)	4.0	3.9	3.4	2.3
Fossil energy (GJ)	11.8	11.3	10.0	6.6
Renewable energy (MJ)	1001	961	851	561

S3 is then the scenario that shows the most important environmental gains, estimated to be about 38.2% with respect to S0. This is due to both a reduction of the number of vehicles used (44% with respect to S0) and to the drastic reduction of the total number of traveled kilometers (34% with respect to S0). We observe that the construction and end-of-life phases of the life cycle have an important impact to the environment. Indeed, the gains for S1 and S2 are mainly due to indirect impacts; but, when regarding S3, a good usage of the vehicle with an operational phase that leads to a decrease of direct emissions has also an important contribution to the reduction of global environmental impacts.

Finally, it is important to add that in this scenario we consider an urban consolidation system which has enough demand to be economically viable and that leads to a real reduction of the traveled distances by a direct economy of scale. Indeed, by sharing all customers and vehicles into a unique consolidation center, the number of trips increases because freight needs to go from each carrier’s location to the consolidation center, but the aggregation and consolidation made at this new platform leads to a drastic reduction of the total number of vehicles and a more rational use of the resources.

4. Conclusion

This paper presented, via a scenario assessment using a life cycle analysis method, four possible configurations of vehicle fleets and their impacts on the environment. Four configurations were assessed: a reference situation (no IPSS), a leasing system with internal logistics reorganization, a vehicle sharing system and an urban consolidation-based system. We observe that if the number of vehicles used has a strong impact to the environment (related to the construction and end-of-cycle phases of the vehicle's life cycle), the total number of kilometers (i.e. the operational organization, having an impact on direct emissions) is also important, and the combination of both levers lead to important environmental impacts (with a reduction of 44% of vehicles and of 35% of the total traveled distances, we observe a total reduction of 38.2% in terms of overall environmental impacts).

However, other dimensions of the comparison should be considered by logistic decision makers such the motivation to implement an urban distribution center. That configuration assumes a strong collaboration among carriers and a disposal of using urban consolidation, which is nowadays not still a uniform statement (most urban consolidation initiatives remain testimonial, and have difficulties to be deployed in industrial scales). But since the main reluctances to use this type of systems are related to a lack of knowing the real impacts of such systems, a generalization of the present work in a practitioner's decision support viewpoint will help, not only public decision makers, but also private carriers managers (both strategic and operational) to find the best configuration of urban consolidation services in order to develop and deploy them to make real economies of scale and then reduce strongly the environmental impacts of urban goods transport.

Finally, we note that this method may be transferable for transport sector if the same type of functional unit can be considered. We noticed that changing the unit that is used to describe the physical system in order to estimate its environmental impacts (tons, ton-kilometers, vehicle-kilometers, number of stops, number of parcels…) may have a significant impact on the results. In our future researches, we plan to analyze more deeply this influence on the results, of this "transfer unit" between the physical and the modeled system. Concerning scenarios, we plan to introduce new types of vehicles, mainly in terms of engine (electric vehicles or gas vehicles among others).

Acknowledgements

This paper was partially financed by the French National Agency (ANR), more specifically by VBD program (2013-2017), project ANNONA.

References

[1] Gonzalez-Feliu J, Semet F, Routhier JL (Editors). *Sustainable urban logistics: Concepts, methods and information systems*. Heidelberg: Springer; 2014.

[2] Taniguchi E, Thompson RG (Editors). *City Logistics: Mapping The Future*. CRC Press.

[3] Macharis C, Melo S (Editors). *City distribution and urban freight transport: multiple perspectives. Northampton*: Edward Elgar Publishing; 2011.

[4] Macharis C, Melo S, Woxenius J, van Lier T (Editors). *Sustainable Logistics*. Emerald Group Publishing, series: Transport and Sustainability, N. 6; 2014.

[5] Gonzalez-Feliu J, Morana J. Assessing urban logistics pooling sustainability via a hierarchic dashboard from a group decision perspective. In Macharis C, Melo S, Woxenius J, van Lier T (Editors). *Sustainable Logistics*. Emerald Group Publishing, series: Transport and Sustainability, N. 6; 2014. p. 113-135.

[6] Goedkoop MJ, van Halen CJG., te Riele HRM, Rommens PJM. *Product Service Systems, Ecological and Economic Basics*. Report for Dutch Ministries of Environment (VROM) and Economic Affairs (EZ); 1999.

[7] Baines TS, Lightfoot HW, Evans S, Neely A, Greenough R, Peppard J, … Wilson H. State-of-the-art in product-service systems. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *221*(10); 2007. p. 1543–1552.

[8] Beuren FH, Gomes Ferreira MG & Cauchick Miguel PA. Product-service systems: a literature review on integrated products and services. *Journal of Cleaner Production*, *47*; 2013.p. 222–231.

[9] Boudouin D, Morel C, Gardrat M. Supply chains and urban logistics platforms. In Gonzalez-Feliu J, Semet F, Routhier JL, editors. *Sustainable urban logistics: Concepts, methods and information systems*. Heidelberg: Springer; 2014. p. 1-20.

[10] Leonardi J, Browne M, Allen J. Before-after assessment of a logistics trial with clean urban freight vehicles: A case study in London. Procedia-Social and Behavioral Sciences, 39; 2012. p. 146-157.

[11] Ambrosini C, Patier D, Routhier JL. Urban freight establishment and tour based surveys for policy oriented modelling. Procedia-Social and Behavioral Sciences, 2(3); 2010. p. 6013-6026.

[12] Gonzalez-Feliu J, Cedillo-Campos MG., Garcia-Alcaraz JL. An emission model as an alternative to O-D matrix in urban goods transport modelling, Dyna. Journal of the Facultad de Minas, Universidad Nacional de Colombia – sede Medellin, 81(187); 2014. p. 249-256.

[13] Muñuzuri J, van Duin JHR. Time constraints: the cost of sustainability. In Gonzalez-Feliu J, Semet F, Routhier JL (Editors). *Sustainable Urban Logistics: Concepts, Methods and Information Systems*. Heidelberg Springer; 2014. p. 165-185.

[14] Faure L, Battaia G, Marquès G, Guillaume R, Vega-Mejí CA, Montova-Torres JR, Quintero-Araújo, CL. How to anticipate the level of activity of a sustainable collaborative network: The case of urban freight delivery through logistics platforms. In Proceeding of the 7th IEEE International Conference on Digital Ecosystems and Technologies (DEST); 2013. p. 126-131.

[15] Su F, Roorda MJ. The Potential of Urban Freight Consolidation for the Toronto Central Business District. In Transportation Research Board 93rd Annual Meeting (No. 14-2104); Washington; 2014.

[16] Gonzalez-Feliu J. Cost optimisation in freight distribution with cross-docking: N-echelon location routing problem. *PROMET-Traffic & Transportation*, 24(2); 2012. p. 143-149.

[17] AFNOR. ISO 14040 :2006.

[18] AFNOR. *Analyse du cycle de vie - La série des normes ISO 14040*. Paris : Afnor éditions ; 2012.

[19] François C, Gondran N, Nicolas JP. Empreinte GES et évaluation environnementale de la mobilité urbaine. *Séminaire « Empreinte carbone des organisations, des produits et des services : Evaluer et agir - Un enjeu interdisciplinaire pour la recherche ? »*; Paris; 2015.

[20] Schweimer GW, Levin M. *Life Cycle Inventory for the Golf A4*. Wolfsburg: Volkswagen; 2007. Retrieved from http://www.volkswagenag.com.

[21] Frischknecht R, Rebitzer G. The ecoinvent database system: a comprehensive web-based LCA database. Journal of Cleaner Production, 13(13); 2005. p. 1337-1343.

[22] Thériault N. *Dans le cadre d'une ACV, conception d'un outil d'aide à la sélection d'un jeu de catégories d'impact pour les entreprises européennes et nord-américaines du secteur textile*. Québec: University of Sherbrooke; 2011.

[23] Goedkoop M, Heijungs R, Huijbregts M, Schryver A, De, Struijs J, van Zelm R. *A life cycle impact assessment method which comprises harmonized category indicators at the midpoint and the endpoint level*. ReCiPe; 2008. p. 126.

[24] U.S. EPA, *Life Cycle Assessment: Principles and Practice*, Office of Research and Development. National Risk Management Research Laboratory, Editor 2006, U.S. EPA: Cincinnati, OH.

[25] Warburg, N., Forell, A., Guillon, L., Teulon, H., & Canaguier, B. *Analyse du cycle de vie comparative véhicule électrique - véhicule thermique. Elaboration selon les principes des ACV des bilans énergétiques, des émissions de gaz à effet de serre et des autres impacts environnementaux induits par l'ensemble des filières*. Final report for the French Environment and Energy Management Agency (ADEME); 2013. p. 281.