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The Kaldor–Hicks Criterion Applied to Economic Evaluation of Urban Consolidation Centers

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Abstract

Urban Consolidation Centers (UCC) cases, like in Tenjin, Japan, or in Lucca, Italy, have shown vehicle optimization and a decrease in environmental and social impacts of freight transportation activities. Nonetheless, financial sustainability is a barrier for their operation, especially because it is not common to consider environmental and social impacts in cost–benefit analysis. There is a lack of literature about the economic evaluation of UCC addressing stakeholder's cost–benefit with reduction of externalities. The objective of this paper is to present an example of how to incorporate social and environmental impact in a UCC economic evaluation and according to the Kaldor–Hicks criterion, to demonstrate that UCC implementations might be justified even when public subsidies are necessary. A neighborhood of São Paulo city, Brazil, was used as a reference for a simulated UCC implementation. The simulated direct costs of the UCC operations were 13.7% higher than the baseline scenario, however, using the Kaldor–Hicks criterion and incorporating benefits for stakeholders, the benefits compensate the additional operating cost. This new approach to UCC economic evaluation that monetizes and incorporates environmental and social benefits for stakeholders might support decision-makers to optimize freight transportation systems while reducing negative effects of this activity.

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Keywords: Urban Consolidation Center; The Kaldor–Hicks criterion; Stakeholders; Social and environmental impacts; Economic Evaluation

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1. Introduction

Supplying goods in urban centers with high levels of traffic congestion is a challenge. The global urbanization rate increased from 30% in 1950 to the current 55% and it is expected that will reach 68% in 2050 (World Bank, 2017). In Brazil the rate was 84.4% in 2010 (IBGE, 2017a) and will reach 91% in 2050 (UN, 2014). The increase in populational concentration reflects on travel demand that according to OECD/ITF (2017), the global travel demand in cities will increase by 95% between 2015 and 2050, and travel demand by private cars will reach levels of +185% in the same period of time in Brazil. The elevated motorized travel demand, including cargo vehicles, coupled with the low investment in transportation infrastructure in some countries, as in Brazil (Frischtak & Noronha, 2016), might increase traffic congestion, local pollutant levels, and greenhouse gas (GHG) emissions.

The urban flow of goods is mostly carried by trucks (Diziain et al., 2014, MTPA, 2017) that aggravates the problems of congestion. Nonetheless, it is essential to meet the demand for products and servicees by the population and to foster the economic development, once more than 80% of world's gross domestic product (GDP) is generated in cities (WB, 2017). The combination of optimizing the flow of urban goods and minimizing the adverse social and environmental effects is the cornerstone of City or Urban Logistics (Thompson and Taniguchi, 2008; Taniguchi et al., 200; Dablanc 2007).

Socio-environmental benefits like reduction of GHG emission, fuel consumption and local pollutants are widely cited in city logistic projects (Browne et al., 2005; Allen el al., 2012; Browne et al., 2011; van Duin et al., 2013). One solution is the Urban Consolidation Center (UCC), that can be defined as "a facility involving the trans-shipment of goods directed to urban areas, aiming to consolidate deliveries, and thus provide greater efficiency in the distribution process by increasing the truckload factor and decreasing the number of trucks used, which help mitigate urban congestion and air pollution" (Panero et al., 2011). Despite positive aspects, there are few examples of established UCCs and financial sustainability is pointed out as one of the main challenges for many reported examples, also public subsidy is mentioned as an important factor to enable and to maintain some UCC implementation (Browne et al., 2011; Panero et al., 2011; Kin et al., 2016; Janjevic and Ndiaye, 2017).

Although socio-environmental benefits are reported in the literature as benefits of UCC implementation, there are opportunities to explore how to include them in economic evaluation.

The objective of this paper is to contribute with an economic evaluation that goes beyond the conventional cost accounting restricted to UCC operating costs and savings. It incorporates the benefits of last mile optimization for carriers, receivers, local population and government and uses the Kaldor–Hicks Criterion, from the research field of Welfare Economics, to present a point of view that if the benefits for society and environment compensate additional costs of UCC implementation, this city logistics solution might be socially desirable and subsidies might be justified.

This work uses one hypothetical case study to exemplify the economic evaluation using the Kaldor–Hicks Criterion, but the concept could be explored and applied in other situations.

2. Literature Review

This literature review presents research publications about benefits of UCC implementation and the incorporation of social and environmental impacts of economic evaluations.

One solution of Urban Logistics is the UCC that allows reduced pollutant emissions and other negative traffic impacts, once the main objective of this type of solution is to increase the vehicles´s load factor by using transshipment and delivery consolidation at the UCC (Browne et al., 2005; Browne et al., 2011; Panero et al., 2011; Allen et al., 2012; Janjevic and Ndiaye, 2017).

UCC is an urban freight solution that might contribute to organize the flow of goods in cities. Some results of its imply the reduction of the number of trucks serving the Tenjin-District Joint Distribution Program in Fukuoka, Japan, by 65% and the total distance traveled (km/day) by 87% (Karrer and Ruesch, 2007). The UCC in Kassel, Germany, reduced the trips to the city center of Bremen by 12.7% and there was a 60% reduction of cargo vehicles within the UCC service area (Browne et al., 2005). Van Rooijen and Quak (2010) studied the UCC Binnenstadservice.nl and the local impact of urban deliveries, and according to their modelling, the reduction of the number of vehicles could reach 58.6%, at full capacity. In Lucca, Italy, the implementation of the UCC with a fleet of electric vehicles resulted in a reduction of traffic congestion, number of vehicles in the historic center and levels of air pollution (a reduction of 20% of CO_2 and 27% of particulate matter) (SUGAR, 2011).

Financial support from a public institution is mentioned in many UCC cases (Browne et al., 2011; Panero et al., 2011), especially during the initial years of operation. It reinforces the notion that economic viability is the main constraint for UCCs. Kin et al. (2016) demonstrated that stakeholders of city logistics (i.e., shippers, receivers and carriers) are not willing to pay additional costs for using then.

Van Rooijen and Quak (2014) warn that “Because of the high competitiveness in the sector it is often necessary that the public authorities provide initial funding and assistance to potential participants of freight schemes. However, financial planning should demonstrate financial viability within a reasonable timeframe.”. The financial viability is the ideal, nonetheless, it might be considered that the social and environmental benefits of a UCC implementation to decide if subsidies by public authorities are worthwhile. Gonzales-Feliu et al. (2014) presents public funding and explain a funding approach that has been used in urban logistics projects, the Collective Utility: “By collective utility we intend the socio-economic interest that a project can bring to a society”, which could be used to support public financing of urban logistics.

Some scholars have been addressing the economic analysis of UCC implementation (Roca-Riu et al., 2016; Janjevic et al., 2016) and the incorporation of social and environmental benefits in project analysis. Browne et al. (2015) describe variables and indicators to be considered at a comprehensive UCC evaluation. Fernandez-Barcelo and Campos-Cacheda (2012) formulate a model of social costs related to urban distribution of goods. Lin et al. (2016) present a methodology to examine the effectiveness of urban delivery consolidation considering logistics cost, vehicle energy consumption, and emissions. Taniguchi et al. (2014) highlighted the relevance of urban freight vehicles on pollutant emissions and presents approaches of some models to predict the emissions associated with urban freight operations. These efforts to measure additional benefits might facilitate the building of a comprehensive UCC evaluation.

3. Incorporating Social and Environmental Impacts at Economic Evaluation

The importance and difficulties of incorporating externalities, as social and environmental impacts, were mentioned by Browne et al. (2005), who say, “The evidence suggests that the benefits are more difficult to quantify and allocate than the costs” and “… there is a danger that the UCC will be seen mainly as a financial drain as a result of a focus on the direct monetary costs associated with its operation.”

An UCC economic evaluation under the supply chain point of view tends to pursue operational cost reduction and exclude external impact on the environment and the local population. Due to the competitiveness of the market, most companies are continuously reevaluating their supply chains toward internal efficiency, leaving few changes that could lead to cost reductions. A comprehensive UCC economic evaluation exploring the differences among stakeholders might facilitate a deepening of social and environmental issues, and to build an analysis from the point of view of the city, pursuing cost reduction for the supply chains, for the local population or public services for the population and the environment. This approach might broaden opportunities to implement solutions that provide benefits considering all urban logistic stakeholders.

This work uses the Welfare Economics research field to explore this point of view. Also, research was carried out with institutions that foster economic development with high degrees of concern about social and environmental impacts such as Multilateral Development Banks as well as some recent studies in Brazil about monetizing environmental impacts.

3.1. *The Kaldor–Hicks Criterion*

According to Buchanan (1959), “The ‘new’ welfare economics was born in response to the challenge posed by the positivist revolution. The intellectual source of this subdiscipline is Pareto, whose earlier attempts to introduce scientific objectivity into the social studies led him to enunciate the now-famous definition of ‘optimality’ or ‘efficiency.’” and “The definition may be transformed into a rule which states that any social change is desirable which result in (i) everyone being better off or (ii) someone being better off and no one being worse off than before the change.”.

The Kaldor–Hicks criterion can be described as a less stringent criterion than Pareto efficiency and it is the most commonly adopted criterion to apply the compensation principle (Platts, 1978). Following this criterion, a change is socially desirable if it means that at least one stakeholder would favor the effects of change (be “better off”) and the gains would be able to compensate the “losers” and still be better off, even if the compensation is not in fact paid (Hohl and Tisdell, 1997; Kaldor, 1939; Hicks, 1939; Reckon Open, 2010; Coleman, 1980). The Kaldor–Hicks criterion is largely mentioned in Welfare Economics and applied in analyses focused on public policies, sustainability, wealth distribution (Posner, 1980; Jones and Sugden, 1982) and some transportation projects (Lane and Sherman, 2013; Isa et al., 2018).

Compared with a usual CBA that evaluates impacts in aggregate form, the Kaldor–Hicks criterion evaluate benefits and losses by stakeholders, separately, and allows a compensatory approach among them, different from a CBA considering Pareto efficiency. This approach provides a more complete representation of the stakeholder interests than an aggregate financial analysis, facilitating the inclusion of social and environmental impacts in the UCC economic evaluation and strengthening the importance of changing the point of view restricted to supply chains and extend it citywide.

3.2. *Multilateral Development Banks Approach*

Examples of monetizing social and environmental benefits can be found in publications of Multilateral Development Banks (MDB), as Inter-American Development Bank (IDB), World Bank (WB) and Asian Development Bank (ADB), which are supranational institutions set up by sovereign states, which also are their stakeholders. They provide financial and technical support to developing countries to help them strengthen economic management, reduce poverty and address the effects of climate change (European Investment Bank, 2017; U.S. Department of the Treasury, 2017). MDBs are a very important resource of investment for projects classified as costly, risky, complex or that focus on social and environmental issues (Ferraz et al., 2013), especially for developing countries. Their project evaluations tend to be more complex and comprehensive, and for some MDBs there are examples of calculations of social and environmental costs for economic evaluations that might be a source of reference for researchers.

To understand if externalities were already incorporated in MDB's project economic evaluations, some representative MDBs were selected with the recognized participation of Brazilian transportation infrastructure investment and research was conducted into their publications. The selected banks were the WB, IDB, ADB and the Development Bank of Latin America (CAF). The New Development Bank and Banco Nacional de Desenvolvimento Econômico e Social (National Economic and Social Development Bank) were also analyzed but there are no publications available. The result of this publication review is summarized in Table 1.

Table 1. Summary of economic evaluations for transportations projects of MDB's publications

MDB	How are social and environmental issues incorporated in the operations of the Bank?
IDB	Among some publications of the theme, there is a technical note highlighting the importance of expanding project evaluation by including monetized social and environmental impacts and also redesigned project cost–benefit analysis (CBA) incorporating costs and benefits after mitigation measures. This document presents an example of different CBA considering (i) no social and environmental impacts, (ii) including them and (iii) including them with mitigation actions (Dixon, 2012).
WB	There are some studies and reports that express the importance of analyzing social and environmental impacts on CBA of transportation projects and two of these were chosen: a cost–benefit modeling framework that was applied in four simulated projects considering black carbon emissions (WB, 2014) and a guideline to monetize health effects of air pollution from traffic congestion (WB, 2012).
ADB	A guideline is available with examples of social and environmental impacts that could be considered on CBA, including a suggestion of value of GHG emission per ton.
CAF	CAF's guideline related to infrastructure projects lists main procedures and reports that loan solicitants should complete; some of them are related to social and environmental aspects but there are no specifications regarding economic evaluation (CAF, 2017).

According to MDB's publications and literature review, there is no standardization of incorporating externalities, indicating that there might be opportunities to explore methodologies and applications for city logistics economic evaluations.

3.3. *Monetizing Social and Environmental Impacts*

As mentioned by Browne et al. (2005), there are few examples of monetizing social and environmental benefits in economic evaluation of city logistics projects. Studies conducted in Brazil provide information that can be used as a reference to monetize the cost of reduction of traffic congestion (Firjan, 2014) and local pollutants, specifically Particulate Matter (PM) (ISS, 2017).

Firjan (2014) estimates the amount of money lost by population stuck in traffic congestion based on the city data as GDP, economically active population (EAP), average working hours, traffic congestion extension, average number of vehicles in congested lanes and average of passengers per vehicle, also considers the value of wasted fuel.

ISS (2017) considers the current level of a local pollutant, PM emissions in São Paulo (Brazil), average emissions by the fleet of diesel buses (that is the same technology for trucks) and impact on health problems . The study monetizes the reduction of hospitalization and premature deaths of city's EAP related to a decrease of PM emissions.

4. Strategy to Apply the Kaldor–Hicks Criterion to UCC Economic Evaluation

4.1. *Context and Case Study Structuring*

The aim of this part of the paper is to present an example of the application of the Kaldor–Hicks criterion to UCC economic evaluation. Once it considers stakeholders' costs and benefits, the example has been structured focusing on the monetized impact of each player.

Due to the lack of information of a complete case study, this example considers data from projects, empirical data of Brazilian the market and studies conducted in Brazil. UCC operating and freight costs are based on IDB project (IPPUC, 2014) and available public data from São Paulo city. Firjan (2014) is used to monetize the benefits of reducing traffic congestion and ISS (2017) is the basis of monetizing the impact on reducing local pollution. The location chosen for this application is a neighborhood of São Paulo city which has a high concentration of stores and elevated level of traffic congestion. This area has heavy-duty access restriction during the day and permission of circulation for cargo vehicles with a capacity of up to three tons.

The area studied is 4,000 m^2 and has a population of 33,892 inhabitants.

4.2. *Direct Cost Estimation*

4.2.1. *Baseline Scenario*

The Baseline Scenario considers a usual operation with loading at the Shipper (suppliers), transport by Carriers (logistics operators) and delivery to receivers (customers) located at the area selected.

The cost estimation is based on Table 2.

Table 2. Baseline Scenario Cost Estimation

Description	Value	Observation
Annual Volume delivered (ton)	26,400	
Delivery Cost (USD/ton)	64.39	Freight based on IPPUC (2014)
Annual Delivery Cost – Baseline Cost (USD)	*1,699,795*	

4.2.2. *UCC Scenario*

It is assumed that the UCC is located close to the service area with easy access by road, including for heavy-duty vehicles. The total volume and delivery characteristics are the same as in the Baseline Scenario. The transport from Shippers to the UCC are carried out at night (10 p.m. to 6 a.m.) by original Carriers, which are consolidated (higher ton per vehicle).

The difference between the original cost of freight (Shippers to Receivers) and the cost from Shippers to the UCC will be used as earnings for the UCC. UCC operating costs and freight costs from UCC to Receivers will be allocated to the Government.

Costs related to UCC operations were estimated based on cases found in the literature, on market price and IDB project (IPPUC, 2014). UCC direct costs are described in Table 3:

Table 3. UCC Operating Costs and UCC Scenario Cost Estimation

Item	Value	Observation
Freight: Shippers to UCC (USD/ton)	34.77	Based on IPPUC (2014) and assuming a reduction of Vehicle Kilometer Traveled due to deliveries consolidation
Freight: UCC to Receivers (USD/ton)	13.90	Based on IPPUC (2014), considering the last mile costs and an increase of load factor provide by route optimization
UCC operation (USD/ton)	24.53	Based on IPPUC (2014), considering fixed costs, workforce, investment on equipment, etc.
Total Operating Cost (USD/ton)	*73.20*	*Considering freight and handling costs*
Annual Volume delivered (ton)	26,400	
Annual UCC Operating Cost	*1,932,522*	

Analyzing only direct costs related to UCC operations, the implementation of the UCC represents a cost increase of 13.7% compared with the Baseline Scenario.

4.3. *Estimation of the Benefits for Stakeholders*

As the Kaldor–Hicks criterion refers to compensation among stakeholders, their costs and benefits were calculated individually.

The UCC benefits for each stakeholder (Figure 1) are: (i) to Carriers, improvement of vehicle productivity; (ii) to Receivers, reduction of receiving operations; (iii) to Population, reduction of losses related to traffic congestion and local pollutant emissions; and (iv) to Government, also reduction of losses related to local pollutant emissions.

There is no impact for Shippers, due to the fact that the value of freight expenses stay the same.

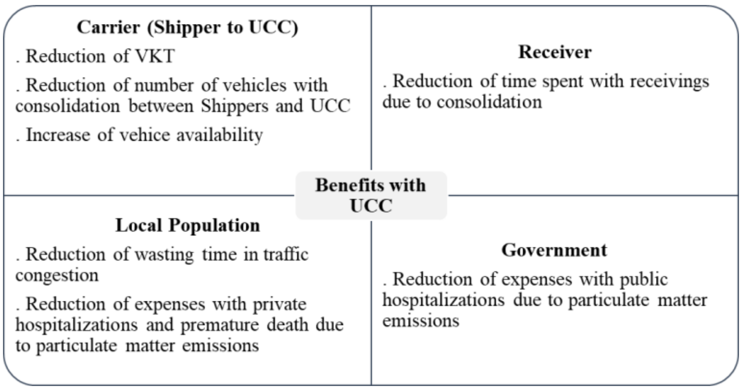

Fig 1. Benefits for stakeholders with UCC

Benefits related in Figure 1 were monetized with the aim of composing a comprehensive cost–benefit analysis of the UCC.

4.3.1. *Benefits for Carriers*

Carriers have a reduction in the scope of work. However, it was assumed that their profit remains the same as they charge customers according to the complexity of the operation.

Although, it was considered that the difference between the original freight and the freight cost from Shipper to UCC, US$29.62 per ton or USD 781,906 per year, is fully transferred to Government as income of the UCC.

4.3.2. *Benefits for Receivers*

There was a reduction of 13% in the number of deliveries per year for Receivers, based on Kassel UCC operation (Browne et al., 2005). Also, empirical data was used to accomplish the calculation, as described in Table 4:

Table 4. UCC Operating Costs and UCC Scenario Cost Estimation

Item	Value	Observation
Number of deliveries per day at Baseline Scenario	500	
Number of deliveries per day at UCC Scenario	435	Considering delivery consolidation and the delivery reduction in Kassel UCC
Annual Reduction of Deliveries	17,160	
Average time per receiving (hour)	0.25	
Average of labour hour per delivery (USD)	9.55	
Annual Reduction of labour hour with Receivings (USD)	*40,953*	

4.3.3. *Benefits for Population from the Reduction of Traffic Congestion*

For UCC vehicles in charge of deliveries to Receivers, it is assumed that the load factor increased by 57.5% (median value between 15% and 100% (Browne et al., 2005)). At the Baseline Scenario, the average volume per vehicle is 1 ton, demanding 100 vehicles per day. At the UCC Scenario, with the increase of load factor, the average volume per vehicle is 1,575 ton, demanding 63.5 vehicles, which represents 36.5% less than the Baseline Scenario.

It is assumed that the reduction of vehicles is proportional to the reduction of the size of traffic congestion. On the other hand, the size of traffic congestion directly affects the value of losses in the city (FIRJAN, 2014).

The estimated reduction on cost due to reduction of vehicles is presented in Table 5:

Table 5. Estimation of the Costs with Traffic Congestion

Item	Value	Observation
Size of Traffic Congestion in Metropolitan Region of São Paulo (Km)	300	Based on FIRJAN (2014)
Value of losses with Traffic Congestion (USD)	22.1 billion	Based on FIRJAN (2014)
Total Fleet of Metropolitan Region of São Paulo (number of vehicles)	7,123,534	CETESB (2013)
Reduction of Trucks with UCC Scenario	36.5	
% Reduction of the Total Fleet of Metropolitan Region of São Paulo	0,0005%	
Reduction of the value of losses with Traffic Congestion in 2013 (USD)	113,178	
Reduction of losses with Traffic Congestion in 2017 (USD)	*149,853*	*Adjustment using linear interpolation and data from FIRJAN (2014)*

The adjustment using linear interpolation is considered, as other data of this study refers to 2017.

4.3.4. *Benefits of the Reduction of Particulate Matter (PM)*

PM is defined by the United States Environmental Protection Agency (EPA) as a mixture of solid particles and liquid droplets found in the air. $PM_{2.5}$ are fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller, resulting from complex reactions of chemicals such as sulfur dioxide and nitrogen oxides, which are pollutants emitted from power plants, industries and automobiles (EPA, 2017).

Assuming the premise that the circulating fleet is distributed equally throughout the Municipality of São Paulo (MSP), the truck fleet estimated for the service area, which is 0.3% of the MSP area (IBGE, 2017b), is 208.7 vehicles.

Based on CETESB (2016), the emission of $PM_{2.5}$ by trucks in the MSP is 3.67 $\mu g/m^3$ and is directly related to the circulating fleet. The impact of reducing vehicles is shown in Table 6.

Table 6. Estimation of Reduction of $PM_{2.5}$

Item	Value	Observation
Circulating Fleet in MSP	79,433	CETESB (2016)
Truck fleet circulating at UCC Area	208.7	Proportional to the UCC Service Area
Reduction of Trucks with UCC Scenario (Table 5)	36.5	
% of Reduction of trucks on MSP Circulation Fleet	17,5%	
$PM_{2.5}$ Emissions by trucks (μg/m^3)	3.67	
Reduction of $PM_{2.5}$ Emissions (17,5%) (μg/m^3)	0.642	

Considering that $PM_{2.5}$ emissions have mainly a local impact, the reduction of vehicles in the UCC service area represents a reduction of 0.64 μg/m^3 of the annual average concentration of $PM_{2.5}$ for the analyzed area.

Reductions in $PM_{2.5}$ exposure reduce respiratory and cardiovascular system problems and the risk of premature death (WHO, 2006).

The impacts of the reduction of $PM_{2.5}$ emissions by motorized vehicles were evaluated and monetized focusing on cumulative costs of premature deaths and on annual expenses with public and private hospitalizations related to exposure to $PM_{2.5}$ for the MSP. For 2017, the estimated data attributable to $PM_{2.5}$ emissions are 3,610 premature deaths, 1,979 public hospitalizations and 2,009 private hospitalizations, resulting in costs of US$407,320,580, US$1,007,170 and US$3,065,128, respectively (ISS, 2017).

The results of simulations performed indicated that a reduction of 0.64 μg/m^3 generated a decrease of 7.32% in the premature deaths attributable to $PM_{2.5}$ emissions, 7.39% in public hospitalizations and 7.40% in private hospitalizations (ISS, 2017).

The UCC service area has 33,892 inhabitants, which represents 0.3% of the MSP population (IBGE, 2017). Considering the impact of emissions and the local population, the benefits associated are shown in Table 7:

Table 7. Impact of reduction of 0.64 μg/m^3 of $PM_{2.5}$ on premature death and hospitalization attributable to $PM_{2.5}$ emissions

Item	Premature Death	Hospitalization	
		Public	Private
Costs associated for MSP (US$)	407,320,580	1,007,170	3,065,128
Impact of reduction of 0.64 μg/m^3	–7.33%	–7.39%	–7.41%
% impacted population	0.30%	0.30%	0.30%
Benefits associated for UCC service area (US$)	*89,871.35*	*224.25*	*683.67*

4.4. *Applying the Kaldor–Hicks Criterion to UCC Economic Evaluation*

As the Kaldor–Hicks criterion considers the stakeholders' losses and gains, the cost-benefit analysis is elaborated considering direct costs and monetized benefits and costs for Receivers, Population and Government. UCC direct cost are allocated for Government, as shown in Table 8:

Table 8. Cost and Benefits analysis by stakeholder

Stakeholder	Annual Gains with UCC (US$)
Carriers (Profit)	0.00
Government (Direct Cost of UCC Scenario – Direct Cost of Baseline Scenario)	–232,727.15
Receivers (Reduction of receivings)	40,953.35
Population (Reduction of traffic congestion)	149,853.08
Population (Reduction of premature deaths and private hospitalizations)	90,555.02
Government (Reduction of public hospitalization)	224.25
TOTAL	*48,858.55*

The evaluation shows a positive result and according to the Kaldor–Hicks criterion, as the stakeholders' gains surpass the Government's losses with the UCC costs, the implementation of the UCC might be socially desirable because it provides more benefits than the Baseline Scenario. Considering this approach, subsidies from the government might be justified by the benefits for the population due to traffic congestion and pollutant emission reduction.

6. Conclusion

Despite the shown benefits of reduction in the number of vehicles, fuel consumption, and GHG and local pollutant emissions as a result of UCC implementations (Browne et al., 2005; SUGAR, 2011), there are still many barriers to overcome, mainly economic sustainability (Browne et al., 2005; Panero et al., 2011). Evidence suggests that it is more difficult to allocate benefits than costs (Browne et al., 2005), this might be one relevant constraint to develop comprehensive economic evaluations, considering impacts on society and environment.

This paper contributes with this subject by exploring studies that monetize the cost of traffic congestion and the cost of $PM_{2.5}$ emitted by diesel vehicles and incorporating the benefits for the stakeholders to the cost-benefit analysis. Benefits for stakeholders considered are: (i) Reduction of time taken by Receivers in the process of receiving deliveries; (ii) Fewer economic losses by the Population due to traffic congestion; (iii) Decrease of early deaths and private hospitalizations due to problems related to $PM_{2.5}$ emissions on the Population; and (iv) Fewer losses for Government, with public hospitalizations due to complications caused by inhalation of $PM_{2.5}$.

The model presented, based on a UCC project, empirical data from operations in Brazil and results found in the literature, confirms that the gains of vehicle optimization are not enough to compensate additional costs when another handling operation is included in the supply chain, but incorporating benefits for population, receivers and government, the cost-benefit presents a positive result. Also, this model is one example of how to incorporate external benefits, and other methodologies and studies could be explored to improve and enlarge the economic evaluation. In addition, costs related to $PM_{2.5}$ emissions were based on a study over buses; despite the vehicle technology of diesel buses and trucks being similar, the average emission by a truck fleet can be higher than a bus fleet, amplifying possible benefits related to the reduction of $PM_{2.5}$ emissions. Implementation of UCCs with clean energy vehicles to carry out the deliveries, such as the Italian model in the city of Lucca, should be considered in urban planning for areas with high levels of congestion because it would bring a relevant reduction of health costs and premature death related to $PM_{2.5}$ emissions.

The Kaldor–Hicks criterion of the research field of Welfare Economics, is largely applied in analyses of public policies, sustainability and wealth distribution. It states that a change is socially desirable if the losses might be compensated by the gains. This theme is mentioned to ground the discussion of eventual implementation of urban logistics solutions. Also, frm the point of view of the city, public financing might be discussed and even justified as a public policy that would result in benefits for society and the environment.

Lastly, there are many discussions over how UCC can be financially sustainable. However, considering benefits for society and environment, sustainable urban solutions might be fostered by local government.

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References

1. Allen, J., Browne, M., Woodburn, A., Leonardi, J., 2012, The Role of Urban Consolidation Centres In Sustainable Freight Transport. Transport Reviews, Vol. 32, No. 4, 473–490, July 2012
2. Browne, M., Sweet, M., Woodburn, A., Allen J., 2005. Urban Freight Consolidation Centres – Final Report. Transport Studies Group, University of Westminster, London.
3. Browne, M., Allen, J., Leonardi, J., 2011. Evaluating the use of an urban consolidation centre and electric vehicles in central. IATSS Research Vol. 35, 2011, pp. 1–6.
4. Buchanan, J., 1959. Positive Economics, Welfare Economics, and Political Economy, The Journal of Law and Economics 1959, 2, 124-138
5. CAF, 2017. "Guía para la gestión ambiental y social de proyectos de infraestructura", CAF

6. CETESP, 2013. Emissões Veiculares no Estado de São Paulo 2013 (Vehicle Emssions in the State of São Paulo 2013). Companhia Ambiental do Estado de São Paulo, Série Relatórios, 2013.
7. CETESP, 2016. Qualidade do Ar no Estado de São Paulo 2016 (Air Quality in the State of São Paulo 2016). Companhia Ambiental do Estado de São Paulo, Série Relatórios.
8. Coleman, J. L., 1980. "Efficiency, Utility, and Wealth Maximization". *Faculty Scholarship Series*. 4202. <https://digitalcommons.law.yale.edu/fss_papers/4202>
9. Dablanc, L., 2007, Goods transport in large European cities: Difficult to organize, difficult to modernize. Transportation Research Part A 41 (2007) 280–285
10. Diziain, D., Taniguchi, E., Dblanc, L., 2014, Urban Logisitcs by Rail and Waterways in France and Japan. Procedia - Social and Behavioral Sciences 125 (2014) 159 – 170
11. Dixon, J., 2012. "Economic cost-benefit analysis (CBA) of project environmental impacts and mitigation measures: implementation guideline", Inter-American Development Bank
12. Ferraz, J., Além, A., Madeira, R., 2013. A contribuição dos bancos de desenvolvimento para o financiamento de longo prazo (Contribution of development banks to long term financing), Revista do BNDES, Rio de Janeiro, n. 40, p. 5-42, dez. 2013.
13. IBGE, 2017a. Historical and Statistical Series, Urbanization Rate. Brazilian Institute of Geography and Statistics <http://seriesestatisticas.ibge.gov.br/series.aspx?vcodigo=POP122>. Accessed Jul. 26, 2017.
14. IBGE, 2017b. Cidades@ São Paulo, São Paulo. Brazilian Institute of Geography and Statistics <http://cidades.ibge.gov.br/xtras/perfil.php?codmun=355030>. Accessed Jul. 26, 2017.
15. EPA, 2017. Particulate Matter (PM) Pollution. https://www.epa.gov/pm-pollution/particulate-matter-pm-basics. Accessed Jul. 26, 2017.
16. European Investment Bank, 2017. <http://www.eib.org/about/partners/development_banks/index.htm> Accessed in Jul 2017.
17. Fernandez-Barcelo, I., Campos-Cacheda, M., 2012. Estimate of social and environmental costs for the urban distribution of goods. Practical case for the city of Barcelona. Procedia - Social and Behavioral Sciences 39 (2012) 818 – 830
18. FIRJAN, 2014. Os custos da (i)mobilidade nas regiões metropolitanas do Rio de Janeiro e São Paulo (Costs costs of (im)mobility in metropolitan regions of Rio de Janeiro and São Paulo) . Federação das Indústrias do Rio de Janeiro (FIRJAN), N.o 3, 2014
19. Frischtak, C., Noronha, J. 2016. O Financiamento do Investimento em Infraestrutura no Brasil: uma agenda para sua expansão sustentada (Financing investment of infrastructure in Brazil: An agenda for its sustained expansion). National Confederation of Industry (CNI), Brasília.
20. Gonzales-Feliu J., Taniguchi E., d`Arcier B., 2014. Financing Urban Logistics Projects – From Public Utility to Public-Private Partnership, Sustainable Urban Logistics: Concepts, Methods and Information Systems, Springer Heidelberg New York Dordrecht London, pg 245-265, DOI 10.1007/978-3-642-31788-0
21. Hicks J., 1939. The Foundations of Welfare Economics. The Economic Journal, Vol. 49, No. 196, 1939, pp. 696-712
22. Hohl, A., Tisdell, C., 1997. Ethics in Modern Economic Thought and Their Consequences for Environmental Conservation, Land and Resource Use. Humanomics, Vol. 13, Issue: 2, 1997, pp.1-37. https://doi.org/10.1108/ eb018789
23. IPPUC, 2014. Estudo de Logística Urbana de Curitiba (Support to Improve City Logistics Performance in Curitiba). Available at: www.ippuc.org.br/visualizar.php?doc=http://admsite2013.ippuc.org.br/arquivos/documentos/D327/D327_004_BR.rar, Accessed on 27 Aug 2018.
24. Isa, S., Lima Jr., O., Ribeiro, K., (2018), Urban Consolidation Center Evaluation According to Kaldor-Hicks Criterion, Poster Presentation at Transportation Research Board 97th Annual Meeting, Washington D.C., United States.
25. ISS, 2017. Avaliação e Valoração dos Impactos da Poluição do Ar na Saúde da População Decorrente da Substituição da Matriz Energética do Transporte Público na Cidade de São Paulo (Evaluating and Monetizing Impacts of Air Pollution on Population Health Due to the Replacement of Energy Matrix of the Public Transportation in the City of São Paulo). Instituto de Saúde e Sustentabilidade, São Paulo.
26. Janjevic, M., Ndiaye A., 2017. Investigating the financial viability of urban consolidation centre projects, Research in Transportation Business & Management 24 (2017) 101–113
27. Janjevic, M., Lebeau, P., Ndiaye, A., Macharis, C., Mierlo J., Nsamzinshuti, A., 2016. Strategic scenarios for sustainable urban distribution in the Brussels capital region using urban consolidation centres. Transportation Research Procedia 12 (2016) 598 – 612
28. Jones P., Sugden R., 1982. Evaluating Choice, International Review of Law and Economics (1982), 2, 47-65.
29. Kaldor, N., 1939. Welfare Propositions of Economics and Interpersonal Comparisons of Utility. The Economic Journal, Vol. 49, No. 195, 1939, pp. 549-552
30. Karrer, R., Ruesch, M., 2007. Road pricing and Urban Freight Transport - Urban Freight Platforms. BESTFUS II, Best Practice Update 2007 Part I.
31. Kin , B., Verlinde, S., van Lier, T., Macharis, C., 2016. Is there life after subsidy for an urban consolidation centre? An investigation of the total costs and benefits of a privately initiated concept. Transportation Research Procedia, Vol. 12, 2016, pp. 357 – 369.
32. Lane, B., Sherman, C., 2013. Using the Kaldor–Hicks Tableau to assess sustainability in cost–benefit analysis in transport: An example framework for rail transit, Research in Transportation Business & Management 7 (2013) 91-105.
33. Lewis, A., Lagrange, A., Patterson, D., Gallop, N., 2007. South London Freight Consolidation Centre Feasibility Study – Final Report, Transport and Travel Research Ltd.
34. Lin, J., Chen, Q., Kawamura, K. (2016). Sustainability SI: logistics cost and environmental impact analyses of urban delivery consolidation strategies. Networks and Spatial Economics (2016) 16: 227. https://doi.org/10.1007/s11067-014-9235-9.

35. MTPA, 2017. Anuário Estatístico de Transportes 2010-2016 (Statistical Yearbook of Transport 2010-2016), Ministry of Transport, Ports and Civil Aviation, Brasilia, 2017.
36. OECD/ITF, 2017. ITF Transport Outlook 2017. OECD Publishing, Paris, 2017. <http://dx.doi.org/10.1787/9789282108000-en>
37. Panero, M., Shin, H., Lopez D., 2011, Urban distribution centers - A means to reducing freight vehicle miles traveled. New York State Energy Research and Development Authority and New York State Department of Transportation.
38. Platts, A., 1978. The use of the measures of economic surplus in cost-benefit analysis. Journal of Economic Studies, Vol. 5 Issue: 2, pp.133-145
39. Prefeitura de São Paulo, Dados Demográficos (Demographic Data), 2017, <https://www.prefeitura.sp.gov.br/cidade/secretarias/subprefeituras/subprefeituras/dados_demograficos/index.php?p=12758>, Accessed Jul. 26, 2017.
40. Posner, R., 1980. The Ethical and Political Basis of the Efficiency Norm in Common Law Adjudication, Hofstra Law Review: Vol. 8: Iss. 3, Article 2.
41. Quak, H., Tavasszy, L., 2011. Customized solutions for sustainable city logistics: the viability or urban freight consolidation centres. In: van Nunen J., Huijbregts P., Rietveld P. (eds) Transitions Towards Sustainable Mobility. Springer, Berlin, Heidelberg
42. Reckon Open, 2010. "Pareto improvements and Kaldor-Hicks efficiency criterion". 2010-12-14T16:50:46 <http://www.reckon.co.uk/open/Pareto_improvements_and_Kaldor-Hicks_efficiency_criterion> Accessed in June 2018.
43. Roca-Riu, M., Estrada M., Fernández E., 2016. An evaluation of urban consolidation centers through continuous analysis with non-equal market share companies, Transportation Research Procedia 12 (2016) 370 – 382
44. SUGAR, 2011. City logistics Best Practices: a handbook for authorities. Sustainable Urban Goods Logistics Achieved by Regional and Local Policies (SUGAR), Bologna.
45. Taniguchi, E., Thompson, R. G., Yamada, T. and van Duin, R. (2001). City logistics: Network modelling and intelligent transport systems. Pergamon, Oxford.
46. Taniguchi E., Thompson R., Yamada, T., 2014. Recent Trends and Innovations in Modelling City Logistics, 8th International Conference on City Logistics, Procedia - Social and Berorohavioral Sciences 125 (2014) 4 – 14
47. Thompson, R., Taniguchi, E., 2008. City Logistics and Freight Transport. in Handbook of Logistics and Supply-Chain Management (Handbooks in Transport, Volume 2) (Ann M. Brewer, Kenneth J. Button, David A. Hensher (ed.)), Emerald Publishing, 2008, pp.393 – 405
48. United Nations, 2001. Environmental Management Accounting Procedures and Principles, United Nations, New York.
49. United Nations, 2014. World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352). Department of Economic and Social Affairs.
50. U.S. Department of the Treasury, 2017. <https://www.treasury.gov/resource-center/international/development-banks/Pages/index.aspx> Accessed in Jul 2017.
51. van Duin, J., Tavasszy, L., Quak, H., 2013. Towards E(lectric)- urban freight: 28 first promising steps in the electric vehicle Revolution. *European Transport*, 2013, Issue 29 54, Paper n° 9, ISSN 1825-3997
52. van Duin, J., van Dam, T., Wiegmans, B., Tavasszy, L., 2016. Understanding Financial Viability of Urban Consolidation Centres: Regent Street (London), Bristol/Bath & Nijmegen, Transportation Research Procedia 16 (2016) 61 – 80.
53. van Rooijen, T., Quak, H., 2010. Local impacts of a new urban consolidation centre - the case of Binnenstadservice.nl. Procedia Social Behavior Sciences, Vol. 2, 2010, pp. 5967–5979.
54. van Rooijen, T., Quak, H., 2014. City Logistics in the European CIVITAS Initiative. 8th International Conference on City Logistics.
55. WHO, 2006. WHO Air Quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide - Global update 2005 - Summary of Risk Assessment. World Health Organization, Geneve.
56. World Bank (2012), "Transport Emissions and Savings in Health Costs" - The International Bank for Reconstruction and Development/The World Bank
57. World Bank (2014), "Reducing Black Carbon Emissions from Diesel Vehicles: Impacts, Control Strategies, and Cost-Benefit Analysis". The International Bank for Reconstruction and Development/The World Bank
58. World Bank (2017), Urban Development. http://www.worldbank.org/en/topic/urbandevelopment/overview . Accessed Jul. 26, 2017.