Multi-actor multi-criteria analysis for sustainable city distribution: a new assessment framework

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Abstract: Urban areas are facing several challenges, especially to organise freight transport in a sustainable way. Many innovative city distribution concepts have failed because not all stakeholders were taken into account in the decision-making process. Evaluating urban freight solutions summons the need for a new approach, taking into consideration different conflicting objectives from different stakeholders. Within STRAIGHTSOL (strategies and measures for smarter urban freight solutions, EC FP7), a systematic impact assessment framework dedicated to freight transportation has been developed. The so-called city distribution – multi-actor multi-criteria analysis (CD-MAMCA) incorporates the city distribution actors and their objectives as the primary focus complemented with a MCDA performed with the PROMETHEE – GDSS method. In this paper, the specific framework dedicated to city distribution is fully explained through a case study in the UK charity sector with Oxfam which tested remote monitoring of the banks leading to dynamic collection scheduling.

Keywords: PROMETHEE-GDSS; multi-actor multi-criteria analysis; MAMCA; CD-MAMCA; sustainable city distribution; decision-making.

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Biographical notes: Lauriane Milan is a Research Associate in the research group MOBI. Her PhD work focused on the development of a new impact assessment framework for measures applied to urban-interurban freight transport interfaces presented in this paper. This innovative framework was applied to the live demonstrations of the STRAIGHTSOL project and developed specific recommendations for future freight policies and measures. She is currently working on multi-criteria analyses in the field of sustainable city distribution.

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Sara Verlinde holds a Master of Engineering, a degree in Architecture and a Master of Complementary Studies in Business Economics. Her PhD research addresses urban freight distribution solutions and mainly focuses on consolidation concepts and off-hour deliveries. She has been involved in a European project on strategies and measures for smarter urban freight solutions called STRAIGHTSOL.

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1 Introduction

The high concentration of people, commercial and other activities in urban environments requires substantial volumes of goods to be transported. These transport flows cause nuisances such as noise, air pollution, safety risks and greenhouse gas emissions. The 20-20-20 targets and the goal to decarbonise urban transport by 2050 [White Paper on transport (2011)], show that the European Commission is ambitious to improve the energy efficiency within urban transport. Also, an increased number of local governments are looking for urban freight concepts that are environmentally friendly as well as efficient for their citizens and entrepreneurs.

In Lammgård and Hagberg (2013) and Dablanc and Giuliano (2013), thorough overviews are given of the possible measures that can be taken within cities. They provide different cases and expert judgements, as well as an overview of the current knowledge on the possible impacts of these measures. However, this knowledge is still scattered as many cities implement new concepts all over the world with little connection to other initiatives. Also, no comprehensive evaluation framework exists, which entails partial impact studies that focus only on specific nuisances such as noise for night delivery schemes or emissions for road pricing schemes [see Browne and Goodchild (2013) for an overview of the models used in city logistics research]. Moreover, the implementation of these new concepts is hampered by the fact that city distribution is by definition an area where several stakeholders are involved, such as the receivers, shippers, logistic service providers, citizens and the government. These stakeholders have their often conflicting objectives which are rarely taken into account. Many studies illustrate the importance of these stakeholders within the city distribution context (Dablanc, 2011; Taniguchi et al., 2011), but up to now, these stakeholders have not explicitly been included in evaluation processes. Stakeholder involvement at a very early stage of the decision process is crucial in the success of an innovative concept in this field, notably because of the conflicting criteria of each group of stakeholders which can considerably hinder the smooth run of a long-term project. Mutual understandings increase the chance to reach a consensus in the future implementation of new concepts and are greatly facilitated by the approach proposed in this paper.

Multiple criteria decision analysis (MCDA) is especially useful to support stakeholders decisions in systems in which decision-making is complex and involves different considerations (Figueira et al., 2005; Vincke, 1992), which is the case of city distribution. This paper proposes a new city distribution–multi actor multi criteria analysis (CD-MAMCA) assessment framework that incorporates the city distribution actors and their objectives as the primary focus complemented with a multi-criteria decision analysis performed with the PROMETHEE-GDSS method (Macharis et al., 1998). This framework has been developed within the STRAIGHTSOL project (strategies and measures for smarter urban freight solutions, EC FP7) and is tested within seven demonstration projects that are run within the project. In order to include the stakeholder-based approach, the multi-actor multi-criteria analysis (MAMCA) (Macharis, 2007) is a crucial element in the framework as it stresses the involvement of various stakeholders in the decision-process as well as on the measures' impact, both on society and the private sector. Hereafter, a short overview of the evaluation methods that have been used in the past is given (Section 2), followed by a comprehensive evaluation model based on stakeholder involvement (Section 3). In Section 4, this stakeholder-based approach is illustrated by a case study in the UK charity sector with Oxfam which tested remote monitoring of the banks (Mcleod et al., 2013) leading to dynamic collection scheduling which is a complete novelty in the donating sector (Section 5). Finally, conclusions are drawn.

2 Impact assessment methods for city logistics concepts

Within the transport sector, projects like investments in new infrastructure or the implementation of new transport measures are mostly evaluated through the use of social cost benefit analyses (SCBA), multi-criteria analyses (MCA) or a combination of both. The use of business modelling (BM) is also quite popular in order to assess the potential of measures for a private investor (Quak et al., 2014). In some countries, for example in Belgium and the Netherlands, a standardised methodology has been elaborated for the evaluation of infrastructure projects, mostly based on a social cost benefit approach. However, a SCBA has some drawbacks, as every cost or benefit has to be monetised (see Damart and Roy, 2009; Van Wee and Rietveld, 2013). In addition, several European projects present interesting ideas. A range of EC-funded and related projects has approached the urban freight transport context. BESTUFS and BESTUFS II (Best Urban Freight Solutions)[1] established a network between different stakeholders in order to identify, describe and disseminate best practices, success criteria and bottlenecks with respect to the movement of goods in urban areas. Both projects delivered policy and research recommendations and presented best practice handbooks for urban freight transport solutions. CITYFREIGHT[2] analysed several inter- and intra-urban freight distribution networks and evaluated their socio-economic and environmental impacts in an urban context, with a common assessment methodology. It set up a list of criteria for evaluating those logistic schemes and the related accompanying policies (legal framework, land use planning, road traffic regulation, pricing). It was evaluated by looking at the technical feasibility, the market efficiency and the environmental impacts. There is a focus on innovative and promising logistic schemes in seven European countries. CITYLOG[3] aims at increasing the sustainability and the efficiency of urban delivery of goods through an adaptive and integrated mission management and innovative vehicle and transport solutions. The CIVITAS initiative[4] deals with both freight and passenger transport issues, which help cities to achieve a more sustainable, cleaner and energy efficient urban transport system by implementing and evaluating an ambitious and integrated set of technology and policy-based measures. Other projects focusing on the urban dimension of freight transport are:

- START[5] (short term actions to reorganise transport of goods) looked at short term approaches and combined actions such as access restrictions, consolidation centres and incentives in order to make goods distribution in city centres more sustainable and efficient
- SUGAR[6] (sustainable urban goods logistics achieved by regional and local policies) focuses on addressing the problem of inefficient and ineffective management of urban freight distribution
- TURBLOG[7] addresses urban logistics from a wider (geographical) perspective, focusing on a worldwide level
- URBAN TRACK[8] develops tests and validates a series of innovative products and methods concerning urban rail infrastructure.

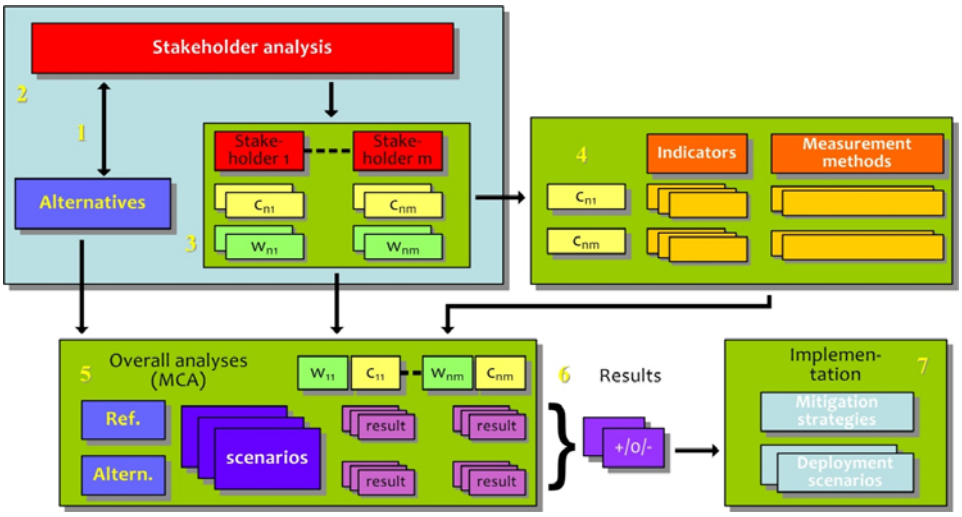
Within all these projects, information on systematic impact methodologies was only scarcely found. In European cities, more than 100 experiments have been carried out in the BESTUFS (2008) project and are further refined in best practice factory for freight in the BESTFACT[9] (2013) project. Despite all these activities, it remains impossible to fully evaluate their efficiency and to compare them. Most often, the methodologies used in the feasibility and follow-up analyses are not similar and moreover, the observed units and measurements are frequently found to be different from one implementation to another. The full details on the methodologies used and the underlying data often remain confidential (Patier and Browne, 2010). A classification of the city logistics projects (Benjelloun et al., 2010) provides a better understanding in the similarities and differences of these projects and their evaluation that mainly focuses on financial analysis, traffic analysis and environmental assessment. Hence, the methodology chosen is not mentioned. A number of authors have noted the importance of evaluation and the need for guidelines (see for example Thompson and Hassall, 2006; Van Duin et al., 2007). Moreover, Anand et al. (2012) underline city logistics modelling efforts for urban freight analysis as a first step to undertake for a systematic assessment.

Different types of multi-criteria analysis can be used for the evaluation of city logistics concepts. Technique for order of preference by similarity to ideal solution (TOPSIS) has been applied for supply chain management and logistics, including supplier selection, transportation, and location problems. Behzadian et al. (2012) found over 74 articles where TOPSIS is used for logistics problems evaluation. Logistics and transportation is also one of the earliest research areas in which PROMETHEE (preference ranking organisation method for enrichment evaluations) was used. The topic often discusses some specific areas such as location problems, outsourcing and selection of suppliers in the different fields, and transportation. Behzadian et al. (2010) found a total of 20 papers using different combinations of PROMETHEE. Analytic hierarchy process (AHP), developed by Saaty (1988) is also popular in logistics. Recently, Saaty (2013) proposed to design specifically AHP to choose the best city for the future. An overview of AHP applications relates 15 papers for the transportation industry and stresses the importance of logistics as application fields for AHP (Sipahi and Timor, 2010). MAUT (Bose et al., 1997) and ELECTRE (Labbouz et al., 2008; Leyva Lopez and Fernandez-Gonzales, 2003) are used as well. These multi criteria methods can be combined to strengthen the evaluation (Awasthi and Chauhan, 2012; Macharis et al., 2004).

In most case, however, the assessment is not based on a systematic approach but on a dedicated modelling of the taken measures (Taniguchi, 2005). For example in Russo and Comi (2011), a model system is developed in order to support ex-ante assessments of city logistics measures. It allows to simulate the choices of every decision-maker involved in urban freight transport and logistics and to investigate how policies and measures can influence these choices.

The developed framework combines a social cost benefit analysis (SCBA), a BM and a MAMCA for the evaluation of city distribution concepts. In the assessment of sustainable mobility, a combination of MCDA with (S)CBA could overcome their mutual weaknesses (Beria et al., 2012). The SCBA enables to see if the concepts are good for society as a whole, the BM looks into the possible business opportunities. Finally MAMCA looks at the impact of the concept on the stakeholders. In this paper, we focus on the MAMCA for city distribution using PROMETHEE-GDSS as this is the most novel part of the framework.

Figure 1 Multi-actor multi-criteria analysis (see online version for colours)



Source: Macharis (2000)

3 Multi-actor multi-criteria analysis

The MAMCA is an extension of the existing multi-criteria analysis. A MAMCA allows researchers and decisions-makers to evaluate different alternatives (policy measures, scenarios, technologies, etc.) with regard to the objectives of the different stakeholders that are involved in the decision-making process. The methodology was developed by Macharis (2005, 2007) and has been used for many applications, mainly in transport related decision-making problems (for an overview see Macharis et al., 2009). The MAMCA consists of seven steps as is depicted in Figure 1.

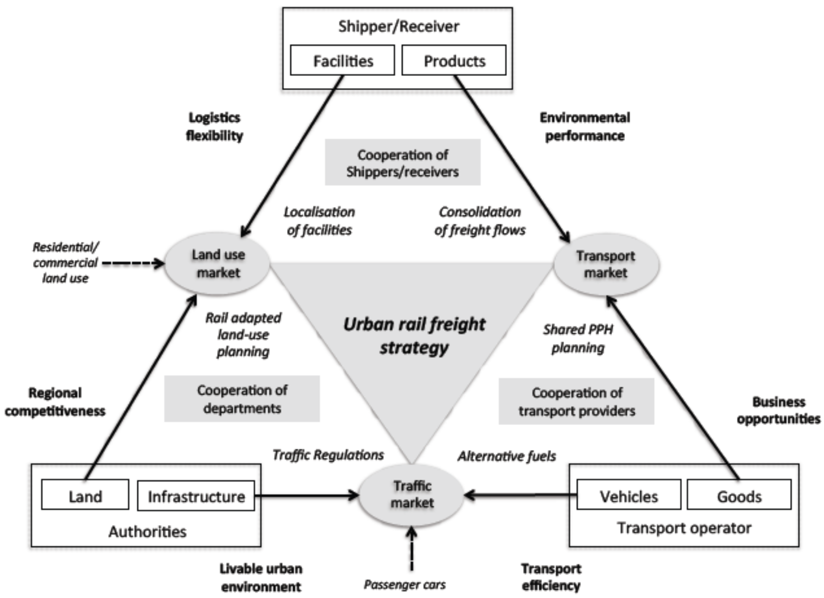
3.1 Possible alternatives

Within a city distribution context, the alternatives (step 1) can be the possible measures to be implemented in a city, or different variants of a certain measure, for example different technologies that can be implemented to enhance the control of loading/unloading places or different time windows for deliveries. These alternatives are usually elaborated through a discussion with the stakeholders (Keeney, 2013).

3.2 Stakeholders

Five important stakeholder groups within the city distribution context are included in this framework: the receivers, the shippers, the authorities, the citizens and the logistic service providers (Quak, 2008; Browne et al., 2004). Behrends (2011) provides an interesting framework for sustainable urban freight transport by rail, in which these actors and their interactions are shown (Figure 2).

Figure 2 Framework for sustainable urban freight transport



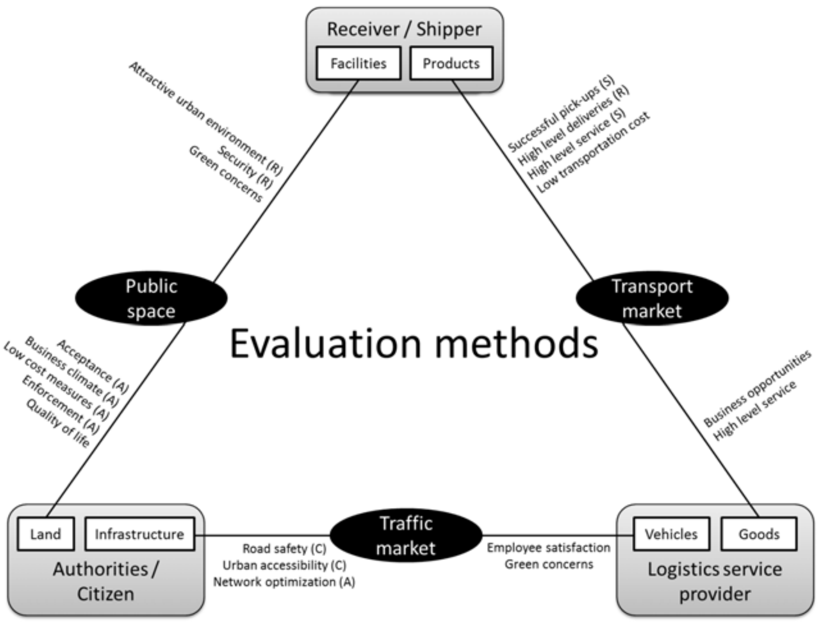
Source: Behrends (2011)

These stakeholders interact with one another on different impact domains, namely the transport market, the land use market and the traffic market, in which supply and demand come together. In the transport market, the material flow demand is matched by the supply of transport services, resulting in actual goods flows. The vehicle flow that results from this is matched by the supply of transport infrastructure capacity on the traffic market. In the land use market, the shippers' demand for locations for their economic facilities is matched with the supply of land by local authorities, which aim for economic settlements in their city or region. Consequently, the stakeholders meet on their common impact domain (Behrends, 2011).

3.3 The objectives of the stakeholders

Depending on the evaluation, it is possible to focus on key stakeholders. For each of the stakeholder groups, the objectives have been identified (step 3). The identification has been done by a thorough literature study (STRAIGHTSOL, 2012b) complemented by interviews with representatives of these stakeholder groups amongst the pilot projects. These objectives have been validated by the STRAIGHTSOL expert panel. Within Figure 3, the objectives of the stakeholder groups are represented on the arcs connecting the stakeholders. Some of the objectives are shared by several stakeholders, such as the quality of life objective, which is shared by authorities and citizens.

Figure 3 Stakeholders and their criteria



Source: Milan 2012

Next, the criteria weights have been determined. These weights represent the importance the stakeholder groups attach to their criteria. Several methods can be used to determine the weights (Macharis et al., 2004). Within STRAIGHTSOL, a survey was set up to elicit the weights for each stakeholder group. The pairwise comparison method, as used within the AHP method (Saaty, 1990) has been chosen as it provides a systematic way to allocate the weights (Saaty and Vargas, 2000). As the number of criteria is not too high, it is still user friendly.

3.4 Indicators and measurement methods

In order to evaluate the different options, the criteria are measured by selected indicators and measurements (step 4). This allows measuring the performance of each alternative in terms of its contribution to the criteria of specific stakeholder groups. Key performance indicators were specified so that they can be used for the three methods, MAMCA, SCBA and the BM. An overview of the indicators and measurement methods for each criterion can be found in STRAIGHTSOL (2014a). The CD-MAMCA primarily focuses on impact assessment based on collected data. It is however possible to perform an ex-ante evaluation which would be based on stakeholder perception.

3.5 Analysis

Any MCDA method could be used to assess the different strategic alternatives (step 5). In fact, the second generation multi-criteria analysis methods, the group decision support methods (GDSM), are well suited for the MAMCA methodology, as they are able to include the stakeholder concept. These GDSM methods give each stakeholder group the liberty of having their own criteria, weights and preference structure while only at the end of the analysis; all the different points of view are being confronted. The AHP (Saaty, 1988) and PROMETHEE (Macharis et al. 1998) methods have been used in a complementary way within this project. PROMETHEE-GDSS extends PROMETHEE method to focus on stakeholder integration and has been applied in several applications (Macharis et al. 2015). The applications show the potentiality of the approach and related methodological tools (Ishizaka and Nemery, 2012).

In case of PROMETHEE-GDSS every stakeholder ST_r acts, at first, as if he is the only decision maker and uses the following PROMETHEE II method to score and rank each scenario of the decision problem. First, for each criterion f_j ($j = 1,\ldots, k$) a specific preference function $P_j(a,b)$ has to be defined to translate the deviation between the evaluations of any two alternatives a and b into a preference degree ranging from 0 to 1. This preference function is a non-decreasing function of the deviation $d = f_j(a) - f_j(b)$ between the evaluations of the alternatives on the considered criterion, as shown in formula 1. A preference function is associated with each criterion. The multi-criteria preference index (Formula 2) is the basis for the computation of the positive φ + (a) and negative φ – (a) preference flows that measure, on average, how each alternative (a) is outranking (see formula 3) or is outranked (see formula 4) by the other n-1 alternatives. The difference between these two preference flows is the net preference flow φ(a) (see formula 5), which is a value function whereby a higher value reflects a higher attractiveness of alternative a.

$$\begin{cases} P_j(a,b) = G_j\left\{f_j(a) - f_j(b)\right\} & (1) \\ \pi(a,b) = \sum_{j=1}^{k} w_j P_j(a,b) & (2) \\ \varphi^+(a) = \frac{1}{n-1}\sum_{b}\pi(a,b) & (3) \\ \varphi^-(a) = \frac{1}{n-1}\sum_{b}\pi(a,b) & (4) \\ \varphi(a) = \varphi^+(a) - \varphi^-(a) & (5) \end{cases}$$

In a second phase, we suppose that R stakeholders (ST_r, $r = 1,\ldots,R$) are evaluating the same set of alternatives using PROMETHEE. The individual rankings are aggregated into a group ranking. To aggregate the individual rankings, each individual net flow ranking will be considered as a criterion of the group problem. In other words, in the second phase, each stakeholder will act as a criterion of the group performance matrix. As each stakeholder has specific preferences a different net flow is obtained for each of them:

$$\varphi^r(a_i) = \sum_{j=1}^{k} \varphi_j^r(a_i) w_j \quad (6)$$

with

$$\varphi_j^r(a_i) = \frac{1}{n-1}\sum_{x \in A}\left\{P_j^r(a,x) - P_j^r(x,a)\right\} \quad (7)$$

where $\phi_j^r(a_i)$ is the single criterion net flow obtained by considering only criterion $f_j(.)$ by stakeholder ST_r. Different weights (ω_r) can be assigned to the stakeholders when appropriate, otherwise equal weights are used. Then the global net flow provides the PROMETHEE II ranking of the alternatives according to the global preference of the group:

$$\Phi^G(a_i) = \sum_{r=1}^{R} \phi^r(a_i)\omega_r \quad (8)$$

The evaluation of a scenario on a group criterion is equal to the net flows of that scenario in the individual ranking. Thus PROMETHEE-GDSS has the ability to open up the decision process to all involved actors. In a city distribution context, stakeholders have different interests and therefore decisions have to be made by different group of people. Rarely do all the stakeholders of the problem requiring a decision have completely identical perceptions and preferences with regard to the problem. Consequently the MCDA results enable to see who is in favour of the implementation of the city distribution concept and who has doubts. The stability of the ranking can be further assessed through sensitivity analyses. The last stage of the methodology (step 7) includes the actual implementation. When the decision is made, steps can be taken to implement an alternative by creating deployment schemes.

4 Application

Within the STRAIGHTSOL project, several innovative city distribution concepts are tested (STRAIGHTSOL, 2012a). In the UK, a demonstration was set up by Oxfam and followed closely by the University of Southampton. Oxfam is an international organisation which by fair trading aims to overcome poverty and suffering. Therefore different products such as clothing are collected for resale. There are 1,300 donation banks across the UK where the general public can donate old textiles, books and shoes. Currently these donation banks are emptied by scheduled roundtrips based on historical fill levels whereas the planning is fixed from one week to the next. In addition, during the same roundtrips unwanted goods are collected from Oxfam shops. This way of working entails several problems. First of all, lengthy journeys are made to banks which contain very little stock. If the fill level would have been known in advance, the trip could have been avoided. Secondly, some donation banks can overflow and herewith Oxfam loses some donations because potential donors take their items elsewhere or, alternatively donations are dropped next to the banks. Thirdly, unusual stock patterns are not known (e.g., in the case of theft).

Oxfam's main goal is to improve transport efficiency by testing remote monitoring of the banks that leads to new dynamic routing (Mcleod et al., 2013). Remotely monitoring banks using fill-level sensors, assists Oxfam by providing insight into the real-time amount of goods placed in the banks in order to avoid trips to banks with little stock and prioritises banks which are overflowing. Companies that already use this monitoring solution in practice experience reduced operational costs, nuisance and theft from overflowing banks and/or bins.

4.1 Scenarios description

A subset of Oxfam's shop and textile bank infrastructure was used in the case study which concerned the collection of rejected or unsold textiles from 75 shops and donated goods from 58 textile bank sites, undertaken by the same vehicle fleet (1 van and 5 lorries), with goods taken to a regional depot near Milton Keynes. The collection region covers an area of approximately 11000 km² and lasts 9 weeks. In total three scenarios were formulated in close collaboration with an Oxfam representative in order to be compared with Business As Usual (BAU). The first scenario (S1) is the demonstration. The other two scenarios are possible future extensions, one in terms of geographical scale, one with the same concept extended both to shops and donation banks.

The scenarios developed in collaboration with Oxfam representative are:

- *BAU:* the *pilot area,* which is – according to Oxfam – representative for the whole of the UK, there are *58 donation bank sites and 75 shops.* Following a *fixed pick-up schedule*, the drivers of Oxfam leave the warehouse (in Milton Point) with *1 van and 5 lorries* to collect goods from these donation banks and shops. Afterwards they drive back to Oxfam's depot with the collected goods.
- *Scenario 1 (S1):* the demonstration whereby in the *pilot area*, *1 van and 5 lorries* collect goods from *58 bank sites and 75 shops*. *40 banks* at 21 banks sites were *equipped with sensors* (sometimes there are multiple banks at a bank site)*. 21 out of 40 successfully monitored* the fill rate of the bank *(success rate of 53%)*. The shops

have a fixed pick-up schedule whereas the banks visits are *dynamically scheduled based on the data from the remote monitoring sensors*.

- *Scenario 2 (S2)*: the scaled scenario whereby the pilot area is multiplied by 5 and includes 290 banks sites and 375 shops. 5 vans and 20 Lorries are operating in this area. 200 banks are provided with sensors, of which 53% operates successfully (106).
- *Scenario 3 (S3):* similar to the *demonstration (1 van and 5 lorries)* with remote monitoring sensors for daily dynamic vehicle schedules for donation banks (*58 banks, 40 with sensors and 21 successfully monitored)* and shops (*75)*. In this scenario *both shops and donation banks are visited dynamically*. The main assumptions are that sensors are not appropriate for shops and hence do not have to purchased (shop managers call when collections should be made), there can be 15% of time and distance savings, more frequent pick-ups lead to less need for storage, but variable collection days could cause difficulties for shop managers in organising staff and floor space. This scenario has been *evaluated off-line*, with good results, but may be less likely to be rolled out if it causes problems for shops.

During the demonstration there was a success rate of 53% of the sensors in the donation banks that worked. The same percentage is used when the area is multiplied by 5. In these two scenarios the successfully monitored donation banks are dynamically scheduled for collection. In terms of size and success rate the third scenario is similar to the demonstration. However, the addition is that goods are not collected from the shops anymore according to a fixed schedule but that these are also included in the dynamic schedule.

Table 1 Stakeholders classification

Stakeholder name	*Description*	*Shipper*	*Logistics service provider*	*Receiver*	*Citizen*	*Local authority*
OXFAM	Own (or rent) and manage all of their donation banks	X	X	X		
	Manage and operate their own collections using their own vehicles and drivers (LSP)					
	Purchase and install remote sensors in the banks and additional software on top of their transport management system					
	Own shops.					
Citizens	People living in the surrounding area of donation banks and shops				X	
Local authorities	Authorities in the areas where the banks and shops are located					X

4.2 Stakeholders' involvement

The viewpoint of highly representative stakeholders from the stakeholder groups is considered. In this case, there are three stakeholders because of the specific role Oxfam which is threefold. It is the receiver of the goods which it collects itself as an LSP and ships these goods from the donation banks and their own shops to the warehouse. These stakeholders can be classified as defined by the stakeholder framework (Table 1).

4.3 Weights allocation

In the case study, the stakeholders were asked to allocate weights for each criterion by the AHP pairwise comparison through an online survey using ExpertChoice Comparion. The interviews include one representative of Oxfam, 6 for local authorities and 178 citizens. This number of respondents takes into account an inconsistency ratio strictly inferior to 0.1 as recommended by the Saaty (1988) rule.

Table 2 Allocation of weights by stakeholders

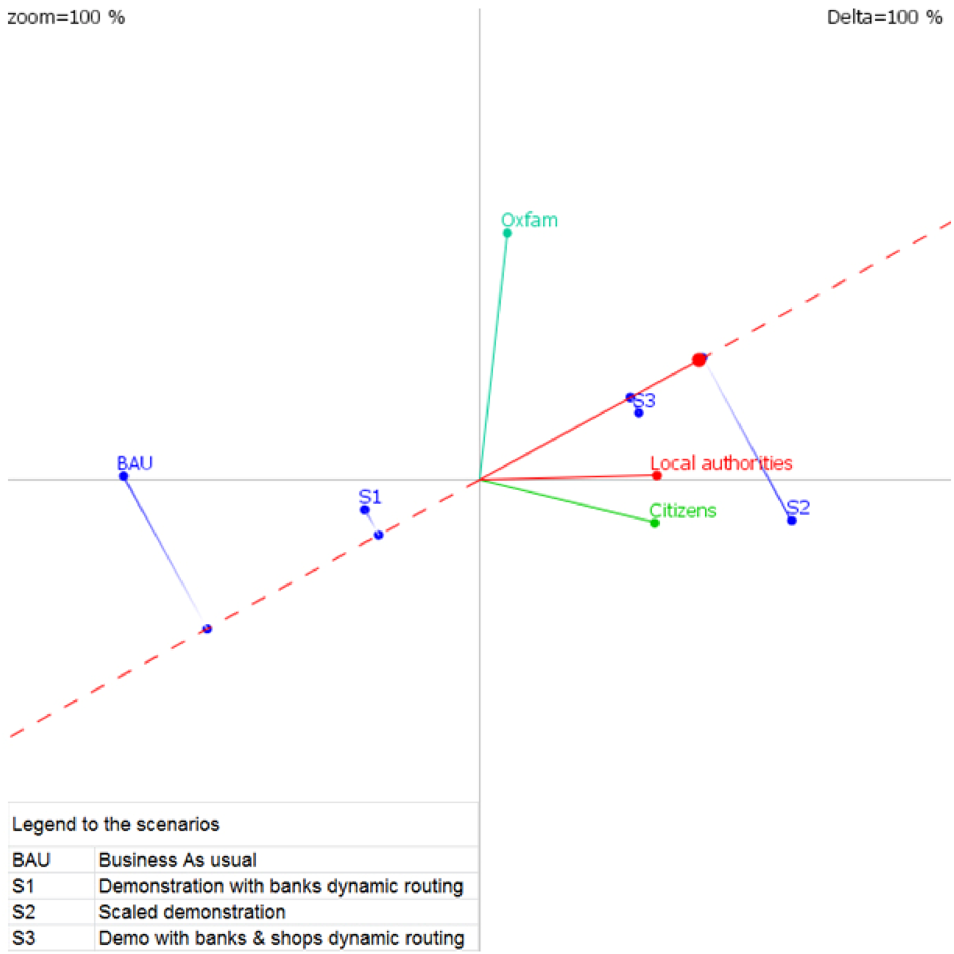
Stakeholder group	*Criterion*	*Criterion definition*	*Weight*
Oxfam	Viability of investment	A positive return on investment	35.7
	Profitable operations	Making profit by providing logistics services	28.6
	Green concerns	Positive attitude towards environmental impact	21.4
	Employee satisfaction	Employees are satisfied with their work and working environment	14.3
Citizens	Emissions	Reduce emissions of CO_2, NO_X, $PM_{2.5}$, PM_{10}	56.7
	Urban accessibility	Reduce freight transport, less congestion	31.4
	Visual nuisance	Tighter bank sites and less space occupancy by trucks	11.9
Local authorities	Network optimisation	Optimal use of existing infrastructure	35.6
	Social political acceptance	Citizens support for measures	35.2
	Quality of life	Attractive environment for citizens	29.2

As the framework aims to be generic, it is still flexible and the stakeholders can vary. Accordingly, some variation might also occur in the set of criteria and the allocated weights for one specific stakeholder. The criteria that are neither mentioned for this stakeholder group nor for the other two are not impacted. As shown in Table 2, Oxfam is primarily interested in the financial repercussion of the measures but is also involved in a positive attitude towards environmental impact and willing to ensure a nice working environment for the employees. The local authorities favour a network optimisation and measures that could be supported by the citizens. The local authorities want to ensure an attractive environment for citizens. The citizens are the people living nearby donation banks and shops of Oxfam. Their main stake is to be able to live their lives as they want in a safe and healthy environment. The citizens give the highest priority to the reduction of emissions, which has a direct impact on their quality of life. They are influenced by the vans and lorries that collect the goods from the donation banks and the shops and deliver these to the warehouse and the shops. The citizens want to be able to circulate easily in their city with their vehicles and also benefit of an attractive urban environment with not too many trucks in the streets. There is not only visual nuisance because of space occupancy by vehicles but also because of goods that are dropped next to donation banks (i.e., untidy bank sites).

4.4 Data collection

The data collection was performed using the templates elaborated within the STRAIGHTSOL (2012c) project. A set of indicators to measure the criteria was set up. In our analysis, only the impacted criteria are measured. When an absolute value is missing, the qualitative scale from 1 to 5 (very bad, bad, average, good, very good) is used, filled by the University of Southampton experts in close collaboration with Oxfam.

Figure 4 Multi-actor GAIA plane view (see online version for colours)



Note: D-Sight[10], own setup

4.5 Results

Several PROMETHEE methods can be used to analyse the multi-criteria decision problem. PROMETHEE II produces a complete ranking of all the alternatives from the best to the worst, based on the net preference flow. The complete ranking shows the best score for the scaled scenario, followed by the demonstration with banks and shops dynamically scheduled. It is, however, not the same ranking for each stakeholder which can be explained by the multi-actor view analysis with the GAIA plane which is a visual representation of the decision problem, in which the alternatives and their contribution to the criteria are displayed. The GAIA plane (Figure 4) is based on a principal component analysis. The axes represent the projections of the multi-criteria table of flows in the two dimensions, taking into account the scales of the criteria with the preference functions. The decision stick leads in the direction of a consensus for the points of view of the stakeholders and shows the amount of consensus or conflict within the group. For a multi-actor GAIA plane; the position of the alternatives with respect to the stakeholder axes indicates how well alternatives are performing for the different stakeholders. The alternatives' performances are projected under this decision stick to show the PROMETHEE II ranking. The delta value gives an estimation of the representation quality (high values correspond to good representations). A first observation can be made from the GAIA plane (Figure 4) drawn with D-Sight software (De Smet and Lidouh, 2013) considering that each stakeholder group has the same weight. This shows that the scaled scenario (S2) scores highest with regard to the criteria of all stakeholders combined, whereas BAU has the lowest score. The scenario with the same area as the demonstration but with shops included in the dynamic schedule (S3) follows closely after the scaled scenario.

One can observe that there is less similarity in the preferences between Oxfam and the citizens who are closer to the local authorities. There is thus a difference in preferences of the citizens and the local authorities on the one hand and Oxfam on the other hand.

Indeed the current situation (BAU) contributes least to all criteria of the citizens. In this situation there are trips that could have been avoided as well as donation banks that are overflowed with goods dropped next to it. Citizens attribute a high importance to emission reduction. More efficient planning leads to fewer miles per vehicle thus to more emission savings and a better urban accessibility. Therefore compared to BAU, amongst other emissions, CO_2 emissions saved by fewer driven miles led to 6,656 kg/year for S1, 33,280 kg/year for S2 and 13,884 kg/year for S3 which explain that the scaled demonstration scores the highest for the citizens, closely followed by the dynamic routing for banks and shops. In broad terms, the scores of the scenarios regarding the citizens' criteria apply to the local authorities as well: the local authorities aim to take into account citizens interests with the quality of life and their support with the social political acceptance criterion. Moreover the criterion on network optimisation is based on distance savings and urban accessibility indicators. A note in this regard is that the inclusion of criteria more related to economic actors (a positive business climate) could have given another picture. These were however not measurable or impacted.

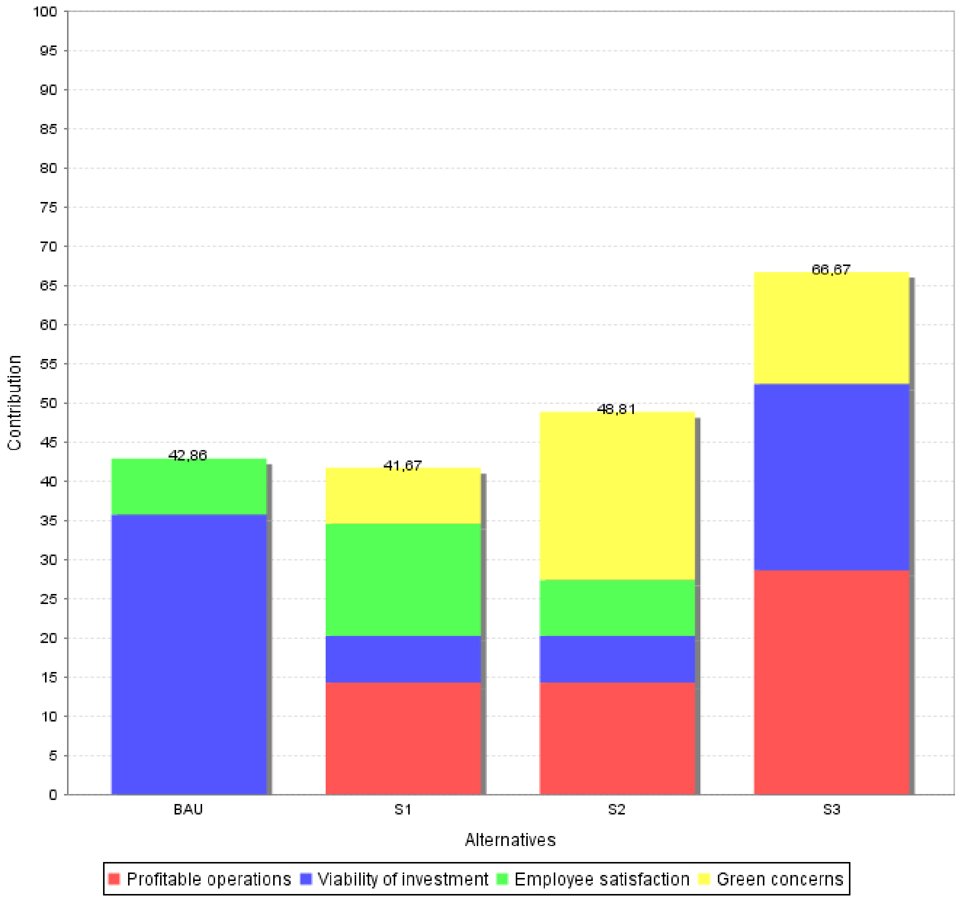
Thus, for each stakeholder group, an analysis can be made, which displays its particular points of interests. A detailed example is given for Oxfam with input data and PROMETHEE parameters given in Table 3.

Table 3 Decision matrix for Oxfam

Criteria	*BAU*	*S1*	*S2*	*S3*	*Function*	*Indifference*	*Preference*
Profitable operations (€)	11,755	11,795	11,795	11,900	Linear	0	1
Viability of investment	Very good	Average	Average	Good	Usual		
Employee satisfaction	3,33	3,67	3,33	2,33	Linear	0	0,01
Green concerns	Bad	Average	Very good	Good	Usual		

Figure 5 visualises to what extent the scenarios contribute to the criteria of the Oxfam with the criteria contribution chart set up with D-Sight software (Hayez et al., 2012).

Figure 5 Criteria contribution for Oxfam (see online version for colours)



Note: D-Sight, own setup

For the demonstration, Oxfam purchased and installed remote sensors in the donation banks and additional software on top of their transport management system to communicate with the sensors which created additional investment costs. This also requires additional activities from the transport planner (transportation manager) within Oxfam. Other employees of Oxfam are the drivers and the shop owners.

Except for viability of investment, there was a higher contribution to all criteria during the demonstration (S1). During the demonstration, the return on investment was lower than in BAU because of the purchase of 40 sensors. This cost was not outweighed by the extra benefits. Moreover, only 21 out of these 40 worked properly. Hence, the return on investment was low. Opposite, there was a higher contribution to the profitability of operations. Due to the sensors it was known when donation banks needed to be emptied and this resulted in fewer unnecessary trips. Consequently there were fewer driven miles which caused lower transportation costs. Although the operating benefits were marginal, they were positive. By avoiding lengthy journeys to donation banks which contain very little stock, the green concerns of Oxfam are addressed. Employees of Oxfam are the transportation manager, drivers and shop manager. Although the transportation manager faced an increased workload (~2 hours per day), this person enjoyed the challenges involved and stated that his job satisfaction during the demonstration remained the same as in the current situation. Whereas there were no changes for the shopping manager, the drivers indicated that there were considerable positive changes (i.e., shorter rounds, better distribution of work, visiting fuller banks). In total there is thus a higher contribution to employee satisfaction.

In the scaled scenario (S2) where 5 vans and 20 lorries are used to collect goods from 290 donation banks and 375 shops, we assume that also 53% of the donation banks are successfully monitored. Because this percentage is assumed to be the same as during the demonstration, there are no changes with regard to the criteria on viability of investment and profitable operations. The profits per pick-up stayed the same, whereas for the return on investment it can be stated that the operating benefits are equal. In total this scenario scores slightly higher than both BAU and the demonstration. It involves the highest contribution to green concerns of all scenarios, because scaling leads to higher emissions savings. The criterion on employee satisfaction scores lower than during the demonstration but is equal to the score in BAU. Whereas the drivers are as satisfied as during the demonstration, the transportation manager faces an even higher workload and therefore his satisfaction declines. Since the shopping manager is not involved in the new way of working, his satisfaction is equal to the current situation and the demonstration.

The third scenario (S3) has the highest score. Although the same amount of donation banks as during the demonstration is monitored, shops are included in the dynamic routing as well. This causes extra time and fuel savings and hence higher profits. The criterion on viability of investment shows the highest score after BAU. Even though the same number of sensors is purchased, there are higher operational benefits due to the inclusion of shops. Compared to the demonstration, transport is more efficiently organised in the area with the same size. Therefore there is higher contribution to the criterion on green concerns. The higher score in the scaled scenario is, however, explained by a larger decrease of emissions in absolute terms. Employee satisfaction shows the lowest score of all scenarios. Whereas truck drivers show most satisfaction in this scenario, the other two employee groups are less satisfied. Compared to the demonstration the transportation manager faces an increased workload because of the inclusion of shops. The shop owners are less satisfied because they only know on a short notice when goods are going to be delivered or picked-up.

Finally to ensure the reliability of the results, as sensitivity analysis has been carried out. The ranking of the alternatives is very robust for all citizens' criteria and local authorities' criteria as the weights of each criterion can vary from 0 to 100% without changing any ranking. As explained in Oxfam analysis, the scores for BAU and the demo are very close and the criteria somewhat discriminating. Consequently a weight variation might induce significant changes from criterion to criterion. The ranking of the BAU as first choice for Oxfam is robust with regard to the weight allocated to profitable operations that might vary from 6.25% to 100% and with regard to the weight allocated to viability of investment that might vary from 0% to 62.50%. It is also quite robust with regard to the employee satisfaction and green concerns criteria whose weights have at least to double to notice a change in the ranking.

4.6 Roll-out plans and further challenges

In the demonstration (S1) and the scaled scenario (S2) the dynamically planned collection from the donation banks needs to fit within the fixed schedule for the shops. By including both shops and donation banks in the dynamic schedule, efficiency increases and there are fewer driven miles per vehicle. The only drawback in the scenario (S3) would be the low contribution to the employee satisfaction criterion of Oxfam which is caused by the additional labour for the shop managers and the transportation manager (i.e., planner). For citizens and local authorities, the main differentiating factor is the emission of pollutants, followed by the use of the infrastructure (urban accessibility and network optimisation). The local authorities' criteria are mostly based on the satisfaction of the citizens. As such, for these stakeholders, the scaled scenario where many vehicles drive less miles is the scenario that contributes most to their criteria whereas the current situation contributes least. In conclusion, it can therefore be said that both the amount of shops and the size of the area – because of the size of the vehicle fleet – are decisive factors for successful implementation. Hence, a scenario where both a large area – to serve the criteria of the non-economic actors – and dynamic routing with shops – to serve the criteria of Oxfam – contributes most to the criteria of all the stakeholders combined.

Although the local authorities and the citizens benefit when dynamic routing is introduced, Oxfam is the one responsible of the possible future implementation. The success of the dynamic routing is dependent upon two factors. First of all, sensors need to be reliable. During the demonstration there were some connection problems and only 21 out of 40 sensors worked well. In this case the return on investment is lower because not all the purchased sensors worked. Consequently time, distance and fuel savings were lower than they might have been. Secondly, for Oxfam the amount of shops in the area is decisive for the success of the solution. The more shops are included in the dynamic routing, the more time and fuel costs are saved. For all stakeholders the best scenario would be one in a large area where donation banks are equipped with reliable sensors and shops are included in the dynamic routing.

5 Conclusions

This framework provides a step-by-step approach for a thorough evaluation of city distribution projects. Stakeholders' preferences are now taken into account in the evaluation at each stage of the decision process, thereby increasing the chances of success of any initiative. It is important for a MAMCA to achieve a thorough understanding of the problem along with a definition of the various alternatives, the different stakeholders and their objectives. This paper deals with these aspects and aims to provide the framework for a MAMCA devoted to urban and inter-urban freight transport called CD-MAMCA. It determines the five relevant stakeholders and their objectives. Using the PROMETHEE-GDSS method which is particularly suited to involve stakeholders in the decision making process, the user friendliness of this framework is illustrated by the remote bring-site monitoring of Oxfam which implemented a new dynamic schedule of donated clothes collection.

This impact assessment framework has been fully applied to seven demonstrations during 2013 and 2014. Further results for the multi-criteria analysis of the demonstrations are available in STRAIGHTSOL (2014b). For the European Commission, to reach their goals of sustainable transport (European Commission, 2011), the experiences obtained through the demonstrations will also contribute to the transfer of knowledge and experiences across Europe and will facilitate the systematic assessment of measures. Thus the CD-MAMCA framework will be improved based on the current experiences and new project's demonstration in different contexts such as developing countries or case specific projects.

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Notes

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