Analysis of urban freight distribution measures

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Abstract
Urban Freight Distribution (UFD) represents a very important activity in terms of cities economy, but can also be a problem for the daily life of citizens, due to traffic, noise and environmental contamination. Therefore UFD activities must be managed cautiously, to avoid or minimise external negative effects. In this context, this research aims to evaluate existing UFD measures, ranking them from the best to the worst one, according to experts' opinions. The proposed evaluation process is flexible in order to allow evaluating future UFD measures that may arise.
Keywords: urban freight Distribution; urban logistics; sustainability.

1. Introduction

Urban Freight Distribution (UFD) generates conflicts between carriers and other stakeholders involved in urban traffic [Muñuzuri et al., 2005]. However, while municipalities expect companies to lead new logistic services, companies wait municipalities to start such services that could be poorly profitable and highly risky [Dablanc, 2007]. Although the interests of both parts may sometimes be confronted, they should be complementary in order to achieve sustainable urban systems from a social, environmental and economic standpoint. In this context, the imposed restrictions by local administrations aiming to protect citizens' interests heighten the challenge of finding appropriate measures for the UFD. These constraints, not always sufficiently evaluated [Quak & de Koster, 2009], generally do not solve the main problems of urban logistics, as it has been shown in the literature [Sathaye et al., 2009; Cantillo & Ortúzar, 2009].

Many works review different measures implemented worldwide and their results following diverse approaches. Different classifications of implemented measures can be found in literature [van Duin & Quak, 2007; Russo & Comi, 2011]. In any case, possibly the most known projects reviewing and analysing the impacts of UFD measures implemented in Europe are BESTUFS I and II [BESTUFS, 2005; 2007]. These projects conclude about the need of ex-ante assessments to avoid applying measures leading to undesired or unexpected results [Fillippi et al., 2010; Ibeas et al., 2012]. In this sense, many models for assessing UFD measures are proposed in literature [Anand et al., 2012; Gonzalez-Feliu & Routhier, 2012; Gonzalez-Feliu et al., 2014]. These approaches conceive UFD as a global problem with many stakeholders involved and study a set of measures that can be applied to a specific context in order to determine their appropriateness, mainly in terms of environmental sustainability.

In general terms, most works develop interesting models to assess measures before their implementation. However, the amount of measures studied is generally limited and the works tend to consider UFD in a large scale (interregional or national contexts), while the local scale is less studied [Filippi et al., 2010]. A key issue is to develop methods for the ex-ante evaluation of measures that can be used by local administrators to respond to citizens and companies' needs [Ibeas et al., 2012]. In this context, this paper presents a procedure to evaluate and prioritize the implementations of a set of existing measures at urban scale. More specifically, the aim of this work is to evaluate 38 existing

measures applicable to the UFD through a set of 30 attributes that allow analysing their benefits or disadvantages on the society. For this purpose, the opinions of experts in the field of UFD are gathered and examined, since an appropriate analysis of stakeholders' points of view is a key issue for ensuring implementing adequate measures [Domínguez et al., 2012]. Note that even if the proposed procedure can be utilized in any context, in this paper a particular emphasis is put on the sector of the food distribution.

2. Evaluation of UFD measures

The proposed procedure to evaluate UFD measures is made up of five steps, which are presented in this section. As shown in Table 1, 38 existing UFD measures were compiled from literature review [BESTUFS, 2005; Muñuzuri et al., 2005; BESTUFS, 2007; Browne et al., 2007; van Duin &Quak, 2007; Sanz et al., 2013].

Table 1. List of measures

M1	Urban tolls
M2	Time restrictions to access to the city
M3	Access to the city restricted according to maximum weight
M4	Access to the city restricted according to vehicles' age
M5	Access to the city restricted according to the cargo
M6	Close the city centre to private vehicles
M7	Time restriction in loading/unloading zones
M8	Use of reserved places
M9	Use of controlled parking zones
M10	Combined use of loading/unloading zones
M11	Multi-use lane
M12	Loading/unloading exclusive zones for UFD vehicles
M13	Reservation of loading/unloading zones
M14	Vigilance of loading/unloading zones
M15	Temporary closure of streets
M16	Logistic platform out-of-town
M17	City terminals
M18	External delivery zones
M19	Underground urban logistics platform
M20	Shuttle areas
M21	Use of public and private parking
M22	Last mile with electric vehicles
M23	Urban railway for freight
M24	Use of special vehicle positioning systems
M25	Logistics containers easily manageable
M26	Suitable equipment for loading/unloading zones
M27	Communication equipment in vehicles
M28	Advanced transport management systems
M29	Intelligent transport systems
M30	Night delivery
M31	Sharing vehicles with other loaders
M32	Urban logistics services
M33	Self-storage space for cargo unloading
M34	Providers centralization in Distribution Centres
M35	Efficient integration of reverse logistics
M36	Home delivery logistics
M37	Time scheduling in the loading/unloading zones
M38	Agreements for sharing loading/unloading zones

Step 1: Attributes definition

Thirty attributes were defined to ease the evaluation of the impacts of the measures analysed in this paper (Table 2). The identification emerged from the literature review, the professional and research experience of the authors and previous discussions with UFD experts.

Table 2. List of attributes

A1	Decrease of road occupation
A2	Reduces the ambient noise
A3	Reduces congestion in the area
A4	Respects the urban landscape
A5	Increases roads safety
A6	Reduces CO2 emissions
A7	Reduces damage to urban pavement
A8	Appropriate unloading systems
A9	Qualified personnel for unloading
A10	Fast unloading in the shop
A11	Synergies with other loads
A12	Reduces the travel time
A13	Reduces occupational risks
A14	Reduces energy consumption
A15	Increases flexibility in management
A16	Increases the control of the operation
A17	Reduces operating costs of vehicles
A18	Smooth work load in distribution centres
A19	Investment costs for Public Administration
A20	Maintenance costs for Public Administration
A21	Difficult application for Public Administration
A22	Delayed deliveries of goods to the shop
A23	Second deliveries
A24	Increases handling costs
A25	Investment costs for companies
A26	Operating costs for companies
A27	Difficult reverse logistics
A28	Difficult operational management
A29	Difficult supply management
A30	Difficult implementation by companies

Step 2: Attributes relevance

This research was carried out with 26 UFD experts, who were surveyed and interviewed. Experts' profiles were managers from food distribution companies, logistics operators and other companies from the food industry, mobility city officers, researchers and political decision-makers. To determine the weights of the attributes the surveys of the 26 experts were taken into account. However, for the sake of clarity, not 30 but 22 attributes were presented to the experts, discarding the least representatives: A1, A4, A7, A8, A9, A15, A23 and A29. With this information, the global relevance of each attribute was calculated. To avoid trade-offs between attributes, a calculation algorithm was developed (Fig. 1) based on three indexes: the arithmetic mean, the median and the mode. Note that the expression *round.multiple -0.5 (a)* is used to round *a* to the nearest half, i.e. obtaining only whole or half numbers.

```
Let be me = mean, md = median, mo = mode, ov = objective value

if md = mo then
    if md = mo = me then     vo = me
    else     vo = round.multiple –0.5 (average(md,me))
    end if
else     vo = round.multiple –0.5 (average(md,mo,me))
end if

where round.multiple –0.5 (a) means rounding to the nearest half of a
```

Figure 1. Algorithm used to calculate attributes' relevance

The algorithm described in Fig. 1 was used for the 22 attributes asked to the experts. The relevance of the remaining 8 attributes was determined from the authors' professional experience.

Step 3: Measure-attribute assessment

As in Step 2, for the sake of clarity, only 22 attributes were evaluated and only the most significant measures were analysed. In particular, 12 of them were selected with the following indicators from Table 1: M1, M2, M11, M13, M16, M22, M25, M28, M30, M31, M32 and M34. To calculate the global rates of each attribute for each measure, as in Step 2, an algorithm was developed (Fig. 2) based on three indexes that allow taking into account experts' evaluation and dispersion in the answers: the arithmetic mean, the median and the mode. The experts evaluated the accomplishment for each couple measure–attribute in a 0–10 scale. As shown in the algorithm, if the three indexes coincide, this is the rate considered, while if only the median and the mode coincide, the considered rate is the integer immediately greater or lower than the median, depending on whether the mean is greater or lower than the median, respectively. In exchange, if the median and the mode are not the same, the considered rate depends on the absolute difference of the three indexes. Complementarily, the authors rated each couple measure–attribute, based on their professional experience. Thus, a global rate was finally obtained for the 30 attributes and the 38 measures.

Step 4: Measures global index

Once calculated the relevance of the attributes and the rates of each attribute for each measure, the global index for each measure is calculated as the weighted average of the scores for the corresponding attributes. The global index allows classifying the UFD existing measures.

Step 5: Feasibility thresholds

Basing decisions only on the global index could be counterproductive. In some cases, a low attribute rate described as very bad could be compensated by higher positive ratings obtained in other attributes. To avoid this possibility, some minimum feasibility or viability thresholds of the attributes are defined. This means that a measure is considered feasible if the rates of all the corresponding attributes are within such pre-set margins. The minimum thresholds proposed in this research were established based on the values of the attributes A21 and A30. If a measure achieved the top score in either of these two attributes, it was considered infeasible and was consequently discarded.

```
Let be me = mean, md = median, mo = mode, ov = objective value

if md = mo then
    if md = mo = me then     vo = me
    else
        if md > me then
            if integer(me) < md – 1 then     vo = md – 1
            else     vo = md
            end if
        else
            if integer(me) ≥ md + 1 then     vo = md + 1
            else     vo = md
            end if
        end if
    end if
else
    if |md – mo| > 1 then     vo = round.greater (average(md,mo))
    else
        if |md – me| ≥ |mo – me| then     vo = mo
        else     vo = md
        end if
    end if
end if
```

Figure 2. Algorithm used to calculate attributes' rate for each measure

3. Results and discussion

3.1. Attributes' relevance

To evaluate the relevance of each attribute, the experts were asked to assign a weight between 0 and 4 to the 22 attributes presented to them. Little consensus was found among the consulted experts who assigned different weights to each attribute. Thus, a cluster analysis was realized to establish whether there were groups of experts with similar response patterns and with significant statistical differences with respect to other groups. The analysis confirmed the existence of 2 clusters according to experts' profile. The first cluster was identified as the companies sector and included 19 experts. The second cluster was identified as academicians and politicians and included 7 experts. The attributes involving an inconvenience for companies operating in UFD were more relevant for the companies sector cluster than for the academicians and politicians cluster. In contrast, the attributes representing an inconvenience for citizens were more relevant for the academicians and politicians cluster than for the companies sector cluster. Although initially the scale to evaluate the relevance was defined from 0 to 4, the range was extended to a scale from 0 to 10 multiplying by 2.5, for the sake of clarity. Table 3 shows the relevance obtained by using the algorithm shown in Fig. 1 for the 30 attributes.

3.2. Global index for each measure

The general assessment of the measures was obtained averaging the advantages and disadvantages. Depending on the intended use of the evaluation, more importance could be given to some advantages-disadvantages over the others. The assignment of the same weight to each group was assumed since it represents an example of global assessment. Table 4 shows, for each measure, the ratings by society and business group; the global indexes; and the classification. To validate these results this ranking was shown to interviewed experts, who confirmed results' consistency.

Table 3. Relevance of the attributes

	Attribute	Relevance
A1	Decrease of road occupation	7,0
A2	Reduces the ambient noise	7,5
A3	Reduces congestion in the area	8,5
A4	Respects the urban landscape	5,0
A5	Increases roads safety	6,5
A6	Reduces CO2 emissions	7,5
A7	Reduces damage to urban pavement	5,5
A8	Appropriate unloading systems	4,0
A9	Qualified personnel for unloading	4,0
A10	Fast unloading in the shop	8,5
A11	Synergies with other loads	7,0
A12	Reduces the travel time	8,5
A13	Reduces occupational risks	5,5
A14	Reduces energy consumption	7,0
A15	Increases flexibility in management	6,0
A16	Increases the control of the operation	7,5
A17	Reduces operating costs of vehicles	8,5
A18	Smooth work load in distribution centres	7,5
A19	Investment costs for Public Administration	7,0
A20	Maintenance costs for Public Administration	6,5
A21	Difficult application for Public Administration	7,5
A22	Delayed deliveries of goods to the shop	8,5
A23	Second deliveries	5,5
A24	Increases handling costs	7,5
A25	Investment costs for companies	8,5
A26	Operating costs for companies	8,0
A27	Difficult reverse logistics	5,5
A28	Difficult operational management	7,0
A29	Difficult supply management	4,0
A30	Difficult implementation by companies	7,5

4. Conclusions

In this paper existing measures applicable to the UFD are evaluated. The evaluation is realized following a proposed novel procedure defined in 5 steps. First a list of attributes is defined to evaluate the impacts of the measures. Then the attributes are weighted to determine their relevance and rated for each measure. Finally the global indexes of each measure are calculated considering some minimum standard thresholds. This whole procedure was realized together with a group of experts in the field of UFD, who were surveyed and interviewed, giving to the research a very practical approach. The proposed procedure obtained a final ranking of measures according to their appropriateness and priority to be implemented in urban context.

Table 4. Global index of measures

	Measures	Provides benefits		Provides inconv.		Global index	Position
		Soc.	Bus.	Soc.	Bus.		
M28	Advanced transport management systems	2.16	1.81	0.00	1.14	1.42	1
M35	Efficient integration of reverse logistics	1.88	1.12	0.00	0.30	1.35	2
M30	Night delivery	3.13	1.99	1.38	1.27	1.23	3
M37	Time scheduling in the loading/unloading zones	1.62	1.13	0.00	0.48	1.14	4
M33	Self-storage space for cargo unloading	1.78	2.09	0.36	1.27	1.12	5
M26	Suitable equipment for loading/unloading zones	1.34	1.50	0.00	0.66	1.09	6
M38	Agreements for sharing loading/unloading zones	1.62	1.13	0.00	0.60	1.08	7
M27	Communication equipment in vehicles	1.00	1.64	0.00	0.52	1.06	8
M6	Close the city centre to private vehicles	3.28	1.82	3.05	0.00	1.03	9
M11	Multi use lane	1.34	1.33	0.67	0.00	1.00	10
M34	Providers centralization in distribution centres	2.03	1.22	0.00	1.25	0.99	11
M12	Loading/unloading exclusive zones for UFD vehicles	1.48	1.16	1.02	0.00	0.81	12
M31	Sharing vehicles with other loaders	2.18	0.95	0.00	1.58	0.78	13
M4	Access to the city restricted according to vehicles' age	1.46	0.68	0.00	0.78	0.68	14
M36	Home delivery logistics	2.14	0.00	0.00	0.90	0.62	15
M22	Last mile with electric vehicles	1.74	0.51	0.00	1.04	0.61	16
M9	Use of controlled parking zones	1.00	0.93	0.67	0.13	0.57	17
M24	Use of special vehicle positioning systems	1.48	0.93	0.00	1.29	0.56	18
M8	Use of reserved places	1.18	1.25	1.38	0.00	0.52	19
M10	Combined use of loading/unloading zones	1.00	1.05	1.02	0.00	0.51	20
M5	Access to the city restricted according to the cargo	3.00	0.52	1.69	1.04	0.40	21
M14	Vigilance of loading/unloading zones	1.04	0.71	1.02	0.00	0.36	22
M15	Temporary closure of streets	1.47	0.15	0.71	0.25	0.33	23
M1	Urban tolls	1.59	1.02	1.71	0.65	0.13	24
M2	Time restrictions to access to the city	2.21	0.56	1.02	1.61	0.07	25
M29	Intelligent transport systems	2.75	1.78	3.69	0.77	0.04	26
M25	Logistics containers easily manageable	1.05	0.82	0.00	1.93	-0.03	27
M7	Time restriction in loading/unloading zones	1.18	0.94	1.33	0.90	-0.06	28
M13	Reservation of loading/unloading zones	1.00	1.17	1.69	0.79	-0.16	29
M16	Logistic platform out-of-town	2.06	1.73	2.69	2.20	-0.55	30
M3	Access to the city restricted according to maximum weight	1.61	0.70	1.02	2.41	-0.56	31
M23	Urban railway for freight	2.86	1.96	3.69	2.37	-0.62	32
M17	City terminals	1.73	1.64	2.69	2.02	-0.68	33
M32	Urban logistics service	2.64	1.01	2.38	2.90	-0.81	34
M19	Underground urban logistics platform	1.73	1.64	3.02	2.02	-0.84	35
M20	Shuttle areas	2.47	0.76	2.36	2.65	-0.89	36
M21	Use of public and private parking	1.59	0.89	2.41	2.32	-1.12	37
M18	External delivery zones	1.18	1.34	3.00	3.08	-1.78	38

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