





Criteria to implement UDCs in historical cities: a Brazilian case study

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Abstract

Urban Distribution Centres (UDCs) are beneficial for the functioning of urban transport systems. However, implementing them poses a challenge because they incur high costs, coordinating different agents and multiple criteria. In historical cities, a UDC is an alternative to efficient urban freight transport (UFT) in terms of sustainability and preservation of historical heritage. This study analyses the operational, economic, social, cultural, and environmental criteria that influence the implementation of a UDC in historical cities, considering the different perspectives of four agents: residents, traffic wardens, retailers and carriers. We conducted semi-structured interviews with traffic wardens and retailers, and a survey was developed with all the agents. Univariate and multivariate statistical analyses were applied to find the relevant criteria for implementing a UDC according to the agents. Considering the viewpoint of all agents, the vehicle size was the most relevant common criteria when setting up a UDC to supply retailers in the historical city centre of Ouro Preto. Residents and traffic wardens had very similar points of view and agreed with the negative effects of UFT (air pollution level, visual intrusion level, insecurity, and congestion), while most retailers and carriers disagreed with these impacts.

Keywords: Urban Distribution Centre; Urban Freight Transport; Multivariate Factorial Analysis; Historical cities.

1. Introduction

Most historical cities still face the challenge of not only establishing urban mobility and accessibility projects, but also making them compatible with the preservation of cultural heritage (SPHAN, 2014). In these city centres, such as Verona (Italy), La Valletta (Malta), Lörrach (Germany), Porto (Portugal) and Ouro Preto (Brazil) historical buildings, narrow streets, and a high concentration of pedestrians can be found. There is

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a wide range of small retailers (National Historic and Artistic Heritage Institute – SPHAN, 2011), which are traditional and popular that are not supplied by optimized deliveries (Van Duin et al., 2016).

Regarding urban freight transport (UFT) in historical cities, one way to design this process more efficiently, considering sustainability and heritage preservation, is to implement Urban Distribution Centres (UDCs), even though there are key barriers to this process (Nordtomme et al., 2015). The basic principle of UDCs is to enable freight consolidation (Taniguchi and Thompson, 2015) for different receivers and temporary storage for retailers in terms of improved social and environmental aspects (Johansson and Björklund, 2017), as well as a reduction in local traffic problems in urban areas (Allen et al., 2012). This idea is not new as it first emerged in the 1940s. However, it is still controversial (Holguín-Veras et al., 2018) and recent studies have shown us different results. On one hand, some benefits are: (a) improvements in logistics operations regarding customer service (Browne et al. 2011) such as a reduction in the total distance travelled (Holguín-Veras et al., 2018), improvements in load factors, facilitated reverse logistics, packing and preparation of products and better inventory control (Quak and Tavasszy, 2011); (b) reduction in negative externalities (de Vasconcellos, 2005). According to Veličković et al. (2018), UDCs provide large externality reduction, although they may require infrastructure support, facility investments and trial costs. A reduction in distance levels leads to a reduction in traffic congestion, noise and pollution levels, less conflicts between freight vehicles and other users, resulting in more safety (Quak and Tavasszy, 2011).

On the other hand, implementing UDCs has provided poor track records (Holguín-Veras et al., 2018). For instance, in 2008, the Italian Government invested millions of Euros in Italian cities to implement UDCs. Few of them survived financially without public subsidies or strong political commitment, although Padua is an exception (Danielis, Rotaris and Marcucci, 2010). Another exception is Lucca, where the implementation process has not only depended on local government funding but also on public-private partnership (Nocera and Cavallaro, 2017). The main negative aspect includes: high costs incurred by operations and high investment in properties, clash of interests among the agents (Paddeu et al., 2018), and improvements of customer service are justified if there is a large-scale gain, for instance, moving retailers logistics activities to the UDCs (Johansson and Björklund, 2017).

Europe has shown a special interest in the development of UDCs (Chwesiuk et al., 2010). Nevertheless, a few UDC studies include the view of multiple agents and multiple criteria. Some studies were designed for urban areas of Swedish municipalities from the perspective of local authorities; others were conducted as field research with retailers in the Swedish cities of Linköping and Norrköping (Johansson and Björklund, 2017), in London, Bristol/Bath (England) and Nijmegen (The Netherlands) (Van Duin et al., 2016) and in several cities adjacent to Vicenza (Italy) and Fano (Italy) (Lindholm, 2010; Faccio and Mauro, 2015; Marcucci and Danielis, 2008; Marcucci and Danielis, 2008); and others focusing on some supply chains (Danielis, Rotaris and Marcucci, 2010; Morganti; González-Feliu, 2015). Other studies have included agents but with a limited number of criteria to be analysed (Zhou and Wang, 2014; Oliveira and Correia, 2014; Oliveira and Oliveira, 2016). However, as stated by Duin et al. (2018),there is a significant variance among the perceptions of agents regarding UDC, because they do not perceive those issues and misunderstand the main elements involved.

This paper analyses the operational, economic, social, cultural, and environmental criteria that influence implementing a UDC in historical cities, considering the different perspectives of four agents: residents, traffic wardens, retailers and carriers. The idea is to analyse the main aspects concerning implementing a UDC in historical city centres (Browne et al., 2005) in order to provide further insights into the local municipality, private companies or public-private partnership (PPP) (Van Duin et al., 2016). In our study, the historical city of Ouro Preto was defined as the research unit for multi-agent criteria evaluation.

The contribution of this research is to provide a criteria analysis, focusing on elements regarding historical cities, evaluated by the main agents in UFT. We analysed a wide range of criteria, some of them not yet researched, taking into account the opinions of residents and traffic wardens, which are usually overlooked. The literature addresses various studies related to agents' perceptions of urban freight policies, although in most cases, studies include the opinion of carriers and receivers/retailers, while the opinion of residents are frequently neglected. Our research also discloses that retailers are the key agent to be heard of implementing a UDC. Cities and their residents have much to gain from implementing a UDC (Johansson and Björklund, 2017).

The structure of this paper is as follows: Section 2 describes the agents involved in UFT. Section 3 shows the main criteria that influence the establishment of a UDC, while Section 4 describes the methodological procedures. Section 5 shows the results found for each agent. Section 6 we provide overall conclusions, lessons learned based on viewpoints of the agents and limitations of the study.

2. Agents in Urban Freight Transport

Urban Freight Transport (UFT) is complex and involves various agents, with different requirements and perceptions (Ballantyne et al., 2013). Shippers, carriers, administrators and residents (consumers) constitute the main agents, with different objectives and perspectives towards their own goals (Taniguchi et al., 2012). There are also other agents who have indirect interests in city logistics (Ballantyne et al., 2013), related to economic, environmental, social and cultural improvements. For example, there are vehicle manufacturers which are interested in selling vehicles that suit the UFT operation and commercial associations that stimulate the economic and social development of a community. They can potentially impact the operations of UFT through regulations for a particular policy (e.g. retailer association) and institutions that aim to preserve historical cities considered world heritage, according to the United Nations Educational, Scientific and Culture Organization (UNESCO) and the SPHAN (in Brazil). Table 1 shows the main agents and their interests in an UDC.

Agent	Interests in UDCs	Reference
Residents	Minimize the disutility caused by UFT (e.g. traffic congestion and large trucks using local roads); Maintain attractiveness of the urban area; Cost efficiency; Provide a safe environment at central areas; Prevent noisy atmosphere and air pollution at central areas.	Taniguchi et al. (2003) Russo and Comi (2010) Taniguchi et al. (2012) Ballantyne et al. (2013)

Table 1: Agents of UFT and their interests in UDCs.

Carriers	Avoid wasting time in deliveries at central city (e.g. parkin problems, congestion, etc.); Minimize delivery restrictions; Enable customer accessibility; Cost effectiveness; Provide high-quality transport operations; Ensure satisfaction of shippers and retailers.	g Van Duin et al. (2010)
Public authorities	Maintain attractiveness of the urban area; Increase the quality of life; Attempt to attract businesses and visitors to the area; Enhance the economic development of the city; Increase employment opportunities; Reduce traffic congestion; Improve the environment; Reduce traffic collision at central areas.	Taniguchi et al. (2003) Ballantyne et al. (2013)
Shippers	Improve goods delivery and reduce costs; Meet customer needs; Provide advantages in efficiency and competitiveness.	Russo and Comi (2010) Ballantyne et al. (2013)
Receivers	Enable product delivery at a short leadtime; Provide better transport conditions; Provide value-added services (inventory monitoring, and information collection and analysis); Enable return and waste collection services, with tracking of returned products.	Huschebeck and Allen (2005) Russo and Comi (2010) Campbell et al. (2010) Zunder and Marinov (2011) Allen et al. (2012) Van Duin et al. (2012)
Other	Indirect interests related to economic, environmental, socia and cultural improvements.	^{ll} Ballantyne et al. (2013)

In general, residents and public authorities have similar interests. Public authorities act by means of governance and implementation of legislations that encourage solutions for city logistics. Traffic wardens represent the public authorities who enforce legislations, and guide drivers on the city's specific laws. Carriers and retailers are most impacted by law, especially in the case of historical cities, which generally have specific restrictions in terms of size, weight and scheduling for cargo vehicles operations.

This paper focuses on the perspectives of four agents: residents; public authorities, represented by traffic wardens; receivers, represented by retailers; and carriers.

3. Criteria to analyse the implementation of an UDC in historical cities

The UDC acts as an interface between urban and long-distance transport (Olsson and Eugenius, 2014) and can bring benefits to agents in different aspects: operational, economic, social, cultural, and environmental.

The **operational** aspect refers to the structure, operational activities and opportunities offered by UDC. The criteria found at literature, associated with operational issues of UDC are summarized in Table 2.

Table 2: Criteria and benefits related to operational aspects in UDC.

Criteria	Benefits	Author (Year)
Parking spaces	Increases the facility to find parking spaces to freight vehicles.	Zunder; Marinov (2011) Awasthi; Chauhan (2012)

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Congestion	Reduces congestion caused by trucks blocking streets and parking problems.	González-Feliu (2008) González -Feliu; Morana (2010) Kin et al. (2016)
Professional qualification	Provides professional qualification, such as driver training.	Henriot et al. (2008)
Vehicle size	Considers the use of smaller vehicles.	Browne et al. (2005, 2007)
Maximization of load factor	Attends more customers on fewer trips in urban areas.	Allen et al. (2012)
Use of technology	Information Technology (IT) provides real-time traffic information, automated parking, traffic rules, toll collection and access control.	Dablanc et al. (2013)
Confidentiality of information	Protects the information from the companies by the confidentiality of information.	González-Feliu (2012)
Conflicts of responsibility	Reduces conflicts regarding transport operations between partners and customers of the UDC (e.g. legal conflicts).	González-Feliu (2012) Van der Donk (2015)
Partnership	Manages the provision of the service in	Van der Donk (2015)
between users	cooperation with other transport companies.	Oliveira; Correia (2014)
Compliance with legislation	Considers compliance with legislation.	Agrebi et al. (2015) Rao et al. (2015)

Related to the economic aspect, Table 3 summarizes the criteria and their benefits.

Criteria	Benefits	Author (Year)				
Local prosperity	Increases jobs creation and incentivizes competitiveness.	Russo; Comi (2010)				
Customer service level	Improves reliability and punctuality in delivery.	Henriot et al. (2008) Rao et al. (2015)				
Investments and costs	Studies the initial investments and costs required to make the UDC feasible. Investments can be obtained from different sources, as a public initiative that obligate the use of the UDC	Ville et al. (2010) Panero et al. (2011)				
Obligation of use	A new source of money as it obligates the use of the UDC; Brings benefits to its users or adds restrictions to the carriers that did not use the facility.	Ville et al. (2010) Panero et al. (2011)				
Sharing costs and profits	Stimulates collaboration between different agents to share UDC costs and profits.	Awasthi; Chauhan (2012) Van der Donk (2015) Janjevic et al. (2016)				

Table 3: Criteria and benefits related to economic aspects in UDC.

Regarding social aspects, Table 4 considers the following criterion and benefit.

Table 4: Criteria and benefits related to social aspects in UDC.

Criterion	Benefit	Author (Year)					
Insecurity	Reduction of accidents due to unsafe loading/unloading in the city centre, large vehicle traffic and recklessness of drivers.	Anderson et al. (2005) González -Feliu; Morana (2010) Awasthi; Chauhan (2012) Agrebi et al. (2015) Kin et al. (2016)					

Cultural aspects are listed in Table 5, with their specific benefits related to UDC in historical cities.

Criteria	Benefits	Author (Year)
Shaking of the architectural heritage	Protect historical centres (as recommended by the United Nations General Conferences in 1976, 1977 and 1986); Contributes to reduce the shaking of the architectural heritage and decreases the impacts caused by heavy vehicles in the surface of walls.	Browne et al. (2005) Azevedo; Patrício (2001) Resende et al (2011)
Depletion of buildings by collision	Prevents accidents caused by vehicles which collide with historical buildings.	Zarinato (2008)

Table 5: Criteria and benefits related to cultural aspects in UDC.

Regarding the **environmental** aspect, UDC can bring the benefits listed in Table 6 to each criterion.

Criteria	Benefits	Author (Year)
Air pollution level	Reduces the air pollution, which causes degradation of rocky materials of monuments, and the black smoke from trucks, which causes the blackening of buildings.	Quak (2008) Reys et al. (2008) Rao et al. (2015)
Visual intrusion level	Reduces visual intrusion caused by the freight vehicles, which cause the interaction of the individual with the environment.	SPHAN (2014) Quak (2008) Reys et al. (2008) Zarinato (2008) Rao et al. (2015)
Noise nuisance level	Reduces the perceptions of vibrations and sounds caused by vehicle movements.	Anderson et al. (2005) González -Feliu (2008) Quak (2008) González –Feliu; Morana (2010) Rao et al. (2015)
Use of alternative fuel vehicle	Enables the use of clean vehicles that run on natural gas or electricity	Allen et al. (2007) Ville et al. (2010) Browne et al. (2011) Allen et al. (2012) Giuliano et al. (2013)

Table 6: Criteria and benefits related to environmental aspects in UDC.

Table A1 (see appendix A) joins all cited studies and shows the evaluation for each criterion on UDC for the different agents interviewed.

4. Methodology

The methodological approach consists of semi-structured interviews and descriptive research (Forza, 2002) applied to four UFT agents: residents, traffic wardens, retailers and carriers. Moreover, we analysed the secondary data as follows: the Municipality of Ouro Preto provided a list of retailers who work in the historical centre including their identification, address and main activity. The Municipal Secretary of the Government provided the legislation related to the transportation of goods inside the city. The

department responsible for traffic wardens provided the number of notifications for fines (traffic tickets) processed by location and type of infraction.

Protected by mountains, the city embodies the history of Brazil's gold rush era from the seventeenth and eighteenth centuries. The city's economy was based on gold and diamond mining in the 17th century, but these products did not sell, leading the authorities to encourage other activities, which had been produced before (Fogelman, 2018). We chose the historical centre of Ouro Preto as the focal point of this study because it is a representative historical Brazilian city with narrow streets, antique buildings and mountain landscape where companies, residents and policy makers deal with UFT issues. "Ouro Preto is (...) the most unique of cities in Brazil: it is the most complete living proof we have of the colonial era. Elsewhere is this or that building, this or that colonial monument; Ouro Preto is nothing less than a "colonial city perfectly preserved in the integrity of its details" (Delamare, 1935, p. 241). The city was declared as a National Monument in 1933 and protected by SPHAN in 1938. It was the first Brazilian city included in the UNESCO World Heritage List in 1980 (Oliveira, 2016).

The population of Ouro Preto is 73,994inhabitants (IBGE, 2017). From 2006 to 2015, economic activities were focused on industry (around 60%), and 86.4% of the taxes came from this sector, although the number of stores is much higher than factories. Even though industry is the main sector, retailers have increased their contribution in State taxes by 18.5% between 2016 and 2017; supermarket/grocery stores and clothes stores are the biggest contributors, and 93.9% of retailers are very small (Almeida et al., 2018). Industries in the surrounding area, the population growth and an increase in traffic have brought about an imbalance in the harmony inherited from the past (Ferreira et al., 2013).

The city faces several problems, which have also been identified in other historical Brazilian cities, (São João Del Rei, Tiradentes, Paraty, Salvador, Laguna, Paranaguá, etc.) cited by Iphan (2014, p.73): narrow streets; no signs, or unsuitable ones, for freight vehicles; insufficient regulated parking zones (or lack of them) or non-compliance with loading and unloading areas; heavy goods vehicles transit in the centre and vehicle congestion in the central area, where commercial and institutional activities are concentrated. To avoid UFT issues, the city follows legislation from 2006 to 2014, regarding the size of trucks and the capacity of buses allowed to transit in the city centre (Prefeitura Ouro Preto, 2006, 2007, 2014). Data from March of 2018, according to Almeida et al. (2018), 59.80% of vehicles were cars, 19.32% were motorcycles, 3.26% were trucks, 0.83% were buses, 1.05% were light vehicles (which normally are used in UFT), and 15.74% others.

We studied this historical area (Figure 1) due to the concentration of stores in the city centre (3,239 all together representing 15% of all retailers), delimited by a UFT restriction zone.



Figure 1. The scope of the study.

This centre occupies an area of about 0.23 km², which represents approximately 0.018% of the entire city (including the districts), which contains 1,246 km² according to IBGE (2015). The established policies related to the transportation of goods are: time window (from 6 a.m. to 9 a.m. and from 7 p.m. to 10 p.m.) for loading/unloading on weekdays in the restricted area; the circulation of vehicles exceeding 8.0m in length, 3.5m high, 2.6m wide and total weight exceeding 7 tons is prohibited.

4.1 Semi-structured interviews

We conducted semi-structured interviews with traffic wardens and retailers. The questions in the semi-structured interviews were related to:

- (i) knowledge and effectiveness of the actions from the public authority concerning the regulation of parking areas and restriction of vehicles in the historical centre;
- (ii) agreement with the establishment of a place to tranship goods to retailers located in the historical centre;
- (iii) using money collected from traffic fines as an alternative subsidy for maintaining a UDC; and
- (iv) the possibility of a public-private partnership (PPP) to implement and operate an UDC.

4.2 Survey design

We used a structured questionnaire for each agent considering the literature review (residents, traffic wardens, retailers and carriers). Pilot tests were performed based on Forza (2002). Data collection procedures were carried out according to the agents:

- face to face: residents, retailers and carriers;
- online questionnaire: residents;
- semi-structured interview: traffic wardens.

All agents were requested to express their opinion on four different types of questions: open-ended questions; multiple-choice questions applying a five-point Likert scale (from strongly agree [1] to strongly disagree [5]); closed or dichotomous questions, and action questions.

4.3 Survey sample and procedures

For residents and retailers, the sample was calculated based on a finite and known population (Cochran, 1985). We considered a 95% confidence level, a sample error margin of 6% and a standard deviation of 0.5.

The data collection was carried out between July and August, 2016. We collected 342 questionnaires from residents over 18 years old. The Mahalanobis distance (D^2) measure was used (Hair et al., 2003; Zijlstra et al., 2013) to detect 31 atypical observations. The final sample had 311 residents (46% male and 54% female). To ensure the representativeness of the sample, it was compared to the proportions of the population (gender and age groups) presented in the IBGE demographic census (2010). All traffic wardens answered the survey and no atypical observations were found. Regarding retailers, there were 557 businesses located in the centre, of which 196 were retailers (jewellery stores were excluded). We interviewed 122 retailer representatives from different sectors and no atypical observations were found. The sectors were distributed in supermarket/grocery stores (37%), clothes stores (32%), stationers (15%), drugstores/healthcare (11%), crafts/handcrafts (10%), and others (6%). Their location is shown in Figure 2. Finally, we collected 46 questionnaires from carriers and the Mahalanobis test detected no atypical observations. From all the carriers, 63% were employees and 37% were autonomous.





4.4 Data analysis

We used median and mode as measures of central tendency (Maroco, 2007), quartiles as measures of dispersion (Cooper and Schindler, 2003, p.181) and frequency distributions. We also used the multivariate Factor Analysis (FA) technique to find the factors that influenced the implementation of a UDC to supply the retailers in the

historical city centre. The aim of FA was to generate linear combinations (Hair et al., 2005) called factor loadings. The higher the factor loading, the more the variable contributes to this factor (Harman, 1976). Based on Hair et al. (2005), we performed four tests to ensure the application of FA, which were all above their respective cut-offs:

- Correlation matrix analysis (>0.3);
- Kaiser-Meyer-Olkin (KMO) sample adequacy measure (>0.5); Bartlett sphericity test (BTS), significant at 1%;
- Measures of sampling adequacy (MSA) by anti-Image (>0.5).

To determine the number of factors, we used the eigenvalue and explained the total variance (Hair et al., 2005). To obtain a better interpretation of the factors and eliminate possible ambiguities, the orthogonal varimax rotation was selected. We also observed the communalities above 0.5 (Hair et al., 2005) and the Cronbach's alpha was used to re-specify the factorial model and validate the factorial matrix (>0.5) (Hair et al., 2003).

5. Results

In this section, we present the results for each agent. In some cases, we used semistructured interviews with strategic agents to confirm or refute the results found.

Regarding the use of UDC as an opportunity to improve UFT, 91% of residents believed that off-hour delivery programs could improve urban traffic. About the freight vehicles that circulated in the centre, 56% observed trucks irregularly parked and old freight vehicles moving in the city.

A total of 94% of traffic wardens were favourable to the UDC, considering it an opportunity to improve UFT in the historical centre of Ouro Preto. The Secretary of the Municipal Government (representative of the traffic wardens) mentioned: "The transshipment area would allow better planning, with lower impacts to the movement of people and goods, with scheduling of operating hours and reduction of number and size of vehicles".

The traffic wardens gave some suggestions to improve UFT. They reinforced the need to install a transshipment site, as 50% of them cited this solution; some reported the importance of adapting traders and/or carriers to the loading and unloading schedule according to the law. Others supported changes and kept an open access to discuss with residents, retailers and traffic wardens the solutions regarding freight transport at the central region. Therefore, one of the traffic wardens said: "The unloading schedule does not attend retailers and the drivers are in a difficult situation when they disrespect the laws and are punished for something, they do not have much to do". When asked about the efficiency of measures related to cargo transportation, the Secretary of the Municipal Government said that they are roughly efficient, because "despite the occasional difficulties, there was no supply crisis and there was a significant decrease in the flow of heavy vehicles within the Municipality".

A total of 84% of small retailers, located in the historical centre, answered our survey. Figure 3 shows the evaluation of value-added services for retailers offered by an UDC.



Figure 3: UDC as an opportunity of value-added services for retailers.

Almost all retailers (95%) reported the importance of dividing UFT into two parts or legs, with UDC included as a buffer between the cargo that comes from other cities and the retailers' supply. In general, the added-value services of less interest were those that were carried out inside the store and could be transferred to the UDC. This shows that retailers were afraid to outsource their activities. On the other hand, activities related to transportation pointed out a greater interest to be modified.

In general, carriers come from the Belo Horizonte Metropolitan Area (BHMA), which is located at 100 km from Ouro Preto (65% of cargo) and from the 'Zona da Mata' region whose cities are between 100 and 250 km from Ouro Preto (30% of cargo). In terms of size, 50% of vehicles coming from BHMA have cargo vehicles between 3 and 5 tons; however, small cargo vehicles (1 ton) are also observed in the delivery of goods from BHMA and 'Zona da Mata'. The food sector operates vehicles with greater capacities.

Considering the use of an UDC as an opportunity to improve UFT, 85% of the carriers reported the importance to divide freight transport into two legs, separating large vehicles (from shippers to UDC) and small vehicles (from UDC to retailers). In addition, 65% would like to collect goods returned from retailers (for example, unsold stocks) at an external location, while 45% would be against such action due to a possible loss of contact with the retailers. In addition, 89% of drivers agreed to have a location to pick-up goods working for 24 hours.

5.1 Views on the criteria to implant an UDC

Most agents agreed with the division of the UFT into two legs to improve the whole system, inside and outside the historical city centre (Table 7).

Agents	Agree with UFT division	Disagree with UFT division
Residents at historical city centre	92%	8%
Residents outside historical city centre	96%	4%
Traffic wardens	94%	6%
Retailers	95%	5%
Carriers	85%	15%

Table 7: Agents' point of view about UDC.

Subsequently, the criteria considered to implementation of an UDC for supplying retailers at the historical centre were discussed and supported by descriptive statistics measures. We evidenced the main results in terms of agreement and disagreement among the agents. The criteria questioned by each agent are summarised in Table A1 (see appendix A). Values close to one indicate greater agreement. The comparison of the level of agreement of agents is in Table A2 (see appendix A).

Regarding the **operational aspect**, at least 75% of residents, retailers and carriers were favourable to create new **parking spaces** to carriers, while half of traffic wardens had somewhat agreed with this statement. Marcucci and Danielis (2008) reinforce the low availability of parking spaces in historical centres, which makes it more time-consuming to unload cargo, since the route is often done on foot (Pereira and Teixeira, 2002).

Retailers and carriers disagreed with the fact that UFT generates **congestion** in the centre. The stipulated delivery window suggests that the vehicles theoretically do not remain for a long period in the centre. Quak (2008) states that the main difficulties faced by carriers are the restriction policies in several urban centres. Most delivery windows occur in the early morning. In addition, smaller vehicles with lower capacity are allowed to replace larger trucks. As independent retailers in general do not have optimized deliveries, in contrast to retail networks (Van Duin et al., 2016), the number of small vehicles in the city centre increases, consequently raising the congestion. Thus, carriers prefer to have free access and a 24-hour delivery window, without road congestion (Afzal and Kim, 2014).

Contrary to retailers and carriers, more than 75% of residents and traffic wardens believe that parking problems and trucks blocking the streets are factors that generate congestion in the city centre.Freight traffic increases congestion, especially at narrow streets, characterized by a scarce availability of parking spaces (Johansson and Björklund, 2017; Nordtomme et al., 2015; Marcucci and Danielis, 2008). These are common characteristics of historical cities.

At least 50% of all agents considered the need of providing courses and trainings for drivers and employees (**professional qualification**). Although European Commission (2000) and Anderson et al. (2005) emphasize the importance of driver training, some drivers suggested training to traffic wardens, stating that they are not well informed about traffic legislation. The head of the technical office of SPHAN in Ouro Preto affirms that the law would be more effective if there were more control actions.

However, despite qualification issues, traffic wardens reinforce the need to **comply with legislation**, as an obligation of their duty. Almost all agents agreed with the use of a freight transhipment site, as this facility is ideal for areas with restricted access time for cargo vehicles (Allen et al., 2012; Afzal and Kim, 2014), which would facilitate compliance with municipal laws restricting **vehicle size** (Lin et al., 2016). At least 75% of all agents agreed with the use of small vehicles to provide UFT in the historical centre. Reduced vehicle size is one of the main functionalities of UDCs (Browne et al., 2005; Van Rooijen and Quak, 2010; Allen et al., 2012) aligned to the current transport law (Lin et al., 2016) of goods within the cities. On the other hand, a balance must be considered between the quantity of deliveries and the **load factor** of each type of vehicle that supplies the retailers. Load factor maximization is a positive criterion to reduce trips, but the frequency of trips depends on the rhythm of demand.

To comply with the law, retailers and carriers use **technology information** as an operational aid, a criterion that had a high level of agreement among agents (>75%);

however, this resource refers to the technology embedded by agents in the Ouro Preto's case.

This lack of collaboration between agents is observed in the criterion **partnership between users**. Most traffic wardens were favourable to partnership, while at least 25% of carriers disagreed and a minimum of 25% of retailers were indifferent or also disagreed. This is a point of concern, since the use of UDC should include the effective participation of its different users (Trentini et al., 2015; Van Der Donk, 2015). This disallowance happens due to the incompatibility between the needs of the retailers and carriers (Nordtomme et al., 2015). As an example, the need for **confidentiality of information** was considered essential for retailers (at least 75%) but a minimum of 25% of drivers disagreed with this criterion. Since information sharing is the basis of a good collaboration, if one or more partners do not want to share information for reasons of competition, the efficiency of the sharing approach may considerably decrease (Gonzalez-Feliu, 2012).

Regarding the **economic aspect**, the possibility of UDC generating **local prosperity** was positively evaluated by at least 75% of all agents, corroborating with Russo and Comi (2010). At least 75% of drivers strongly agreed on the importance of improving the **customer service level**. Transport operators can make adjustments to their operations by making the deliveries to the UDC with one large vehicle instead of multiple smaller vehicles that can access the delivery area (Kin et al., 2016). In addition, most retailers and traffic wardens agreed with the importance of improving service level. Inventory levels of stores are determined primarily by frequency of delivery. Thus, with the use of UDC, this level is balanced by temporary storage. Therefore, this activity stimulates agents to use the UDC. However, Johansson and Björklund (2017) highlight that this improvement can be explained by large-scale gain and the possibility of retailers to the UDCs.

Due to the high initial cost of deployment of an UDC (Kin et al., 2016), at least 75% of retailers and carriers agreed on the importance of analysing **investments and costs**. In addition, 75% of carriers favoured the **sharing cost and profits** among the partners involved in UFT. However, at least 25% of retailers disagreed completely with this sharing, indicating that this cost should be allocated to local government (Quak, 2008). However, the manager of the Commercial and Entrepreneurial Association of Ouro Preto (ACEOP – *Associação Comercial e Empresarial de Ouro Preto*) highlighted the importance of sharing decisions and costs, affirming that the penalization of retailers with more costs with this operation would be unfair. Janjevic et al. (2016) emphasized that the mechanism of allocation of costs and profits among the agents of the private supply chain is essential for the implementation of an UDC.One possibility would be to create a PPP, as observed in London, Bristol/Bath (England) and Nijmegen (Netherlands) (Van Duin et al., 2016).

Considering the **obligation of using UDCs**, at least 50% of carriers and retailers agreed partially and the highest agreement for this criterion came from traffic wardens (at least 75%). The reason given by some drivers and retailers is that if a solution is not compulsory, no one will put it into effect. A carrier stated that "if the solution will improve the UFT, it must be obliged to use it". It is known that UDCs implemented in Parma and Vicenza (Italy) practically obliged carriers to use the facility. In La Rochelle (France), benefits were granted to users with the implementation of some traffic restrictions but permission for UDC vehicles to use bus lanes (Ville et al., 2010).

Regarding the **social aspect**, at least 75% of residents and traffic wardens agreed that movement of freight vehicles creates **insecurity caused by the number of accidents for pedestrians**. However, Quak (2008) explains that there are generally fewer people at central areas in the early morning (when windows of time for delivery are usually placed), and thus safety increases. As a result, 50% of carriers and 25% of retailers disagreed with the insecurity created by UFT. Some of the carriers stated that vehicles do not create insecurity for pedestrians, but rather the pedestrians (especially tourists), who walk off the sidewalks and on the streets, cause insecurity to themselves.

Considering the **cultural aspect**, regarding the **shaking of the architectural heritage** and the **depletion of buildings by collision** asset, all agents (except carries) agree that they are intensified by freight vehicles, corroborating the conclusions of Azevedo and Patrício (2001), Zarinato (2008) and Resende et al. (2011). Considering the **depletion of buildings by collision**, retailers are also less concerned.

Concerning the **environmental aspect**, except for carriers, at least 75% of the other agents agreed that the **air pollution level** should be considered in the creation of solutions for UFT. Similarly, at least 75% of residents and traffic wardens agreed that UFT in the centre generated **visual intrusion** and **noise problems**. Air pollution is a serious health problem caused by UFT (Quak, 2008), which accounts for 16 to 50% of atmospheric pollution in the urban area (Dablanc, 2007). Nonetheless, carriers consider this criterion less important, justified by the existence of a specified delivery window that would be enough to reduce pollutant emissions in the historical city centre. Thus, residents prefer an attractive urban area, free of visual intrusion, and the public authorities tend to agree and fulfil the wishes of citizens (Ballantyne et al., 2013; Ogden, 1992).

Finally, the **use of alternative fuel vehicles** in the UFT was well regarded by residents and traffic wardens (at least 75%), compared to 50% of retailers and carriers. Retailers stated that this is "a reality far from our country". However, 25% of carriers were totally against the use of this type of vehicles, as this action would oblige them to switch their vehicles to greener options. This aversion is justified by the fact that electric and hybrid vehicles have high acquisition costs, limited load capacity and low vehicle availability (Browne et al., 2011; Quak et al., 2016).

5.2 Analysis of the pivotal criteria from the point of view of residents and retailers

We used the FA to find the criteria that influenced the implementation of a UDC to supply retailers located in the historical centre of Ouro Preto. This technique was used for retailers and residents as the major agents in this case. The results are shown in Table A3 (see appendix A).

Six factors were identified for retailers. The first one concerns the conservation of historical heritage as all variables directly affect the state of conservation of the buildings of a historical city. In historical cities, UFT results in the depletion of buildings by collision, caused by mechanical shocks against the architectural patrimony while vibrations cause shaking of architectural heritage. Both contribute to the appearance/increase of cracks in the walls of the historical buildings (Azevedo and Patricio, 2001). The noise nuisance level reflects a consequence of the mechanical vibrations, not only to historical buildings, but also to people (Quak, 2008).

The second factor is interpreted as the level of cooperation between users, since it integrates the partnership among users, such as the cooperation with other transport companies (Oliveira and Correia, 2014). Such a partnership may also include using

technology to facilitate communication between the agents involved in the UFT, allowing fleet visibility and quick contact with the customer in case of delays in delivery. The number of parking spaces is also related to the degree of cooperation of the agents. The more the agents use the facility, the greater the possibility of consolidating the load of two or more vehicles from different suppliers in only one, thus leaving more spaces for parking that would be occupied by surplus vehicles.

The third factor is related to local prosperity. The CDU may represent a more efficient distribution system, which would help create jobs, besides promoting competitiveness in the retail sector, and more opportunities to obtain professional qualifications by training employees (Russo and Comi, 2010; Henriot, 2008). Using alternative fuel vehicles impacts the service level when the customer requires their suppliers to have actions towards sustainability or have related certifications. Finally, the visual intrusion level is the only variable of this factor that had a negative aspect of freight transport, especially for local agents.

The fourth factor includes the negative perception of UFT (insecurity and congestion) (Quak, 2008, Van Rooijen and Quak, 2010, Kin et al., 2016) while the fifth factor is interpreted as cost and level of air pollution. Finally, the sixth factor is a structure factor because it integrates confidential information and vehicle size, related to the CDU vehicle fleet.

Residents performed three factors. The results are shown in Table A4 (see appendix A). The first factor concerns the conservation of historical heritage. The second factor is interpreted as a measure of air quality. Finally, the third factor consists of the effects of freight transport on the road network and local prosperity. In this factor, there are three variables related to the search for a reduction in negative effects of freight transport (increase in parking spaces, insecurity and professional qualifications). As there are more parking spaces, supplying the retailers is easier as it reduces drivers' bad behaviour and provides security during deliveries in the city centres.

Both agents are concerned about preserving historical heritage, as noted by the first factor in the FA. Considering that Ouro Preto has narrow streets and huge mountainous landscapes, the last-mile deliveries by using large vehicles or even motorised vehicles may have an impact on the architectural heritage. This result corroborates the previous descriptive analysis. Most studies in European historical cities do not take this into account, perhaps because this issue is not relevant or the policies are well established by using small and environmentally friendly vehicles more suitable for last-mile delivery as in Copenhagen (Denmark) (van Heeswijk, Larsen and Larsen, 2019), Lucca (Italy) (Nocera and Cavallaro, 2017) and in London, Bristol/Bath (England) and Nijmegen (The Netherlands) (Van Duin et al., 2016). Oslo is an exception, as the appropriate policies for small vehicle access restrictions do not exist in Norwegian legislation (Nordtomme et al., 2015). For Brazilian historical cities, this research may indicate substantial results. Other Brazilian historical cities, such as Salvador, Tiradentes, Olinda and Sabará also experience the same issues.

Both agents indicated that vehicle size is also an important criterion to be used when implementing a UDC. Smaller cargo vehicles facilitate circulation in the steep and narrow roads, contributing to preserving the architectural heritage. The UDC reduces the number of freight vehicles in the historical city centre (Van Duin et al., 2010; 2016). The literature also shows that the UDC improves the quality of life by using alternative fuel in the cargo vehicles (Morganti; González-Feliu, 2015;Nocera; Cavallaro, 2017).

Thus, the challenge is to find economic feasibility due to the retailer and carrier demand, and in the compliance of local policies.

The discussion of the UDC implementation with all agents can contribute to bring this feasibility. The UDC can be feasible in historical cities with access restriction (Van Duin et al., 2016), or to place mini-hubs in parking areas and open zones in city centres, smaller areas than UDC during specific time window under supervision of the traffic wardens (Munuzuri et al, 2012).

6. Conclusions

This paper analysed the criteria that influenced the implementation of a UDC in a historical city, considering the viewpoint of four agents: residents, traffic wardens, retailers and carriers.

We conclude that the difficulty of the UFT in the historical centre of Ouro Preto shall be taken as a point of improvement by the city authorities because despite the absence of a supply crisis, the short window of time available for delivery of goods has negative consequences for retailers, carriers and still hinders traffic wardens' work. In addition, public authorities should listen to the opinion of retailers in the clothing and food sectors, which are predominant in the city centre of Ouro Preto, accounting for the greater volume and frequency of cargo received. The opinion of these companies would also help improve the urban infrastructure to receive cargo, update the rules for access of cargo vehicles to the centre and the elimination of externalities. In line with this, research carried out by Danielis, Rotaris and Marcucci (2010) may help describe the characteristics of the distribution channels of retailer sectors, mainly pharmaceutical products and clothing & footwear.

In the case of Ouro Preto, a place of transhipment of goods could be initially installed, providing few aggregated activities, such as transportation and home delivery (the most favourable activity according to retailers), as suggested by Munuzuri et al. (2012). The installation of a UDC is still understood as a complex decision, as there is an imbalance concerning the importance given to the criteria by most of the UFT agents (Nordtomme et al., 2015). It is assumed that the implementation of a pilot project (Browne et al., 2005), with a fixed time of operation, would be necessary to indicate to the agents the strengths and weaknesses of the use, initially, of a transhipment rather than a structured UDC (van Duin et al., 2016).

The results of the research do not indicate a need for investment in aggregate activities for the UFT in the historical centre of Ouro Preto. The most important aspect is to have a place for less-than-truckload, which can be carried out in an area allocated by the local authority, ensuring safe access to all carriers that deliver in the city. It is suggested that the place of transhipment should operate with smaller vehicles, which can be used by the carriers that deliver in the city, in exchange for greater ease of delivery and the possibility of sharing goods with different customers. The facility would be created to supply the city centre especially and could extend in the long run (after other studies) to the entire city and even to the closer city of Mariana, which is also a historical city and has laws restricting traffic (as in the example of the UDC serving the historical cities of Bristol and Bath).

As pointed out by van Duin et al. (2016), the PPP initiative is a great option for implementing a UDC. There is a federal law in Brazil that establishes a series of general rules for bidding and contracting PPPs. These rules must be complied with, including the minimum value of the contract and minimum period of operation. In addition,

money collected from penalties cannot be used as an auxiliary subsidy for maintaining this place, due to national legislation. Therefore, a point that deserves attention is determining the subsidy of the installation.

6.1 Lessons learned based on viewpoints of the agents

Table 8 sheds light on some policies that could be faced by the agents, followed by the main criteria that should be considered according to the opinion of agents before implementing a UDC. The four aspects considered in our analysis are also linked to each criterion. This means that if there was an initiative to implement a UDC, which agents should be heard and what policies and criteria should be considered? For instance, the retailers appear to be the pivotal agent due to taking part in all policies.

agents			
Policies	Agents' Viewpoints	Aspects	
Conservation of historical heritage	Re, TW and Rt	Shaking of architectural heritage Depletion of building by collision	Cultural Cultural
Vehicle restrictions (weight, engine type)	TW, Rt and C	Vehicle size Use of technology Compliance with legislation	Operational Operational Operational
Environment law	Re, TW and Rt	Air pollution level Visual intrusion level Noise nuisance level, Use of alternative fuel vehicle	Environmental Environmental Environmental Environmental
Access restrictions (narrow street, parking spaces, time window, L/U)	Re, Rt and C	Parking spaces Load factor maximization	Operational Operational
Collaborative initiatives	Re, TW, Rt and C	Local prosperity Insecurity Investments/costs Customer service level Sharing costs/earnings	Economic Social Economic Economic Economic

Table 8. Major policies and criteria that affect the implementation of an UDC by the agents

Note: Carriers = C; Residents = Re; Retailers = Rt; Traffic wardens = TW.

Although the criteria regarding cultural and environmental aspects were the most relevant in implementing a UDC, Table 8 shows that carriers do not agree with this opinion. Carriers focus on logistics operations and they are the only agent that does not experience the city as a whole; they may not care about the conservation of historical heritage.

The lessons learned may also arise considering the agents' viewpoints. Vehicle size and local prosperity were the most relevant common criteria for supply retailers in the historical city centre of Ouro Preto. Moreover, except for the shaking of the architectural heritage, which was reported as a factor of great importance by the residents, traffic wardens and retailers, the criterion with the highest level of agreement was the compliance with legislation, vehicle size and air pollution level. The criterion of compliance with the current law, pointed out as important by traffic wardens, is consistent with the professional duties of this agent. However, residents show that they do not know the difficulties faced by retailers and freight carriers. Deliveries are made primarily early in the morning (most of them by trucks), thus many residents may not see freight vehicles loading/unloading operations in the central areas (Quak, 2008). In addition, traffic wardens give greater importance to the quality of life and size of vehicles.

However, the agents show a different point of view. Retailers in the food sector (the highest rate sector in the historical city centre) tend to receive deliveries more frequently, as their products are for immediate consumption, as supported by Danielis, Rotaris and Marcucci (2010). Thus, greater contact with the carriers is required to avoid the lack of inventory. The vehicle size is an important criterion because vehicles carrying food and beverages are the ones with the highest capacity, and therefore routinely face problems such as lack of parking spaces. In line with this, the investment of light vehicles for deliveries could be a solution; because they still represent only 1.05% of the fleet circulating.

Considering the opinion of retailers, product disposition and customer transportation were crucial to the disagreement of most possibilities for providing value-added services in the UDC as pointed out by Johansson and Björklund (2017). Among retailers of the food and clothing sectors, tracking products was the most accepted value-added activity, although other value-added activities were not well evaluated. This situation confirms the fact that windows of time do not coincide with store opening hours, causing employees to work overtime to receive the goods (Quak, 2008). Thus, due to the lack of interest of most retailers considering value-added activities, the revenue generated from these activities could hardly be used as an alternative subsidy of UDC. Danielis, Rotaris and Marcucci (2010) state that this channel can be supplied by own-account carriers instead of third-party operators. On the other hand, using the UDC as an intermediary to split deliveries into two legs was well evaluated by all agents.

In the case of the carriers, the same criteria as the retailers had greater agreement, as well as the customer service level and increase in parking spaces. Then, carriers also highlight the need to use smaller cargo vehicles and preferably equipped with technologies, such as cell phone and palmtop in the UFT in the historical centre. Carriers have also expressed concern about improving the service level, as they stated that the time allowed by the law to carry goods in the centre is not very long. Additionally, there is a difficulty in finding suitable parking places, which forces drivers to park far away from the retailers and carry the goods or use a trolley. Alternatively, they park close to the establishment and deliver very fast, almost without having any contact with the customer (retailer). Once again, the importance of these criteria is explained by the sample profile, where most of the cargo transported belongs to the food and beverage sector, i.e., they are products of fast consumption and, consequently, high frequency of delivery, in which this lack directly affects the level of service.

Residents and traffic wardens had very similar points of view and agreed with the negative effects of UFT (air pollution level, visual intrusion level, insecurity, and congestion), while most retailers and carriers disagreed with these impacts. Thus, the local government and community wanted to have minimal noise, low emissions, minimal congestion, and few traffic accidents to have a healthy urban quality of life (Afzal and Kin, 2014). Carriers and retailers tended to soften their viewpoints considering the negative effects of UFT. Even being part of the group of professionals

who work directly in transportation (Quak, 2008; Yanqiang, 2014; Ballantyne et al., 2013; MDS Transmodal Limited, 2012), carriers and retailers had different viewpoints among themselves and in relation to residents and traffic wardens. This result confirms the convergent view of public authorities and those affected (Quak, 2008; Ballantyne et al., 2013; Afzal and Kim, 2014), respectively, traffic wardens and residents.

6.2 Limitations and future studies

As we used a wide range of criteria applied to four different agents, some of them with a restrictive number of sampling, univariate and multivariate analyses were carried out with a different number of criteria. Then, we provide criteria analysis, instead of a homogeneous group of criteria by each agent. It is a field survey, which seeks the individual perception of a given statement; the use of the Likert scale from 1 to 5 may not accurately reveal the real difference between the opinions of the interviewees.

To compensate this first limitation, some statistical analyses were performed and crosschecking revealed robustness of the data. We interviewed some local authorities to provide a triangulation of data and added some nuances to the results. The second limitation refers to the lack of knowledge of the carriers, which does not affirm that the number of interviewees represents sample variability.

In order to take full advantage of the opportunity of having interviewed the main stakeholders involved in this study, for future research, new methodologies to analyse cargo transportation based on a multicriteria. In addition, studies that show the impact of UFT on historical heritage, including the assessment of cultural and social aspects, and buildings to be saved and maintained in city centers, may be an opportunity to show implications for public managers. It is also an opportunity to compare the results with other studies regarding urban freight terminal located inside large cities.

We hope that our results can be used as a basis for future discussions when developing urban logistics planning in Ouro Preto and other historical cities.

Appendix A

Table A1: Descriptive analysis

1) Research question: The following items are related to the implementation of an UDC in Ouro Preto. Please indicate your agreement level for each:1 – Strongly agree; 2 – Somewhat agree; 3 – Neither agree nor disagree; 4 – Somewhat disagree; 5 – Strongly disagree.

Criteria	A 4		Res	idents		r	Fraffic	wardens		Retailers				Ca	rriers		Maria	
Criteria	Aspect	Mode	1Q	Median	3Q	Mode	1Q	Median	3Q	Mode	1Q	Median	3Q	Mode	1Q	Median	3Q	Main authors
Parking spaces	0	1	1.00	1.00	2.00	1	1.00	2.00	3.50	1	1.00	1.00	2.00	1	1.00	1.00	1.00	Zunder and Marinov (2011), Awasthi and Chauhan (2012), Brasileiro et al. (2015)
Congestion	0	1	1.00	1.00	2.00	1	1.00	1.00	2.00	1	1.00	2.00	5.00	5	2.00	4.00	5.00	(2016), Gonzalez-Feliu (2008), Kin et al. (2016), Gonzalez-Feliu and Morana (2010)
Professional qualification	0	1	1.00	1.00	2.00	1	1.00	2.00	3.00	1	1.00	1.00	3.00	1	1.00	2.00	5.00	European Comission (2000), Henriot et al. (2008)
Vehicle size	0	1	1.00	1.00	1.00	1	1.00	1.00	1.00	1	1.00	1.00	1.00	1	1.00	1.00	1.00	Browne et al. (2005), Browne et al. (2007)
Load factor maximization	0	-	-	-	-	-	-	-	-	1	1.00	1.50	3.00	1	1.00	2.00	4.00	Allen et al. (2012)
Use of technology	0	-	-	-	-	1	1.00	1.00	2.00	1	1.00	1.00	1.00	1	1.00	1.00	1.00	Dablanc et al. (2013)
Confidentiality of information	0	-	-	-	-	-	-	-	-	1	1.00	1.00	2.00	1	1.00	2.00	4.25	Gonzalez-Feliu (2012), Takebayashi (2015)
Conflicts of responsibility	0	-	-	-	-	2	1.50	2.00	4.50	1	1.00	1.00	2.00	1	1.00	2.00	3.25	Gonzalez-Feliu, 2012, Van der Donk (2015)
Partnership between users	0	-	-	-	-	1	1.00	1.00	2.00	1	1.00	1.00	3.00	1	1.00	2.50	5.00	Van der Donk (2015), Oliveira and Correia (2014)
Compliance with legislation	O;E	1	1.00	1.00	1.00	1	1.00	1.00	1.00	1	1.00	1.00	4.00	5	2.00	4.00	5.00	Agrebi et al. (2015), Rao et al. (2015)
Local prosperity	Ec	1	1.00	2.00	2.00	1	1.00	1.00	2.00	1	1.00	1.00	2.00	1	1.00	1.00	2.00	Russo and Comi (2010)
Customer service level	Ec	-	-	-	-	1	1.00	1.00	2.00	1	1.00	1.00	2.00	1	1.00	1.00	1.00	Henriot et al. (2008), Rao et al. (2015)
Investments and costs	Ec	-	-	-	-	1	1.00	2.00	2.50	1	1.00	1.00	2.00	1	1.00	1.00	2.00	Ville et al. (2010); Panero et al. (2011)
Obligation of use	Ec	-	-	-	-	1	1.00	1.00	2.00	1	1.00	2.00	5.00	1	1.00	2.00	5.00	Ville et al. (2010), Panero et al. (2011)
Sharing costs and profits	Ec	-	-	-	-	-	-	-	-	1	1.00	2.00	5.00	1	1.00	1.00	1.25	Awasthi and Chauhan (2012); Van der Donk (2015), Janjevic et al. (2016)
Insecurity	S	1	1.00	2.00	2.00	1	1.00	1.00	2.00	1	1.00	2.00	5.00	5	1.00	4.00	5.00	Anderson et al. (2005), Gonzalez- Feliu and Morana (2010), Awasthi and Chauhan (2012), Agrebi et al.

(2015), Kin et al. (2016)

Shaking of architectural heritage	С	1	1.00	1.00	1.00	1	1.00	1.00	2.00	1	1.00	2.00	2.00	2	1.75	2.00	5.00	Browne et al. (2005); Azevedo and Patrício (2001), Resende et al. (2011)
Depletion of buildings by collision	С	1	1.00	1.00	2.00	1	1.00	1.00	2.00	1	1.00	1.00	3.25	1	1.00	2.00	5.00	-
Air pollution level	Е	1	1.00	1.00	2.00	1	1.00	1.00	2.00	1	1.00	1.00	2.00	1	1.00	2.00	4.00	Quak (2008), Reys et al., (2008), Rao et al. (2015)
Visual intrusion level	Е	1	1.00	1.00	2.00	1	1.00	1.00	1.50	1	1.00	2.00	4.00	5	1.00	2.00	5.00	Reys et al. (2014), Quak (2008), Rao et al. (2015)
Noise nuisance level	Е	1	1.00	1.00	2.00	1	1.00	1.00	2.00	1	1.00	3.00	4.00	5	2.00	4.00	5.00	Anderson et al. (2005), Gonzalez- Feliu (2008), Quak (2008), Gonzalez-Feliu and Morana (2010), Rao et al. (2015)
Use of alternative fuel vehicle	Е	1	1.00	1.00	2.00	1	1.00	1.00	2.00	1	1.00	2.00	3.00	1	1.00	2.00	4.25	Allen et al. (2007), Ville et al. (2010), Browne et al. (2011), Allen et al. (2012), Giuliano et al. (2013)

Note: 1Q and 3Q are the first and third quartile, respectively Note 2: E (Environmental); Ec (Economic); S (Social); O (Operational); C (Cultural)

Criteria	Residents	Traffic wardens	Retailers	Carriers
Parking spaces	++	+	++	++
Congestion	++	++	+-	-
Professional qualification	++	+	+	+-
Vehicle size	++	++	++	++
Load factor maximization			+	+-
Use of technology		++	++	++
Confidentiality of information			++	+-
Conflicts of responsibility		+-	++	+
Partnership between users		++	+	+-
Compliance with legislation	++	++	+-	-
Local prosperity	++	++	++	++
Customer service level		++	++	++
Investments and costs		++	++	++
Obligation of use		++	+-	+-
Sharing costs and earnings			+-	++
Insecurity	++	++	+-	-
Shaking of architectural heritage	++	++	++	+-
Depletion of building by collision	++	++	+	+-
Air pollution level	++	++	++	+-
Visual intrusion level	++	++	+-	+-
Noise nuisance level	++	++		-
Use of alternative fuel vehicle	++	++	+	+-

Table A2: Comparison of the level of agreement of the agents on the criteria for implantation of an UDC.

Legend

++ At least 75% agree

+- At least 50% agree, but at least 25% disagree +-- At least 50% agree, but at least 25% is indifferent or disagree

- At least 50% disagree

-- At least 50% is indifferent or disagree

Table A3: Extracted factors for retailers

Extracted factors for retailers							
Criteria	F1Rt	F2Rt	F3Rt	F4Rt	F5Rt	F6Rt	Communalities
Depletion of building by collision	0.855	-0.052	-0.035	0.088	0.151	0.118	0.779
Shaking of architectural heritage	0.846	0.136	0.178	0.028	0.047	0.159	0.794
Noise nuisance level	0.656	0.197	0.125	0.330	-0.104	-0.156	0.629
Partnership between users	-0.033	0.768	0.095	0.125	0.145	-0.106	0.648
Parking spaces	0.008	0.742	0.161	-0.075	-0.104	0.118	0.606
Use of technology	0.136	0.594	0.027	-0.001	0.071	0.271	0.450
Sharing costs and earnings	0.145	0.517	0.012	0.188	0.383	-0.017	0.471
Use of alternative fuel vehicle	0.170	0.119	0.685	-0.010	0.261	-0.005	0.580
Local prosperity	-0.173	0.226	0.628	0.343	-0.141	0.016	0.613
Visual intrusion level	0.478	-0.050	0.595	0.183	0.166	0.047	0.648
Professional qualification	0.187	0.418	0.457	0.331	0.153	0.250	0.615
Insecurity	0.066	-0.005	0.325	0.769	0.046	0.003	0.704
Congestion	0.338	0.117	-0.069	0.729	0.158	0.096	0.699
Air pollution level	0.095	0.095	0.010	0.172	0.811	0.096	0.715
Investments and costs	-0.009	0.089	0.397	-0.080	0.630	-0.083	0.576
Confidentiality of information	-0.008	0.093	-0.116	0.161	0.032	0.858	0.786
Vehicle size	0.256	0.157	0.401	-0.161	-0.023	0.663	0.717
Explained cumulative variance (%)	14.305	26.817	38.308	47.998	56.477	64.878	
Cronbach's alpha (0-1)	0.770	0.623	0.682	0.620	0.452	0.465	KMO=0.728

Extracted factors for residents					
Criteria	F1Re	F2Re	F3Re	Communalities	
Depletion of building by collision	0.819	0.035	0.231	0.725	
Visual intrusion level	0.701	0.214	0.054	0.540	
Shaking of architectural heritage	0.701	0.125	0.264	0.576	
Vehicle size	0.684	0.122	-0.057	0.486	
Noise nuisance level	0.485	0.328	0.030	0.343	
Use of alternative fuel vehicle	0.205	0.773	0.088	0.648	
Air pollution level	0.172	0.761	0.018	0.609	
Parking spaces	0.020	-0.228	0.738	0.596	
Local prosperity	-0.306	0.386	0.620	0.628	
Congestion	0.327	0.100	0.550	0.420	
Insecurity	0.365	0.281	0.480	0.442	
Professional qualification	0.209	0.362	0.399	0.534	
Explained variance	23.382	38.238	52.902		
Cronbach's alpha (0-1)	0.760	0.563	0.574	KMO=0.796	

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