Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 79 (2024) 345–352

Transportation Research Procedia

www.elsevier.com/locate/procedia

City Logistics 2023

# Analysis of accessibility components related to the spatial distribution of food warehouses: empirical evidence from Fortaleza, Brazil

Carlos Pinheiro[a]*, Antonio Comi[b], Bruno Bertoncini[c]

[a]Federal Institute of Education, Science and Technology of Ceara (IFCE), CE 422,S/N, Caucaia- 62670-000, Brazil
[b]University of Rome Tor Vergata, Viale del Politecnico, 1, Rome- 00133, Italy
[c]Federal University of Ceara, Campus do Pici - Bloco 703, Fortaleza-60440-554,Brazil

**Abstract**

This research delves into the spatial distribution of accessibility components related to the placement of food warehouses in Fortaleza, Brazil. This is accomplished by merging spatial analysis and logistic regression with the Moran index. The outcomes expose how warehouses of differing sizes are dispersed across the region, each finding its place within zones featuring distinct accessibility attributes. Furthermore, the study underscores the significance of factoring in the individual accessibility component for the formulation of effective transportation and land-use policies.



*Keywords:* Urban logistics; city logistics; warehouse location; accessibility; spatial pattern.

## 1. Introduction

The density of urban space and the distribution of facilities substantially influences the extent and efficiency of freight movements (Nuzzolo et al., 2014; Sanchez-Diaz et al., 2016; Dhulipala and Patil, 2021). Moreover, an extensive body of research underscores the significance of facility positioning in the urban freight movement context (Hounwanou et al, 2018).

In this context, the performance of the transportation system takes on a pivotal role in shaping the accessibility of diverse zones within an urban expanse. This is due to its impact on the overall cost (or disutility) of reaching different zones, whether through active accessibility, reaching other zones or passive accessibility, being reached from other zones. Accessibility refers to the degree to which land-use and transportation systems facilitate the receipt of people, goods, and information by companies, facilities, and other activity places at different times of the day (Van Wee, Annema, and Banister, 2023). In the context of Urban Freight Transport (UFT) and its alignment with this concept of accessibility, four key components can be identified. Firstly, the *land-use* component considers the spatial distribution

* Corresponding author. *E-mail address:* carlos.pinheiro@ifce.edu.br


10.1016/j.trpro.2024.03.046

of supply and demand for various opportunities, particularly in relation to freight movement facilitating urban activities. Secondly, the *transportation* component quantifies the disutility of covering distances between origins and destinations using specific transport modes, encompassing both passenger and freight transport. Thirdly, the *temporal* component addresses time constraints, such as delivery time requirements and restrictions imposed by authorities, which significantly impact urban freight efficiency. Lastly, the *individual* component reflects the unique needs, abilities, and characteristics of stakeholders involved in UFT, including their type, size, economic sector, and fleet characteristics, which are the main features to be considered for effective urban freight management and planning (Geurs and Van Wee, 2004). While numerous studies have examined accessibility and highlighted these four components, as seen in Table 1, few of them have simultaneously focused on all four components in relation to the location of warehouses in urban contexts.

Table 1. Accessibility components and warehouse location in urban logistics context

| Reference | Method used | Accessibility Components |
|---|---|---|
| Hong (2007) | Nested logit models | Transportation |
| Portugal *et al.* (2011) | Analytic hierarchy process (AHP) | Transportation, land-use and individual |
| Durmus and Turk (2012) | Logistic regression model | Transportation |
| Gonzalez-Feliu *et al.* (2014) | Delivery-to-commodity model; VPR algorithm and accessibility calculation | Transportation |
| Iwakata *et al. (*2015) | Logit model and data aggregation | Transportation |
| Sakai *et al.* (2015) | Discrete choice model | Transportation, land-use and individual |
| Verhetsel *et al.* (2015) | Revealed preference study and stated preference study | Transportation |
| Heitz *et al.* (2017) | Regional statistics for a descriptive analysis | Transportation |
| Aljohani and Thompson (2020) | TOPSIS method | Transportation |
| De Oliveira *et al.* (2020) | Method of successive intervals (MSI) for Descriptive Analysis and Kernel Density for locational analysis | Transportation, land-use and individual |
| Sakai *et al*. (2020) | Multinomial logit (MNL) model | Transportation and land-use |
| De Oliveira *et al.* (2022) | Warehouse Freight Trip Generation Model; Method of successive intervals (MSI) for Descriptive Analysis and Kernel Density for locational analysis | Transportation, land-use and individual |

From Table 1, located in the rightmost column, it is evident that the temporal aspect of accessibility is conspicuously absent, which holds relevance within freight transport and, in particular, in the food supply chain, where delayed deliveries can lead to damaged goods (Taniguchi and Ando, 2005; Russo *et al.*, 2009). Furthermore, the imposition of time windows by local authorities can significantly impede supply chain efficiency (Bachofner et al., 2022). Moreover, despite the need to establish a connection between the accessibility components of transportation and land-use, an examination of Table 1 reveals that most authors predominantly focus solely on the transportation component.

Regarding the individual component, neglecting it can present challenges for policymakers. The absence of consideration is problematic because there is heterogeneity in the location preferences for logistics facilities among various facility sizes. This suggests a necessity for land-use policies that address the unique requirements of different target groups (Sakai et al., 2015; De Oliveira et al., 2022).

Furthermore, it is vital to acknowledge that a decision-maker's selection of a particular alternative can be influenced by the decisions made by other decision-makers in proximity (Gingerich et al., 2014). In the realm of urban freight transport, spatial models demonstrate superior performance in elucidating the phenomenon of urban goods displacement (Dhulipala and Patil, 2023) as well as in facility location (Aljohani and Tompson, 2020). While several studies underscore the significance of spatial statistics in determining the location of urban logistical facilities, only a subset of these studies incorporate aggregation factors into their analytical methodologies.

In this context, this paper focuses on the location of food warehouses, as food accounts for most freight flows moved in urban areas, and the food supply chain is currently expanding and evolving, negatively impacting the urban environment (Govindand, 2018). The food supply chain is crucial for most of the sustainable development goals, such as zero hunger, good health and well-being, clean water and sanitation, responsible consumption and production, and climate action (UN, 2015; Thomé, 2021). The proposed investigation methodology is applied in Fortaleza (Brazil), where approximately 20% of all goods invoices are issued by food wholesalers, having significant impacts on the transport system, and generating traffic externalities (Fortaleza, 2019). The primary goal of this study is to analyze the interplay among the four components of accessibility. This is done by considering the utility (accessibility) of the locations and the spatial distribution of food warehouses, with twofold objectives: (1) it enhances our comprehension of the spatial arrangement patterns adopted by food warehouses, and (2) it propels methodological progress by enabling an encompassing examination of accessibility elements, all the while considering the spatial autocorrelation of the phenomenon.

## 2. Materials and Methods

### 2.1. Study area

Fortaleza, the capital of the State of Ceara, is in north-eastern Brazil. For this study, the city was divided into 3,026 zones, each covering an area of 0.11 km². Hexagonal grids offer a simpler and more symmetrical nearest neighborhood, addressing the limitations of rectangular grids. They better align grid distances with straight-line distances, making them more suitable for modelling dispersion, particularly in the context of urban logistics and, for scenarios where nearest neighborhood, movement paths, and connectivity are crucial, such as in urban logistics, rectangular grids may not be as appropriate (Birch et al., 2007).

### 2.2. Data source

This study focuses on the spatial distribution of food warehouses. The data related to the geographic location of the entire population of food warehouses in Fortaleza in 2012 and 2022, with their size, were obtained from the Brazilian Federal Revenue (BFR) database. Small warehouses were defined as having nine or fewer employees (BFR, 2022). After geolocating each establishment, the sum of small and large warehouses was calculated for each zone using QGIS®. This software was also used to calculate all the geographical variables.

The accessibility of each zone was calculated by combining different attributes that characterize the zone in terms of land use, transportation, temporal, and individual variables. To account for the land-use component, the population (POP) was calculated using the latest available census data, and the number of retailers (RET) was calculated using the geographic location of each establishment from the Brazilian Federal Revenue (BFR) database for the two years of investigation (BFR, 2022).

Besides, given a warehouse, the number of close retailers was identified through the identification of a buffer. The number of retailers within the buffer (RB) were calculated using a circular influence area with a radius of 1700m, the median of the freight trips in Fortaleza (Fortaleza, 2019), as follows:

$$\mathrm{RB}_{\mathrm{i}}^{\mathrm{s,t}} = \frac{\sum_{\mathrm{a=1}}^{\mathrm{n}} \mathrm{NWR}_{\mathrm{a,i}}^{\mathrm{s,t}}}{\mathrm{n}} \tag{1}$$

where $RB_i^{s,t}$ is the average number of retailers in the buffer of the food warehouses of type *s* (small or large), in the year *t* (2012 or 2022) in a given zone *i*; $NWR_{a,i}^{st}$ is the number of retailers in buffer of each warehouse *a* of type *s* in the year *t*, in a given zone *i*, and *n* is the number of warehouses type *s*, in the year *t,* in the given zone *i.*

Regarding the transport component, road length (RL) was calculated as the total length of roads within each zone, and the distance to the nearest expressway (EXP) from the centroid of each zone was also taken into consideration. The temporal component is associated with the presence of roads with time-window access restrictions. The density of roads with time windows (WT) was calculated as the length of roads with temporal restrictions on the circulation of freight vehicles with respect to the zonal surface (PETRAN, 2019). It is worth noting that the City Hall of Fortaleza implemented time windows in the city after 2012, which explains why this year was chosen as a reference compared to 2022. Moreover, it is assumed that there have been no significant changes in population and the road network in the last 10 years. Additionally, the results of the correlation analysis showed that there was no high collinearity (r > 0.8) among the considered independent variables.

### 2.3. Spatial analysis

*2.3.1. Descriptive spatial analysis and Local Indicators of Spatial Association (LISA)*

A spatial descriptive analysis for the number of small and large warehouses for the years 2012 and 2022 in each zone was developed. Besides, spatial data of the variables used in the study were analyzed in order to spatially relate the accessibility components and the location of the warehouses.

The local spatial association of the number of warehouses was assessed using the methodology of exploratory spatial analysis (Anselin, 1995). The *l*ocal *i*ndicators of *s*patial *a*ssociation (LISA) allows the identification of local spatial clusters and outlier relationships as follows (Anselin, 1995):

$$I_i = z_i \sum_j (w_{ij} \tilde{z}_j) \quad (2)$$

where $I_i$ is the local indicator of spatial association *(LISA) of zone* i; $z_i$ is the deviation of the mean of the investigated attribute of zone i; $\tilde{z}_j$ are the deviations from the mean of the investigated attribute of the close zone j belonging to the set $J_i$, and $w_{ij}$ is the element *ij* of the queen contiguity-based matrix, which is adequate considering the aggregated characteristic of the data (Guerin et al., 2021).

The LISA allows *us* to characterize the zones in four classes: high-high clusters (HH) and low-low (LL), the locations have similarly values compared to their neighbors, and high-low (HL) and low-high (LH), zones with values that are clearly different from the values of their surrounding locations (Liu et al, 2021).

*2.3.2. Differential Local Moran's $I^D$.*

The second step was to determine whether there was a spatial difference in the distribution of food warehouses between the years 2012 and 2022. For that, the differential local Moran was used. The differential Moran's $I^D$ is an alternative to the bivariate Moran index between a variable at one point in time (*t*) and its neighbour at the preceding time (*t-1*), by calculating the spatial autocorrelation of the variables (*i*) at two times *t* and *t-1* (Ghodousi et al*.,* 2021).

The differential local Moran's $I^D$ statistic is the local counterpart of the differential Moran's *I*. The formal expression for this statistic consists of the cross product of the difference between the observed values of the attribute of zone *i* at time *t* ($z_{i,t}$) and $z_{i,t-1}$ as follows (Anselin, 2020):

$$I_i^D = (z_{i,t} - z_{i,t-1}) \sum_j w_{ij} (z_{j,t} - z_{j,t-1}) \quad (3)$$

To interpret the results, it is important to note that in cases where both positive and negative change values exist in the dataset, High-High (HH) locations will tend to have a large increase (positive change) and be surrounded by other locations with similarly large increases. Conversely, Low-Low (LL) locations will be characterized by a large decrease (negative change) and be surrounded by locations with similarly large decreases.

*2.4. Logistic regression associated with index of Moran*

A logistic regression model was employed to examine the location choices and deduce the perceived accessibility (utility) of each zone. Zonal accessibility was defined as a linear combination of the accessibility components, associated with the LISA of each zone, to investigate the relationship between warehouse location and the degree of spatial association of the zone. To account for the significance of each accessibility component in relation to each warehouse type, separate models were established for small and large warehouses for both the years 2012 and 2022.

Then, given a warehouse of type *s* at time *t*, located in zone *i*, the perceived accessibility (utility) to be in zone *i* can be expressed as follows:

$$U_i^{s,t} = V_i^{s,t} + \varepsilon_i^{s,t} \quad (4)$$

where $U_i^{s,t}$ is the perceived accessibility to be in zone *i*, in relation to food warehouses of type *s* in the year *t*; $V_i^{s,t}$ is the systematic accessibility of zone *i* related to food warehouses type *s* in the year *t,* and $\varepsilon_i^{s,t}$ the error component. Then, the probability to be in a zone *i* can be expressed through logistic regression. Thus, the dependent variable is the probability of a particular warehouse of type *s* being in zone *i* at time *t*. The systemic component ($V_i^{s,t}$) is expressed as a linear combination of some zonal attributes, Including the LISA index, through a set of parameters that have to be estimated. Estimations of such parameters were performed by the Maximum Likelihood method, comparing the observed distribution of warehouse location in the study area and the aggregate model location shares/probabilities.

## 3. Results and discussions

### *3.1. Descriptive spatial analysis and results for LISA*

In Fortaleza, both small and large food warehouses tend to be concentrated within the first road ring or in areas close to expressways. However, large warehouses tend to be in regions closer to BR-116. Therefore, in terms of accessibility, it is expected that the distance from the zone to the nearest expressway will have a negative relationship with the number of food warehouses, and especially for large warehouses, there will be a trend towards greater concentration around BR-116 in 2022 compared to 2012.

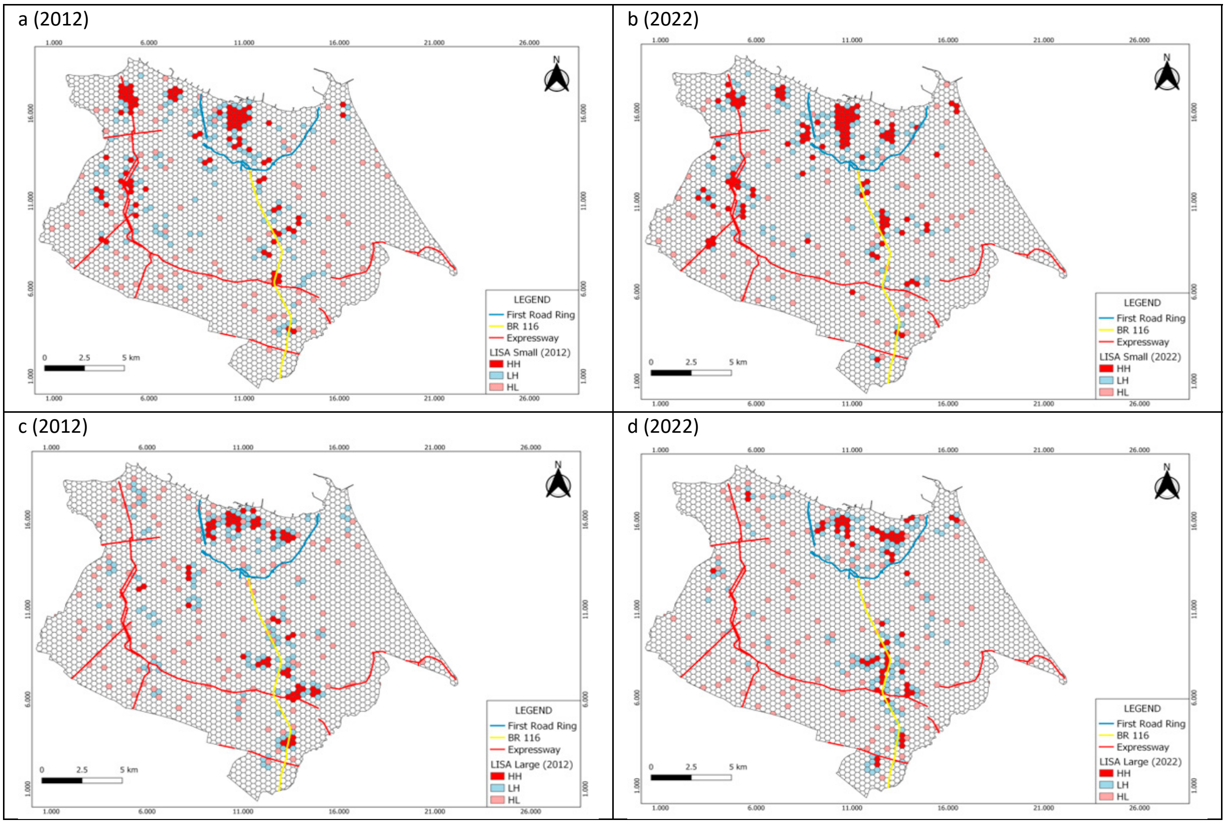


Figure 1. Results for LISA. (a) small warehouses in 2012; (b) small warehouses in 2022; (c) large warehouses in 2012; (d) large warehouses in 2022

Regarding population (POP), the majority is in the western region of the city, and the significant population clusters are not in the inner area of the first road ring. Here, the population variable can serve as a proxy for land prices, and a negative relationship is expected in relation to the presence of warehouses. The number of food retailers (RET) in 2012 and 2022 increased in all areas of the city. Locations with more significant numbers of retailers tend to attract more warehouses. The number of retailers within the buffer (RB) increased on average between 2012 and 2022, but this increase was more significant in the western zone of the city and within the first road ring.

Additionally, the transportation component is also related to the sum of road lengths in the zone, with a higher road density within the first road ring and the city's western region, as well as a greater concentration of streets near BR-116. A positive relationship is expected concerning the presence of warehouses. Finally, concerning the temporal component of accessibility, it is worth noting that time windows were enforced in regions where the presence of food warehouses was already substantial, particularly within the first ring road. Despite being a factor that typically has adverse effects on the supply chain, it is also possible to observe a potentially positive relationship, especially for large warehouses. This may be attributed to the significant number of large warehouses still located in these zones, possibly due to other zone-specific attributes or the associated costs of relocation, compelling stakeholders to adjust their reception and delivery practices.

In terms of the local indicators of spatial association for small warehouses, Figure 1 reveals that the HH clusters are situated in areas near the expressways and within the first road ring. From 2012 to 2022, there appear to be no significant variations in spatial concentration for small food warehouses according to the local indicators of spatial association. As for large warehouses, HH clusters are present in the first road ring and the BR-116 regions. The concentration of these warehouses near the BR-116 has increased between 2012 and 2022. There is no indication of LL clusters for small or large warehouses in either year.

### *3.2. Differential Local Moran's $I^D$*

Regarding the spatial distribution of food warehouses from 2012 to 2022, both small and large warehouses exhibit a significant presence in LL zones, particularly in the eastern inner areas of the first ring road. This trend could be linked to the introduction of time-window restrictions in the region. Additionally, there are clusters of zones where the number of small warehouses has decreased, especially in areas near expressways, which were considered HH clusters in 2012. This suggests that these small warehouses may be less concerned about passive accessibility and are expanding further. In contrast, large warehouses in proximity to BR-116 show an increase in numbers, surrounded by areas with a higher concentration of such establishments.

### *3.3. Logistic regression associated with the index of Moran*

The results of the logistic regression are consistent with the spatial analysis findings presented earlier. In Table 2, we illustrate the impact of each attribute on the probability of a warehouse being in a specific zone. The models developed effectively captured the association between food warehouses and zonal characteristics. These outcomes are in line with prior research in the field. Concerning land-use components, the models suggest that food warehouses tend to locate in regions with lower population density, a trend also observed by Hong (2007), Sakai *et al.* (2020), and De Oliveira *et al.* (2022). Additionally, the presence of a higher population negatively affects large warehouses more than small ones. The number of food retailers in the area is positively correlated with the number of warehouses in all models. Notably, the coefficients for variables related to the number of retailers in a 1700-meter buffer were higher for large warehouses, suggesting their preference for areas with easier access to a greater number of retailers. Furthermore, accessibility in terms of distance to customers emerged as a critical factor in warehouse location choice, consistent with the findings of De Oliveira *et al.* (2020).

Concerning the transport components, all models indicate a positive correlation between the availability of roads in the region and warehouse location, aligning with the findings of Iwakata *et al.* (2015). Regarding the distance from the nearest expressway, the models exhibit the expected behaviour, consistent with research by Durmus and Turk (2012), Sakai *et al.* (2015), Aljohani and Thompson (2020), and De Oliveira *et al.* (2020). In other words, a shorter distance to the nearest expressway is associated with a higher number of establishments, likely due to reduced transport costs in such regions.

As for the temporal component, the density of roads with time-window restrictions, applicable only in 2022, shows an expected relationship. For small warehouses, the model shows that a higher density of roads with temporal restrictions is linked to a lower number of establishments. Conversely, for large establishments, the behaviour is opposite, suggesting that large wholesalers may prefer adapting their receiving and delivery processes rather than relocating due to cost considerations. Moreover, a decade may not provide ample time to observe substantial changes in land-use patterns resulting from the time restriction measures.

Regarding spatial autocorrelation, the model reveals positive autocorrelation for both small and large establishments in both years under study. However, the effects of autocorrelation are more pronounced for larger establishments than for smaller ones.

It is important to emphasize that the modelling technique employed in this study is intended solely for analysing the relationship between variables representing accessibility and LISA and the probability of a specific warehouse being in a zone.

Table 2. Results for Logistic Regression Model

| Dependent Variable | Accessibility Components and LISA | | | | | | | $R^2$ |
|---|---|---|---|---|---|---|---|---|
| | *POP* | *RET* | *RB* | *RL* | *EXP* | *WT* | *LISA* | |
| Probability of a Small Warehouse in 2012 | -0.277 | 1.752 | 3.157 | 0.502 | -0.125 | - | 0.011 | 0.834 |
| Probability of a Large Warehouse in 2012 | -0.514 | 2.270 | 3.937 | 0.619 | -0.187 | - | 0.018 | 0.792 |
| Probability of a Small Warehouse in 2022 | - | 0.586 | 1.855 | 0.374 | -0.083 | -0.153 | 0.013 | 0.799 |
| Probability of a Large Warehouse in 2022 | -0.613 | 0.696 | 2.633 | 0.603 | -0.224 | 0.413 | 0.027 | 0.457 |

## 4. Conclusion

This paper carried out a spatial analysis of accessibility components related to the location of food warehouses in Fortaleza, considering four accessibility dimensions over two different years. The findings reveal that large warehouses are increasingly concentrating around the critical expressway (BR-116), while smaller ones are moving away from main roads. The introduction of time window restrictions in the first ring road region appears to be connected to clusters where the number of establishments decreased.

The logistic regression model indicated that the probability of a food warehouse being in a particular region is associated with a lower population, particularly for larger warehouses. Furthermore, the importance of proximity to food retailers decreased between 2012 and 2022. Regarding the transport component, all models highlighted the significance of the region's road supply and the proximity to expressways. This association increased with large warehouses, to the detriment of small ones. Finally, the time component analysis revealed that some wholesalers preferred to bear the cost of adjusting their receiving and delivery mechanisms rather than changing regions for just a ten-year period. Moreover, larger food warehouses exhibit stronger spatial correlations than the smaller ones, thereby underscoring an indication of zones with heightened levels of accessibility for significant establishments.

Regarding the formulation of land-use public policies, the findings underscore the importance of integrating the individual accessibility component when deliberating on warehouse locations. This is particularly relevant as smaller-scale establishments may have distinct accessibility requirements compared to larger ones. This implies the potential need for public incentives to support the establishment of small warehouses in regions with a significant presence of retailers. These insights highlight the urgency of comprehensively assessing accessibility in UFT. This approach goes beyond the common practice among many researchers (Table 1) by considering not only the transport component but also incorporating land-use dynamics, temporal dimensions, and proxies for individual preferences, which are crucial in selecting logistic facility locations. By adopting a more comprehensive perspective on accessibility, policymakers can make informed decisions, fostering sustainable urban freight transportation management. Additionally, the methodology proposed in this research can be extended to other sectors operating in urban areas, such as pharmaceuticals and automotive parts distribution, allowing for tailored decision-making for specific economic activity groups.

One limitation of this study is the absence of census data for the year 2022 and the inability to gather information on factors like congestion during the study years. For future research, the spatial heterogeneity of accessibility components related to the location of food warehouses should be explored. In addition to spatial heterogeneity, future studies should aim to develop an accessibility indicator that encompasses all accessibility components. Such an indicator can provide a more comprehensive understanding of accessibility and enable its correlation with social and environmental aspects, effectively harnessing the concept of accessibility to contribute to the achievement of Sustainable Development Goals of Agenda 2030 in UFT.

## Acknowledgements

The authors thank CAPES, FUNCAP and the University of Rome Tor Vergata for granting scholarships in Italy.

## References


Aljohani, K., and R. Thompson. (2020). "A Multi-Criteria Spatial Evaluation Framework to Optimise the Siting of Freight Consolidation Facilities in Inner-City Areas." *Transportation Research Part A: Policy And Practice.* 138, 51–69.

Anselin, L. (1995). Local indicators of spatial association—LISA. Geogr. Anal, 27, 93–115.

Anselin, L. (2020). Local Spatial Autocorrelation. Geodacenter. Available online: https://geodacenter.github.io/workbook/6a_local_auto/lab6a.html. (Accessed on 28 December 2022).

Bachofner, M., Lemardelé, C., Estrada, M., Pagès, L. (2022) City logistics: Challenges and opportunities for technology providers. *Journal of Urban Mobility.* 2, 100020.

Birch, C.P.D., Oom, S.P. and Beecham, J.A., (2007). Rectangular and hexagonal grids used for observation, experiment and simulation in ecology. Ecological Modeling, 206(3-4), pp.347-359. Doi: 10.1016/j.ecolmodel.2007.03.041

Brazilian Federal Revenue. (2022). Database of legal entities. Brazil.

Dhulipala, S. and Patil, G. (2021). Regional freight generation and spatial interactions in developing regions using secondary data. *Transportation*.

Durmuş, A.,Turk, S.S. (2014) Factors Influencing Location Selection of Warehouses at the Intra-Urban Level: Istanbul Case, *European Planning Studies*, 22:2, 268-292.

De Oliveira, L. K., Lopes, G. P., Oliveira, R. L. M. & Bracarense, L. S. F. P. (2020) Locational Context for Warehouse Facilities in Urban Areas: A Case Study in Belo Horizonte (Brazil). *15th WCTR*, Bombai.

De Oliveira, L.K., Lopes, G.P., de Oliveira, R.L.M., Bracarense, L. dos, S.F.P., Pitombo, C.S. (2022). An Investigation of Contributing Factors for Warehouse Location and the Relationship between Local Attributes and Explanatory Variables of Warehouse Freight Trip Generation Model. *Transp. Res. Part A Policy Pract*. 162, 206-219.

Fortaleza (2019). *Origin-Destination Search. Sustainable Accessibility Plan of Fortaleza* – PASFOR. Technical Report

Geurs, K. T.; Van Wee, B. (2004) Accessibility evaluation of land-use and transport strategies: Review and research directions. *Journal of Transport Geography, 12 (2)*, 127–140.

Ghodousi, M., Sadeghi-Niaraki, A., Rabiee, F., Choi, SM. (2020), Spatial-Temporal Analysis of Point Distribution Pattern of Schools Using Spatial Autocorrelation Indices in Bojnourd City. *Sustainability.* 12, 7755.

Gingerich, K.; Maoh, H.; Anderson, W. (2014) Choice of land use development type within commercial and industrial zoning. *J. Urban Plan. Develop*., 141 (2), p. 04014024

Gonzalez-Feliu, J., Grau, J.M.S., Beziat, A. (2014) A location-based accessibility analysis to estimate the suitability of urban consolidation facilities. *International Journal of Urban Sciences, 18:2*, 166-185.

Govindan, K. (2018). Sustainable consumption and production in the food supply chain: A conceptual framework. *International Journal of Production Economics, 195*, 419-431.

Guerin, L., Vieira, J.G.V., de Oliveira, R.L.M., de Oliveira, L.K., de Miranda Vieira, H. E., Dablanc, L. (2021). The geography of warehouses in the São Paulo Metropolitan Region and contributing factors to this spatial distribution. *Journal of Transport Geography. 91*, 102976.

Heitz, A.; Dablanc, L.; Tavasszy, L. A. (2017). Logistics sprawl in monocentric and polycentric metropolitan areas: The cases of Paris, France, and the Randstad, the Netherlands, *European Regional Science Association (ERSA),* Louvain-la-Neuve, 4, 93-107.

Hong, J. (2007). Location Determinants and Patterns of Foreign Logistics Services in Shanghai, China. *The Service Industries Journal*, 27:4, 339-354.

IBGE, "IBGE Cidades," Instituto Brasileiro de Geografia e Estatística, Brasília. [Online]. Available: https://cidades.ibge.gov.br/brasil/ce/fortaleza/panorama.

Iwakata, M., Okamoto, N., Ishida, H., Hyodo, T. (2015). A study of freight facility location in Tokyo metropolitan and its future. *Journal of the Eastern Asia Society for Transportation Studies.* 11, 722-738.

Nuzzolo, A., Comi, A. and Papa, E. (2014). Simulating the Effects of Shopping Attitudes on UrbanGoods Distribution. *Procedia – Social and Behavioral Sciences 111*.

PETRAN. (2019). Geographic database. Fortaleza.

Portugal, L. S., Morgado, A. V., Lima Júnior, O. (2011). Location of cargo terminals in metropolitan areas of developing countries: the Brazilian case. *Journal of Transport Geography.* 19, 900-910.

Russo, F., Vitetta, A. and Comi, A. (2009). Estimation of target time distribution for agri-food products by road transport. *Schedule-Based Modeling of Transportation Networks: Theory and Applications*, N. H. M. Wilson and A. Nuzzolo (eds.), DOI: 10.1007/978-0-387-84812-9_14, Springer Science + Business Media, 267 – 283.

Russo, F. and Comi, A. (2020). Investigating the Effects of City Logistics Measures on the Economy of the City. *Sustainability 2020, 12(4)*, 1439.

Sakai, T., Kawamura, K., Hyodo, T. (2015). Location Choice Models of Urban Logistics Facilities and the Impact of Zoning on their Spatial Distribution and Efficiency. *Proceedings of the 95th Annual Meeting of the Transportation Research Board*. Washington D.C.

Sakai, T., Beziat, A., Heitz,. (2020). A. Location factors for logistics facilities: Location choice modeling considering activity categories. *Journal of Transport Geography.* 85. 102710.

Sanchez-Diaz, I., Holguin-Veras, J. and Wang, X. (2016). An explanatory analysis of spatial effects on freight trip attraction. *Transportation 43*, pp. 177-196.

Taniguchi, E. and Ando, N. (2005) An experimentation study on the performance of probabilistic vehicle routing and scheduling with ITS. Proceedings of 4th Conference on City Logistics, Langkawi, Malaysia.

Thomé, K. M., Cappellesso, G., Ramos, E.L.A., de Lima Duarte, S. C. (2020). Food supply chains and short food supply chains: coexistence conceptual framework. *J. Clean. Prod.* Article 123207.

UN. (2015). United Nations: Transforming Our World the 2030 Agenda for Sustainable Development. United Nations. Retrieved from https://sdgs.un.org/sites/default/files/publications/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

Verhetsel A., Kessels R., Goos P., Zijlstra T., Blomme N., & Cant J. (2015) Location of logistics companies: a stated preference study to disentangle the impact of accessibility. *Journal of Transport Geography, 42*, p. 110- 121.