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NEW CHALLENGES FOR XXI CENTURY CITIES

Global warming, ageing of population, reduction of energy consumption, immigration flows, optimization of land use, technological innovation

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The cover image shows older people climbing Via Raffaele Morghen's stairs in Naples (Source: TeMA Journal Editorial Staff).

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The cost of shopping: measuring virtual and physical access for obtaining goods

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Abstract

The rise of e-commerce, bolstered by advances in information and communication technology (ICT), has made it possible for consumers to shop online without the need to physically travel. The unexpected emergence of COVID-19 further accelerated this shift towards online shopping. This paper compares virtual versus physical access to goods, drawing from dual access theory. It aims to offer a comprehensive understanding of the disparities in accessibility between digital and brick-and-mortar shopping experiences. Our results indicate that, when considering the complete private costs — including the intrinsic costs of shopping and those incurred *en-route* like travel and delivery fees — online shopping typically offers greater accessibility and is more cost-effective than its in-store counterpart. While physical access to shopping displays a pattern where the central city has a distinct advantage over the suburbs, virtual access presents a more uniform distribution throughout the city.

Keywords

Accessibility; Online VS in-store shopping; Physical VS virtual; Dual access; Wuhan city; COVID-19.

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1. Introduction

Accessibility, fundamental in transport and land use policies, represents the convenience of reaching various opportunities (Hansen, 1959). Numerous studies have been dedicated to exploring accessibility related to jobs, schools, transport hubs, and other essential destinations (Alotaibi et al., 2021; Bondemark, 2020; Cui & Levinson, 2020; Guida & Caglioni, 2020; Lee & Kim, 2023; Levinson, 1998; Manfredini & Di, 2018; Pirra et al., 2021; Preston & Rajé, 2007; Schuetz et al., 2012). Given the interconnection of economic growth and urban planning, shopping access has gained traction, predominantly from the perspective of customers physically visiting stores to procure goods (Apparicio, Cloutier & Shearmur, 2007; Hamidi, 2020; Larsen & Gilliland, 2008; Sakai, Kawamura & Hyodo, 2019; Visser & Lanzendorf, 2004; R. E. Walker et al., 2010; Woudsma et al., 2008). With the advent of e-commerce and information and communication technologies (ICTs), online shopping has surged (Saphores & Xu, 2021). Data from the National Bureau of Statistics in 2019 revealed that online retail sales in China stood at 853.9 billion CNY, which amounted to 20.7% of the total, giving China the highest share of online retail (Mofcom.PRC, 2019). Although numerous studies dissect the dynamics between online and brick-and-mortar shopping, the investigation into their accessibility remains scant. The COVID-19 pandemic, which imposed widespread travel restrictions (Altay & Şenay, 2023), prompts a re-evaluation of shopping accessibility. This necessitates an inclusion of scenarios where customers predominantly engage in online, telephonic, or mail-order shopping, awaiting home delivery. This mode is termed "virtual access." In contrast, the traditional form, primarily rooted in travel costs and including the monetary expense of the products, is termed "physical access."

The standard procedure for calculating physical access relies on the cumulative opportunity measure, which assesses how many opportunities are attainable within a set travel time (Li & Kim, 2020; Schuetz et al., 2012). Some scholars highlight the significance of balancing supply and demand in accessibility, leading to the 2-step floating catchment area (2SFCA) method (Alford-Teaster et al., 2021; Guida & Caglioni, 2020; Wang & Luo, 2005). Nonetheless, the 2SFCA overlooks the influence of travel time and cost. Integrating such measures, including gravity-based models (Handy & Niemeier, 1997) which weigh cost impedance when assessing opportunities, or utility-based models (Ben-Akiva & Lerman, 2018) which differentiate individual travel costs and destination values, into virtual access poses challenges:

- Traditional access methodologies primarily revolve around potential spatial interactions and derived benefits. In virtual access, however, shoppers aren't physically traveling (though delivery may entail some travel, such as a self-pickup cabinet situated in an apartment's lobby—this aspect wasn't factored into our considerations). Consequently, determining spatial friction in virtual access can be complicated;
- Defining "opportunities" in the context of virtual access is tricky. While some argue that virtual access opportunities should form a segment of the total, presupposing no addition from ICTs (Shen, 1998, 2000), others assert that the frequency of online shopping introduces more opportunities (Ding & Lu, 2017; Farag et al., 2006; Farag et al., 2007).

Cui and Levinson (2019b) introduced a new accessibility measure wherein travel cost required to access a set number of opportunities is the performance metric. Instead of emphasizing the quantity of available opportunities, this method uses them as a preset benchmark or constraint. This approach sidesteps debates about the equivalence of opportunities in both physical and virtual domains, especially when the main interest lies in fulfilling a specific opportunity (e.g., acquiring an item) rather than counting alternative sources of said opportunity. The focus shifts to the expense of ensuring goods arrive at the demanded location (like food at home), rather than at the supplied point (e.g., a store or warehouse). Furthermore, in a physical context, the sum of travel time and additional monetary costs represents the *en-route* expense, whereas in a virtual setting, delivery time and fees signify the initial spatial disparity and eventual convergence of goods and buyers. Importantly, the worth of travel and delivery times differ, influencing the comparison between physical and virtual accesses. Other cost components, such as shopping durations (in-store vs. online), product prices — which might fluctuate across platforms and delivery schedule delays, warrant consideration.

This article distinguishes between physical and virtual shopping accesses and delineates their real-world applications. We establish a methodological foundation anchored on dual-access theory. Wuhan City, China, serves as our case study to underscore the framework's applicability. The subsequent sections are structured as follows: Section 2 outlines the methodology for assessing physical and virtual access, including data. Sections 3 presents findings. Section 4 reflects on the insights and concludes the paper.

2. Methodology

The schematic representation of our approach to determine both physical and virtual shopping accessibility is illustrated in Fig.1. This encompasses the necessary data, techniques employed, and the consequent outputs.

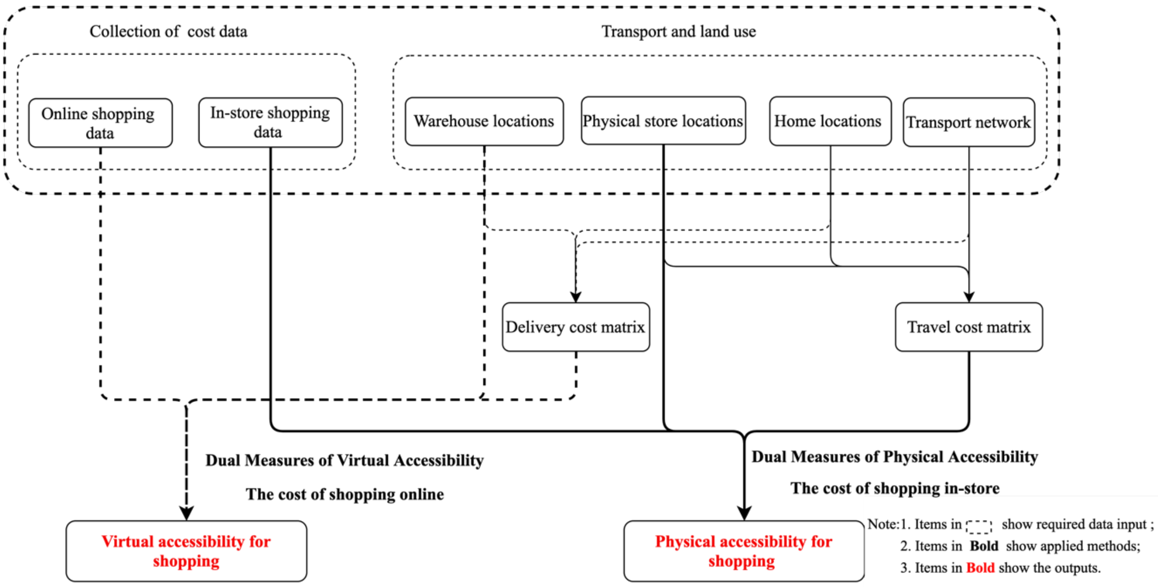

Fig.1 Schematic of computing physical and virtual shopping accessibility

Travel durations for traditional shopping and online shopping delivery are deduced via GIS- based analysis. Specifically, these durations cover the span from starting points (homes for traditional shopping, warehouses for online shopping) to respective endpoints (retail outlets for in-store shopping, residences for online shopping).

For online shopping, the data capture encompasses costs associated with the goods, total waiting duration (incorporating both delivery and order processing time), time invested in online shopping, the monetized value of this online shopping time, and the monetary value attached to delivery duration. In contrast, for in-store shopping, the data comprise travel time, time spent inside the store, the associated monetary value of both these durations, and the costs for the goods purchased in-store. Time valuations can be estimated from shopper surveys.

2.1 Dual physical access

Cui and Levinson (2019b) described the dual access measure as the travel expense needed to reach a specified number of opportunities. This is essentially the converse of Hansen (1959)'s primal measure, which quantifies the opportunities accessible for a predetermined travel cost. The dual approach is particularly advantageous when the availability of opportunities isn't the primary concern, but rather the associated travel time or cost is the focal point (Cui & Levinson, 2020, 2019b). This is consistent with the scenario of shopping accessibility.

For dual physical access, denoted as A_i the mathematical representation is:

$$A_i = C_{iO_N} \tag{1}$$

Where:

- C signifies the pertinent cost;
- i represents the origin zone, and
- O_N marks the position of the Nth closest opportunity (O).

2.2 Cost analysis for physical access

The cost associated with ensuring goods reach the desired location (home) encompasses the round-trip travel expense between customers and stores, the temporal expense of shopping in-store, and the cost of the goods themselves.

The travel expense arises from journeys to and from local stores. Ideally, this should account for time-related expenses, crash costs, emission-related expenses, and direct financial expenses such as tolls and fuel (Cui & Levinson, 2019a). However, in practice, only the travel time and out-of-pocket financial expenses hold significant relevance to travelers. Firstly, these constitute a substantial proportion of the overall travel expenses, approximately 80% for driving. Secondly, most individuals aren't aware of the emission and crash costs they incur or impose during their journey. For simplification, only the travel time, vehicle operational costs, and parking fees (when applicable) are considered in our calculation. However, the travel time is monetized to make these components cumulative. In certain scenarios, shopping may not be the sole purpose of a trip. Such instances require careful valuation of the travel time. This paper presumes shopping as the singular activity during physical journeys.

The duration of in-store shopping starts from the moment customers enter the store and ends upon their exit. Its length is influenced by the number of items being purchased, and its value can be affected by perceptions of time and qualitative factors (like whether shopping is enjoyable or burdensome). The exact valuation of shopping time, whether it's considered beneficial (negative cost) due to positive recreational or social aspects, or burdensome (positive cost), can be complex. Given the essential nature of groceries, this paper treats the value of shopping time as a positive cost. Following Walker & Cude (1983), we approximate the value of shopping time to the hourly wage rate in our case study.

The cost of goods is more direct. Potential discounts provided should also be considered. Thus, the cost function for in-store shopping, used in the physical access computation, is expressed as:

$$C_{ij}^p = \tau \cdot T_{t,ij}^p + C_{t,ij} + \mu^p \cdot T_s^p + C_g^p \cdot (1 - \rho^p) \tag{2}$$

Where:

- τ: Value of travel time;
- $T_{t,ij}^p$:Travel time to and from the pertinent local stores, with i denoting the customer's residence and j the store location;
- $C_{t,ij}$: Monetary travel cost, associated with travel distance, mode, and other relevant factors;
- μ^p: Value of in-store shopping time;
- T_s^p: Duration of in-store shopping;
- C_g^p: Goods' cost for in-store shopping;
- ρ^p: Seller-offered discounts to in-store buyers.

Note that when shopping is the sole reason for a trip, the travel time and cost, represented by $T_{t,ij}^{p}$ and $C_{t,ij}$, are simply derived from the round trip between a home (*i*) and local stores (*j*). However, everyday shopping is often coupled with other activities, such as work. As a result, the specific travel time and expense for shopping are ascertained by the detour of the journey chain, for instance, traveling from work to a store and then to home, as opposed to a direct route from work to home. This cost might be zero if the store lies directly enroute between a person's home and workplace (Huang & Levinson, 2015).

2.3 Cost analysis for virtual access

In the context of virtual access, costs are conceptualized differently than in the physical realm.

In Wuhan City, as of 2020, there exist two predominant online shopping platforms offering distinct delivery services: immediate delivery and package delivery. Immediate delivery is particularly suited for time-sensitive products such as fruits or vegetables. For this type of delivery, a designated courier is appointed, ensuring orders are delivered in mere hours. In contrast, package delivery often requires a span of 1 to 7 days. For this method, goods are typically collated from a warehouse and dispatched to customers via urban distribution centers and local delivery storefronts.

With advances in cold chain logistics in China, time-sensitive items can be procured within a 2-day window. Additionally, online merchants often absorb a portion of the delivery expenses, which augments the total cost offset relative to immediate delivery. Stores offering immediate delivery services operate within a specific coverage area, often defined by delivery time or distance. Suburban areas, having sparse store density, might lack access to immediate delivery services. On the contrary, package delivery services span the entire city. Given our intent to constrast virtual and physical access across the city, this paper will focus on package delivery.

Defining online shopping duration presents a challenge for several reasons: first, online shopping might be spontaneously prompted by unrelated online activities such as reading news or viewing videos, especially when advertisements or promotions are featured prominently. Second, online shopping doesn't always occur in one continuous session. A user might, for instance, add products to their cart during a brief break, only to return and finalize their purchase later. Chiu, Lo, Hsieh, and Hwang (2019) suggested that consumers tend to spend more time shopping online than in physical stores. However, Schmid and Axhausen (2019) posited the opposite, arguing that online shopping conserves time as consumers incur lesser search costs and access more comprehensive information. To facilitate our calculations, we posit that total online shopping time correlates with the number of items purchased. Nonetheless, this domain warrants extensive research, especially given the evolving nature of online shopping technology.

The cost function for online shopping, pertinent to virtual access, is expressed as:

$$C_{ik}^{v} = \sigma \cdot T_{w,ik} + C_{d,ik} + \mu^{v} \cdot T_{s}^{v} + C_{g}^{v} \cdot (1 - \rho^{v}) \qquad (3)$$

Where:

- σ: Value of waiting time (schedule delay);
- $T_{w,ik}$: Waiting time for customers, where k denotes the location of online sellers;
- $C_{d,ik}$: Delivery cost;
- T_{s}^{v}: Time spent shopping online;
- μ^{v}: Value of online shopping time;
- C_{g}^{v}: Online shopping goods' cost;
- ρ^{v}: Discounts offered to online patrons.

2.4 Data collection

Wuhan City serves as the focal point for this study. It is the administrative seat of Hubei Province and stands as the most populous city in central China (Han & Wu, 2004). The city encompasses an area close to 8,500 km^2 and boasts a population nearing 12 million as of 2019.

The data for this research is derived from several sources, as illustrated in Fig.1.

Wuhan City's Road network was sourced from OpenStreetMap and procured via BBBike. This free server facilitates the export of customized sections from OpenStreetMap projects in various formats such as OSM, Shapefile, or GeoJSON, covering over 200 global locales. We opted for the shapefile format, given its seamless integration with Geographic Information System (GIS) software, namely ArcGIS or QGIS, and its utility in computing travel costs.

The study demarcates the region into 1km×1km grid sections, using the centroids to represent origins denoting customer locations for access metrics. While grocery store sites indicate physical access endpoints, the virtual access private cost doesn't demand knowledge of package origins since delivery duration hinges on the shipping costs customers are amenable to. Typically, in Chinese urban areas like Wuhan City, complimentary shipping entails a two-day wait, making it a popular choice for forward-thinking consumers. Anomalies arise when dispatches originate from distant provinces such as Xinjiang or Inner Mongolia, resulting in delivery times exceeding two days, or from Hubei, guaranteeing next-day delivery expectations. In these scenarios, local delivery store locations, crucial for determining 'last-mile delivery' durations, influence package waiting time variations across the city.

Grocery and local delivery store locations were extracted from the Gaode map (Gaode, 2020), and their distributions are presented in Fig.2.

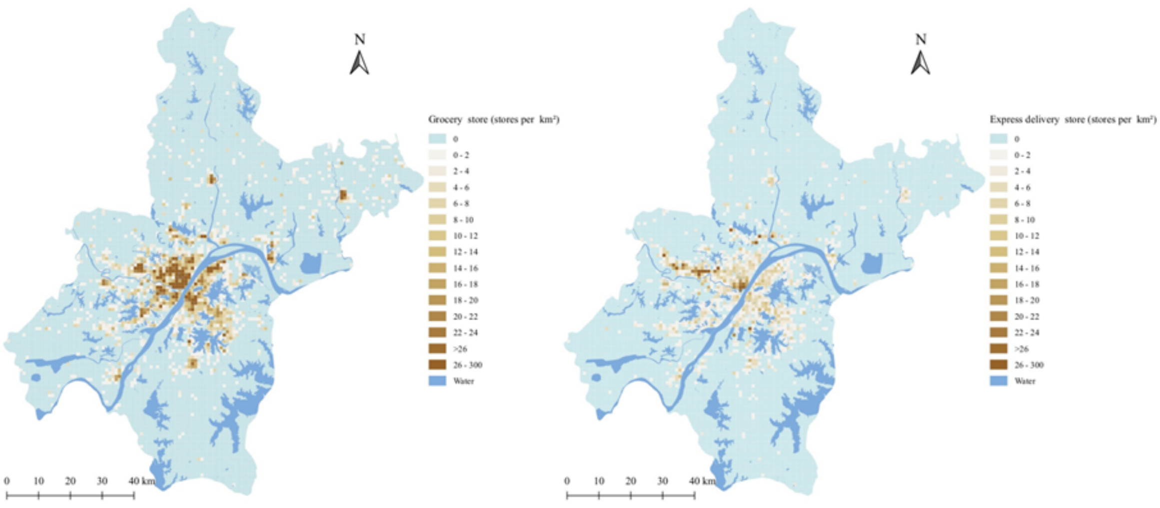

Fig.2 (a) Grocery stores and (b) delivery stores densities in Wuhan City (number/km^2)

3. Results

Physical and virtual access are studied for the case of Wuhan City to understand their spatial distribution patterns and to differentiate them. The methodology for these calculations is depicted in Fig.1 and can be potentially applied to other cities.

3.1 Parameter specification

The parameters present in the cost functions for in-store shopping (Eq.2) and online shopping (Eq.3) including shopping time, cost of goods, and values of time for travel, shopping, and waiting for packages require calibration prior to computing access.

The value of time is generally measured by how much people are willing to pay to save their time (Carrion & Levinson, 2013). The value varies depending on location, purpose, and mode. Previous research has valued travel time and delivery time based on shopping choice models constructed on travel cost, travel time, and delivery time (Hsiao, 2009; Schmid & Axhausen, 2019). We have employed the estimates from Hsiao (2009) as the focus of his studies was on Asian Cities. Few studies have addressed the value of shopping time. However, Walker and Cude (1983) suggested that the value of shopping time could be approximated by the hourly wage rate, which we have applied to Wuhan City. Our estimates of online and on-store shopping time and cost, and delivery cost are developed in the Appendix (section 5).
Tab.1 summarizes the parameters and their corresponding values used in this study, when considering the purchase of 4 items.

Name	Value
Value of travel time	5.29 US$/hour (0.62CNY/min) (Hsiao, 2009)
Value of waiting time	0.76 US$/day (0.0037CNY/min) (Hsiao, 2009)
Value of online shopping time	2.57 US$/hour (18 CNY/hour) (Mohrss.PRC, 2020)
Value of in-store shopping time	2.57 US$/hour (18 CNY/hour) (Mohrss.PRC, 2020)
Online shopping time	27.59 min
In-store shopping time	31.79 min
Delivery cost	4 CNY
Online shopping cost	83.45 CNY
In-store shopping cost	87.81 CNY

Tab.1 Parameter specification: values of parameters used in physical and virtual access measurements

3.2 Access Measurements: Physical vs. Virtual

In Wuhan City, grocery stores are typically situated near residential areas, making them accessible by foot. Thus, for scenarios where shopping is the sole purpose of travel, the minimal walking distance between residences and the nearest store (round trip) determines the travel time required for physical access, assuming a walking speed of 1.24 m/s (& , 1996; Walsh, Xian, Levinson & Rayaprolu, 2019).

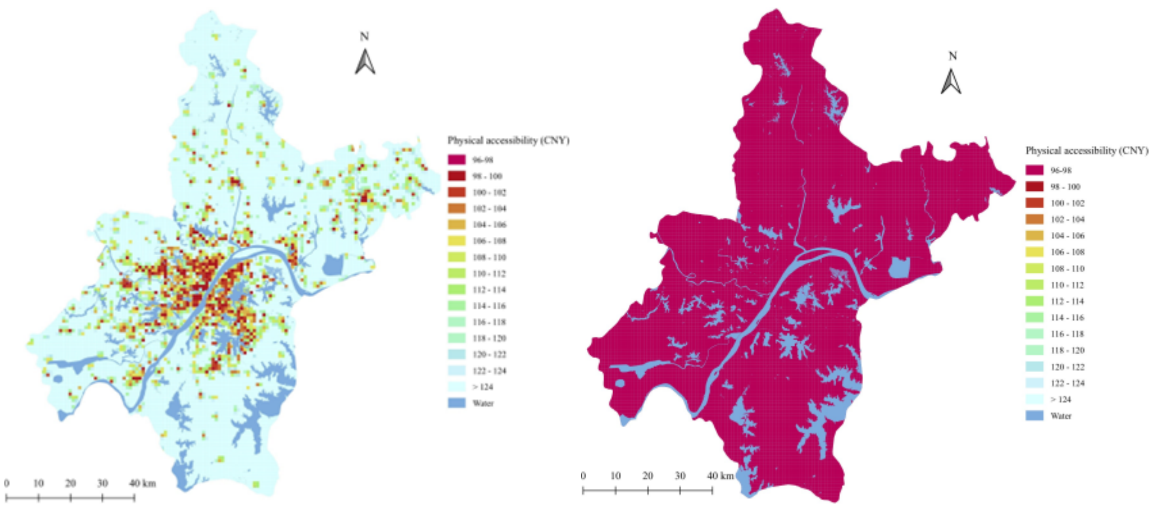

Fig.3 Physical access to 4 items in Wuhan city: (a) shopping as the sole purpose of travel and (b) shopping as part of a multi-stop journey

Fig.3 illustrates the physical access in Wuhan City when considering a basket of 4 items from a single store. The distribution suggests that residents in central Wuhan City enjoy better access to local grocery stores than those living in suburban areas. This spatial distribution is influenced by the clustering of grocery stores, as seen in Fig.2a.

In some situations, shopping is merely one stop in a trip chain. Ideally, this stop shouldn't introduce any detours, meaning that both travel time and cost would not serve as an impedance to in-store shopping activities. This scenario can maximize accessibility, as depicted in Fig.3.

For virtual access, the situation differs. As previously mentioned, if the same delivery services are chosen, there are negligible variations in delivery time and cost. Consequently, we have used the mean value from our experiments, 4 CNY, to represent the delivery cost. Additionally, 863.38 minutes (which is 80% of 1,079.23 minutes) is established as the standard duration for packages to travel from the sender to local delivery stores. The last segment of the delivery, representing the remaining 20% of waiting time, is dependent on the shortest distance from delivery stores to the customers' location. In China, this leg is often completed using electric tricycles, for which we've assumed a speed of 15 km/h based on the study by Zhang, Chen, Li, and Zhong (2019).

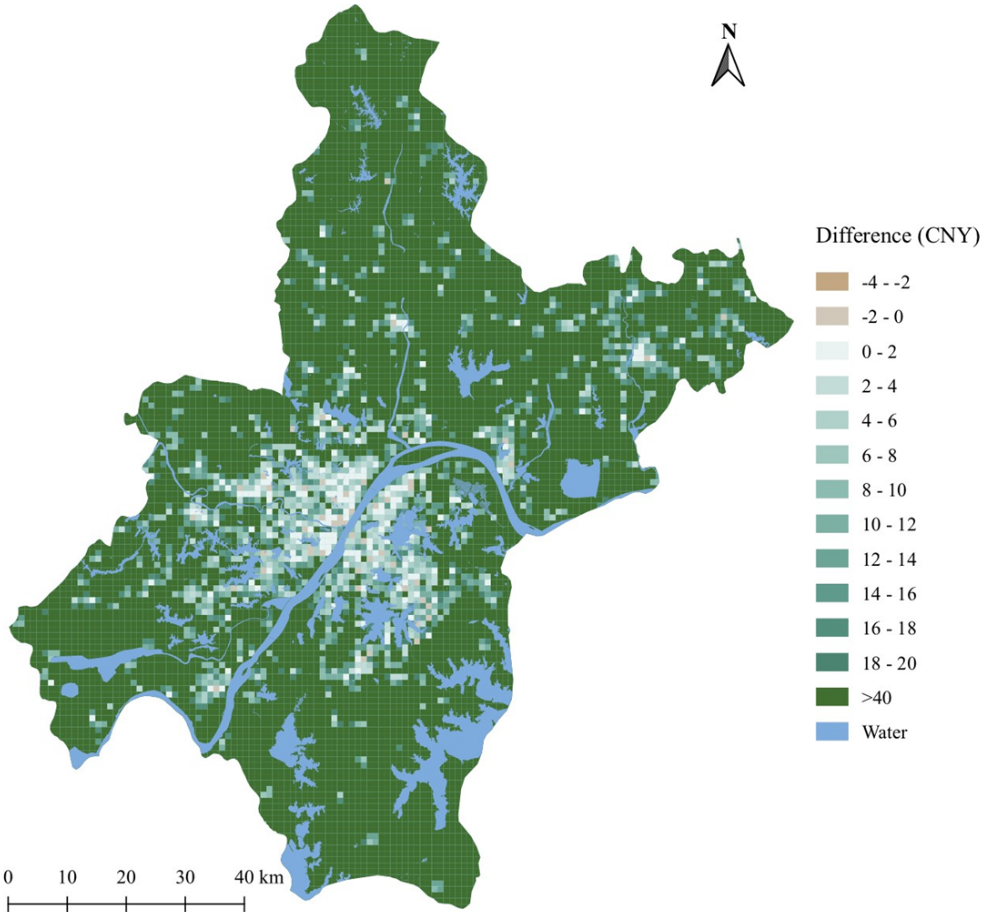

Fig.4 Virtual access for shopping in Wuhan City

Virtual access is determined by aggregating the shopping cost, the time cost of online shop- ping, and both the time and monetary costs of delivery, as visualized in Fig.4. The distribution is mostly uniform across the city, with exceptions in the northern and southern rural regions. In these areas, the local delivery stores are considerably distant. Virtual access offers a consistent online shopping experience in Wuhan City, suggesting that there is minimal variation in access to online shopping across the city. Thus, reducing delivery times could further enhance the equality of online shopping experiences.

Fig.5 contrasts the differences between physical and virtual access. The green regions indicate areas where in-store shopping access is superior to online access. These areas are prevalent throughout the city, implying that while virtual access is generally favorable, in-store shopping becomes a competitive option for residents in the city's core.

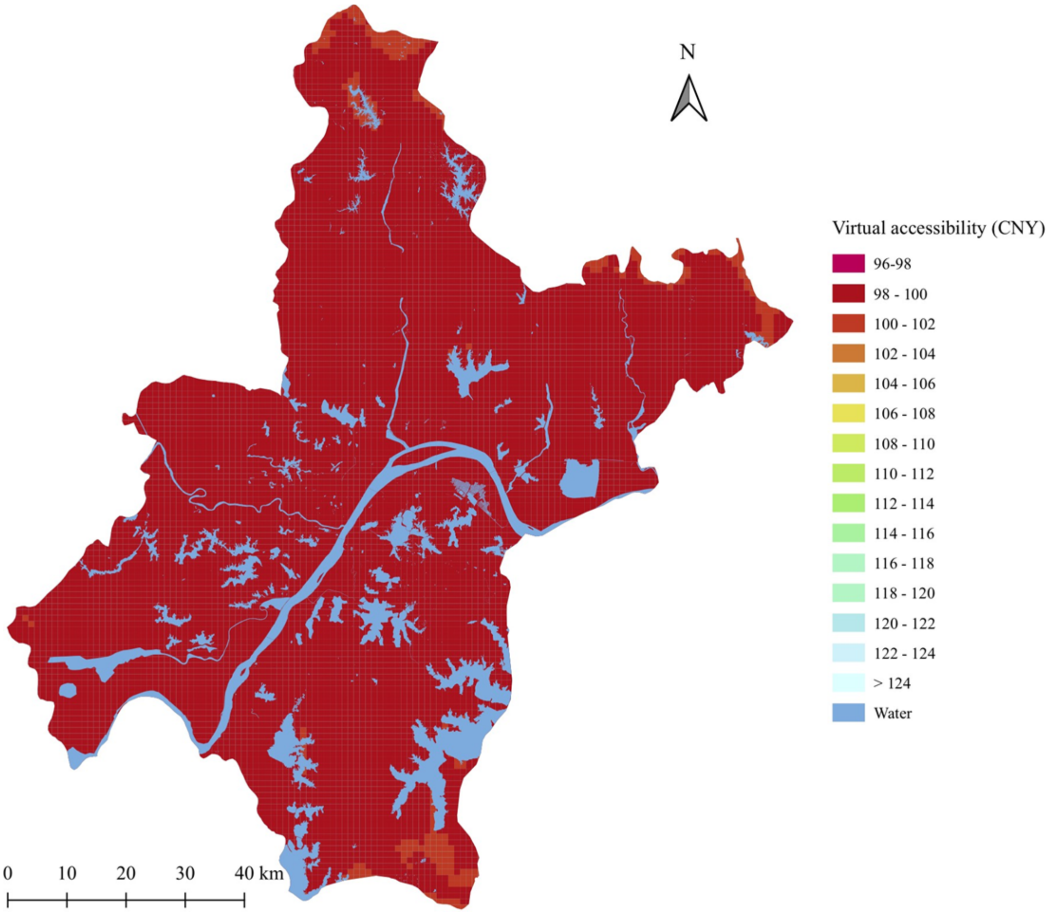

Fig.5 Difference map: physical access minus virtual access

3.3 Sensitivity analysis

The time values for physical travel, package waiting, and both in-store and online shopping have been taken from previous studies. To examine the effect of these values on accessibility measures, sensitivity analyses were conducted.

Fig.6 and Fig.7 display the changes in physical access as the value of travel time and value of in-store shopping time are increased by 25%, 50%, 75%, and 100%, respectively. This takes into account economic growth. While the spatial distributions are largely consistent with Fig.3a, higher values for both parameters correspond to reduced accessibility, aligning with the dual access theory. Nevertheless, as indicated in Fig.6 and Fig.7, the value of in-store shopping has a more profound impact on physical access compared to the value of travel time. This comparison, however, becomes less significant when shopping is merely a stop in a trip chain. It underscores the idea that the influence of travel time value on physical access depends on the additional time spent for shopping within a trip.

Parallel trends are observed for virtual access, as shown in Fig.8 and Fig.9. Virtual access demonstrates a more pronounced shift with the increasing value of online shopping time compared to the value of waiting time.

Tab.2 lists the population-weighted average values for both physical and virtual access. In Wuhan City, virtual access ranks higher than physical access, as evidenced by Fig. 5. Furthermore, the time cost of online shopping plays a more decisive role than in-store shopping for accessibility metrics. This is corroborated by the greater sensitivity of virtual access to online shopping time value, compared to the sensitivity of physical access to the value of in-store shopping time. Similarly, package waiting time has a larger impact on virtual access than the value of travel time does on physical access.

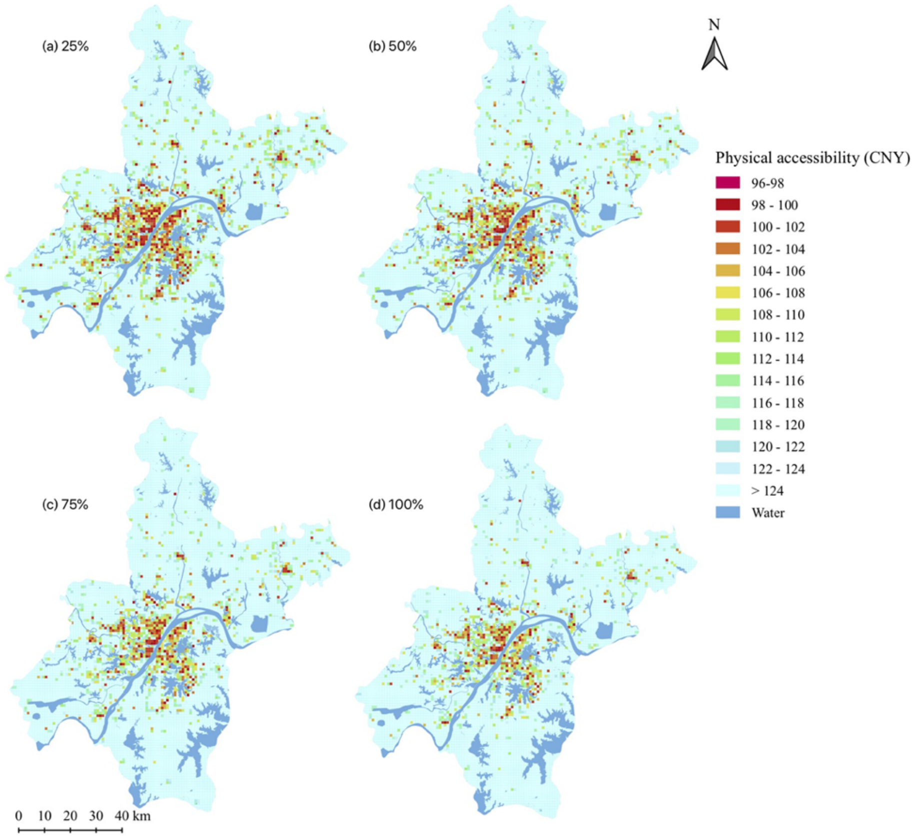

Fig.6 Physical access with the value of travel time increased by 25% to 100%

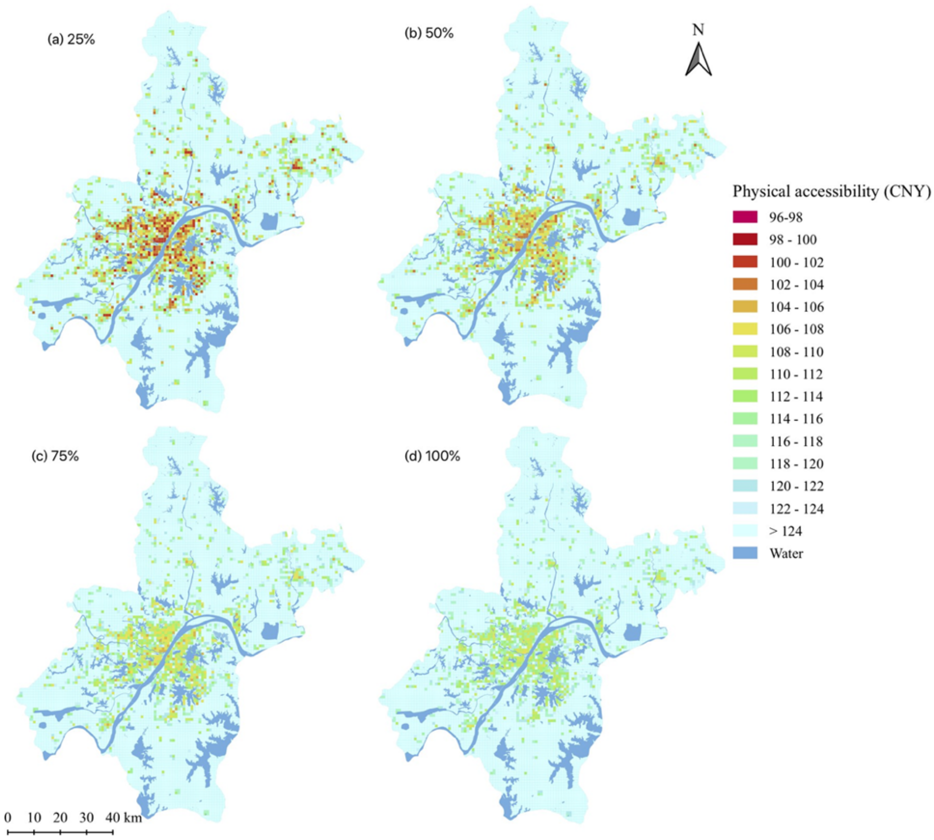

Fig.7 Physical access with the value of in-store shopping time increased by 25% to 100%

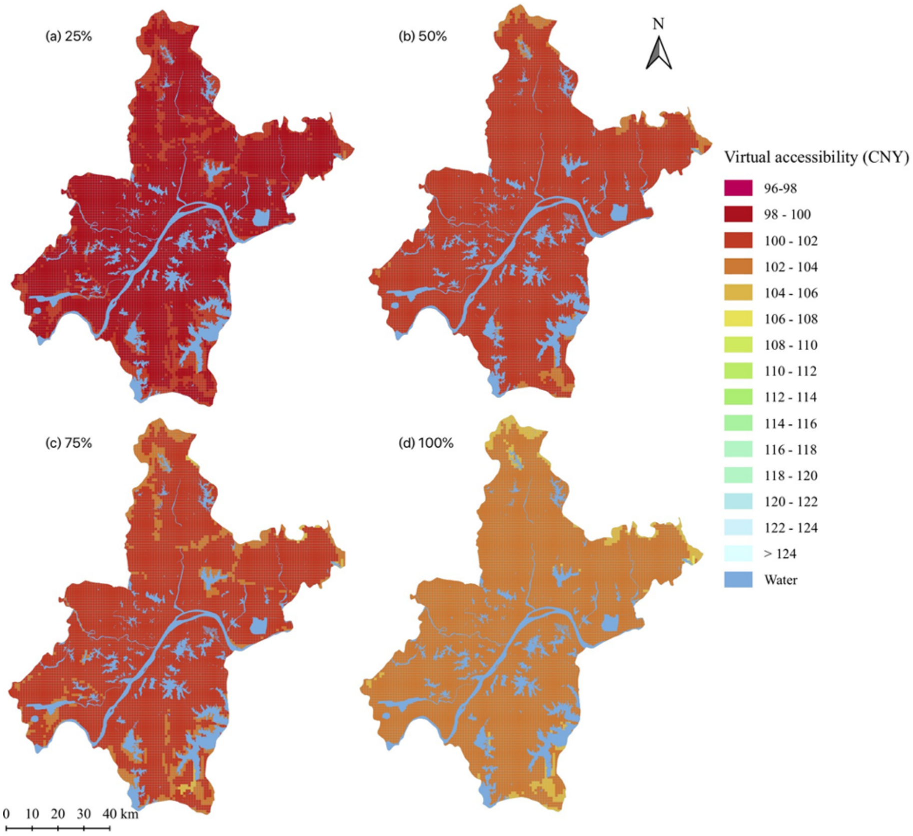

Fig.8 Virtual access with the value of waiting time increased by 25% to 100%

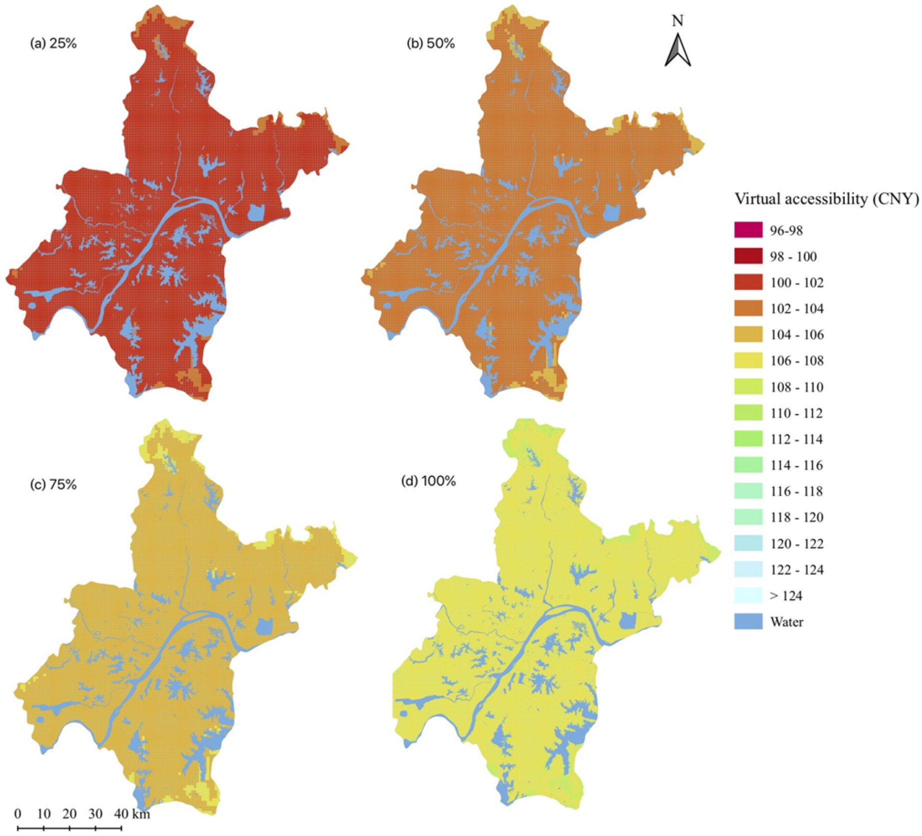

Fig.9 Virtual access with the value of online shopping time increased by 25% to 100%

Name	Variables	Description	Access [CNY]
Physical access			194.05
	Value of travel time	Increase 25%	218.23
		Increase 50%	242.41
		Increase 75%	266.59
		Increase 100%	290.78
	Value of in-store shopping time	Increase 25%	196.42
		Increase 50%	198.80
		Increase 75%	201.18
		Increase 100%	203.56
Virtual access			99.02
	Value of waiting time	Increase 25%	99.85
		Increase 50%	100.67
		Increase 75%	101.49
		Increase 100%	102.31
	Value of online shopping time	Increase 25%	101.09
		Increase 50%	103.16
		Increase 75%	105.23
		Increase 100%	107.30

Tab.2 Population-weighted average access for shopping in Wuhan City

4. Discussion and conclusion

This paper extends the notions of virtual and physical access and introduces a methodological framework to compute them. Wuhan City has been chosen as the case study for a proof-of-concept demonstration.

Distinct differences emerge when contrasting physical with virtual access. Blocks boasting higher levels of physical access are predominantly found in the central part of the city. In contrast, virtual access appears to be more uniformly dispersed across regions. From this standpoint, given access to the Internet, online shopping offers a more equitable experience than physical shopping.

Through the lens of online shopping accessibility, residing in the suburbs holds no significant disadvantage when juxtaposed against living in the central city. Factoring in the probable reduction in travel time alongside the partial substitution effect by Shen (2000), and given the fairly consistent travel time budget as noted by (Levinson & Kumar, 1994), it emerges that virtual access might grant more time for other travel and activities. Virtual access opens the door to many opportunities in the digital realm, some of which remain beyond the reach of physical commuting. This is especially true when virtual access saves time from inconsequential trips, thereby expanding the available travel time budget.

A deeper understanding of both physical and virtual shopping access in urban areas can significantly contribute to transport and land use planning.

The values associated with travel time, waiting time, and both in-store and online shopping time differ across individuals due to factors like income levels, gender, or individual preferences and urgency requirements. Moreover, shopping often dovetails with other activities, which implies that the actual travel cost might undercut our initial assumptions, potentially leading to superior (or lower cost) physical access. Future research could should consider time values for activities like travel, waiting, and shopping. The joint consideration of virtual and physical access can pave the way for a holistic assessment of multifaceted activity and travel outcomes, as posited by (Lavieri et al., 2018). Many digital resources are exclusively or at least partially inaccessible through physical means. Hence, gauging virtual access requires a keen awareness of the overlapping digital and physical realms.

Appendix: experiment of in-store and online shopping

To estimate empirical values of time and cost for shopping virtually and online for the accessibility calculations, experiments were crafted tasking the same 35 participants to engage in both in-store and online shopping, chronicling the time and expenses at each phase as well as itemizing their purchases. Participants were required to acquire identical grocery items both offline and online, ensuring the experiment's sole variance lay in the shopping mode rather than product quantity or type. This ensured any discrepancy in shopping duration was due to the mode, not product diversity (Participants were assured of their data privacy). Online acquisitions were made via platforms like Tmall or JD.com, known for their package delivery services, sidestepping immediate delivery scenarios. Data compilation occurred in April and May 2020, post the ebbing of the COVID-19 pandemic in Wuhan City and the subsequent lifting of lockdowns, albeit with certain behavioral restrictions intact. This data will further inform parameter calibrations for access computations.

Variables	Description	Count	Percentage (%)	Mean	S.D.
Gender	Male (1)	14	40.0	0.40	0.50
	Female (0)	21	60.0		
Age (years)	<19 (1)	0	0.0	2.94	0.76
	19-25 (2)	8	22.8		
	26-35 (3)	24	68.6		
	36-45 (4)	0	0.0		
	46-55 (5)	3	8.6		
Education	High school or less (1)	1	2.8	3.57	0.65
	Colleges/technical school (2)	0	0.0		
	Undergraduate (3)	12	34.3		
	Graduate or more (4)	22	62.9		
Income (CNY)	<3,000 (1)	7	20.0	3.03	1.25
	3,000 - 5,000 (2)	3	8.6		
	5,000 - 10,000 (3)	9	25.7		
	10,000 - 20,000 (4)	14	40.0		
	20,000 - 30,000 (5)	2	5.7		

Tab.3 Descriptive statistics of experiment participants (N=35)

Variables	Description	Mean	Min	Max	S. D.
$T_{t,ij}^{p}$	Travel time (min)	41.91	8	117	31.08
$C_{t,ij}$	Travel cost (CNY)	3.71	0	27	7.35
T_{s}^{p}	In-store shopping time (min)	33.86	3	90	21.54
C_{g}^{p}	In-store shopping cost (CNY)	94.66	4.5	320	64.44
N_{S}^{P}	Number of items (in-store)	4.74	1	13	2.90
$T_{w,ik}$	Waiting time (min)	1079.23	422	3150	535.58
T_{s}^{v}	Online shopping time (min)	28.60	5	120	24.35
$C_{d,ik}$	Delivery cost (CNY)	3.66	0	15	5.24
C_{g}^{v}	Online shopping cost (CNY)	90.05	4.5	310	62.37
N_{s}^{v}	Number of items (online)	4.74	1	13	2.90

Tab.4 Descriptive statistics of variables collected from experiments of in-store and online shopping (N=35, 1 CNY ≈ 0.1428 US$)

Tab.4 furnishes the descriptive statistics. As per Tab.4, among the experiments conducted, online shopping emerges as the cost- efficient alternative. On average, it saves consumers approximately 5.26 minutes and 4.61 CNY compared to in-store shopping. The typical waiting period for online shopping stands at around

1079.23 minutes (close to 18 hours), translating to next-day delivery for most orders. Given the study area's central position in China, inter-province delivery time variations are minimal.
The relationship between shopping time, cost of goods, and the number of purchased items is detailed in Tab.5. As anticipated, the data indicates a linear correlation with positive estimates, statistically significant at the 5% level.

Name		In-store shopping			Online shopping		
		Estimate	**Std. Error**	**Signif.**	**Estimate**	**Std. Error**	**Signif.**
Shopping time	Constant	20.10	6.59	0.004 **	22.03	7.97	0.009 **
	Number of items	2.90	1.19	0.020 *	1.39	1.44	0.343
	R^2		0.1529			0.0273	
Shopping cost	Constant	50.85	19.46	0.013 **	48.01	18.87	0.016 **
	Number of items	9.24	3.51	0.013 *	8.86	3.41	0.014*
	R^2		0.1733			0.1703	

*** p-value<0.001, ** p-value<0.01, * p-value<0.05, . p-value <0.1

Tab.5 Regressions of shopping time and cost (N=35)

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Image Sources

Fig.1: Schematic of computing physical and virtual shopping accessibility;

Fig.2: Grocery and delivery store densities in Wuhan City (number/km2);

Fig.3: Physical access to 4 items in Wuhan;

Fig.4: Virtual access for shopping in Wuhan City;

Fig.5: Difference Map: Physical access minus virtual access;

Fig.6: Physical access with the value of travel time increased by 25% to 100%;

Fig.7: Physical access with the value of in-store shopping time increased by 25% to 100%;

Fig.8: Virtual access with the value of waiting time increased by 25% to 100%;

Fig.9: Virtual access with the value of online shopping time increased by 25% to 100%.

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