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Contribution to the assessment of the sustainability of urban freight transport in Morocco: A PLS-SEM Approach

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A B S T R A C T

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With globalization and the expansion of cities, the movement of goods and people has significantly increased, both economically and socially. This sector serves as a vital component of any economy, fostering economic and social development. However, its detrimental effects pose significant challenges for countries seeking to pursue sustainable development policies. Being one of the most energy-intensive sectors, it emits greenhouse gases and pollutants, contributing to environmental degradation and noise pollution. While increased traffic and mobility offer benefits, they also strain resources and lead to higher energy consumption. The primary objective of this article is to assess the sustainability of freight transport in the Moroccan city of Fez and propose supportive solutions for various stakeholders in urban logistics. This involves examining the complex relationship between different factors and the sustainability of Urban Freight Transport (UFT), including accessibility, congestion, road occupancy, environmental impacts, health impacts, and road safety. The research data were collected from 100 managers and employees of logistics and transportation companies in Morocco. Structural equation modeling was utilized to test and confirm the hypotheses and the research model. The results of these analyses demonstrated a positive impact relationship between the various factors and the sustainability variable. Subsequently, we suggest the establishment of delivery areas and an urban distribution center as two sustainable logistics solutions. The analysis and its findings can be applied to any other city.

1. Introduction

Transport infrastructure plays a crucial role in driving a country's economic growth. It facilitates the movement of people and goods across a network of roads, railways, airports, and ports (Grosso, 2014). Transportation is an ever-evolving human endeavor. Since ancient times, humans have sought to enhance mobility. However, the utilization of fossil fuels, the expansion of transport infrastructure, and the adaptation of cities to accommodate transportation networks have significant environmental repercussions. Despite these adverse effects, transportation delivers a multitude of services to human society, benefiting both economically and socially. The environment represents just one of the three domains where transportation exerts its influence. Unlike its economic and social aspects, transportation's impact on the environment tends to be negative. This article focuses on assessing the environmental impact of urban freight transport. The main objective of this article is to identify the sustainability components of urban freight networks. This is accomplished by addressing the following inquiries: Firstly, what are the primary issues concerning urban freight transport and how do they interrelate? Secondly, what factors contribute to the sustainability of urban freight transport? Thirdly, what influence do individual factors have on ecological sustainability?

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Finally, using the example of the commercial streets in the city of Fez, what sustainable logistics solutions can be proposed to mitigate these impacts?

The primary aim of this article is to provide guidance to decision-makers by presenting a sustainable model for urban goods transit. To enhance the sustainability of urban freight transportation, a set of action principles is proposed. The objectives of the article are as follows: Firstly, to define the key issues related to the sustainability of urban freight transportation. Secondly, to identify the factors determining the sustainability of urban freight transport. Thirdly, to develop a model illustrating the relationships among these variables. Fourthly, to validate the correlations of the model's impacts. Finally, to suggest sustainable logistics solutions, such as delivery areas and urban distribution centers, with a case study focusing on a commercial street in the city of Fez.

2. Literature review

2.1. Theoretical framework

This section introduces a conceptual framework, discussing the theoretical concepts that will be utilized throughout this article. It explores the connection between urban freight transport and the three pillars of sustainable development.

2.1.1. Urban logistics

Urban logistics is a field focused on planning and enhancing distribution systems within urban areas, with its primary goal being the timely delivery of products while meeting customer demands (Chanut et al., 2012). According to Gonzalez-Feliu (2017), urban logistics is defined based on flow types, the involved actors, and sustainability vision. Regarding flow types, much research has concentrated on last-mile logistics (Taniguchi, 2014; Benjelloun & Crainic, 2008; Macharis and Melo, 2011). The initial study on urban logistics addressed distribution in commercial sectors by Demetsky (1974). Woudsma (2001), Behrends et al., (2008), on the other hand, restricted urban goods transport to B2B flows. However, Durand & Lyche (2009) included deliveries to individuals in addition to those to commercial areas within the flows conducted by economic actors and urban logistics professionals. Nevertheless, Gonzalez-Feliu (2017) has suggested various categorizations involving the concept of public and private players (consumers and urban space organizers). For consumers, the stakes revolve around the cost-delay-quality triad: minimal transportation and handling costs, reduced non-value-added time, and maximum quality. For the second category of actors (organizers of public space), the issues are closely linked with the sustainability concept, based on the principle that the city must be a livable, viable, and equitable place (Gonzalez-Feliu, 2017; Gonzalez-Feliu et al., 2014; Patier & Toilier, 2018; Ramirez-Villamil et al., 2021).

2.1.2. Urban goods transport

Urban goods transport, as defined by Serouge et al. (2014), encompasses all movements of goods conducted using mechanized vehicles, excluding pipeline transport and pedestrian travel. The cycle of goods exchanges is vital for the functioning of the city and its inhabitants comprises various elements. Firstly, there is the production system, which encompasses heavy industry, intermediate goods, and consumer goods. Secondly, there is the supply system, which includes logistics platforms for storage, consolidation, deconsolidation, order preparation, wholesale, and retail trade. Additionally, household supply methods, such as in-store purchases, relay point delivery, and drive-through services, are significant. Moreover, personal and business services often entail the removal or installation of material goods. Lastly, there are supporting activities essential for city operations, such as maintaining urban networks, managing construction sites, and handling postal parcels and mail.

2.1.3. Sustainable freight transport

Sustainable transport is the manifestation of sustainable development within the transportation sector, also known as sustainable mobility (Jami & Kammas, 2013). It pertains to the utilization of modes of transportation and routing of goods that align with the objectives of sustainable development. Sustainable transport encompasses multiple dimensions, including the environmental dimension, by providing eco-friendly transport options, as well as the social dimension, by ensuring transportation accessibility for all, and the economic dimension, by offering efficient and competitive transport services. Sustainable freight transport aims to foster complementarity and coherence by integrating these three dimensions. It aims to deliver transportation that is "safe, inclusive, accessible, reliable, affordable, energy-efficient, environmentally friendly, low-carbon, and resilient to shocks and disruptions, including those caused by climate change and natural disasters" (Rothstein, 2015). According to data from the US Environmental Protection Agency (2021), the transportation, industrial, commercial, and residential sectors are responsible for the majority of carbon dioxide (CO_2) emissions. Effective transportation planning within the network is essential to address environmental concerns in the supply chain, and all operations should strive to maintain a low carbon footprint. Carbon emissions increase linearly with the weight of the transported cargo, as depicted in the graphs in Figure 1. Road transportation emerges as the most carbon-emitting mode of transportation, while rail transportation stands out as the most environmentally friendly option (Temizceri & Kara, 2023).

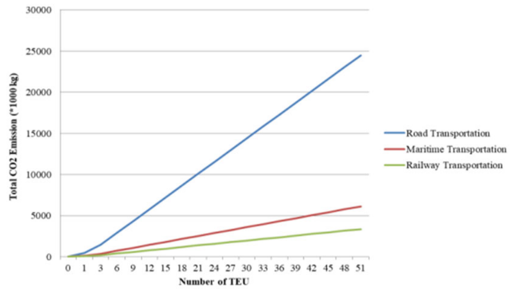

Fig. 1. CO2 emissions of different modes of transport in freight transportation
Source: Temizceri and Kara (2023)

2.2. Moroccan Context: Assessing the Sustainability and Shortcomings of Freight Transport in the Road Haulage Sector

No one can deny that road freight transport in Morocco is far from optimized and is having a negative impact on the environment. Firstly, increased energy consumption is evident; Morocco is one of the most polluting countries in the Arab Maghreb region, consuming 223.6 thousand tonnes of diesel NOx (nitrogen oxides) (Eurostat, 2010, p. 31). Secondly, noise pollution is a significant issue, especially in urban areas, where traffic is a major source of noise. Apart from its unpleasantness, noise (at sound levels > 65 dB) is a source of health problems, including stress, sleep disorders, heart disease, and hearing loss. This depends on several parameters such as volume, intensity, frequency, exposure, duration, and variability. Thirdly, water pollution is another consequence; road transport has both a direct and indirect impact on water quality. Road accidents and vehicle exhaust fumes are both sources of hydrocarbon and hazardous chemical spills. Additionally, accidents have serious consequences for human life and health. Accident and death rates on the roads are rising sharply, and national road safety statistics are alarming. According to the Ministry of Transport and Equipment, Morocco recorded more than 4,000 deaths and thousands of injuries in 2012, with the cost of accidents representing 1% of GDP and estimated at over 12 billion dirhams. OECD sources indicate a comparative analysis of traffic accidents between Morocco and several other countries, revealing alarming facts about road safety. For example, a vehicle in Morocco is 13.77 times more likely to cause fatalities than in France, 18.88 times more than in Sweden, and 10.3 times more than in the United States. Furthermore, modes of land transport cause habitat fragmentation, disrupting the natural environment and dividing it into smaller spaces. Habitat fragmentation has four components. Firstly, transportation networks directly destroy the natural environment by replacing it with infrastructure. Secondly, the passage of transport disturbs the neighboring habitat, leading to pollution via chemical substances, noise, light, etc. Additionally, a roadway creates a barrier separating functional zones within a habitat, resulting in ecosystem division. Lastly, the transportation lane can be the source of direct collisions between animals and moving vehicles (Crainic & Hewitt, 2021).

2.3. Empirical Studies

2.3.1. Assessing the sustainability of urban freight transport

A sustainable freight transport system in a city is built upon five functions, as outlined above: creating and developing infrastructure, organizing urban freight transport (UFT), managing roads and public spaces, preserving the environment, and safeguarding public health. These functions are respectively associated with accessibility, congestion, occupation of public spaces, environmental impacts, health impacts, and safety. For each function, the framework is divided into two main sections: "Strategic" and "Organizational". Sustainable freight transport must align with the following objectives, as articulated by Behrends et al. (2008): Firstly, it should ensure accessibility provided by the transport system for all types of freight transport. Secondly, it should aim to reduce air pollution, greenhouse gas emissions, waste, and noise to levels that do not adversely affect human health or the environment (Borges et al., 2015). Moreover, it should strive to enhance resource and energy efficiency and the cost-effectiveness of freight transport, while considering external costs. Finally, it should contribute to enhancing the attractiveness and quality of the urban environment by minimizing accidents, optimizing land use, and preserving citizens' mobility. From this definition, it is evident that the factors determining sustainable freight transport include accessibility, congestion, road occupancy, environmental impacts, health impacts, and road safety.

Development of accessible logistics infrastructures and Sustainability of the UFT system

Accessibility issues result in increased costs for transporting goods, as well as heightened fuel consumption. Additionally, congestion exacerbates the strain on transmission systems, increases driver stress, and raises the risk of accidents (Bhat et al., 2002; Boudouin et al., 2002; Routhier, 2002). Therefore, we hypothesize that:

H$_1$: *The development of accessible logistics infrastructures has a direct impact on the sustainability of the UFT system.*

2.3.2. Congestion and Sustainable organization of urban freight transport

Indeed, the literature supports the notion that enhancing and developing accessible infrastructure plays a crucial role in promoting traffic flow and, consequently, contributes to the sustainability of the transportation system (Dablanc & Ross, 2012; Morganti et al., 2014). There is a direct correlation between urban congestion and the sustainability of the freight transport system: in urban environments characterized by limited land availability, congestion, pollution, and noise are prevalent (Benjelloun & Crainic, 2008). However, Morana & Gonzalez-Feliu (2015) affirm that maintaining smooth goods flows remains a primary concern for stakeholders. Delaitre (2008) argues that congestion impedes the economic growth of the city, with road congestion specifically hindering the movement of goods. Based on these previous empirical studies, the following hypothesis can be proposed:

H$_2$: *Congestion has a direct impact on the organization of the urban freight transport system.*

2.3.3. Public space management and Sustainability of UFT

Public space planning and road management are crucial factors in ensuring the sustainability of a freight transport system (Delaitre, 2008). For newly developed or growing urban areas, roads are undeniably essential components of the urban infrastructure. A road network with insufficient capacity relative to the volume of traffic leads to congestion, detrimentally affecting the urban economy and exacerbating environmental pollution (Paulley et al., 2004; Delaitre et al., 2007). Consequently, several authors, including Patier et al. (2000), have established the correlation between regulating and controlling the use of road space by both moving and stationary vehicles and the sustainability of the transportation system, and have proposed a set of indicators. Therefore, we posit the following hypothesis:

H$_3$: *The management of public spaces and land has an impact on the sustainability of the UFT system.*

2.3.4. Integrating and implementing an environmental policy and sustainability of UFT

Several stakeholders have emphasized the sustainability of the urban freight transport (UFT) system, particularly its ecological aspect (Liimatainen et al. (2015). Delaitre elucidates these impacts, affirming that air pollution is not the sole environmental concern; rather, vibrations, physical disturbances (visual pollution), and induced noise all contribute to altering the sustainability of the UFT (Delaitre, 2008). To mitigate these disturbances, public authorities initially implemented regulatory and temporary measures in the 1980s, primarily focusing on restricting access or parking by municipal teams. Therefore, we hypothesize that:

H$_4$: *Integration and implementation of an environmental policy on the sustainability of UFT.*

2.3.5. Implementing a public health protection policy and Sustainability of UFT

The literature confirms the link between implementing a public health protection policy involving regulations and practices and the sustainability of the urban freight transport (UFT) system. Indeed, transportation must adhere to sustainable constraints, and often, the transportation of goods in urban areas can only be envisioned through the utilization of green transport, i.e., environmentally friendly transportation, if we aim to mitigate the effects of pollution on citizens' health. This may involve the use of electric and low-noise transport to cater to residents' preferences (Ughetto & Garnaud, 2012; Morana & Gonzalez-Feliu, 2015). Additionally, Delaitre (2008) confirms that urban freight traffic disproportionately contributes to the degradation of quality of life. In major urban areas, regulatory (or recommended) thresholds for air pollution (particulate matter and NO2 concentrations, ozone pollution in geographical extension) and noise exposure limits are frequently surpassed. These exceedances, which lead to various health impacts (respiratory and cardiovascular diseases, cancers, stress), are primarily attributed to road traffic (Andre et al. (2015). Based on these previous empirical studies, the following hypothesis can be proposed:

H$_5$: *The implementation of a public health protection policy: regulations and access restrictions on the sustainability of UFT.*

2.3.6. Implementing a road safety strategy and sustainability of UFT

Transport is considered sustainable or viable when it ensures the safety of individuals and ecosystems while fulfilling mobility needs without compromising renewable and non-renewable resources. An OECD definition underscores the significant influence of road safety strategy on the sustainability of a road transport system (Jami & Kammas, 2013). In Morocco, road safety is among the initiatives proposed by regulatory authorities and professional associations to promote sustainable freight transport. Therefore, one of the objectives of the national logistics strategy (with regard to its ecological component) is to enhance road safety within urban areas. This includes measures such as installing fixed and night radars and implementing a computerized system for managing road violations (Jami & Kammas, 2013). However, Delaitre (2008) suggests a series of actions to achieve road safety objectives, including emergency plans, speed controls, regulations on delivery times and parking, and access restrictions to certain areas. Thus, we hypothesize that:

H_6: *The implementation of a road safety strategy influences the sustainability of the UFT system.*

In our research, we have drawn on the GRAI method, who is of particular interest for the UFT system, as it enables the expression of a global and macroscopic vision of the structure of the system studied. However, the extended literature review reveals that there are a number of factors that contribute and impact on the sustainability of urban transport. The proposed conceptual model includes six independent variables, accessibility, congestion, occupation of public space, environmental impacts, health impacts and road safety, and one dependent variable, sustainability of urban freight transport (Fig. 2).

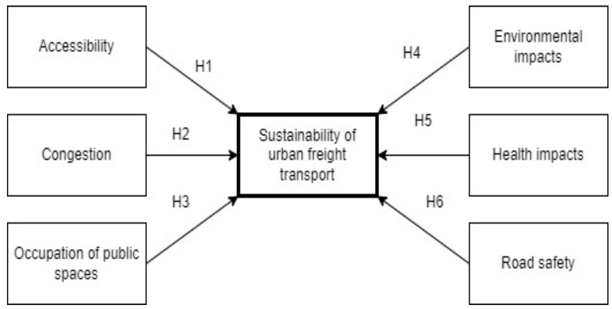

Fig. 2. Proposed research model.

3. Research methodology

3.1. Data Collection and Instrument development

For this investigation, data collection for this study involved the distribution of a questionnaire online via google forms and face to face and administered between September 2023 and November 2023. The questionnaire's formulation drew inspiration from a literature review, where research items were borrowed from empirical studies conducted in different contexts and the questionnaire consists of two sections. The initial section focuses on obtaining data related to the sociodemographic characteristics of the participants. In the second section, we gather data concerning the latent constructs outlined in the conceptual model. The various constructs of our model were transcribed into multi-item measures and assessed using a five-point Likert-type bipolar scale, measuring respondents' degree of agreement or disagreement ranging from “strongly disagree” to “strongly agree”. Such a scale was deemed suitable for the Moroccan context, in contrast to the 7-point scale where respondents often spread their responses and had difficulty orienting themselves (Testa & Simonson, 1996). The table below outlines the measurement instruments.

Table 1
Instrument development

Constructs	No of items	Sources
Accessibility (ACC)	3 items	Dziennus et al. (2016), Piao et al. (2016), Dablanc (2022), Toilier et al. (2005)
Congestion (CNG)	6 items	Dziennus et al. (2016), Piao et al. (2016), Muñuzuri and Van Duin (2014), Dablanc et Ross (2012), Morana & Gonzalez-Feliu, (2012), Van de Berg et al. (2007)
Occupation of public space (OPS)	3 items	Patier et al. (2000), Ambrossini et al. (2011), Gonzalez-Feliu (2008)
Environmental impacts (EI)	4 items	Gonzalez-Feliu (2017), Morana & Gonzalez-Feliu (2012), Dablanc (2008)
Health impacts (HI)	4 items	Spinedi (2008), Maggi (2007)
Road safety (RS)	3 items	Morana et Gonzalez-Feliu (2015)
Sustainability of urban freight transport (SUS)	7 items	Liimatainen et al, (2015), Morana & Gonzalez-Feliu (2012), Gunasekaranet & Kobu (2007), Christopher (2000), Rabbani et al. (2018)

3.2. Data analysis method

In our empirical study, we employed the Structural Equation Modeling (SEM) method using SMART PLS 4 software to assess and confirm the hypotheses and the research model. The initial step in the PLS approach involves verifying the validity of the measurement models by examining both convergent and discriminant validity. Convergent validity requires the assessment of various criteria, namely, Cronbach alpha (Alpha ≥ 0.7), composite reliability (CR ≥ 0.7) and average variance extracted (AVE≥ 0.5) (Hair et al. (2014). Discriminant validity entails assessing two criteria, namely: variable correlation and cross loadings (Henseler et al. (2015). The second stage of the PLS method involves assessing the structural model according to several criteria, namely: coefficient of determination (R2), predictive relevance (Q2), goodness-of-fit (GoF), and hypotheses testing (T-statistics and P-values).

4. Results

4.1. Descriptive analysis

Analyzing the characteristics of respondents in the survey conducted in Fez, Morocco reveals that the sample of 100 individuals encompasses a diverse range of professional roles intricately linked to the city's well-known road traffic and urban transportation dynamics. Among the participants, a significant 29% are Logistics Managers, highlighting the crucial role of logistics services in a city known for its bustling urban road transport. Additionally, a quarter (25%) comprises Freight-holding Drivers, emphasizing the city's importance as a hub for freight transport. Furthermore, the survey captured the perspectives of professionals involved in urban planning and development, with 5% being Managers of the Planning and Transportation Service and 7% belonging to the Urban Studies and Mobility Service within the city's municipality. The presence of 20% Business Managers operating in the busiest commercial areas adds another layer to the dynamic professional landscape under examination. Lastly, environmental and sustainable development perspectives are represented, with 8% being Managers and members of the Regional Observatory for Environment and Sustainable Development, and 6% involved in the Road Transport and Road Safety Service within the Regional Directorate of Equipment and Transport. Regarding the educational level of the survey participants, Forty-four percent hold a master's degree (BAC+5), indicating a significant presence of highly educated individuals. Twenty-seven percent possess a bachelor's degree (BAC+3), while 29% have completed a baccalaureate (BAC), demonstrating the diversity in educational backgrounds within the sample. This variation in educational levels provides valuable insights into the demographic composition of professionals contributing to the survey from Fez, Morocco.

4.2. Results of outer models assessment

The validity of the measurement model encompasses four elements: Cronbach's Alpha, Composite, Rho_A, and AVE. According to Table 2, we observe that all seven variables adhere to the accepted values for Cronbach's Alpha, Composite, Rho_A, and AVE. However, scrutiny within the SMART PLS model reveals two items presenting a loading value lower than 0.7, these items are "ACCESS3" and "CONGT6". The items concerned were removed to enhance the model. In the second test, the figure 3 indicates that all items have an index exceeding 0.7, confirming that the second step of the measurement model's validity aligns with the scientific standards of management science (Hair et al., 2014; Tenenhaus, 1999; Tenenhaus et al., 2004). Additionally, discriminant validity is assessed through the Fornell and Larcker criterion, demonstrating that the diagonal values are higher than any values below the diagonal (Table 2). Similarly, the discriminant validity of the outer models is established using the cross-loading criteria, and according to Table 2, it indicates that the highest correlation coefficient is recorded at the intersection points of each variable with one another. All these findings confirm the discriminant validity of the scale. Furthermore, the discriminant validity of the outer model is evaluated through the cross-loading criterion, demonstrating that the loadings of the items are greater than all its cross-loadings (Table 2).

Table 2
Results of reliability, convergent and discriminant validity

Construct	CA	CR	Rho_a	AVE	ACC	CNG	EI	HI	OPS	RS	SUS
ACC	0.810	0.913	0.816	0.840	**0.916**						
CNG	0.964	0.972	0.971	0.874	0.765	**0.935**					
EI	0.886	0.920	0.908	0.743	0.390	0.386	**0.862**				
HI	0.892	0.933	0.896	0.822	0.554	0.565	0.742	**0.906**			
OPS	0.951	0.968	0.969	0.910	0.445	0.452	0.813	0.690	**0.954**		
RS	0.941	0.971	0.943	0.945	0.660	0.668	0.718	0.850	0.691	**0.972**	
SUS	0.934	0.947	0.937	0.720	0.729	0.756	0.759	0.850	0.763	0.926	**0.848**

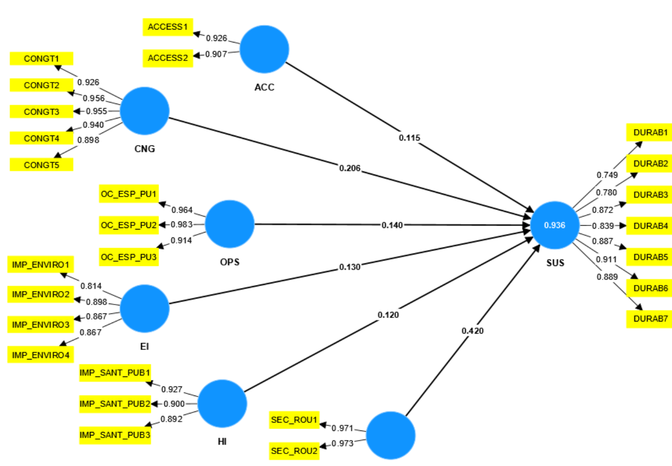

Fig. 3. Measurement model validation.

Table 3
Discriminant validity based on the cross-loading criteria

	ACC	CNG	SUS	EI	HI	OPS	RS
ACCESS1	**0.926**	0.740	0.702	0.356	0.527	0.437	0.602
ACCESS2	**0.907**	0.659	0.631	0.359	0.487	0.374	0.608
CONGT1	0.706	**0.926**	0.740	0.381	0.594	0.432	0.660
CONGT2	0.721	**0.956**	0.707	0.408	0.521	0.477	0.610
CONGT3	0.753	**0.955**	0.768	0.398	0.621	0.459	0.697
CONGT4	0.775	**0.940**	0.729	0.374	0.497	0.437	0.636
CONGT5	0.599	**0.898**	0.559	0.211	0.372	0.280	0.491
DURAB1	0.905	0.764	**0.749**	0.372	0.541	0.441	0.617
DURAB2	0.709	0.934	**0.780**	0.397	0.609	0.442	0.673
DURAB3	0.528	0.563	**0.872**	0.789	0.735	0.938	0.771
DURAB4	0.500	0.467	**0.839**	0.865	0.692	0.797	0.793
DURAB5	0.584	0.618	**0.887**	0.720	0.889	0.653	0.811
DURAB6	0.597	0.652	**0.911**	0.645	0.817	0.580	0.926
DURAB7	0.565	0.545	**0.889**	0.659	0.733	0.630	0.880
IMP_ENVIRO1	0.162	0.084	0.475	**0.814**	0.424	0.666	0.479
IMP_ENVIRO2	0.322	0.303	0.663	**0.898**	0.634	0.744	0.648
IMP_ENVIRO3	0.319	0.360	0.629	**0.867**	0.628	0.663	0.581
IMP_ENVIRO4	0.470	0.491	0.783	**0.867**	0.792	0.725	0.718
IMP_SANT_PUB1	0.552	0.570	0.824	0.740	**0.927**	0.667	0.792
IMP_SANT_PUB2	0.479	0.534	0.723	0.593	**0.900**	0.536	0.751
IMP_SANT_PUB3	0.471	0.431	0.759	0.675	**0.892**	0.667	0.768
OC_ESP_PU1	0.488	0.510	0.797	0.784	0.708	**0.964**	0.739
OC_ESP_PU2	0.446	0.431	0.755	0.807	0.671	**0.983**	0.688
OC_ESP_PU3	0.318	0.334	0.610	0.734	0.582	**0.914**	0.525
SEC_ROU1	0.623	0.655	0.880	0.659	0.824	0.604	**0.971**
SEC_ROU2	0.659	0.645	0.919	0.735	0.828	0.736	**0.973**

4.3. Results of assessing structural model

Testing the inner model includes verifying multiple criteria, such as the coefficient of determination (R2), the predictive relevance (Q2), and the goodness-of-fit. The study findings indicate that an R2 value of sustainability of urban freight transport is 0.936, indicating an appropriate degree of determination of this dependent variable (Fig. 4).

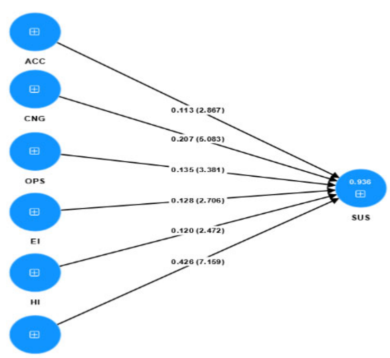

Fig. 4. Hypotheses testing results.

As shown in Table 4, the Q² value for supply chain performance is greater than 0.39, which is 0.561, providing proof of the model's predictive relevance (Hair et al., 2020). Lastly, the GoF value is 0.76465, reflecting a large goodness-of-fit (Henseler et al., 2009). Based on the PLS-SEM outputs, six hypothesis relationships were confirmed (Table 4 and Fig. 4).

Table 4
Hypotheses testing results

Hypothesis	Structural path	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T-statistics	P-values	Result
H1	**ACC → SUS**	0.113	0.106	0.040	2.867	0.004**	**Accepted**
H2	**CNG → SUS**	0.207	0.215	0.041	5.083	0.000***	**Accepted**
H3	**OPS → SUS**	0.135	0.130	0.040	3.381	0.001***	**Accepted**
H4	**EI → SUS**	0.128	0.126	0.047	2.706	0.007**	**Accepted**
H5	**HI → SUS**	0.120	0.126	0.049	2.472	0.013*	**Accepted**
H6	**RS → SUS**	0.426	0.425	0.060	7.159	0.000***	**Accepted**

*** $p < 0.001$; **$p < 0.01$; *$p < 0.05$. GoF = 0.884739187
Predictive relevance: Q² SUS = 0.696

Firstly, accessibility and congestion are correlated with the variable “sustainability” with significant results: ($T = 2.867$, $p < 0.01$) and ($T = 5.083$, $p < 0.001$). The outcomes of both hypotheses are positive, thereby confirming hypotheses H1 and H2. Furthermore, the results also indicate a direct positive impact of the variable “public space occupancy” on the variable “sustainability” ($T = 3.381$, $p < 0.001$), as well as the variable “Environmental impacts” ($T = 2.706$, $p < 0.01$) on the variable “sustainability”. This validates hypotheses H3 and H4. Finally, it is noteworthy that hypotheses H5 and H6 regarding the positive effect between the variables “Public health impacts” and “Road safety” and the explanatory variable “sustainability of urban freight transport” are validated ($T = 2.472$, $p < 0.05$) and ($T = 7.159$, $p < 0.001$).

5. Discussion and conclusion

5.1. Discussion

The aim of this empirical investigation was to study the impact of different factors of the sustainability of urban transport, including accessibility, congestion, occupation of public space, environmental impacts, health impacts, and road safety on the sustainability of urban freight transport in the Moroccan context. Therefore, this study aimed to fill a gap in knowledge concerning the sustainable transportation literature concerning the correlation between the different factors that impact of the sustainability of urban freight transport. In summary, all six hypotheses of our study have been empirically confirmed and validated. The first finding highlights a positive relationship between the development of accessible logistics infrastructure and the sustainability of the Freight Transport System (FTS). This conclusion aligns with results from prior theoretical and empirical studies, including those by Dablanc and Ross (2012), Morganti et al. (2014), Giuliano et al. (2017), Morana and Gonzalez-Feliu (2012), and Gonzalez-Feliu et al. (2014). Additionally, a positive relationship between congestion and the sustainability of urban freight transport has been established. Therefore, we can infer that congestion positively impacts the sustainability of urban freight transport, consistent with the majority of theoretical and empirical research on this relationship, such as the works of Benjelloun & Crainic (2008), Muñuzuri and Van Duin (2014), Dziennus et al. (2016), Delaitre (2008), and Morana and Gonzalez-Feliu (2015). The result of the third hypothesis confirms that the occupation of public space positively influences the sustainability of the Freight Transport System. This finding is in agreement with the conclusions of certain authors, such as Patier et al. (2000), Ambrosini et al. (2010), Delaitre (2008), and Morana and Gonzalez-Feliu (2015). Regarding the fourth hypothesis, the result indicates that the integration and implementation of environmental policies have a positive impact on the sustainability of the Freight Transport System. These findings align with previous theoretical and empirical studies, including those by Muñuzuri and Van Duin (2014), Gonzalez-Feliu (2008), Delaitre (2008), Dablanc (2008), and Morana and Gonzalez-Feliu (2015). The result of the fifth hypothesis suggests that the implementation of public health protection policies has a positive impact on the sustainability of the Freight Transport System. This observation is consistent with the findings of prior theoretical and empirical research, including those by Dablanc (1997), Delaitre (2008), Gonzalez-Feliu (2008), Maggi (2007), Spinedi (2008), Andre (2015), Andre et al. (2015), Ughetto & Garnaud (2012), and Morana and Gonzalez-Feliu (2015). Finally, the result of the sixth hypothesis (H6) confirms the existence of a positive relationship between road safety and the sustainability of the Freight Transport System. This result is in line with the conclusions of prior theoretical and empirical studies, including those by Delaitre (2008) and Jami & Kammas (2013).

5.2. Conclusion

The objective of this study was to explore the relationship between urban freight transport and sustainability. Six sustainability factors for urban freight transport were identified based on a literature review. Subsequently, we examined the influence relationships between these factors and sustainability using structural equation modeling with the SMART PLS 4 software.
This research work provides operational input for the various players involved in urban logistics. The UFT sustainability assessment model offers a clear view of the degree of influence of each factor and provides decision support for those in charge (companies and public authorities), with the aim of reducing the negative impact of urban freight transport on the various elements of sustainable development. This work makes a real contribution by proposing a field survey and an approach to setting up delivery and distribution urban center areas. It is a support study for public authorities to ensure a balance between the economic, social, and environmental objectives of goods transport within cities. Although this research work makes methodological and operational contributions, it does have several limitations. From a technical point of view, we can't deny that this work has its limits, which can be seen first and foremost in the complexity of carrying out field surveys to validate hypotheses and set up delivery areas and the CDU in our study area on rue Akbet Elayed El khammar (Fez, Morocco). The location of this street in the old Medina made it difficult to count traffic and to apply for video surveillance as an automatic counting technique.

One of the most important limitations of this research work is the choice of a small sample size, which we will try to enlarge by involving other cities to better support the hypotheses and certainly involve other variables. Taking the above-mentioned limitations as a starting point, we propose the development perspectives of this research work. We can start by broadening the sample both spatially and in terms of respondents, and we will then try to validate this model on other, larger samples by collecting data from several other Moroccan cities, which would provide new variations in the freight transport system and imply further hypotheses. Of course, the proposed logistical solutions improve the sustainability of urban freight transport, but the involvement and intervention of public authorities and all the players in the UFT system would add a realistic touch and make the solutions more feasible and effective. It is also very important to build on the achievements and sustainable logistics solutions proposed by other countries, apply them and contextualize them to Moroccan cities.

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