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Developing a Smart City Logistics Assessment Framework (SCLAF): A Conceptual Tool for Identifying the Level of Smartness of a City Logistics System

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Abstract: One of the main building blocks for sustainable cities is the development and efficient operation of a viable and sustainable city logistics system. City logistics exhibit several practical complications due to the conflicting interests of multiple actors involved, as well as the vague role or reluctant involvement of the public sector. Despite the plethora of innovative city logistics initiatives developed in European cities and European policy priorities towards the promotion of smart cities, little is known about the level of smartness of city logistics systems in Europe. In response to that, this paper proposes a conceptual multi-criteria and multi-assessment framework as a guidance tool for city planners, aiming to support the in-depth understanding of the main components of a smart city logistics ecosystem and facilitate the self-assessment of a city's level of smartness. The proposed framework represents a four-level hierarchical assessment pyramid involving four main impact areas: (i) smart governance, (ii) smart economy, (iii) smart actors, and (iv) smart environment. A more in-depth analysis of each impact area is separately conducted by deconstructing the impact areas in specific criteria, sub-criteria, and KPIs. This paper presents in detail the methodology followed and the main components of this tool.

Keywords: assessment framework; smart city logistics; city logistics planning

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1. Introduction

A city's structure has been metaphorically considered by researchers and urban planners as a living and growing organism, since the comparison of a city with a human facilitates the understanding of the city's dynamic socio-economic, technical, and policy environment [1]. Approximately 80% of people live in urban areas in Europe, and cities generate 85% of the European Gross Domestic Product (GDP) [2]. The substantial growth of urban areas results in intensive economic and social activities and the consumption of major energy resources—approximately 70% of global resources are consumed by cities, which implies an even higher demand for delivering products among citizens or companies within the urban environment. On the other hand, the rapid growth of cities introduces serious difficulties to their sustainable development [3]. In particular, the sustainability of urban freight transportation services in terms of environmental, social, and mobility impacts (i.e., CO_2 and GHG emissions, safety issues, congestion, noise, emissions) constitutes a great challenge for city logistics planners due to the heterogeneity and complexity of the urban freight system.

Taking into consideration the European Commission's objective for "CO_2 free city logistics" and a 50% reduction in GHG emissions [4] by 2030, the need for "smart" solutions and ideas for the achievement of an efficient and effective urban freight transportation system is essential [5]. The term "smart city" was introduced in literature in the 1990s, referring to a city that effectively deploys information and communication technologies (ICT) in order to develop integrated and modern infrastructure [6], which was maintained by several researchers who related the term "smart city" with the use of ICT by the city (e.g., network of sensors, smart tools, and devices for monitoring the city's infrastructure) [7,8]. A contradictory approach, though, strongly supports the necessity to integrate the city's soft infrastructure (e.g., human capital, quality of life) to achieve a smart and sustainable city [9,10]. Despite the various interpretations or ambiguities of the "smart city" notion, the research community seems to converge on the fact that the main success factor for a city to become "smart" is to effectively combine the human capital, the social capital, and the use of information and communication technology (ICT) infrastructure [11] for the implementation of smart and efficient solutions [12].

In terms of city logistics, following the global developments and the path towards the digitalization of everything, the need for secure, fair, and sustainable city logistics operations implies the constant use of smart tools and techniques [13]. The significance of smart city logistics within the framework of the broader urban/city freight planning envisages the implementation of new innovative business models for cargo utilization; the use of smart, innovative, and integrated intelligent transport systems (ITS) or information and communication technologies (ICT); and the implementation of new coordination mechanisms such as control towers and dashboards, which would enable the efficient integration of city logistics planning [14]. Effective and efficient urban freight transportation planning implies the understanding of the current state of a city's urban freight transportation (UFT) system along with its strengths and weaknesses. Gaining a clear insight, though, on the current performance—in terms of the effectiveness and efficiency of the existing city logistics system—is still considered a challenge for public authorities and city planners mainly due to the heterogeneity and business-oriented nature of city logistics structure, which had as a consequence, on the one hand, city planners paying attention until recently mainly to passenger transportation [15], and on the other hand, to the lack of easily available information to the public authorities about the characteristics of city logistics operations [16]. Even less is known about how a city performs in terms of "smart city logistics" not only because the term "smart city" is quite new [17] but also due to the fact that the ideal "smart city logistics system" has not been clearly defined yet. More specifically, several attempts can be found in literature on the assessment and ranking of a city's smartness. Some indicative examples are the evaluation framework developed by [17], the "Smart City Wheel" developed by [18], the ICT-oriented assessment framework developed by [19], as well as the Smart Cities Maturity Model and Self-Assessment Tool [20]. All aforementioned efforts propose structured frameworks for assessing and comparing the level of "smartness" mainly among medium-sized and large cities, without specific consideration of the role of city logistics in the broader city ecosystem. It is therefore practically intractable to measure the impact of city logistics operations on the general performance of a city with respect to "smartness".

From another viewpoint, two recent studies pursued the development of assessment frameworks for city logistics. Nathanail et al. [21] demonstrated an evaluation framework for assessing ex-ante and ex-post the performance of urban logistics initiatives and measures throughout the main lifecycle stages: (1) creation: designing/planning the measure, (2) construction: setting up the measure, (3) operation: testing/demonstrating the measure, (4) maintenance: maintaining the measure, and (5) closure: disposal of the measure's implementation (ISO 14040, ISO 14044). Debnath et al. [22], on the other hand, dealt with the smartness of the transportation system as a whole and proposed a detailed methodological approach on how to implement a comparative assessment of the cities' transportation systems—also taking into account the movements implemented by commercial vehicles in terms of their level of smartness—and proposed a generic matrix of indicators for assessing the different components of a smart transportation system. The previous analysis reveals a gap in the current state of the smartness of a city's logistics ecosystem by considering all factors that might influence the city logistics system, the main characteristics of a city logistics ecosystem, and the different stakeholders that are involved in this system [23].

In response to this gap, this paper proposes a conceptual multi-criteria and multi-stakeholder Smart City Logistics Assessment Framework (SCLAF) to:

- Gain clear insight on the main elements of a smart city logistics system;
- Support the public authorities and any interesting party in identifying the level of smartness of a city's city logistics system;
- Facilitate the comparative assessment among different cities or urban areas/regions.

2. Materials and Methods

This paper follows an extensive literature review to identify the current gaps in defining a smart city logistics system and follows a meta-synthesis approach to build a coherent framework to deeply understand its components and main requirements.

More specifically, the methodological approach followed consisted of three main steps:

1. Understanding the (smart) city logistics system: an extensive analysis on existing research for defining a smart city first and after a smart city logistics system is implemented. The ground basis for this analysis lies in deeply understanding the main characteristics and influencing factors of a city logistics system, its main challenges, and the significance in planning for a smart and sustainable city logistics system. The research question that this paper comes to answer in this section is: Why is smart city logistics important and how is it defined?
2. Examining past experiences in assessing a (smart) city logistics system: during this second methodological step, deep analysis of existing assessment methodologies and frameworks for measuring the smartness of a city and more specifically of a city logistics system.

In pursuit of this aim, the literature review implemented in the first two methodologies consisted of different types of publications such as scientific publications (i.e., journal articles and books), research reports about ongoing or recently completed research projects, official policy documents and directives, and handbooks.

The third and final step of the analysis concerned the development of the Smart City Logistics Conceptual Assessment Framework. Following the thorough examination of the inter-related research studies by the researchers, the findings were synthesized and integrated appropriately to provide insight into these elements that best define the smartness of a city logistics system (see Figure 1).

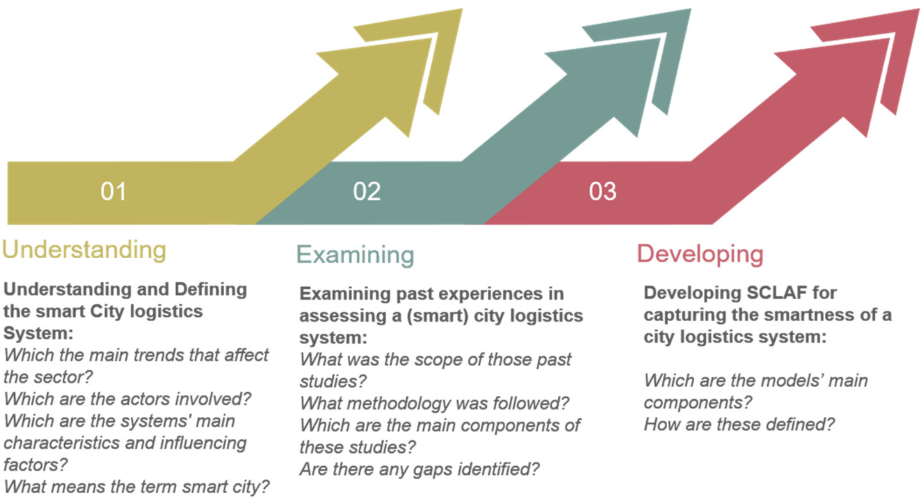

Figure 1. Methodological approach.

3. Understanding the Need for a Smart City Logistics System

3.1. Definition of a Smart City

Although the "smart city" concept can be considered quite new, plenty of different definitions can be found in the literature. Alternative terms such as "intelligent", "sustainable", "creative", or "digital" appear to be often used interchangeably, creating confusion or ambiguities about the real meaning of the term and consequently how a city can become smart [3]. Initially, a "smart city" was mainly viewed as a city that uses information and communication technologies (ICT) and develops modern infrastructure [6]. This approach focuses mainly on how the deployment of ICT and the use of data analytics can help integrate the city's functionality, i.e., optimization and monitoring of public infrastructure and resources, and analysis of human preferences and behavior [24,25]. For example, Chen characterized a smart city based on the level of adoption of information and communication technologies by the city's infrastructure [7], whereas Cretu emphasized the need for a network of sensors and smart devices to consider a city smart [8].

An alternative "smart" approach can also be identified in literature, accounting for the human and social factors affecting the smartness of a city, and hence focusing mainly on the city's soft infrastructure (i.e., human capital, enhancement of life quality, safety, culture heritage) [9,10].

Considering the various approaches and definitions, a smart city can be defined as *a city that emphasizes the development of integrated systems and services by supporting the implementation of innovative ideas and measures while simultaneously using its own resources effectively and efficiently* [11,12].

Besides the criticism and lack of agreement on the exact definition of a "smart city", six main dimensions have been discussed and commonly agreed on by the relevant research community [17]: (i) smart economy, which refers to the smartness of the business sector of a city as well as its interconnection with the global business community; (ii) smart governance and the development and use of services and interactions for the integration of public, private, civil, and European community organizations; (iii) smart living, pertaining to citizens' quality of life and the development of new efficient, integrated, and more controllable ways of living [26]; (iv) smart people, which concerns the development of e-skills, the guarantee of access to education and training, effective and efficient human resources, and capacity management that improves creativity and fosters innovation; (v) smart environment, dealing with the smart use of energy in manifold aspects of a city (e.g., buildings, pollution, ICT renewable, resource usage, waste management); and (vi) smart mobility of inhabitants through smart and integrated ICT-supported transportation systems as well as innovative business models for clean and non-motorized transportation. It is, however, noticed that in terms of smart mobility, emphasis is given mainly to passenger transportation, whereas the role and impact of the urban freight transportation on the performance of a city in terms of smartness is not sufficiently taken into consideration.

3.2. Why Is Smart City Logistics Important after All?

3.2.1. The City Logistics System

The term "city logistics" was defined by Rodrigue J.P. as "the means over which freight distribution takes place in urban areas and the strategies that can improve its efficiency while mitigating congestion and environmental externalities" [27], with urban freight transportation (UFT) considered the movement and use of vehicles for carrying goods in and out of an urban area [28]. Each movement may pertain to various types of goods (e.g., retail products, construction machinery), times/periods of the day (e.g., night to early-morning deliveries), delivery points (e.g., home delivery, locker banks, collection points), modal choices (e.g., from bike to vehicle, from minivan to truck), or operational purposes (e.g., from e-commerce to garbage collection) [14,29]. Bektas et al. provided an analysis of the city logistics system, specifying three distinct components [30]:

1. The system's characteristics, including:
    - **Urban freight demand** which determines the traffic flows within the city;
    - **Existing facilities** that operate to facilitate UFT. By UFT facilities, one may consider any intermediate location for the freight flows used by different types of stakeholders (e.g., urban freight consolidation centers and satellites such as parking lots) [31–33];
    - **The layout of the system**. City logistics networks are generally distinguished in single-tier or multi-tier networks. Single-tier UFT networks refer to urban freight movements that are based on one level of consolidation and distribution activities. Multi-tier city logistics systems, on the other hand, are advanced systems that operate with multiple types of facilities, transport modes, and fleets [30];
    - **The type of transportation used** for the freight movements (e.g., motor vehicles, freight bicycles/tricycles, freight rail) [30,34].
2. The planning processes at a strategic, tactical, and operational level of decision-making. The complex nature of city logistics structure requires appropriate planning at all decision-making levels by both private and public actors. An example of decision-making at a strategic level might be the high-level design and configuration of the city logistics network (e.g., single-tier or multi-tier, types and number of logistics infrastructures needed and their exact location), whereas at tactical level, an essential decision would be planning how the demand will be satisfied (e.g., number and types of vehicles, departure times and routes). Operational decision-making is mostly related to fleet and resource management (e.g., vehicle routing and scheduling or fleet repositioning) [30].
3. The appropriate business models for the development and viability of new initiatives and concepts in city logistics [35–37]. Some indicative examples are cargo consolidation business models through the use of urban consolidation centers' micro hubs or freight hotels, as well as the combination of people and freight flows through business models such as cargo hitching and crowd-sourced deliveries [38,39], shared transport capacity, and intramodality through stakeholder cooperation, etc.

Besides the three main components identified by Bektas et al., the level of complexity of a city logistics system also depends on external factors [30]. Previous studies refer to these factors as "external influences" [40], "external forces", or "influencing factors" and classify them into various categories [41]. For example, according to Halatsis et al., the factors influencing city logistics processes can be classified as follows: (i) economical, (ii) environmental, (iii) demographics, (iv) new technologies, and (v) regulatory [42]. Woudsma emphasized the significance of the size and type of a city [29] and Bauwens the market size [40], the UFT demand, and the livability of the citizens. Following the high diversity of the researchers' opinions on that ground, Hongmei and Haifang observed a lack of factors related to the evaluation of logistics service level [43]. Therefore, they enhanced the abovementioned list of factors and arrived at four main city logistics influencing factors: (i) logistics infrastructure (e.g., transport route networks, use of train or underground system, ship terminals, logistics centers, air freight hub, human resources, information and communication infrastructure), (ii) environmental effects (e.g., fuel consumption, pollutant emissions, freight/vehicle-related accidents, traffic congestion), (iii) governance measures (e.g., road pricing, load factors controls, access controls, noise regulations), and (iv) logistics service level (e.g., on-time deliveries, logistics cost, customer satisfaction, transportation reliability).

The complicated structure and multitude of characteristics, processes, and stakeholders involved in each freight movement with different needs, priorities, and interrelations are among the reasons rendering this field, until recently, "unattractive" to public decision-makers. Recent evidence reveals, though, that the public authorities lack awareness on the current state of the city logistics sector in their city (i.e., the sector's strengths and weaknesses), its main characteristics, and its general performance in terms of efficient and effective city logistics operations. Therefore, solutions for urban freight transport problems are usually fragmented and short term, and unfortunately the UFT operations are still considered to be rather inadequate [15].

3.2.2. The Significance of a Smart City Logistics System

Considering the global developments, the continuous growth of urbanization, and consequently, the significant increase in demand to deliver products among citizens/companies within the urban environment, UFT constitutes a fundamental component of city life, and the need for secure, fair, and sustainable city logistics supply chains is higher. Therefore, the integration of city logistics and urban freight transportation and its harmonization with the city's ecosystem is one of the main requirements for the achievement of smart mobility and, subsequently, setting a fertile ground for the development of smart city capabilities.

Under the term "efficiency", the research community and the policy bodies refer to the achievement of fewer freight vehicles on the street (i.e., increased load factors), as well as overall service quality and operation flexibility [28]. To address these city logistics problems and challenges, several new, innovative, and smart city logistics schemes have been proposed and implemented (either tested through pilots or real cases) in several cities worldwide. The city logistics initiatives can be clustered into two main categories [44]:

1. City logistics initiatives implemented by governing bodies: These involve the introduction of policies and measures such as the development of sustainable urban logistics plans, the involvement of private stakeholders in planning processes, the development of new infrastructure, the provision of public technological immaterial infrastructure, or the establishment of ITS tools for the efficient usage of public infrastructure, etc., reinforcing city logistics companies/operators towards more sustainable operation [45–47].
2. Measures implemented by companies: These essentially include measures aiming to reduce the impacts of freight operations such as administrative interventions (e.g., traffic bans or restrictions), urban/freight consolidation activities and shared logistics solutions [46], route optimization through the use of ICT [48,49], and the use of eco-friendly vehicles. The ultimate objective of these measures is to achieve a simultaneous decrease in external impacts of urban freight operations along with operational savings in transportation or other logistical costs. In any event, the necessity of changing traditional city logistics operations towards even smarter city logistics solutions is also justified by the three main logistics mega-trends, diagnosed by Dablanc and presented in the following Table 1 [13].

Table 1. Main logistics mega-trends.

Main Logistics Mega-Trends	
Security awareness	All operations are implemented basically through technological tools/equipment (e.g., PCs, smartphones) that are connected online through the use of the Internet. This change towards technology comes, however, together with some risks. Harmful attacks such as hacking data systems (e.g., cameras) could bring operations immediately to a standstill. Therefore, smarter solutions towards digital security need to be adopted by UFT actors [50,51].
New energy resources	The main challenges that the global economy faces due to climate change and the limited availability of energy resources, energy security, and pollution rings the bell of the sustainable use of energy and the adoption of alternative business models on urban freight transport such as off-hour deliveries, alternative transport modes, multimodality in urban logistics, etc. [52,53].
Digitalization of everything	The significant growth of e-commerce, the replacement of brick-and-mortar establishments with web-stores, and emerging logistical or manufacturing trends such as 3D printing represent vivid examples of the digitalization of everything. As a result, city logistics stakeholders should be prepared for this paradigm shift and drastic change in culture and adapt as fast as possible [50,51,54,55].

Today, taking also into consideration the technological change and Industry 4.0., a plethora of smart devices and tools is available that can strongly support the efficiency and effectiveness of city logistics operations [56]. In light of the above, smart city logistics can be defined as the optimization process of city logistics activities in terms of traffic environment, safety issues, resources allocation, and, within the framework of a market economy, the use of advanced information systems acting as facilitator [46,50].

4. The Smart City Logistics Conceptual Assessment Framework (SCLAF)

4.1. Past Experiences on Comparative and Self-Assessment of a City's Performance

The term "evaluation" is known worldwide as a technique for examining the performance of any subject of interest (e.g., process, project, program, people, city/country) based on specific set of criteria and/or sub-criteria or indicators. The main purpose of an assessment process is to enable judgements on the efficiency and effectiveness of the subject and consequently facilitate the decision-making for corrective actions towards the improvement of the evaluation subject [57]. For the implementation of this process, the collection and analysis of information—either quantitative or qualitative—on specific assessment criteria and/or indicators is required. The general assessment, however, and the conclusion to specific results can be implemented by plenty of different methods and techniques depending on the initial scope of the assessment [58]. As far as the assessment of cities is concerned, benchmarking of cities' performance through city rankings enjoys great popularity nowadays and attracts significant attention from the public. Especially due to the worldwide economic and technological changes over the last decades, cities and regions aim at improving their general performance in terms of the three sustainability factors, namely, economy, society, and environment, in order to achieve a comparative advantage and improve their position in the European and national urban system [59]. In addition, taking into account the European's Commission main agenda for sustainable and effective cities by 2030 [4], city rankings have become an important empirical base for disclosing comparative advantages and sharpening specific profiles and consequently for defining goals and strategies for future development. Two main attempts can be found in the literature, which implemented city rankings based on the level of smartness of each city. The first one relates to the evaluation framework developed by Giffinger et al., which was implemented to compare the level of "smartness" among medium-sized and large cities [17], and the second being the "Smart City Wheel" suggested by Cohen [18]. The foundation of both evaluation frameworks is based on the fragmentation of the term "smart city" into six main sub-areas of analysis: (i) smart economy: measuring the entrepreneurships, the productivity, the innovation, and the flexibility of the labor market of a city; (ii) smart governance: examination of the political participation of people and the efficiency and effectiveness of the administration, etc.; (iii) smart living: analyzing aspects such as culture, health safety, tourism, social aspects, etc.; (iv) smart people/citizens: assessing the level qualification/education and the openness of people socially; (v) smart environment: examining the effort towards environmental security and the attraction of natural and renewable resources; and (vi) smart mobility: assessing the use/availability of information and communication technologies (ICT) and intelligent transport systems (ITS) as well as modern transport systems.

The main structure of these frameworks was based on a hierarchical model that comprised three main levels, with each level further analyzed by the results of the level below. More specifically, the first level consists of the six main sub-areas, which are further analyzed in the second level by different factors. Giffinger identified 31 factors and Cohen 18 factors, which further split into the third and final level by numerous key performance indicators (KPIs) [17,18]. Following an extensive analysis of both frameworks and their results in real applications in European cities, it was noticed that although urban freight transportation plays an important role in the mobility of a city's environment, the term "smart mobility" was exclusively oriented toward the smartness of passenger transportation. Thus, it was practically difficult to understand the interrelations among the performance of a city logistics system and the general performance of a city in terms of smartness and how they affected each other.

In addition to city rankings, the self-assessment of a city's performance in terms of attaining specific strategic goals is also crucial and necessary for urban planning and development. Self-assessment provides grounds to a city to continuously improve a strategic idea or initiation both during its implementation (adaptive management) and after its completion through the replication of good practices (DOs) and information provision for the avoidance of mistakes (DONTs). Conducting a self-evaluation leads to the assessment of the degree to which initial goals and objectives have been met and the realization of possible future actions needed for the improvement of the city's performance [60]. Past relevant experiences are the ICT-oriented assessment framework developed by the International Telecommunication Union (ITU) of the United Nations; the Smart Cities Maturity Model and Self-Assessment Tool, both representing self-assessment tools of the smartness of a city in general [20]; and other efforts on assessing the capability of cities in terms of digital transportation [61].

In terms of self-assessment tools dedicated to city logistics, two recent studies have been identified. The first one, which was published in 2015 by the EU-funded Novelog project [21], focused on assessing ex-ante and ex-post the performance of urban logistics initiatives and measures on the four main lifecycle stages: (i) creation, (ii) construction, (iii) operation, and (iv) maintenance and closure. The evaluation process followed was based on a structured evaluation framework consisting of four modules: (i) impact assessment, (ii) social cost–benefit analysis, (iii) adaptability and transferability analysis, and (iv) behavioral modeling. The second study, identified in the literature, concerns a benchmarking tool for smart transport cities developed by Debnath et al. [22]. The proposed methodological framework initially defined the general concept of the smartness of an urban transport system (including passenger mobility as well as urban freight transportation), where four basic and three advanced smart system capabilities were identified, namely:

- Basic:
    1. The collection of detailed and accurate information;
    2. The processing of this information and the extraction of valuable knowledge;
    3. The actions for implementing the decision made;
    4. The communication among the previous steps.
- Advanced:
    1. The ability of the system to accurately predict problems or other scenarios;
    2. the ease of a system to heal and recover from potential problems;
    3. The ability of the system to prevent potential failures.

Following the concept analysis and definition, a generic matrix of indicators appropriate for assessing each of the abovementioned capabilities was identified. Finally, a benchmarking exercise among 26 big cities—in terms of population size—of economically developed countries was conducted. Although these frameworks were dedicated to city logistics and urban freight transportation, they were focused on specific aspects of the city logistics system, i.e., the assessment of the UFT system and the assessment of the effectiveness of specific UFT measures without explicit consideration of the performance of the city logistics ecosystem as a whole [62]. In the subsequent section, we capitalize on past relevant efforts and integrate assessment frameworks for smart cities and city logistics in order to develop the comprehensive, multi-criteria, and multi-stakeholder Smart City Logistics Assessment Framework (SCLAF) for either self-assessing the smartness of a city logistics system as a whole or implementing comparative assessment among different cities or regions.

4.2. SCLAF Foundation

The main purpose of the development of an assessment framework for the smart city logistics ecosystem is to systematically monitor the performance of the urban freight environment, portraying the complexity of city logistics systems in terms of the several factors influencing the city logistics system as well as the various actors involved. The SCLAF resulted from a synthesis of various components, criteria, and key performance indicators (KPIs) employed by existing frameworks dealing with the assessment of either the smartness of a city [17–20] or the effectiveness of specific aspects of the urban freight transportation system [22].

The final structure of the SCLAF is based on three main aspects:

1. Smart city classification, as proposed by Giffinger and Cohen [17,18];
2. The three main components of the city logistics ecosystem identified by Bektas et al. [30] (city logistics characteristics, planning processes, and business models);
3. The main external factors influencing the city logistics system and demonstrating the level of complexity of the city logistics sector.

Finally, for the identification of the main assessment elements and thematic areas, the interrelations of city logistics with other urban systems (e.g., passenger, land-use patterns, types of goods, regional development, employment, and socio-economic environment) were also examined.

4.3. The SCLAF's Main Structure and Components

Considering the smart city classification proposed by Giffinger and Cohen and the main characteristics and influencing factors of a smart city logistics system, the SCLAF proposes the fragmentation of the smart city logistics system into four main impact areas, which will also constitute the basis of the assessment framework [17,18]. These are:

- SCLAF Impact Area 1—Smart Governance: Smart governance in city logistics refers to the tools a public administration uses/provides to enable efficient and effective city logistics, as well as the role of private UFT actors towards public initiatives and planning [17].
- SCLAF Impact Area 2—Smart Economy: The assessment of the general city logistics economy aims at capturing the UFT stakeholders' financial condition, being one of the main influencing factors of city logistics operations [42] and the general behavior of the UFT actors towards new technological developments and innovations.
- SCLAF Impact Area 3—Smart Actors: According to a study implemented by [63], one of the main obstacles in the development of smart city logistics lies in the lack of digital culture and training in freight transportation and logistics companies. The third impact area aims at identifying and measuring the smartness of city logistics actors in terms of responsiveness, responsibility, and visibility of the UFT operations.
- SCLAF Impact Area 4—Smart Environment: Freight vehicles that operate in urban areas emit a greater proportion of certain pollutants per kilometer traveled than other means of transportation. This is due to the high fuel consumption per unit of distance traveled and the fact that many of them use diesel as a fuel [64]. A smart city logistics environment presupposes the minimization of environmental impacts while maximizing the effectiveness of the city logistics operations. Therefore, the main purpose of the Smart Environment" impact area is to quantify the level of ecological awareness of the UFT actors and the extent to which a city promotes and uses environmental management techniques in UFT operations.

The SCLAF structure is based on a four-level assessment pyramid—as is shown in Figure 2—where the top of pyramid constitutes the main smart city logistics impact areas, and then each impact area is further fragmented into specific criteria and sub-criteria (second assessment level) that aim to clarify further the area of influence of each impact area and facilitate the assessment process. Following the identification of the main criteria and sub-criteria describing the main impact areas, it is necessary to examine how these criteria can be measured, either qualitatively or quantitatively.

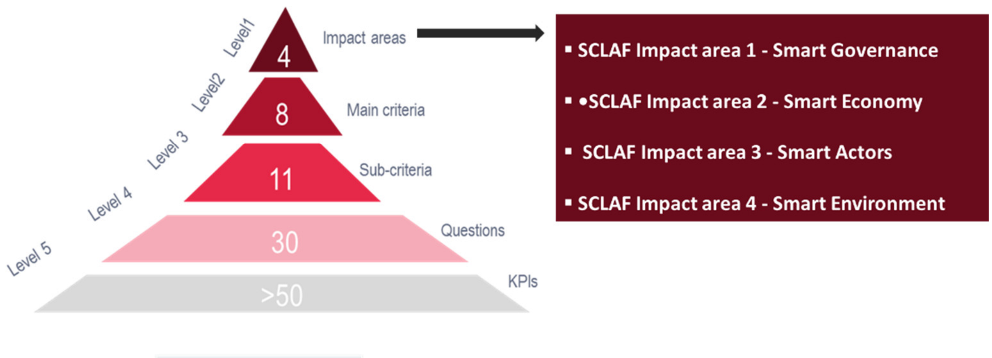

Figure 2. SCLAFS hierarchical levels and impact areas.

Therefore, the SCLAF proposes two alternative performance measurement processes of each criterion and sub-criterion and lets the user of the tool choose which one suits the city's needs and current situation best, i.e., availability of resources, data, time, etc., which are:

1. The qualitative approach (third assessment level): The SCLAF proposes a set of easy-going and well written questions to qualitatively assess each criterion and sub-criterion. The use of qualitative research questions can provide quite rich and detailed information on specific topics that cannot be measured easily by KPIs. The expression of each questions was careful chosen and studied in order to avoid any misunderstandings of the questions by the evaluators or the provision of long text answers that might cause problems in the extraction of the respective outcome. One method for implementing this process is to follow semi-structured methods such as interviewing a sufficient number of experts in the field together with observation techniques [65].
2. The quantitative approach (fourth assessment level): The SCLAF proposes a sample set of the most appropriate KPIs for measuring the performance of each criterion and sub-criterion. However, considering the size of the SCLAF, the identification of the most appropriate KPIs for each impact area and the conclusion of the final list of KPIs still remains a future research subject and requires a significant number of resources to be sufficiently achieved. Thus, the presented paper focuses on presenting mainly the qualitative approach.

Taking into consideration the obstacles that might occur in collecting reliable data and enough of it (either qualitative or quantitative) for a city logistics system due to the business nature of the system and the involvement of several and different types of stakeholders with usually conflicting interests and needs, the SCLAF was designed as a multi-stakeholder tool. More specifically, the SCLAF highlights the need to involve in the assessment process a sufficient number of stakeholders that operate in the city's city logistics environment in order to extract valuable information about the performance in terms of the smartness of a city logistics system.

A detailed representation of the SCLAF assessment pyramid and each assessment level is presented in Figure 3, and a detailed analysis of the three assessment levels (impact areas, criteria/sub-criteria, qualitative assessment questions) follows.

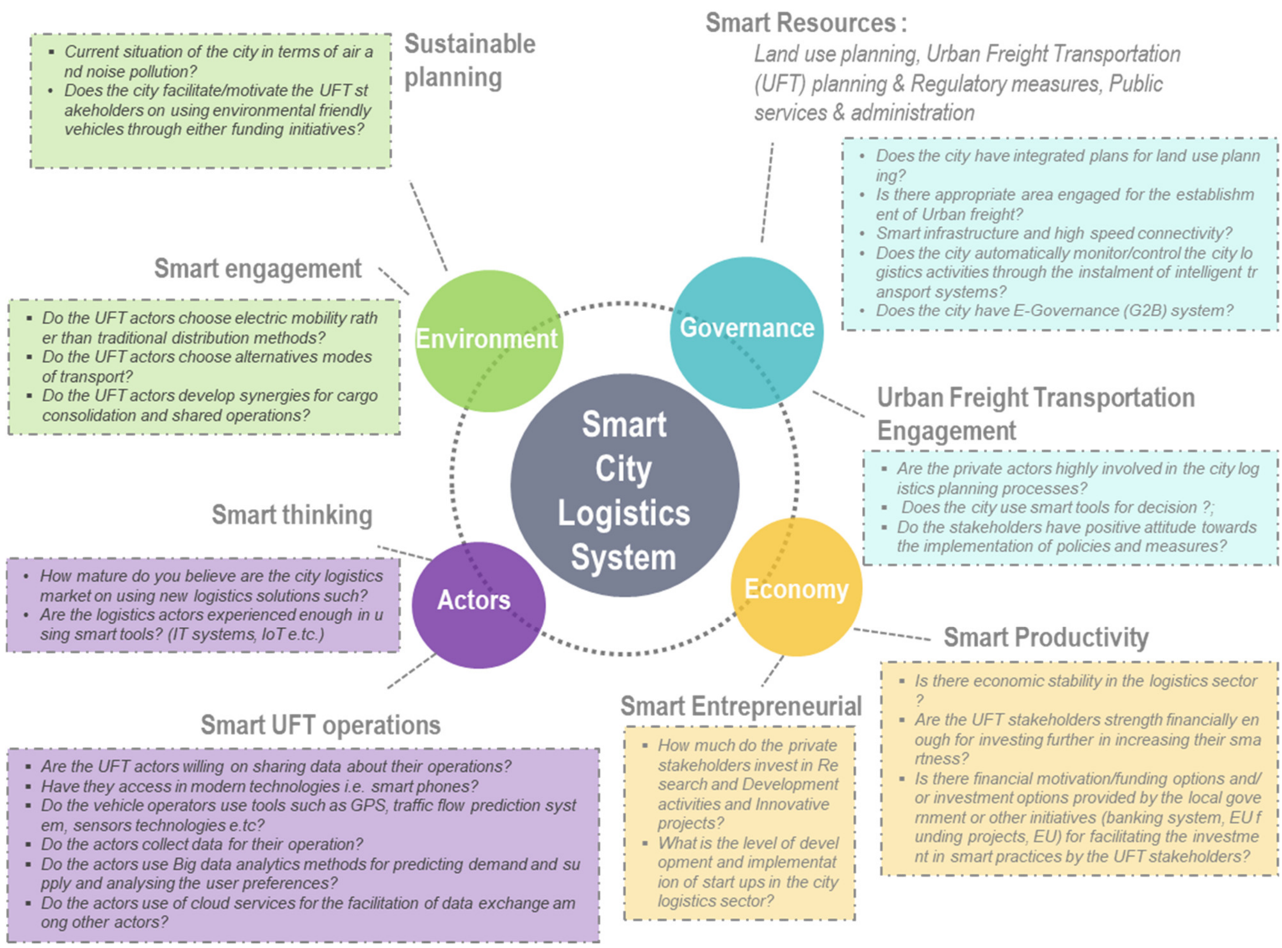

Figure 3. A multi-criteria framework for assessing the smartness of a city logistics system.

4.3.1. Impact Area 1: Smart Government

Following an extended literature review on the possible measures and actions that could be implemented by governing bodies towards a more sustainable and smarter city logistics environment, a cluster of two main areas of interest related to smart governance were identified. The first one is dedicated to the general resources provided by the city authorities in order to facilitate the city logistics operations, whereas the second one is related to the stakeholders' engagement process, which is considered necessary for the viability of public initiatives and measures [66]. More specifically, this impact area splits into the following criteria and sub-criteria:

- Criterion 1 (Smart Resources): This criterion aims at assessing the smartness of the resources provided by the government related to the urban freight sector. In particular, these resources refer to the actions and tools provided by city authorities for:
    - Sub-criterion 1.1 (smart land-use planning and infrastructure): Efficient and effective distribution of goods presupposes a holistic approach to land-use planning by city authorities. Several land-use planning policies and measures were identified in the literature, such as the appropriate design of parking spaces for freight vehicles or specific loading spaces, the implementation of advisory truck routes on streets [44], the development of logistics terminals and pick-ups [67], the development of urban consolidation centers [64], etc. However, integrated plans for land-use planning require deep knowledge on the demand for UFT and the general needs of the freight actors [28]. Therefore, smart land-use planning aims to address specific questions regarding the existence and development of appropriate infrastructure facilitating urban freight activities, as well as the provision of

appropriate tools for effective communication and information exchange among the UFT actors. In particular, these can involve (i) smart physical infrastructure and (ii) immaterial infrastructure. The physical infrastructure dedicated to urban freight transportation can be either for monitoring the city logistics activities through the use of, for example, ITS systems such as flow sensors, radars, or automatic number plate recognition cameras (ANPR) to monitor the urban freight flows inside the city center or facilitate urban freight activities through the engagement of enough public space, or the provision of integrated ITS systems such as parking sensors, online booking systems, smart traffic signals, etc. The second type refers to immaterial infrastructure such as the level of high-speed connectivity with, for example, several Wi-Fi hotspots and the provision of high Internet download speeds that would facilitate city logistics operations through faster communication and data exchange. The following table (Table 2) presents indicative qualitative questions for assessing the smartness of sub-criterion 1.

Table 2. Indicative assessment questions for smart land-use planning and infrastructure.

Indicative Assessment Questions for Smart Land-Use Planning and Infrastructure:	
1	Does the city have integrated plans for land-use planning?
2	Is there an appropriate area engaged for the establishment of urban freight activities (e.g., storage, loading/unloading activities, handling, or transshipment)?
3	Does the city facilitate urban freight operations through the provision of smart infrastructure and high-speed connectivity?
4	Does the city automatically monitor/control city logistics activities through the deployment of intelligent transport systems (ITS)?

- Sub-criterion 1.2 (smart UFT planning and regulatory measures): The main purpose of strategic UFT planning is to achieve effective and efficient UFT by satisfying the economic, environmental, and social needs while minimizing any adverse impact and associated cost [44]. Civitas Wiki Consortium classified the regulatory measures for efficient UFT into five main categories: (i) time restrictions for freight movements in city centers in order to reduce freight traffic, (ii) parking regulations such as the provision of smart vehicle parking reservation systems and timeshare of parking spaces, (iii) environmental restrictions such as the implementation of low-emission zones, (iv) size/load access restrictions such as vehicle size and weight restrictions and load factor restrictions, and (v) measures for better freight traffic flow management such as the establishment of a priority network for heavy goods [64]. This criterion aims, therefore, to assess the activity of the public administration towards the implementation of strategic and innovative regulatory measures for effective and efficient UFT (Table 3).

Table 3. Indicative assessment questions for smart UFT planning and regulatory measures.

Indicative Assessment Questions for Smart UFT Planning and Regulatory Measures	
1	Does the city have strategic and long-term plans for urban freight transportation (sustainable urban logistics plans (SULPs)/sustainable urban mobility plans (SUMPs))?
2	Has the city implemented smart policy incentives and measures (e.g., time windows for UFT, shared public and private infrastructure, priority access to freight vehicles, electronic benefit payments, online parking booking system)? If the answer is yes, please choose one of the below (e.g., time windows for UFT, shared public and private infrastructure, priority access to freight vehicles, electronic benefit payments, online parking booking system, other).

- Sub-criterion 1.3 (smart public services and administration): According to the EU e-Government Report [68], an effective and efficient government shall be able to provide immediately and electronically to the citizens who use the government's online services any crucial information that affects them (e.g., status of an application, steps for an administration process). Consequently, this criterion concerns the need for optimized and transparent public services and administration that can be accessed by the UFT stakeholders via web or mobile systems (Table 4).

Table 4. Indicative assessment questions for smart public services and administration.

Indicative Assessment Questions for Smart Public Services and Administration	
1	Does the city have an e-Governance (G2B) system?
2	What is the transparency of public services?

- Criterion 2 (smart UFT engagement): A smart city and, consequently, a smart city logistics environment is highly interdependent on the level of engagement among the public and private actors. Several public and private cooperative schemes have been initiated by city authorities and implemented in order to engage private stakeholders in the city logistics planning process [69]. Many different terms for these schemes can be found in the literature such, as "freight quality partnerships", "public–private partnerships", "local freight network", and "peer-to-peer exchange" [16]. Therefore, this main component of the assessment framework aims to identify whether such initiatives exist in a city's environment and assess the general behavior and attitudes of the stakeholders towards changes and public initiatives in the city logistics environment [70] (Table 5).

Table 5. Indicative assessment questions for smart public services and administration.

Indicative Assessment Questions for Smart Public Services and Administration	
1	Are the private actors highly involved in the city logistics planning processes (e.g., through freight quality partnerships, multi-stakeholder platforms)?
2	Does the city use smart tools for decision-making (e.g., use of web consensus building tools, online surveys, analysis of decision-making acceptance through data obtained from social media)?
3	Do the stakeholders have a positive attitude towards the implementation of policies and measures?
4	Has the city implemented a privacy policy for the protection of confidential UFT data?
5	Does the city provide information to the UFT actors in the form of open data access?

4.3.2. Impact Area 2: Smart Economy

Smart economy aims to measure mainly the economic stability and productivity of the urban logistics sectors as well as to identify the level of the introduction and implementation of new, smart ideas. Therefore, the second impact area can be further analyzed in the following two criteria:

- Criterion 1 (smart productivity): The economic stability and the financial condition of the UFT actors in general is one of the major factors that may influence the smartness of the city logistics sector. The investment in any new and innovative solution requires a low risk of failure in order to be widely accepted by the interested actors. Wealthy enterprises are more likely to invest in new and innovative information and communication systems that would facilitate their operations. Finally, evidence shows that public funding initiatives by city authorities constitute a strong motivation factor for private actors to invest in smart systems and operations [71] (Table 6).

Table 6. Indicative assessment questions for smart productivity.

Indicative Assessment Questions for Smart Productivity	
1.	Is there economic stability in the logistics sector?
2.	Is the UFT stakeholders' financial strength sufficient enough to invest further in increasing their smartness?
3.	Are there financial motivation/funding options and/or investment options provided by the local government or other initiatives/organizations (e.g., banking system, EU funding projects, the EU) to facilitate the investment in smart practices by the UFT stakeholders?

- Criterion 2 (smart entrepreneurial): Over the past decades, a change has been observed in the logistics sector towards the development of micro-trends and start-ups, which promote new technological developments and innovations to facilitate logistics operations. In some cases, logistics operators have already started collaborations with such start-ups, whereas others breed their own in-house innovations [13]. In that respect, this criterion examines the level of investment by the UFT actors on research and development activities and city logistics start-ups (Table 7).

Table 7. Indicative assessment questions for smart entrepreneurship.

Indicative Assessment Questions for Smart Entrepreneurship	
1	How much do the private stakeholders invest in research and development activities and innovative projects?
2	What is the level of development and implementation of start-ups in the city logistics sector?

4.3.3. Impact Area 3: Smart Actors

As is strongly expressed by the research community, the complexity of the urban logistics sector lies mainly in the involvement and coordination of plenty of different actors with different and in some cases conflicting interests and needs. Therefore, the analysis and assessment of the smartness of the actors that are involved in the sector and their ability and willingness to use smart tools and techniques in the framework of their occupation is crucial. This impact area is further broken down into two main criteria:

- Criterion 1 (smart UFT operations): This pertains to the identification of how smartly the UFT actors operate by measuring whether the UFT stakeholders have access to modern technologies and the use of smart tools such as Internet-connected operations, e.g., the use of smart devices for communication and data exchange, dedicated route guidance systems, big data analytics methods for predicting demand and supply and analyzing user preferences, the use of cloud services for the facilitation of data exchange, in-vehicle safety systems, GPS, traffic flow prediction system, sensor technologies, etc. Finally, the difficulty of gathering data about private operations due to heterogeneity and competition is another main factor that influences the efficient operation of freight movements. More specifically, the lack of visibility along the supply chain represents one of the main barriers to both urban freight planning and effective private operations. For that reason, as part of this criterion, we aim to assess the level of visibility along the supply chain by assessing the willingness of the stakeholders to share data and use smart tools such as cloud logistics, real-time delivery information sharing on mobile devices, interconnected ERP systems for data exchange, etc. (Table 8).

Table 8. Indicative assessment questions for smart UFT operations.

Indicative Assessment Questions for Smart UFT Operations
1. Are the UFT actors willing to share data about their operations?
2. Do they use smart tools such as cloud logistics, real-time delivery information sharing on mobile devices, or interconnected ERP systems for data exchange?
3. Do they have access to modern technologies (e.g., 3D printing, blockchain, mobile apps, etc.?)
4. Do they use IoT in their operations (e.g., dedicated route guidance system, Internet-connected operations)?
5. Do vehicle operators use tools such as GPS, traffic flow prediction systems, sensors technologies, etc.?
6. Do they collect data and use big data analytics methods to predict demand and supply, analyze user preferences, use cloud services for the facilitation of data exchange, etc.?

- Criterion 2 (smart thinking): This criterion focuses on the identification of the UFT actors' attitude towards innovative solutions such as the use of driverless vehicles for last-mile distribution, 3D printing, and unmanned aerial vehicles, and their level of experience in using smart systems [13] (Table 9).

Table 9. Indicative assessment questions for smart thinking.

Indicative Assessment Questions for Smart Thinking
1. What is the level of maturity and potential acceptability of the city logistics market for the deployment of new logistics solutions such as driverless vehicles for last-mile distribution, 3D printing, unmanned aerial vehicles, etc.?
2. Are the logistics actors experienced enough in using smart tools and technologies (e.g., IT systems, IoT)?

4.3.4. Impact Area 4: Smart Environment

The last impact area splits into the following criteria:

- Criterion 1 (smart ecological awareness): This criterion deals with the identification of the ecological awareness of the city logistics actors through their attitude towards the development of synergies with other actors (e.g., cargo consolidation, shared logistics/warehousing) in order to minimize these impacts, as well as the use of alternative modes of transport or electric mobility for UFT operations (Table 10).

Table 10. Indicative assessment questions for smart ecological awareness.

Indicative Assessment Questions for Smart Ecological Awareness
1. Do the UFT actors choose electric mobility rather than traditional distribution methods?
2. Do the UFT actors choose alternative modes of transport (e.g., bikes, tricycles, rail) for UFT operations?
3. Do the UFT actors develop synergies for cargo consolidation and shared operations in UFT operations

- Criterion 2 (sustainable planning): The assessment of sustainable planning towards a smarter environment consists of two main areas of interest. The first area considers the identification of the current situation of the city in terms of air and noise pollutants due to UFT operations, and the second area concerns the activities of the governmental bodies to facilitate and motivate UFT actors to achieve more environmentally friendly UFT operations. (Table 11)

Table 11. Indicative assessment questions for sustainable planning.

Indicative Assessment Questions for Sustainable Planning
1. What is the current situation of the city in terms of air and noise pollution?
2. Does the city facilitate/motivate UFT stakeholders to use environmentally friendly vehicles through funding or other initiatives?
3. Has the city launched policy initiatives towards environmentally friendly distribution, such as initiating smart automated congestion charging systems or the prohibition of the movement of specific vehicle types in the city center?

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, and the experimental conclusions that can be drawn.

5. Discussion

This paper presents a conceptual framework for assessing the level of smartness of a city logistics ecosystem. Following an extended literature review on the smart city concept and on the main trends and drivers that affect the city logistics sector along with its main characteristics and the actors involved, the proposed framework, called the Smart City Logistics Assessment Framework (SCLAF), is structured as a four-level assessment pyramid. Based on a top-down assessment approach, the SCLAF's foundation, and the top of the pyramid, is based on the main impact areas of the smart city logistics concept, meaning smart economy, smart environment, smart governance, and smart actors. Each impact area is further expressed in criteria and sub-criteria, and the final two levels of the pyramid provide guidance directions on how to eventually measure the performance of each impact area either qualitatively through a holistic set of questions or quantitatively based on a sample set of KPIs proposed within the framework of the fourth assessment level.

The main purpose of the proposed Smart City Logistics Self-Assessment Framework is to constitute a practical tool that will aid any beneficiary in self-assessing the current situation of a city's urban freight transportation and logistics environment and facilitate the development of more sustainable cities in line with the 11th Sustainable Development Goal for Sustainable Cities and Communities defined by the United Nations. A second usage of the tool could also be the implementation of cross-comparisons among cities in terms of the smartness of their city logistics environment. The future scope of this research is to integrate the existing conceptual model with the necessary mathematical model to be able to use it and conclude on empirical results in terms of a city's smart city logistics index. Analytical step-wise guidelines will be provided to the potential users of the tool on how to apply this model either for self-assessing the current state of a city logistics system or making a comparative assessment among different cities. Finally, a validation process on the structure and components of the framework, by means of any consensus building methods with the participation of recognized logistics experts, might be very fruitful.

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