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# Conceptual Model for Assessing Logistics Maturity in Smart City Dimensions

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**Abstract:** The advancement of new technologies and the increasingly inseparable presence of logistics systems in the daily life of cities, industries, companies, and society has been modifying how logistics processes are implemented in these environments based on technological innovations, internet, virtual businesses, mobility, and the use of multi-channel distribution. Together with these changes, urban centers have been connecting to the smart city concept as the understanding of this theme advances into the debate and improvements in the agendas of either public or private management. This research proposes a conceptual model for evaluating logistics maturity in the smart city dimensions. The method has a qualitative, exploratory, and descriptive approach, supported by the Delphi method, which uses a questionnaire and interview as a data collection instrument with specialists on the subject. We identified that qualifying logistics in the urban environment is complex and requires a specialized look at identifying cities' structural, geographic, regional, social, and environmental characteristics. As a social–technological contribution, the proposition of the logistics maturity assessment scale in smart city dimensions can serve as an evaluative model of logistics, which means helping in urban planning and strategic management of cities, offering smarter solutions to the realities of urban spaces.

**Keywords:** logistics; maturity; smart city; smart city dimensions



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## 1. Introduction

The growth of cities has been influenced over the last decades by social, economic, and technological transformations, resulting in the formation of urban spaces adjusted to the social dynamics of movement guided by the intense use of the internet and technological innovations, which have influenced the flow and mobility of people, transport, objects, services, and information in cities.

From this context, the search for solutions focused on logistics, mobility, infrastructure, business, environment, society, pollution, quality of life, and city management, under the smart city theme's prism, has attracted experts' and scientists' attention. The topic of smart cities is linked, among other aspects, to the treatment given to its six dimensions: smart economy, smart environment, smart governance, smart life, smart people, and smart mobility, as highlighted by Taniguchi (2001), Giffinger et al. (2007), Cohen (2012), Dameri (2017), and The Smart City Model (2018). These axes are fundamental to be considered for developing cities with smart initiatives and their relationship with urban logistics (Giffinger et al. 2007; Fernández-Güell et al. 2016; Dameri 2017).

In recent years, the increased flow of cars in urban areas has resulted in traffic congestion, environmental, air and noise pollution, traffic accidents, and greenhouse gas emissions (Dameri 2017). Forecasts show that the activities of transport companies concerning 2005 will have grown by around 40% in 2030 and over 80% in 2050. At the same time, passenger transport could also increase by 34% in 2030 and 51% in 2050. With the advancement of this mobility pattern, the problem could be even bigger in 2050, when passenger cars can contribute more than 60% of the total passenger transport (Kiba-Janiak 2016).

We should mention that, in recent years, due to the economic changes caused by the COVID-19 pandemic, the cost of oil has increased globally, which, in turn, has increased the final price of fuels and derivatives (Blulm et al. 2021), besides the gradual investment that automobile industries have used in research on different sources of alternative energy, such as automobile electrification, either by the critical application of an electrical system in the cars or through its hybrid combination with another fuel. This transformation has changed the dynamics of mobility and transport of people in cities regarding the perspective of the use of private cars, which can stimulate their replacement by public transport, bicycles, and remote work (Araújo and Lua 2021).

The annual report issued by Reed (2019) reveals that travel in city centers continued to tread levels before the start of the COVID-19 pandemic, which means a possible continuity of mobility patterns equivalent to the pre-pandemic scenario. Travel to US centers is down 22% from pre-pandemic levels, while city-center travel in the UK and Germany is down 19% and 0%, respectively. The shift in travel patterns resulting from the home office, cycling, and using public transport has continued throughout 2021—leading many experts to believe that these trends will extend beyond the post-pandemic.

In Brazil, investment in the logistics sector in 2018 was around 12% of the Gross Domestic Product (GDP), which amounted to USD 1.3 trillion (Mota 2018). Therefore, the development of logistics depends on the sector's investment. According to the National Bank for Economic and Social Development (BNDES 2019), investments in cargo logistics influence the development of most economic activities, which reflects the competitiveness of companies and the population's quality of life. According to Assis et al. (2017), some indicators place Brazilian logistics costs in the 55th position among 160 countries, positioned behind developed countries such as Germany (1st), the USA (10th), or even some BRICS members (China, 27th; India, 35th). The perspective of investments between 2017 and 2020 in Brazil in sectors related to logistics was estimated at USD 5.7 billion in urban mobility, USD 7.9 billion in highways, USD 6.8 billion in railroads, USD 3.6 billion in ports, USD 2 billion in airports, and USD 89.3 billion in infrastructure.

City logistics uses the smart city concept to discuss important and necessary aspects for the maintenance and management of cities, such as infrastructure, energy, environment, government, life, mobility, education, health, and so on (Perboli et al. 2014). This context shows that embedded logistics in smart city studies can improve the efficiency and control of urban mobility, optimize the flows of objects and people transport, and adopt better information management practices through different technological means (Michelucci et al. 2016). Given that logistics complements smart city dimensions, qualifying it in each evaluated dimension to show its importance and application became necessary.

Considering this scenario, the importance of logistics performance is fundamental for smart city initiatives from the perspective of the six dimensions pointed out by Giffinger et al. (2007), Caragliu et al. (2011), Lombardi et al. (2012), Neirotti et al. (2014), Albino et al. (2015), Dameri (2017), and The Smart City Model (2018). In this sense, based on the understanding that logistics activities are important for the development of cities and on aspects related to their improvement, this study aims to propose a conceptual model for evaluating logistics maturity in the smart city dimensions.

The following section will address the literature review, followed by the methodology, presentation and analysis of results, conclusion, and references.

## 2. Literature Review

### 2.1. Logistics in the Smart City Dimensions

The review of some scientific works observed in the research by Cheshmberah and Beheshtikia (2020) in the area of supply chain management, a field of study related to logistics, has categorized the dimensions of maturity with the dimensions presented in this study. The research by Cheshmberah and Beheshtikia (2020) identifies, among other dimensions, human resources, environment, social responsibility, logistics, and planning (policy making). While Gonzalez-Feliu et al. (2020) presented in their study an analysis of the elements that must be included in the design of an urban logistics maturity model, which are practices, processes, stakeholders, and their relationships, and issues related to information flow management and physical, which can help in the planning and decision-making process. In this way, these studies can contribute to and expand the understanding of the dimensions embarked on in this work on smart cities, which seeks to discuss a model of logistical maturity in dimensions related to the economy, environment, governance, quality of life, mobility, and people.

The logistics approach applied to the smart economy concept arises from the smart mobility project, specific to the city for the movement of people and industrial and commercial goods, and urban transport, supported using the internet, digitalization, and automation of transport processes (Kumar and Dahiya 2017). In the study by Moustaka et al. (2017), some correlations between smart economy and logistics are pointed out, highlighting the financial concern of stakeholders with the local government budget, the existence of urban planning for mobility, and its aspects related to the city, and organization and control of activities related to the area of logistics, transport, and urban mobility.

Applying the smart city concept in some cities is not an isolated phenomenon but an integral part of a broader transition to a digital economy. The dimensions of smart cities were created based on aspects related to their needs, limitations, challenges, and growth prospects related to mobility, economy, governance, environment, people, and quality of life (Giffinger et al. 2007; Caragliu et al. 2011; Dameri 2017).

Within the smart environment dimension, some aspects of urban life stand out, linked to efficiency and sustainability supported by technologies. For example, smart sensors help identify levels of air pollution caused by traffic and are equally used to solve the problem of garbage collection and recycling through route optimization and efficient use of container space of collection trucks, reducing traffic pollution (Giffinger et al. 2007; Giffinger and Gudrun 2010; Caragliu et al. 2011; Nam and Pardo 2011; Meeus et al. 2011; Cohen 2012; Neirotti et al. 2014; Angelidou 2017; Dameri 2017).

Regarding the objective of smart governance, we seek to build public governance with a digital perspective, making the offer of public services dynamic and providing access to documents and public information simply and transparently (Giffinger et al. 2007; Giffinger and Gudrun 2010; Caragliu et al. 2011; Lombardi et al. 2012; Neirotti et al. 2014; Dameri 2017). To Kumar and Dahiya (2017), Albino et al. (2015), and Dameri (2017), there are other aspects of smart governance linked to logistics factors, which are: (i) local, national, and global regulations that affect city logistics (passenger and cargo traffic, environmental protection, road safety, etc.); (ii) transparency of public investments in logistics, transport, and mobility; and (iii) e-government.

The quality of life in the context of logistics in a smart city stands out for (i) the promotion of collective or ecological individual transport among citizens; (ii) the promotion of ecological cargo transport between transport and logistics companies; (iii) the application of digital transport monitoring systems, intelligent transport systems; and (iv) monitoring of future trends in the field of city logistics (Kiba-Janiak 2016; Cohen 2012). From the people's (smart people's) point of view, some other aspects are found in the literature, which are: (i) social aspects, such as those related to safe road transport, availability of personnel, experience, and knowledge; (ii) the experience of the city's logistics stakeholders in the implementation of ideas and solutions that allow the improvement of passenger and cargo traffic; (iii) the residents' inclination to use environmentally-friendly transport in a city; for example, the use of eco-friendly vehicles, or bicycles for commuting (Kiba-Janiak 2016).

Mobility is among the most discussed components in the smart city field. In this sense, Albino et al. (2015) define smart mobility as "the use of information and communication technology in modern transport technologies to improve urban traffic". Vanolo (2014) refers to smart mobility as "local accessibility, availability of Information and Communication Technologies (ICTs), modern, sustainable, and safe transport systems". The topic of mobility is an important aspect of growing cities. Transporting people and goods within the city is crucial for developing the economy and everyday life. This issue makes the concept of mobility greater than transport or traffic (Graser et al. 2019). The role of logistics in smart mobility is to rationalize traffic and better manage the fleet of different modes to organize the distribution of products and materials efficiently, seeking to alleviate the intense flow attributed to urban centers due to the growth of cities in decades (Thorne and Griffiths 2014; Albino et al. 2015; Caragliu et al. 2011). To Dameri (2017), smart mobility also seeks to achieve the following objectives: 1. reduce pollution; 2. reduce traffic congestion; 3. increase people's safety; 4. reduce noise pollution; 5. improve transfer speed; 6. reduce transfer costs.

In recent years, the smart city theme has aligned with the proposal of solutions to problems identified in cities due to their rapid growth, pointed out by various city sectors. In this sense, creating evaluative models that best meet these needs has become a challenge for most specialists and researchers. Some models aligned with this theme are found in the works by Caragliu et al. (2011), entitled 'Smart Cities in Europe', Giffinger et al. (2007), in 'The role of rankings in growing city competition', and Cohen (2012), with 'The smartest cities in the world 2015: Methodology'.

### *2.2. Maturity Models*

Maturity models are increasingly popular frameworks to support assessment and guide organizational improvement. Most maturity models have their roots in the quality management movement, particularly in Deming's (1993) plan-make-check-act cycle. This conceptual model was originally conceived by Crosby, who suggested a five-level structure to assess the quality of organizational processes (Crosby 1979). In the same vein, using this five-level framework as a basis, one of the first and most widely recognized maturity models was the capability maturity one developed for software, known as the 'capability maturity model' (CMM), developed by researchers at Carnegie Mellon University (Paulk et al. 1993). Based on the maturity model introduced by the Capability Maturity Model (CMM) concept, maturity models have proliferated across a multitude of domains (De Bruin et al. 2005).

The use of maturity models serves to identify the ideal path for the evolution of a process from an early stage to a more advanced stage, passing through several intermediate stages (Becker et al. 2009; Wendler 2012). These stages should be sequential and represent a hierarchical progression (Wendler 2012). At the earliest and least advanced stage, performance can be quite poor. As the stages progress, activities are carried out more systematically and are better defined and managed (Gimenez et al. 2017). Maturity approaches have been used in different fields, such as quality, processes, management, or software, showing the different purposes they can have (Fraser et al. 2002).

Another characteristic of a theoretical maturity model is that it aims to improve the efficiency and qualification of processes, systems, and activities through indicators and translate indicators into strategic information for interested agents (stakeholders). They can also assist in deciding how, why, where, and when to invest and help identify the cause and effect of changing an organization or field of inquiry; they also help in the evaluation and understanding of current resources to strategically identify the desired resources and determine the improvement activities that will allow the realization of these capabilities (Duncan et al. 1998).

Among the main advantages of using maturity models is the development of a governance structure, standardization, and integration of processes, use of performance metrics, control and continuous improvement of processes, commitment to project management, project prioritization and alignment with organizational strategy, use of criteria for continuation or termination of projects, measure the maturity of the organization's project, program, and portfolio management. Gimenez et al. (2017) state that a maturity model can help public or private companies, industries, governments, or cities better understand their relationship with their external environment and stakeholders.

Regarding the development of smart cities and considering the activities related to transport logistics, theoretical maturity models can contribute to the activities qualification of the organizations' logistics system in interface with the smart city dimensions to better improve and balance the urban space dynamics and the efficiency of the logistics services offered in the cities, addressing more accurate decision-making for managers regarding investment strategies, positioning, and adequacy of logistics activities to the built scenarios from the perspective of smart cities (Burger et al. 2011; Jin et al. 2014; Goncalves Filho and Waterson 2018). This way, progressing paths from current maturity levels to desired levels form a clear roadmap for closing existing gaps. The following section presents the methodology used to develop and reach the results of this study.

## 3. Methods

For the construction of the conceptual model for assessing logistical maturity in smart cities, this study uses the models by Giffinger et al. (2007), Cohen (2012), Oleśków-Szłapka and Lubiński (2016), Luftman (2004), and Garcia Reyes and Giachetti (2010), which present theoretical models for evaluating cities in line with the proposal of this study, and which present some factors and indicators appropriate to the reality of logistics and transport.

Among the contributions of these models is the methodological structuring of maturity levels. This combination of models makes it possible to suggest constructing a proper instrument for logistical assessment related to the context of smart cities. Furthermore, it is possible to infer that this study seeks to understand the proximity of logistics in the dimensions of smart cities. Thus, the path to formulating the conceptual evaluation model includes six steps, as described below.

First stage: Data collection (a. literature review; b. indexes and secondary data).

Second stage: Development of a framework relating to logistics factors, referenced in the studies by Glistau and Coello Machado (2018), Cohen (2012), Kiba-Janiak (2016), de Freitas et al. (2016), Oleśków-Szłapka and Lubiński (2016), Lom et al. (2016), Barreto et al. (2017), Strandhagen et al. (2017), and Hofmann and Rüsch (2017), related to the six smart city dimensions, defended in the works of Giffinger et al. (2007), Giffinger and Gudrun (2010); Albino et al. (2015), Caragliu et al. (2011), Taniguchi (2001), Lombardi et al. (2012), Dameri (2017), and Neirotti et al. (2014).

Third stage: Scale construction of the proposed model's maturity levels, taking as a reference the models presented and validated by Lockamy and McCormack (2004), Garcia Reyes and Giachetti (2010), Afonso et al. (2015), Luftman (2004), Oleśków-Szłapka and Lubiński (2016), and Kumar and Dahiya (2017), using the CMMI, besides a. aligning them with logistics factors and smart city dimensions; b. consultation with experts; c. suitability for the instrument.

Fourth stage: Analysis of the instrument by the specialists to understand how the factors and indicators of logistics are perceived in the smart city dimensions (Delphi Method).

Fifth stage: The content analysis application is based on the experts' answers (content analysis).

Sixth stage: Propose a conceptual model for assessing the logistics maturity of smart cities.

This study comprises a qualitative, exploratory, and descriptive approach and uses the Delphi research method. To Creswell (2014), exploratory research can be used to develop theories when there are partial or inadequate theories for a certain population and existing samples or theories that do not adequately capture the complexity of the problem being examined, in this case, the logistical maturity in the scenario of smart cities.

Delphi is the method used for this research. This method is competent for grading research instruments and is characterized by a tool that helps researchers to obtain reliable data from a group of experts. However, it can solve more complex problems (Landeta 2006).

It comprises a set of questionnaires that are answered sequentially and individually by the respondents, presenting summarized information about the group's responses to the previous questionnaires to develop a collective response. Throughout different rounds of questionnaires, the specialists in the field of logistics present their opinions and compare them with those of the group or individually, according to feedback sent in a summarized way. In the following rounds, they argue and defend their positions and, at the same time, are open to reconsidering and changing them in the face of the arguments of other colleagues or the general trend of the group (Marques and de Freitas 2018). In the same sense, Dalkey (1969) advocates that the Delphi method aims to obtain the most reliable consensus from a group of experts through questionnaires aided by feedback. Thus, from this methodological development, Delphi is understood as a systematic method for collecting scientifically valid expert opinions on a given subject (Dalkey 1969).

The operationalization of the Delphi method for this study followed an order indicated in Figure 1. The Delphi structure has the participation of specialists in logistics and smart cities or areas related to the subject listed for this research: logistics, management, and information and communication technology. A sequence of three rounds of analysis and evaluation of the research instrument was chosen, as identified in Table 1, by sending the Research Instrument associated with a Questionnaire (QI) with open-ended questions.

The research universe and sample are characterized by the application of questionnaires sent by e-mail to professionals from public and private companies who have had experiences with smart city initiatives through participation in scientific research, development of projects or studies on the smart city theme or transversal to the theme, and who have worked with the area of logistics, public, or private management, and information technology in Brazilian or international scope. Thus, nine research participants were instructed on the procedures and protocols to answer the research instrument. It should be noted that a specialist is a professionally or scientifically qualified individual who is recognized in the field of study (Garcia Reyes and Giachetti 2010).

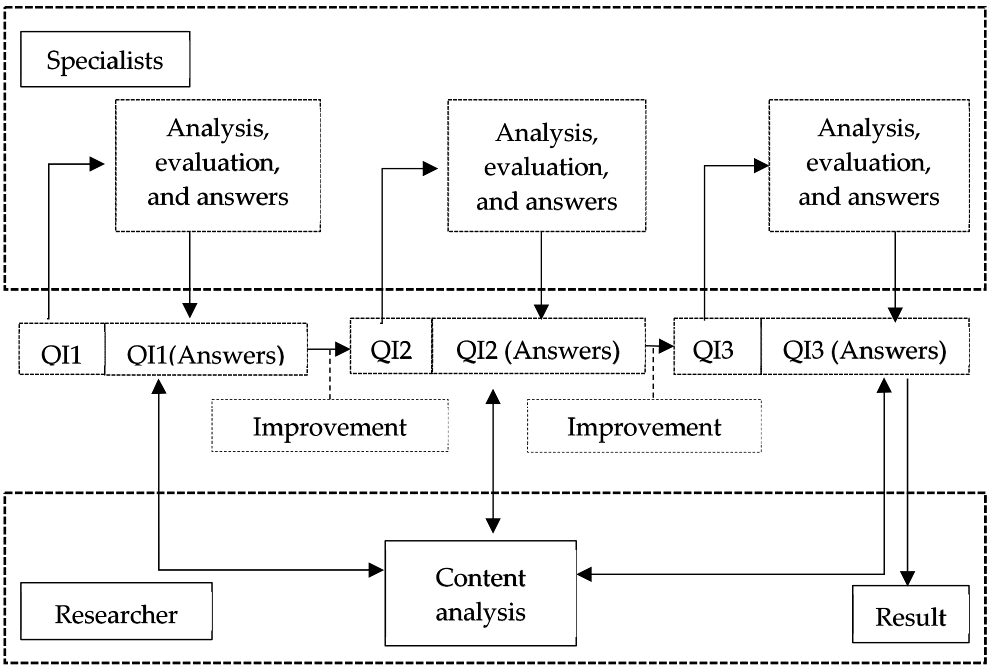


**Figure 1.** Structure of application and analysis of the Delphi method by experts.

**Table 1.** Description of the Delphi method application and analysis rounds.

| Round | Description |
|---|---|
| First | Presentation of the research instrument containing (i) the logistics assessment instrument for smart cities, which comprises five smart city dimensions, ten key logistics factors, and 23 indicators. Then, open-ended questions are asked to specialists on the subject, dimensions, factors, indicators, structure, application, and functionality of the instrument, allowing professionals to express their opinions and perceptions by describing and justifying such inquiries. |
| Second | Presentation of a new instrument and questions based on the answers from the first round. It is possible to present a list of factors and indicators so that the respondent can objectively evaluate, classify, and order according to their criteria in the smart city and logistics theme. |
| Third | Presentation of a research instrument more aligned with the reality of the research objective based on the responses obtained in the second round. Experts may recommend some final adjustments to the proposal of the logistic assessment instrument in smart cities. |

Anonymity was maintained among the experts for each Delphi round. From the second round onwards, in addition to the adjustments to the research instrument, a summary of the other participants' information and opinions was added to provide a greater consensus among professionals. In the interval between each round, the research instrument, composed of the logistic evaluation instrument and the questionnaire, was improved. With the answers of each expert, the researcher chose to apply content analysis appropriate to the content of the answers obtained in questionnaires 1, 2, and 3. After the content analysis, a final version of the instrument for assessing the logistical maturity of smart cities is proposed, considering the expertise and knowledge of the participating experts. The steps followed for the application and analysis of the Delphi method are described in Figure 1.

The questionnaire is the data collection technique used for this research, complementing the instrument's analysis and evaluation of logistics in smart cities. The research instrument of this study was sent to 25 different contacts of representatives from 18 cities with smart initiatives. In total, nine specialists replied, reaching 36% of respondents' participation, a sufficient number for this analysis. After identifying the replies to the assessment instrument, they were contacted via e-mail and digital messaging applications to confirm their participation. Once confirmed, the research instrument was sent via e-mail to confirm their participation and the deadline of the agreed date to return the answers.

The research instrument was built based on the theoretical framework, through secondary data obtained from the research factors and indicators, and through expert feedback to better evaluate urban logistics in the context of smart cities.

The formulated questions in the research instrument were created to allow respondents to assess on a 5-level scale, adjusted to the maturity level models of the Capability Maturity Model Integration (CMMI), inspired by Crosby (1979). To this end, the integration of logistics factors into the five dimensions of smart cities was considered. We chose to use the research instrument via electronic means, considering the nature and extent of the intended research type. The data collection research instrument was built and based on the authors and databases, as highlighted in Figure 2 below:

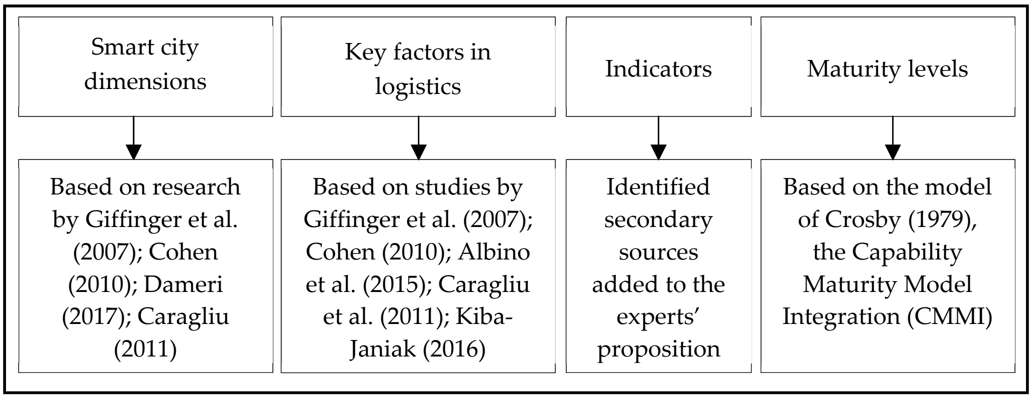


**Figure 2.** Summary of the research instrument's rationale.

To achieve the objectives of this research and the answers to the problem, data collection was performed in three different ways: (i) bibliographic research; (ii) a survey of logistical indicators; and (iii) data obtained through the application of a complementary questionnaire to the research instrument with the specialists.

The bibliographic research was done in the main sources of scientific literature elements to support the bibliographic base of this research, according to the approach on smart city themes, smart cities assessment models, logistical factors and indicators for cities, and maturity models. It also highlighted the ranking of smart cities, the evolution of logistics 4.0, the role of smart city logistics, and logistics in the dimensions of smart cities. The bibliographic survey for these themes was carried out within the main collections of scientific articles, in Portuguese and English, between 2010 and 2019 in the Web of Science, Scopus, Research Gate, Emerald, and Ariane databases (Laval University Canada).

The bibliographic survey (logistical indicators) for this theme was retrieved from electronic sources of organizations, websites, rankings, institutes, universities, councils, and forums that develop projects, research, and studies on smart cities or aspects related to the subject.

The questions listed to the experts refer to the proposal of this work, which, among other research questions, sought to understand: (i) what is the contribution of a logistics assessment instrument for smart cities? (ii) how can logistics contribute to the needs and intelligence of cities through their qualification? and (iii) how is logistics understood in the smart city dimensions? The search for these answers is supported by scientific rigor based on the group of researchers from Vienna who created the dimensions of smart cities and inspired scientists, public and private managers, and other stakeholders to understand the contributions of these dimensions to the development of cities and everything around them (The Smart City Model 2018).

The thinking that led to the development of the logistics maturity assessment model in smart cities aims to understand the performance of logistics activities, through its factors and indicators, in an innovative scenario that has been gaining more and more space in economic, political, entrepreneurial, and organizational agendas in public and private contexts.

The represented design in Figure 3 shows the correlation between the smart cities dimensions and the key logistics factors, measured by the maturity levels, based on the Capability Maturity Model Integration (CMMI). This perspective presents the alignment between the themes and how this work intends to associate them. It is worth noting that for each key factor, there is a set of indicators that support the development of the instrument for assessing logistical maturity in smart cities.

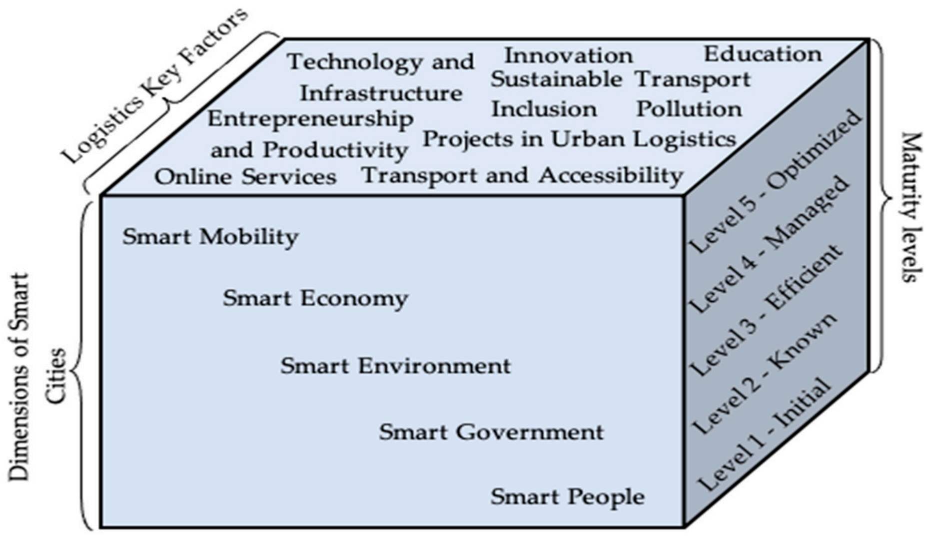


**Figure 3.** Framework for integrating logistical factors, smart city, and maturity levels.

The proposed logistics evaluation model is different from those that already exist, as it addresses an innovative theme and a different methodological configuration, in addition to presenting a problematization that involves logistical factors and indicators associated with smart city dimensions, which was not addressed by the analyzed models, and which can contribute to solving issues in these areas in the organizational, industrial, social, and environmental arenas. Thus, there is an innovative theme and contribution in the practical and scientific field, standing out as a contemporary, innovative, and sophisticated subject that will contribute to the new managerial, economic, social, environmental, governmental, and structural correlations in the field of smart cities.

## 4. Results

With the perspective of proposing a conceptual model to evaluate logistics in the smart cities' environment, this research developed a five-point maturity scale based on the precepts of Crosby (1979), related to the Capacity Maturity Model (CMM), adapted to the reality of logistics in smart cities, where concepts that best represent the graduation of logistics in smart cities were extracted. This approach improved the levels by evaluating the experts participating in the research. The proposed scale aims to present the maturity evolution of the logistics aspects in the cut of smart cities dimensions.

The correlation between the maturity scale and the research instrument aims to gradually identify the stage and evolution of logistics for each key factor in the dimensions of smart cities, hoping to show the evaluator, through the instrument, the reality of logistics for the assessed city. In this way, with each progression obtained at the scale level, the city starts to develop activities related to logistics in the context of smart cities with greater qualifications. With each degree of maturity reached, the city can also offer better applications of logistics related to the dimensions of smart cities presented in this study. Table 2 presents the result of the scale with the logistical maturity levels description in smart cities after the three Delphi rounds.

As previously mentioned in the literature, the importance of identifying and adjusting indicators that will compose the evaluation model was noted. In addition to identifying the indicators, it is important to clarify their understanding and apply it to the assessed context. Data and information must be available so that a more incisive analysis can be carried out with all the considered indicators and factors. In this context, the objective of the evaluation model is to guide the evaluator to understand what is important to evaluate in the city from the logistic point of view in smart cities, considering the main notes of works found in the literature on the subject.

**Table 2.** Scale with the logistical maturity levels description in smart cities (results of the third Delphi round).

| Level | Scale | Description |
|---|---|---|
| 1 | Initial | Logistics indicators do not exist and do not meet the development of mobility, economy, environment, governance, and people dimensions. |
| 2 | Known | The logistics indicators have a 'bad' evaluation result which may result in below-average service in terms of development of mobility, economy, environment, governance, and people dimensions below average. There is no logistical planning system. |
| 3 | Efficient | The logistics indicators have a 'good' evaluation result which may result in average service in terms of development of mobility, economy, environment, governance, and people dimensions. There is a logistics planning system under development. |
| 4 | Managed | The logistics indicators have a 'good' evaluation result which may result in above-average service in terms of development of mobility, economy, environment, governance, and people dimensions above average. There is an established logistical planning system. |
| 5 | Optimized | The logistics indicators have an 'excellent' evaluation result which may result in exceptional service in terms of development of mobility, economy, environment, governance, and people dimensions. The logistics planning system is continuously improved, and the indicators reflect the logistics demand for a smart city. |

After the experts' assessment cycles, the assessment model underwent adjustments to improve the information contained in the tool. Thus, Table 3 represents the third Delphi round, where the experts had a positive weighting on the adjusted instrument result after the second Delphi round.

**Table 3.** Third round result of the Delphi method: an instrument for assessing logistical maturity in smart cities.

| | | | |
|---|---|---|---|
| Smart Mobility | | | |
| Key factors: Transport and Accessibility | | | |
| Ind. * | Types of public land transport offered in the city | | Source |
| Maturity levels | 1 | Bus only | Local Prefecture, National Transport Confederation (CNT) |
| | 2 | Bus and train | |
| | 3 | Bus, train, and subway | |
| | 4 | Interchange between modes (1 + 2 + 3) | |
| | 5 | Optimization of the use of modals (1 + 2 + 3) through the application | |
| Ind. * | Transport infrastructure | | Source |
| Maturity levels | 1 | There is no exclusive lane for transport | Local City Hall, Metrobits, Numbeo, National Transport Confederation (CNT) |
| | 2 | Exclusive lane for one type of transport | |
| | 3 | Two types of transport with a preferential lane (providing space for transporting bicycles and suitcases on buses, trains, and subways) | |
| | 4 | Three types of transport with a preferential lane (low waiting time, punctuality, comfortable transport) | |
| | 5 | Four or more types of transport with a preferential lane (high platform, avoiding steps, covers at stops, air conditioning) | |

**Table 3.** *Cont.*

| Ind. * | Air infrastructure for people and cargo | | Source |
|---|---|---|---|
| Maturity levels | 1 | The city has no airport | National Transport Confederation (CNT), Infraero |
| | 2 | The city has an airport with regional and domestic flights, a parking area, and an air-conditioned passenger area | |
| | 3 | The city has an airport with regular regional, domestic, and international flights capable of transporting international cargo | |
| | 4 | With a high frequency and comfortable regional, domestic, and international flights; airport with all services available and fully operating | |
| | 5 | The airport is a HUB[1] with direct access to the public transport service to the destination city. Facilities such as aero shopping and rest facilities | |
| Ind. * | Traffic management indicator | | Source |
| Maturity levels | 1 | There is no logistics indicator | Local City Hall, Numbeo, Open Street Map |
| | 2 | There is mapping and management of traffic lights | |
| | 3 | There is mapping and management of traffic lights and crosswalks | |
| | 4 | There is mapping and management of traffic lights, crosswalks, and bike lanes | |
| | 5 | There is a mobility plan with the mapping and management of traffic lights, crosswalks, and bike lanes | |
| Ind. * | Modal interchange | | Source |
| Maturity levels | 1 | There is no interchange | National Transport Confederation (CNT) |
| | 2 | Interchange between 2 modes (Ex.: ship and train) | |
| | 3 | Interchange between 3 modes (Ex.: ship, train, and truck) | |
| | 4 | Interchange between 4 modes (Ex.: ship, train, truck, and plane) | |
| | 5 | Interchange between 5 modes (Ex.: ship, train, truck, plane, and pipeline) | |
| | Key factors: Technology and Infrastructure | | |
| Ind. * | Number of types of public transport that provide real-time information to the public (example: automatic payments for devices, passenger monitoring, security, flow monitoring, fuel expenses, physical space at stops, etc.) | | Source |
| Maturity levels | 1 | No type of transport | WiFi Map app, Local City Hall |
| | 2 | Bus only | |
| | 3 | Bus and subway | |
| | 4 | Bus, subway, and train | |
| | 5 | Bus, subway, train, and Light Rail Vehicle (LRT) | |
| Ind. * | Number of software solutions for city logistics | | Source |
| Maturity levels | 1 | No solution | Universities, Specialized Research Centers |
| | 2 | Just one solution for transport logistics | |
| | 3 | Solutions for transport logistics and reverse logistics | |
| | 4 | Solutions for transport logistics, reverse logistics, and urban mobility | |
| | 5 | Solutions for logistics interchange | |

**Table 3.** *Cont.*

| | | | |
|---|---|---|---|
| Smart economy | | | |
| Key factors: Entrepreneurship and Productivity | | | |
| Ind. * | Number of transport companies in the city | | Source |
| Maturity levels | 1 | No company | National Transport Confederation (CNT), Brazilian Institute of Geography and Statistics (IBGE) |
| | 2 | One to ten companies | |
| | 3 | Eleven to twenty companies | |
| | 4 | Twenty-one to forty companies | |
| | 5 | Forty-one or more companies | |
| Ind. * | % of the flow of land cargo transported in the city | | Source |
| Maturity levels | 1 | 0% to 5% | National Transport Confederation (CNT) |
| | 2 | 6% to 25% | |
| | 3 | 26% to 50% | |
| | 4 | 51% to 75% | |
| | 5 | 76% to 100% | |
| Ind. * | Number of businesses in the city focused on smart mobility | | Source |
| Maturity levels | 1 | There is no business in this area | Local government, Specialized companies |
| | 2 | There is only one business type available (example: Uber) | |
| | 3 | There are two types of deals available (example: Uber and bike sharing) | |
| | 4 | There are three types of deals available (example: Uber, bike-sharing, and car-sharing) | |
| | 5 | There are four or more deals available (example: Uber, bike sharing, car sharing, and drone delivery) | |
| Key factor: Innovation | | | |
| Ind. * | Number of awards in smart cities | | Source |
| Maturity levels | 1 | No awards | Local City Hall, Urban Systems |
| | 2 | Just one award | |
| | 3 | Two awards | |
| | 4 | Three awards | |
| | 5 | Four or more awards | |
| Ind. * | Number of projects in smart cities | | Source |
| Maturity levels | 1 | No project | Local City Hall, Urban Systems |
| | 2 | Just one project | |
| | 3 | Two projects | |
| | 4 | Three projects | |
| | 5 | Four or more projects | |

**Table 3.** *Cont.*

| | | | |
|---|---|---|---|
| Smart government | | | |
| Key factor: Projects in urban logistics | | | |
| Ind. * | Number of projects related to urban freight transport in which the local authority has been involved | | Source |
| Maturity levels | 1 | No project | Local City Hall, Urban Systems |
| | 2 | Just one project | |
| | 3 | Two projects | |
| | 4 | Three projects | |
| | 5 | Four or more projects | |
| Key factor: Online public services | | | |
| Ind. * | Number of government services that citizens can access via the web or phone | | Source |
| Maturity levels | 1 | No service | Local City Hall, International Organization for Standardization (ISO) 37.120 |
| | 2 | Just one service | |
| | 3 | Two services | |
| | 4 | Three services | |
| | 5 | Four or more services | |
| Intelligent Environment | | | |
| Key factor: Pollution management | | | |
| Ind. * | Urban sanitation | | Source |
| Maturity levels | 1 | There is no sanitation | National Sanitation Information System (SNIS) |
| | 2 | There is only water sanitation | |
| | 3 | There is water and sewage sanitation | |
| | 4 | There is water, sewage, and solid waste sanitation | |
| | 5 | There is water, sewage, solid waste, and rainwater sanitation | |
| Ind. * | Number of companies providing reverse logistics services in the city | | Source |
| Maturity levels | 1 | No company | National Transport Confederation (CNT) |
| | 2 | One to two companies | |
| | 3 | Three to four companies | |
| | 4 | Five to six companies | |
| | 5 | Seven or more companies | |
| Key factor: Sustainable Transport | | | |
| Ind. * | Number of charging stations for electric cars in the city | | Source |
| Maturity levels | 1 | No station | Specialized research companies |
| | 2 | One to two stations every 150 km | |
| | 3 | Three to five stations every 150 km | |
| | 4 | Six to seven stations every 150 km | |
| | 5 | Eight or more stations every 150 km | |
| Ind. * | Bike share station systems | | Source |
| Maturity levels | 1 | There are no stations | Bike Share, Institute for Transport and Development Policy (ITDP), Local City Hall |
| | 2 | Four to fifteen bicycles per station per 1000 inhabitants | |
| | 3 | Six to twenty bicycles per station per 1000 inhabitants | |
| | 4 | Eight to twenty-five bicycles per station per 1000 inhabitants | |
| | 5 | Ten to thirty bicycles per station per 1000 inhabitants | |

**Table 3.** *Cont.*

| Ind. * | | Number of projects or programs aimed at reducing noise and air pollution | Source |
|---|---|---|---|
| Maturity levels | 1 | No project | Local City Hall |
| | 2 | Just one project | |
| | 3 | Two to five projects | |
| | 4 | Six to ten projects | |
| | 5 | Eleven projects or more | |
| Ind. * | | Waste Management | Source |
| Maturity levels | 1 | There is a landfill | Local City Hall |
| | 2 | There is a controlled sanitary landfill | |
| | 3 | There is a sanitary landfill plus selective collection | |
| | 4 | Items 2+3 and composting system | |
| | 5 | Planning of solid waste collection through sensors | |
| | | Smart people | |
| | | Key factor: Education | |
| Ind. * | | Educational level of the population | Source |
| Maturity levels | 1 | Elementary School | National Institute for Educational Studies and Research (INEP) |
| | 2 | High school | |
| | 3 | University education | |
| | 4 | Master's degree | |
| | 5 | Doctor's degree | |
| Ind. * | | Number of courses in logistics in the city | Source |
| Maturity levels | 1 | There is no degree or technological course in logistics | National Institute for Educational Studies and Research (INEP) |
| | 2 | There is a degree or technological course in the area | |
| | 3 | There is a course in the area at the *Lato Sensu Level*[2] | |
| | 4 | There are courses in the area at the Master's level | |
| | 5 | There is a course in the area at the Doctor's level | |
| Ind. * | | Totems/Terminals with public access to transport information: orientation, timetable information, transport interchange, and ticket sales | Source |
| Maturity levels | 1 | There are no totems | Local government, specialized companies |
| | 2 | There is 1 totem in 1 neighborhood | |
| | 3 | There are 1 to 10 totems in 2 to 5 neighborhoods | |
| | 4 | There are 11 to 20 totems in 6 to 20 neighborhoods | |
| | 5 | There are more than 20 totems in more than 10 neighborhoods | |
| | | Key factor: Social inclusion | |
| Ind. * | | % of people with smartphone access in the city | Source |
| Maturity levels | 1 | 0% to 5% | Brazilian Institute of Geography and Statistics (IBGE), National Telecommunications Agency (ANATEL) |
| | 2 | 6% to 25% | |
| | 3 | 26% to 50% | |
| | 4 | 51% to 75% | |
| | 5 | 76% to 100% | |

* Indicator.

Following the experts' analysis, the third and final round of the Delphi method resulted in the composition of the aspects to be considered in the evaluation of the conceptual model for evaluating logistics maturity in the dimensions of smart cities, identified in Table 4.

**Table 4.** The proposition of the conceptual model for evaluating the levels of logistics maturity in the dimensions of smart cities.

| Smart City Dimensions | Logistical Factors | Indicators | Logistical Performance Level <Low Influence, High Logistics> | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 |
| Smart mobility | Transport and Infrastructure | Public transport network number per inhabitant | | | | | |
| | | Percentage of restricted bus lanes in the public transport network | | | | | |
| | | Number of buses or equivalents operating on public transport | | | | | |
| | | Number of public transport stops per 1000 inhabitants | | | | | |
| | | Passenger air transport and cargo air transport | | | | | |
| | Local accessibility | Satisfaction with access and quality of public transport | | | | | |
| | Sustainable, innovative, and safe transport systems | Mobility sharing (non-motorized vehicles) | | | | | |
| | | Safe urban traffic | | | | | |
| | | Transport with clean energy | | | | | |
| | Technologies | Access to real-time information | | | | | |
| Smart economy | Entrepreneurship and productivity | Number of logistics companies in the city | | | | | |
| | | Number of mobility-oriented businesses | | | | | |
| | | Volume of transported cargo | | | | | |
| | Innovation | Awards and projects on smart cities | | | | | |
| | International market | Import and export flow | | | | | |
| Smart governance | Online public services | Number of government services accessed by citizens via the internet | | | | | |
| | | Coverage of information by sensors. Integrated safety and health operations | | | | | |
| | Urban logistics project | Number of projects related to urban freight transport | | | | | |
| Smart environment | Sustainable transport | Bike-sharing station systems | | | | | |
| | | Number of charging stations for electric cars in the city | | | | | |
| | | Number of projects aimed at reducing noise and air pollution | | | | | |
| | Resource management | Energy, air quality | | | | | |
| | | Waste Management | | | | | |
| | | Total $CO_2$ emissions | | | | | |
| Smart people | Education | Percentage of population aged 15 to 64 with higher education | | | | | |
| | Qualification level | Major research centers, major universities, etc. | | | | | |
| | | Population qualification level | | | | | |
| | | Number of courses in the area of logistics in the city | | | | | |
| Smart life | Quality of life ranking | Quality of life ranking (HDI—Human Development Index) | | | | | |
| | | Percentage of people with smartphone access in the city | | | | | |

For didactic purposes, the conceptual model operationalization for evaluating the levels of logistics maturity considers the final model proposition presented in Table 4, where the evaluator takes as a reference, through a scale from 1 to 5, the levels of logistics maturity presented in Table 2, in order to guide the logistics qualification in each evaluated dimension, corresponding to the degree of logistics influence on indicators and related factors. To complement the conceptual model, Table 3, which is the result of the third Delphi round, presents some sources of references to support the composition of the research results.

Moreover, what to expect from a conceptual model for assessing logistical maturity from the perspective of smart cities? As already mentioned in this investigation, cities have received a greater number of inhabitants over the last few years, which has increased the occupation of urban space. The trend that studies show is that these numbers increase even more. In this way, seeking solutions that alleviate pressures in cities is one of the challenges to be overcome by public managers and all those who use urban space (industries, companies, society, etc.) and who are directly and indirectly involved in the maintenance and development of cities.

Logistics can be treated as a fundamental issue for organizing city movement dynamics, which means that it finds strategic correlations in the dimensions of smart cities since it offers techniques, scientific models, and competent alternatives to improve the supply of services and address fundamental issues for the maintenance of cities concerning mobility, economy and governance, environment, people, and their quality of life.

To analyze and evaluate the degree of logistics qualification in the city, it is imperative to have an instrument that can measure and provide adequate information for the evaluator to make decisions and forcefully analyze the results. With the information from the evaluation model, the evaluator will be able to offer solutions at a strategic level for the best choices of actions in the field of logistics, according to the reality of each city, extracting specific aspects of the area, in order to contribute to the development of smart city initiatives in each region.

The reasons that led to the presented model are related to the contributions that logistics have contributed to the evolution of society, industries, and organizations through its different forms of action. In addition, the different transformations that the theme presents in the face of new challenges and situations are recognized, whether in the organizational, social, urban, environmental, or industrial environment, which is increasingly involved with the use of technological innovations and the internet. In this sense, inserting logistics in the performance of smart city initiatives shows the importance and necessity of this prosperous and fundamental correlation for improving city dynamics.

The proposed conceptual model can help managers to identify the importance and influence that the logistical factor represents for the development of cities. Based on preliminary conclusions, this conceptual model can contribute to the development of logistics activities in cities and can be used to improve the structure and quality of logistics services offered in the context of smart cities. Among the possible results obtained with the conceptual model is the contribution as a comparative aspect in offering good logistics practices between cities, which seek to improve their level of intelligence in the dimensions presented in this study. The table below presents the final proposition of the conceptual model for assessing the levels of logistical maturity in the dimensions of smart cities.

## 5. Conclusions

The evaluation of logistics in smart cities refers to issues linked to mobility, traffic flow, adequate transport, accessibility, reverse logistics, and technologies applied to devices related to logistics. This scenario is found in the works of Neirotti et al. (2014), Kiba-Janiak (2016), and Taniguchi (2001). From the use of the proposed evaluation instrument, the following contributions of logistics are highlighted in terms of their application to cities and organizations.

By identifying indicators and key factors in the dimensions of smart cities, in order to contribute to their qualification in smart cities, this study highlights some conceptual model contributions of logistics evaluation, which show that the tool can (1) help in the comparison between cities in order to learn and extract the main and good logistics practices in the region; (2) present strong solutions with each dimension of evaluated smart city, reverberating in the population's quality of life; (3) be considered as an evaluation tool to aid in decisions about investments in logistics in the city, considering the obtained results with the indicators analysis; (4) be a reference instrument used by managers involved in smart city actions with a logistics bias; (5) contribute to the development of rankings for evaluating smart cities with the logistics approach, which can be considered as a benchmark for good practices; (6) contribute to the identification of the need for skilled labor in logistics in the city; (7) help identify investments in the best type of modal that the city needs; (8) help mayors and public managers in the search for solutions on mobility by analyzing the supply of infrastructure and types of public transport, air infrastructure, people and cargo offered in the city, and traffic management; (9) point to the need to invest in logistics companies and businesses focused on smart mobility; (10) encourage public-private partnership in logistics actions for smart cities; (11) encourage the development of good smart city practices related to logistics, through the presentation of projects, encouraged by awards; (12) help to identify the scenario for the provision of better public services of logistics and mobility for the population; and (13) recommend an ideal scenario for formatting a structure with sustainable transport for the city.

Based on the analysis of the scientific literature on smart cities, it is possible to conclude that this subject is far from being consolidated, especially because it is a multidisciplinary approach, which demands other areas of study to contemplate the objectives that circulate the demands of cities, including economic, logistics and transport, technological, environmental, social, structural, and governmental issues. In this scenario, seeking to qualify logistics in the urban environment is complex and requires a specialized look at identifying the city's structural, geographic, regional, social, and environmental characteristics. This study had the main objective of proposing a conceptual model for evaluating logistics maturity for smart cities, which was achieved given the careful analysis carried out with the theoretical bases that support the proposition of indicators and logistics factors, validated by the expertise of the specialists questioned concerning the proposed model.

As a social–technological contribution, the proposition of a scale for assessing logistics maturity in the dimensions of a smart city can serve as an assessment model of logistics with specialists in the smart city and logistics theme, which means assisting in urban planning and strategic management of cities, enabling more intelligent analysis and solutions, in line with the realities of each urban space.

As research limitations, the time considered for applying bibliometric analysis was identified. Therefore, it is important to consider that cities need indicators to measure their performance to improve their quality of life, and their functional aspects, such as those explored in the smart city dimensions (Kumar and Dahiya 2017; Dameri 2017). Measuring the performance of logistics services, whether in the strategic business aspect, whether at the municipal level, or in the management of transport, mobility, environment, and governance, is directly linked to society's quality of life (Albino et al. 2015; Kumar and Dahiya 2017; Alaverdyan et al. 2018; de Oliveira 2016).

As recommendations for future work, further research may use the theoretical model in practice and in several cities. From the results obtained with the practical application, an analysis can be made of how logistics influence the performance of cities in comparative rankings between smart cities. In addition, it will be possible to translate the importance of logistics for developing cities with more sustainable, humane, dynamic, and intelligent initiatives. This study, therefore, encourages the development of work with a logistics bias in smart cities.

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## Notes

1 These are airports where airlines concentrate their flights and use them as transfer points for their passengers to reach their destinations.

2 *Lato Sensu* comes from Latin and means "in a broad sense". In this context, *Lato Sensu* Level is a set of theoretical or practical courses or research activities within a specific field that partially fulfills the requirements of a graduate-level degree that can be completed within four to eight months.

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