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DOI
10.3390/su12156091

Publication date
2020

Document Version
Final published version

Published in
Sustainability

Citation (APA)
Pennings, R., Wiegmans, B., & Spit, T. (2020). Can we have our cake and still eat it? A review of flexibility in the structural spatial development and passenger transport relation in developing countries. *Sustainability*, *12*(15), 1-25. Article 6091. https://doi.org/10.3390/su12156091

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Review

Can We Have Our Cake and Still Eat It? A Review of Flexibility in the Structural Spatial Development and Passenger Transport Relation in Developing Countries

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Received: 31 May 2020; Accepted: 26 July 2020; Published: 29 July 2020

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Abstract: With growing urban populations, higher mobility needs, limited available space for transport infrastructure, and the increasing need for more attractive urban areas, these urban areas are faced with a complex dilemma, which gets more challenging by the day. This paper examines the role of flexibility in the relationship between structural spatial development and passenger transport, its economic, environmental, and social perspectives, the long-term impacts of this relationship and the role of this relationship in developing countries. The paper identifies the need for a better understanding of long-term flexibility in development options in order to make better future-proof decisions as a key research avenue, and sets a pathway to achieve this. Main research gaps as identified in the paper include the lack of understanding on the potential for flexibility in optimizing the structural spatial development and passenger transport relationship, the valuation of flexibility, and the application of flexibility approaches in developing countries. This paper emphasizes the importance of acting sooner rather than later, since the future costs of sub-optimal development are rising by the day and the bill is being pushed towards future generations.

Keywords: structural spatial development; passenger transport; metropolitan areas; developing countries; flexibility

1. Introduction

More than half of the world's population lives in cities and the urban population is expected to grow by 2.5 billion people in 2050 [1]. Both existing and new metropolitan areas need to cope with this increasing number of inhabitants. Nearly 90% of this urban growth will take place in Asia and Africa [2], and this influx of people into metropolitan areas causes issues such as lack of shelter, insufficient infrastructure and services, inadequate local governments, and environmental issues [3]. Within this paper, the focus is on passenger transport, since it helps to indicates the challenges caused by the growing urban population. With growth in population, increasing urban sprawl, and increasing income per capita, the pressure on urban passenger transport increases [4]. Combined with limited availability of public transport, this leads to higher ownership and usage of motorized private modes, which in turn leads to congestion [5]. Furthermore, many cities in developing countries have a relatively low ratio of urban land allocated to streets compared to cities in developed countries, which also leads to congestion and gridlocks [6]. Since people are attracted by more favorable commute situations, this will affect their job choices [7]. However, trade-offs between economic activities and travel demand need to be found [8]. This means that with potential increasing delays in the system and a balancing act with economic activities, the attractiveness of the metropolitan areas can decrease, which in turn can hamper the economic development of the metropolitan area and herewith the area's subsequent attraction for people and businesses.

At the same time, the growing complexity with respect to governance, society, and competitiveness with other metropolitan areas leads to an increase in developments, which will impact the metropolitan area's future development direction [9]. This growth in complexity and time consumption of infrastructure projects limits the (literal and figurative) space to maneuver for significant physical urban changes [10], which in turn can make the start of large-scale urban infrastructural changes more difficult and therefore affect passenger transportation in existing and newly developed metropolitan areas. UN-Habitat research indicated the urgency of current inefficiencies and lack of urban planning in developing cities, and the need to act on this while land prices are still low, in order to avoid growing future problems (e.g., gridlocks and congestion) [6].

Together, this variety of challenges lead to increasing complexity of decision-making in the development of metropolitan areas. When this decision-making becomes sub-optimal, short-term positive decisions can lead to long-term negative consequences, which can hamper future development of the metropolitan area. In order to be able to cope with these suboptimal developments, flexibility ("the ability to be easily modified" [11]) is a necessity. Therefore, there is strong urgency to build a better understanding of these dynamics, especially in areas where strong urban growth takes place.

This increasing pressure on urban passenger transport and the growing complexity of urban areas are two important trends in the relationship between structural spatial development (SSD) and passenger transport (PT). Both SSD and PT will be further explained below.

- Structural spatial development is defined as the fundamental setup of the (urban) area. The spatial development indicates the development of the spatial structure, which is the "manner [in] which space is organized by the cumulative locations of infrastructure, economic activities and their relations" [12]. This includes the available passenger transport infrastructure, which describes the total of different transport infrastructure that is available for passenger transport in the metropolitan area.
- (Urban) passenger transport is defined as the "provision of access and mobility for people [. . .], linking origins and destinations both internal and external to the urban area" [13]. It makes use of the passenger transport infrastructure of the Structural Spatial Development.

This review paper focuses on the role of flexibility in the SSD-PT relationship. The conceptual diagram can be seen in Figure 1.

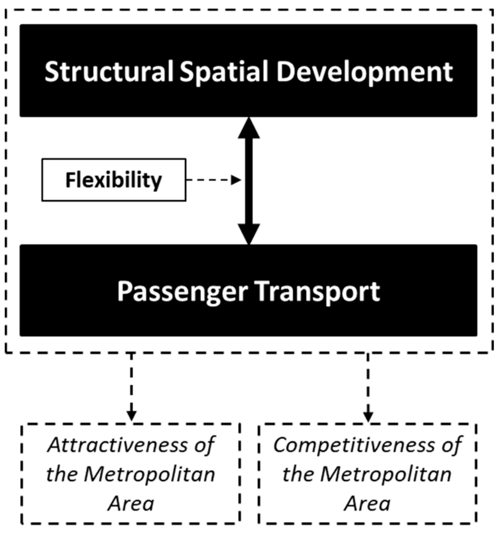

Figure 1. The conceptual diagram for the research.

The objective of the paper is to explore and analyze knowledge gaps on the place of flexibility in the structural spatial development and passenger transport relationship in metropolitan areas in developing countries.

In this paper, Section 2 will describe the methodology of the literature review, Section 3 will discuss the reviewed literature, and Section 4 will conclude this paper with the identified avenues for further research.

2. The Method of the Literature Review

The methodology of the literature review aimed at identifying and covering the existing relevant literature. This Section covers the way the literature was collected and the selection of the relevant papers. The collection was approached by four steps being taken (and visualized in Figure 2):

1. Search on Google Scholar, Scopus, and Web of Science on the topic (search settings on title, keywords, and full abstract; including strings). Key search words were (1) Structural Spatial Development, (2) Passenger Transportation, (3) Metropolitan Area, and (4) Developing Countries. These words have been used in different combinations;
2. Based on the papers found in Step 1, references in and to these papers were followed and included where relevant (snowballing was included);
3. The papers found in Step 1 and 2 were analyzed and structured using the key words as given by the article itself and key words as listed during the analysis per article by the author. This concerned a total of 386 unique keywords;
4. Based on the keywords per article in Step 3, the articles were sieved based on their fit in the scope of the paper. This sieving was based on 18 indicators, which were derived from the listed key words in step 3, which stress the topic(s) of the reviewed papers. These indicators were land use, urban form, infrastructure, transport, accessibility, climate change, density, mobility, policy, public transport, urbanization, sustainability, commuting, compact cities, public transit, urban sprawl, and urban structure.

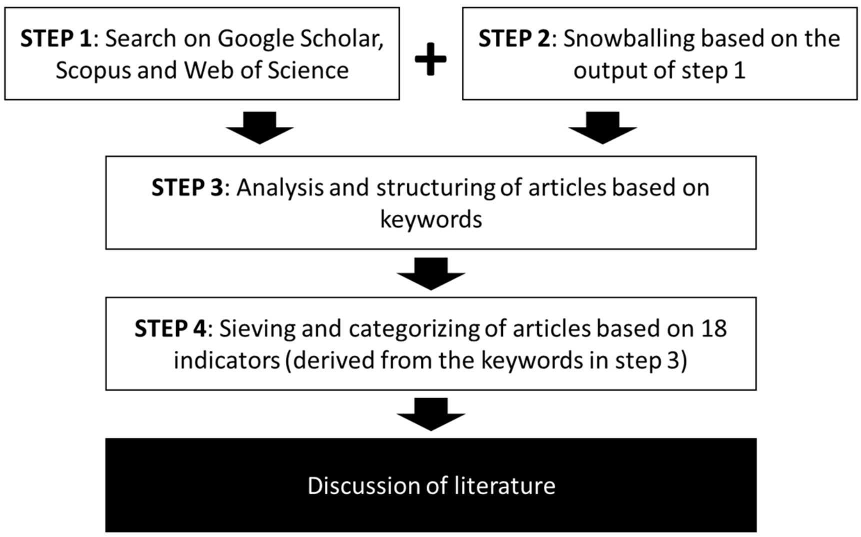

Figure 2. The methodology as applied in this literature review.

These selected papers were grouped based on their main indicators, as described under step 4, and were discussed in paragraph 3 in these respective groupings.

For the selection of the papers found, no limitations were set on timeframe and geographical area. Although the focus was on developing countries, the "SSD-PT" relationship is present in cities in both developing and developed countries. Books were not included in the analysis.

3. The Reviewed Literature

In total, 155 papers were collected and reviewed (see Appendix A).

3.1. Descriptive Analysis

In this part a focus on basic features is made, based on:

- Distribution by journal of publication: Table 1 shows the main journals in which the articles have been published;
- Distribution by year of publication: As can be seen in Figure 3, this shows a growing number of publications over time, with a dip in this number between 2010–2014;
- Distribution by geographical area of focus: Figure 4 shows the geographical distribution. In general, approx. 62% of the articles focused on the developed world, and 38% had a focus on the developing world (based on the UN DESA Country Classification [14];
- Overview of the keywords in the reviewed literature: Figure 5 shows the most common keywords in the reviewed literature;
- Distribution by research method used: Table 2 gives an overview of the main research methods applied.

Table 1. The distribution of the journals by publication (3 and higher).

Journal	Number of References (3 and more)
Journal of Transport Geography	17
Urban Studies	10
Transport Policy	8
Transportation Research Part A	7
Journal of Urban Economics	7
Journal of the American Planning Association	6
Habitat International	6
Energy Policy	5
Transport Reviews	5
Sustainability	4
Land Use Policy	3
Transportation Research Part D	3
Ecological Economics	3

Table 2. DISTRIBUTION BY RESEARCH METHOD.

Research Method	Number of Papers (5 and more)
Analysis	34
Literature review	33
Model	24
Comparison	10
Case study	9
Emperical Analysis	8
Evaluation	6
Discussion	5

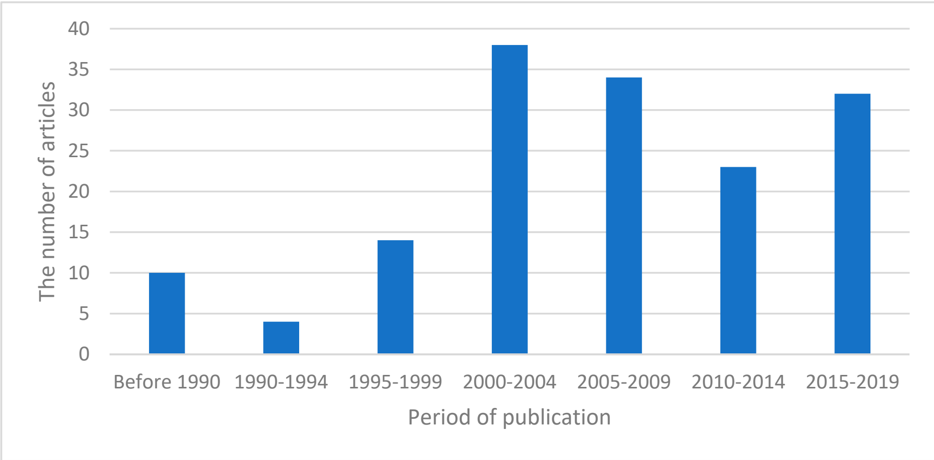

Figure 3. The distribution by year.

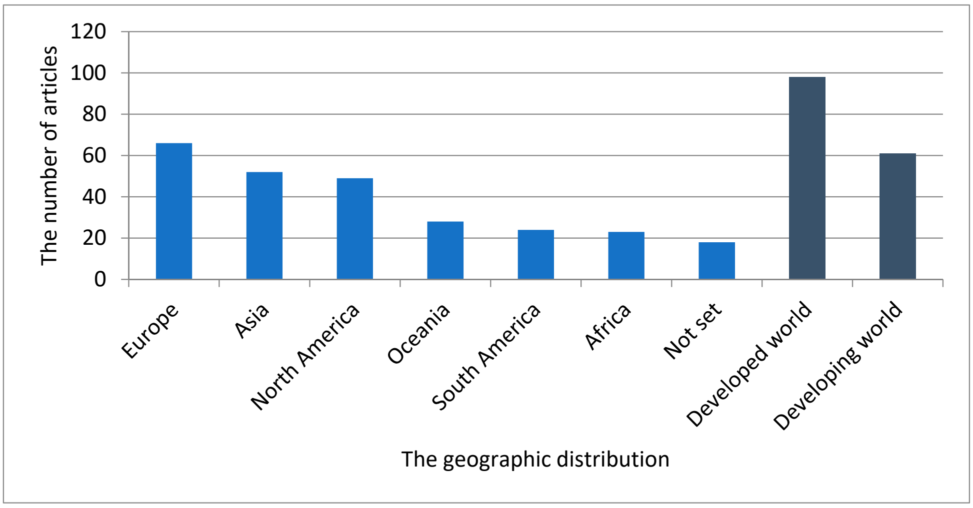

Figure 4. The geographical distribution of the reviewed literature.

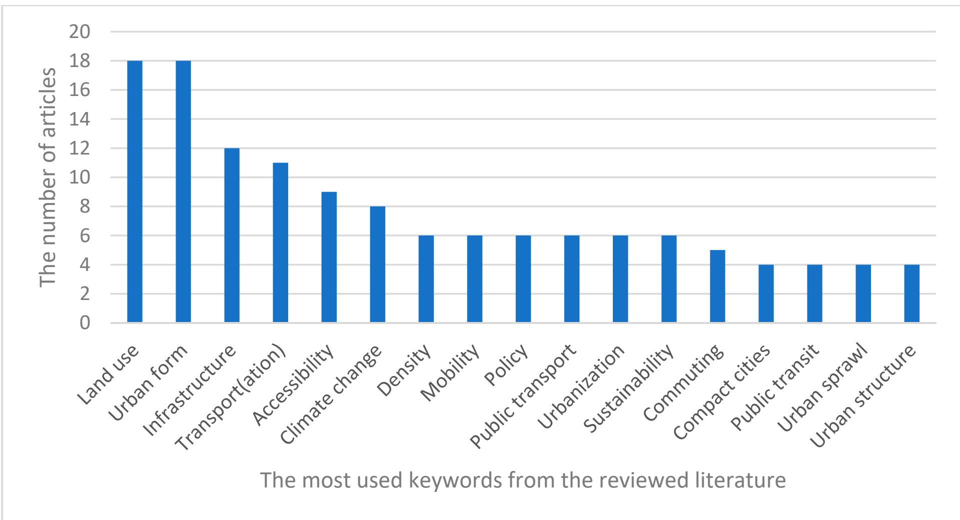

Figure 5. Overview of the key words in the reviewed literature.

3.2. Content Analysis

The content analysis took the direct SSD-PT relationship into account, as well as its impacts, elements which influence the relationship, and its place in the developed and developing world.

The first step was a focus on the direct SSD-PT relationship, specifically from the SSD and the PT perspectives to get a full coverage of the relationship. The second step was a focus on the economic, environmental, and social perspective of the SSD-PT relationship. The third step reviewed the policy point of view. Step four looked at the aspects of interest, based on the findings of the previous subparagraph. The fifth and final step was a focus on the state of the SSD-PT relationship in developing countries. Identified research gaps are indicated by 'RG' and numbered for reference.

3.2.1. The Relationship between Spatial Structural Development and Passenger Transport

In 1959, Hansen indicated the link between accessibility and (residential) land use. This research highlighted the increasing development potential with better accessibility, and it indicated the continuous changing of accessibility and available land over time [15]. Newman and Kenworthy further addressed this relationship and described the disconnection of land use and transport due to automobile dependence. Furthermore, they indicated the need for integrated and coherent transit-based planning [16]. Van Wee showed that mixed land use, high densities, and making optimal use of rail infrastructure will be beneficial for accessibility [17]. This underlines that accessibility changes over time and it remains dynamic.

Van Wee further indicated that land use can influence transport, but many more factors should be taken into account when assessing which land use alternative to choose (including accessibility, congestion, road safety, environmental impacts, residential and firm preferences, financial aspects, and the robustness of the land use-transport system) [17]. This shows the complexity in decision-making. Handy indicated further complexity of the relationship between transport and land use, due to its system of endogenous relationships (e.g., transport investments) and exogenous factors (e.g., sociodemographic characteristics). It emphasizes the lack of available data to (better) approach these complex relationships, the degree of the connection, and the direction of causality. In turn, this challenges the reliability of the impacts of new transport investments on land development patterns or of land use and design strategies on travel behavior [18]. Holz-Rau et. al. further underlined the complexity of the land use and transport relationship, indicating the impact of societal factors such as economic growth, the spatial division of labor, large-scale societal integration, and gender equity [19]. This indicates that due to the complexity, the many influencing factors and the reliability of expected impacts, it is key to have a clear understanding of the impact over time, and to have the ability to steer developments when these impacts do not develop as required. The specific research gap here is the knowledge on the development of future dynamic behavior and its impacts on urban areas [RG 1].

The SSD Perspective on the SSD-PT Relationship

From the SSD perspective, the impact of the built environment on travel demand depends on a variety of factors, as indicated in Cervero and Kockelman's research on the San Francisco Bay area [20], and has both direct and indirect effects, as shown in Lin and Yang's empirical research for Taipei [21]. Krizek analyzed how different dimensions of neighborhood accessibility (density, land use mix, and streets/design) influence travel behavior and/or residential decisions. Its results highlighted the challenge in the measurement of neighborhood accessibility and indicated the need for further research on the relationship between travel behavior and residential location, non-linearity of variables of urban settings, the understanding of the relationships between different dimensions of urban form, and the independent effect of each urban form dimension, and the assessments of neighborhoods on their level of neighborhood accessibility [22]. It indicates that the impact of the relationship varies due to a wide variety of factors. The identified knowledge gap here is in the limited understanding of how to assess, quantify, and handle these factors in order to develop an optimal development path over time for an urban area [RG 2].

Given the different aspects which influence the SSD-PT relationship from an SSD perspective, it is now approached from three aspects, based on the dimensions of neighborhood accessibility, as classified by Krizek: urban form (design), land use, and density [22]. This is done in a decreasing scale, starting at the urban form level.

Urban form is "the spatial imprint of an urban transport system as well as the adjacent physical infrastructures. Jointly, they confer a level of spatial arrangement to cities" [23]. Lui and Shen suggested that lower levels of urban sprawl have a lower negative environmental impact and showed that different built-environment measures lead to substantially different findings regarding the importance of urban form in influencing travel behavior. Urban form has a positive relationship with non-motorized travel modes and a negative relationship with vehicle ownership, which suggests that an appropriate combination of land use transport integration policies can be beneficial in reducing travel distance per vehicle [24]. This is supported by Bento, Cropper, Mobarak, and Vinha's 2005 study in the United States, which indicated that urban form and transit do affect travel behavior, both the number of vehicles owned and the annual distance traveled per vehicle [25], and further supported by Camagni, Gibelli, and Rigamonti's empirical study on Milan, which indicated that higher mobility needs exist due to urban sprawl and in turn generate a negative environmental impact [26]. Jabareen's 2006 work on sustainable urban forms concluded that the ideal sustainable urban form "[...] is that which has a high density and adequate diversity, compact with mixed land uses, and its design is based on sustainable transportation, greening, and passive solar energy" [27]. This high-density and mixed land use links to compact cities. In their 2008 work Chen, Jia and Lau evaluated the compactness (relative high density, mixed land use, and pedestrian-oriented habitation) of 45 Chinese cities in the context of sustainable performance. Their findings concluded that urban compactness improves accessibility of services, reduces per capita energy use, and promotes infrastructure efficiency and use of public transport [28]. Muñiz et. al. concluded that polycentric spatial planning can be a good strategy to reduce the ecological footprint of cities [29]. Overall, these papers show that compact urban forms have a tendency to improve accessibility and have a lower environmental impact, but that many variables influence the actual impact of urban form on PT. Furthermore, it describes an 'ideal' urban form, where the question must be asked, 'how this will develop over time?'. The research gap is whether currently built ideal urban forms are flexible and dynamic enough to match in the future with people's future needs [RG 3].

Land use is how the surface area is used, and can be divided into built environment (e.g., residential, industrial, commercial, institutional, and transport facilities) and open space (e.g., parks and unbuilt area). These patterns of land use have diverse economic, environmental, and social impacts [30]. In Ingram's work, it was shown that decentralized urban structures lead to growing reliability on road-based urban transport (both passenger and freight) [31]. Dulal, Brodnig, and Onoriose indicated that a mixture of high residential and employment density can influence shorter commuter journeys and a reduction in private vehicle use (when supported by public transport systems among others) [32]. Together with this, as supported by Jabareen [27] and Chen, Jia, and Lau [28], mixed land use positively contributes to accessibility, infrastructure efficiency, and the use of public transport. The gap is how land use and capacity differences of different PT modes will develop over time, and how these areas will be able to adapt sufficiently to people's future needs [RG 4].

Density is "the quantity of people [...] in a given area [...]" [33]. In their 1989 research, Gordon, Kumar, and Richardson showed that low residential densities and high industrial densities favor commuting economies, which indicates that low-density metropolitan areas imply a spatial structure conducive to residential site choices with shorter commuting times. [34]. Barter indicated that high density can make it more difficult to physically accommodate private motor vehicles, but at the same time offers opportunities for non-automobile modes of transport [35]. Sun et al. showed that a higher density leads to lower auto ownership [36]. However, higher population densities may also lead to negative environmental externalities (e.g., air pollution, loss of green space, and noise pollution) [28]. The knowledge gap here is how far higher densities, non-automobile modes are able to cope and address people's and business' future needs while maintaining their attraction for current people and business [RG 5].

The PT Perspective on the SSD-PT Relationship

For the PT perspective, first the role of different transport modes will be discussed. This is followed by the accessibility perspective and mobility perspective, in order to cover both the capacity of the system (accessibility) and the movements of its users (mobility).

From the transport modes perspective, Sinha indicated the similarities between trends in urban transport in cities around the world. The growth of automobiles in developing countries is similar to trends as experienced in developed countries decades earlier. Urban density is indicated as a key indicator. With rising income and its subsequent choice in jobs and residential location, this leads to decreasing urban density and negatively affects the use of public transit. The analysis shows that urban-transport sustainability can be greatly enhanced if there are profound changes in urban structures and activities that can slow or reverse the growth in the use of private automobiles and can make transit and other modes attractive and viable [37]. As indicated by Barter for metropolitan areas in Asia, it also seems that low public transport use and a high popularity of motorcycles are connected [35]. Sinha's work further indicates the intrinsic relationship between sustainability, transit, land use, and technology. This is strongest in the existence of seamless intermodal transport systems, which in turn is seen as essential for the success of urban transit and the long-term viability of cities around the world [37]. Overall, this indicates that different transport modes influence the way urban areas develop and impact urban structures. Furthermore, it indicates that seamless intermodal transport systems are essential for long-term success of urban transit. This raises the issue that for currently built areas, changes in modal split will require the urban structure to be able to cope with this. Based on these aspects, the identified research gap is in the flexibility of urban areas (and municipal institutions) to achieve sufficient coping capacity to adapt to changes in transport modes and modal split [RG 6].

Accessibility is the "measure of the capacity of a location to be reached by, or to reach different locations. The capacity and the structure of transport infrastructure are key elements in the determination of accessibility" [12]. The impact of transport infrastructure depends on the network and its context [38]. Its impact on accessibility is dependent on the current level of accessibility provided by existing infrastructure. The higher this present level, as is the case in many advanced economies, the lower the impact of new transport infrastructure on accessibility will be [39]. It shows that accessibility is heavily dependent on the existing transport infrastructure. However, changes in the context over time can strongly influence accessibility. In order to cope with this, it requires flexibility in the system. The lack of methods to identify this flexibility is a research gap. Option values, as in the value in the willingness to pay for maintaining an option, is one way to take the value of flexibility into account prior to developing new and adjusting existing infrastructure. The field of developing and applying option values in urban development indicates a topic for further research [RG 7].

Mobility refers to "the movement of people [...], and it can have different levels linked to the speed, capacity and efficiency of movements" [12]. Kim's 2008 work discusses the Seattle Metropolitan region's residence and workplace mobility patterns under a co-location hypothesis (residents and workers will change their residence or workplace or both adapt to worsening congestion). When people change their locations, they prefer a similar commuting zone (i.e., time and distance) to before and these behaviors cause the average commute time and distance to be stable, regardless of high residence and workplace mobility, and the rapid growth of employment and population [40]. As indicated by Camagni et al., mobility is influenced by the structural organization of an urban area. The more dispersed and less structured an area is, the lower its level of efficiency will be [26]. Mobility is subject to many factors and therefore differs per urban area. As indicated, it can be influenced by variety of factors, which gives it potential to be used to enhance development in an urban area and therefore the potential to be used to enhance flexibility. Limited knowledge of the impact of mobility on flexibility is identified as a research gap [RG 8].

3.2.2. The SSD-PT Relationship from the Economic, Environmental, and Social Perspective

The SSD-PT relationship is now approached from three different perspectives: the economic, environmental, and social perspectives. These perspectives are based on the three dimensions of sustainable development [41], and are used to cover the full spectrum of SSD-PT relation.

Basiago linked different perspectives (economic, environmental, and social sustainability) in cities into an integrated urban sustainability [42]. This integration was further highlighted by Van Wee, who argues that land use policy-making should be made considering all relevant aspects (e.g., travel behavior and environmental impacts). He recommends the use of a combination of a multi-criteria analysis (MCA) and a cost-benefit analysis (CBA) for land use scenarios to cover this [17]. The usefulness of an MCA was further emphasized by Thomopoulos et. al., since this allows for indirect socio-economic impacts of transport projects to be incorporated [43]. This importance of this social element was further emphasized by Roson [44]. Overall, this underlines the importance of a broad approach to the valuation of different perspectives, in order to fully address the economic, environmental, and social impacts.

The Economic Perspective on the SSD-PT Relationship

From the economic perspective, Lakshmanan discussed the limitations of current approaches on the estimation and magnitude of economic consequences of transport infrastructure investments, and highlighted the differences in estimates of economic impact and the lack of information on the underlying mechanism as its main causes. It was indicated that transport improvements help open markets and develop creative conditions in regard to spatial agglomerations, which in turn influence the economic structure and performance. This underlines the importance of general equilibrium analysis of transport-economy linkages [45]. The spatial structure and infrastructure have economic effects, and the magnitude of these effects depend on many factors. The research gap is in the trade-off between investing (with potential burden on local economy in the form of tax) versus not investing (with potential future burden on the local economy in the form of congestion), and the subsequent potential for flexibility in this trade-off [RG 9].

The Environmental Perspective on the SSD-PT Relationship

The magnitude of the SSD-PT relationship's impact on the environment varies, based on a number of factors. Chen, Jia, and Lau found that the influence of urban compactness on studied environmental attributes are not as significant as expected. It was argued that this is because the general environmental quality of a city is a function of various social, economic, climatic, topographical, and institutional variables and that density can be overwhelmed by these other variables. Uncertainties with regard to multi-directional interaction of urban development variables (e.g., urban form, population scope, and density) contribute to the complexity of the relationship [28]. Dulal, Brodnig, and Onoriose's work on the effect of urban design forms, settlement density, housing, and employment activities on the transport sector concluded that urban planning is an important instrument to help reduce GHG emissions from this sector [32]. Ye et al. showed that a low-carbon transport city requires, apart from the compact urban form, effective mix of land use, and appropriate scale of block, an integration with a green traffic system and the green space system [46]. This indicates the potential for spatial planning to influence GHG emissions, but this is challenging due to the complexity of the subject, its interlinkage with many other factors, and differences between urban areas. The identified research gap is in the limited existing knowledge on a holistic approach per urban area. Urban areas seem to have many possible ways to reduce emissions, but a structural approach for optimal pathways needs to be set for all urban areas. The method for setting this is identified as a research gap [RG 10].

Grazi, Van den Bergh, and Van Ommeren's empirical analysis on environmental impacts of urban form and commuting in terms of policy implications suggested that higher urban density is likely to lead to a change in travel behavior. A key challenge is to increase density in existing urban areas, given financial, political, historical, social, and environmental constraints [47]. Banister discussed transport in cities from the perspective of its carbon emissions and subsequent irreversible long-term consequences. It was emphasized that the turn towards sustainable urban transport requires vision and action based on a combination of mutually supporting economic, planning, and technological innovations. This is strongly dependent on the commitment and leadership, requiring a matching up of short-term gains and long-term priorities. The challenge for cities lies in the dilemma between mobility needs (and its environmental) and climate change impacts; which presents a case of conflict between individual preferences and choices and the wider needs for society to protect the environment for future generations. The paper emphasized the need for action on these issues [48]. Holz-Rau et al. concluded that national and supranational level interventions are needed for reductions in GHG emissions, rather than more ineffective local measures [19]. Overall, these papers emphasize the importance of an overall short- and long-term approach in order to achieve reductions in GHG emissions. However, one size will not fit all, and therefore lead needs to be taken on city level. The research gap is in the interdependencies of environmental variables with urban area specific characteristics and therefore a better understanding of the linkage with the dynamics of urban area development, and the effects on the short and long term is needed [RG 11].

The Social Perspective on the SSD-PT Relationship

Geurs, Boon, and Van Wee reviewed the social impact of transport in the Netherlands and the United Kingdom and found that transport appraisals currently address three dimensions of sustainability: economic, ecological, and social. The latter is often underexposed, since these impacts can be difficult to quantify or monetize in practice (e.g., lacking data, research methods, evaluation tools, time, or budget restraints) and concludes that social impacts of transport appraisal needs to be further developed. Furthermore, the validity of social impact identification as a separate entity (from ecological and mainly economic impacts) remains a question of mutual exclusivity [49]. Currie et al. indicated that in a comparison of 88 cities worldwide, cities with public transport operations score better on social sustainability than cities with non-public transport [50]. Overall, it is indicated that the social perspective on the SSD-PT relationship is often underexposed compared to other impacts (economic and ecological/environmental), and is challenging to value. It does play an important part in the renewed focus as in the SDGs, which in turn indicate its importance to the overall dimensions of sustainable development. The research gap is in valuation of the social perspective in an integral linkage to the SSD-PT relationship [RG 12].

3.2.3. Policy and the SSD-PT Relationship

From the policy point of view, Dijst indicated the need for comprehensive understanding of the passenger transport, spatial, and infrastructure issues [51]. Geerlings and Stead further indicated the growing attention for integrated policy approach for transport, land use, and environmental policy, but indicated the dominance of transport in these policies [52].

From the SSD point of view, Van Wee's 2002 work argued that although sufficient evidence exists to conclude that land use can influence travel behavior, it does not mean that policy-makers should choose land use alternatives with the lowest level of car use, but it should be evaluated according to policy makers' priorities [17]. Echenique, Hargreaves, Mitchell, and Namdeo argued that current planning policy strategies for land use and transport have almost no impact on the major long-term increases in resource and energy consumption compared to other trends, such as socioeconomic change and population growth. They indicated that planning policy strategies for land use and transport lead to increased costs and reductions in economic competitiveness [53]. This indicates the complexity for policy-makers in regard to future developments. Although some data evidence exists, the challenge will be on steering towards the right trends in order to make an optimal impact in regard to both goals and costs. The research gap here is in the creation and application of approaches to allow flexibility for adjustments, when new trends emerge [RG 13].

From the PT point of view, Sinha indicated the potential of technological solutions and the need for policy and regulation changes, political will, and changes in travelers' choices and behavior, in order to achieve sustainable transport systems. This implies raising awareness on one's externalities caused by public transport and that private car ownership can only be slowed and guided (and not stopped or reversed) [37]. Lessons from Singapore show that flexible, dynamic, and smart systems help to capture the real cost of travel and improve the efficient use of infrastructure and services. Furthermore, an integrated and systematic approach for policy design and implementation "push" (controlling car ownership and usage) and "pull" (enhancing transit provision) strategies to optimize the enhance the efficiency of the urban system [54]. This, combined with land value capture mechanisms and public-private partnerships, contributes to the development of urban rail transit in East Asia cities [55]. This indicates the importance of a broader approach to assess the impact of SSD policy, PT policy, and combined policies. The need exists for a multi-sector and inclusive approach for all relevant stakeholders in order to cover the bigger picture. The research gap is a full understanding of the effects of policy on the total SSD-PT dynamics of an urban area [RG 14].

3.2.4. The Aspects of Interest of the SSD-PT Relationship

The SSD-PT relationship, and the economic, environmental, and social perspectives indicate the high complexity and strong interlinkages between different fields, as is further shown in the policy point of view. This subparagraph further deepens the highlighted challenges from the previous subparagraphs.

The Time Component of the SSD-PT Relationship

From the SSD perspective, Van Wee warns of the long-term impacts of wrong planning, since once areas are destined for urban activities, they will remain urban areas for a long time. Even if the replacement cycle of dwellings and offices becomes shorter, the major land use category will very likely remain [17]. Together with Gordon and Richardson's work, which challenged the feasibility of changing urban areas towards compact cities due to high resource needs [56], and Naess, who indicated that continuous growth in the building stock will make it increasingly difficult to bring urban development into an ecologically sustainable and equitable in a global perspective [57], this indicates limitations in changing already built areas. Furthermore, the built environment and infrastructure have a slow pace of rework (e.g., 20–30 years) compared to other changes in the metropolitan area [58]. Dulal, Brodnig, and Onoroise indicated that the impact of urban planning on reducing greenhouse gasses has relatively little short-term impact due to time needed to build up the necessary infrastructure, but in the long-term it can be very effective through the shift of from private vehicle dependency to public and alternative environmentally friendly transport modes [32]. From a PT perspective, Knowles indicated that successive transport innovations have resulted in a differential collapse in time versus space. They emphasized the importance of location and therefore the role of geography, especially given issues such as inaccessibility and environmental externalities [59]. A further aspect in the role of time from a transport perspective is that private transport users in general can react more quickly to changes in land use activities than public transport [60]. Overall, this shows that timelines are, in general, long for SSD adjustments to have significant effects, while transport developments can take a much more rapid development and adjustment pace. This means that both the SSD and the PT perspective can be used to steer the development, but that both will have their impacts on different time lines. One can suggest that this implies that PT can be used as a steering mechanism for sub-optimal SSD development. However, this will lead to a situation where optimal development will not be achievable. The gap here is the limited existing knowledge on how much of a balance can be struck between short term PT and long term SSD developments, and how well adaptable the already existing sub-optimal developed urban areas are [RG 15].

The Potential of Flexibility in the SSD-PT Relationship

This difference in adaptability over time of SSD and PT shows that the flexibility of an urban area is subject to a variety of SSD, PT, and other factors. For long-term development, the flexibility in choosing different development options over time can be valued. This is described as the valuation of choice options as a backup for other options or for future use [61]. Geurs and Van Wee argued that option values and non-user benefits are often not included in Cost Benefit Analysis, but there is certainly a need for more thorough theoretical and empirical research to analyze the relevance for social and economic evaluations. Non-user benefits may relate to valuation of the very existence of a choice option for individuals or firms (e.g., infrastructure or a nature area), without current or future use, and valuation of benefits for others (altruistic motives) [61]. This indicates the lacking of taking flexibility fully into account in the valuation (and subsequent decision making) process, and therefore indicating the potential for making sub-optimal decisions. This shows that the gap is the lack of valuation of flexibility in current decision-making. This requires the development of valuation methods and application guidelines [RG 16].

Decision-Making and the SSD-PT Relationship

As indicated in the previous subparagraphs, decision-making requires further deepening. Kennedy, Miller, and Shalaby addressed the challenge of moving towards a more sustainable future in the complexity of urban systems and fragmentation of decision-making. They argued that four (sequenced) pillars are needed: effective governance of land use and transport; fair, efficient, stable funding; strategic infrastructure investments; and attention to neighborhood design. This shows that major investment in public transit infrastructure will likely not suffice if macro land use and micro neighborhood designs are not supportive of these investments. The paper indicates the challenge in achieving and maintaining sustainable urban transport over time in growing regions. It highlights that human organizational capital is key in achieving sustainable cities, with challenges in inter alia trade-offs between community and government, and free market versus integrated public transit. Needs for further studies are the impacts of neighborhood form on urban travel, combined with the presence of well-developed transit systems [62]. Pflieger, Kaufmann, Pattaroni, and Jemelin discussed urban public transport in European cities to understand how far urban infrastructure and form, spatial morphology, cognitive frameworks, instruments, and institutions are factors in the irreversibility of or changes in transport and urban planning policies. The research identified inertia, innovation, and path dependency as historical settings for local policies. It identified options for change beyond the identification of the type of historical embeddedness, which means that changing track is not, per se, a step backwards. Three features common to both past and present transport and urban planning are contingency, reproduction, and innovation [58]. These papers indicate that flexibility within the urban form is present and possible, but is subject to different physical and policy elements and thereby part of a complex system. The gap is the limited understanding of the role and impact of flexibility in this complex system, and thereby its potential for decision-making for short- and long-term development of urban areas [RG 17].

3.2.5. The Impacts of the SSD-PT Relationship in Developing Countries

From the perspective of developing countries, the reviewed literature is discussed below, focused on the SSD and PT perspectives.

From the SSD perspective, there is a strong need for a focus on the formal and informal city, and the needed institutional structures. Balbo described the fragmented character of the spatial organization of cities in the Third World, and emphasized that this leads to higher costs of urbanization. They emphasized the need for recognition of the 'real' city (which includes the physical elements such as illegal settlements) and the need for a more homogeneous and integrated city [63]. Steinberg addressed the importance of strategic urban planning in city development in Latin America, and indicated the need for institutional strengthening and formalization of the process, tailored to each city. Elements of successful cities in strategic planning include political will, institutional framework, thematic focus, participatory and technical processes applied, and technical capacity [64]. Lebel et al indicated the opportunities for decoupling growth in carbon emissions from improvements in well-being within the process of urbanization in Asia, and emphasized that urban redevelopment and renewal programs should have a broader focus (including the provision of cheap, clean, and safe mobility, shelter, work, and food to the poorest), while enabling reductions in GHG emissions [65]. Watson indicated that urban planning in developing countries (Global South) has mainly been based on urban planning practices of developed countries. They argue for inclusion of the poor in urban planning, and urge a new inclusive approach of urban planning in the developing world [3]. Cervero underlined that transportation and land use integration must take a pro-poor approach to support welfare and prosperity [4]. Overall, this indicates the need for strong institutional structures based on both the formal and informal sides of a city, in order to address the economic, environmental, and social challenges of cities in developing countries. These cities should not necessarily follow the same paths as in the developed world. The challenge is in the dynamics and complexity of urban development. This requires more attention for the (further) development of adaptive capacity and possible approaches to enhance this capacity. The research gap is in the limited knowledge of the adaptive capacity and possible enhancement approaches in urban areas in developing countries [RG 18].

In the PT perspective, many challenges in developing countries have an institutional basis. Ingram described the growing reliability on road-based urban transport (both passenger and freight) in developed and developing countries due to decentralized urban structures, and the influence of land markets on development patterns of cities and the variety of efficient infrastructure provision across (sectors of) cities [31]. Gwilliam examined differences between urban transport in the developing and developed world. Cities in developing countries face congestion and deteriorating environmental, safety and security conditions. These cities have limited proportions of urban space available for movement, but rates of motorization comparable to developed countries. The institutional and policy context plays a key role, and less so does the primarily difference in terms of natural endowments. It is emphasized that the most effective contribution to developing countries (by multilateral banks and aid agencies) is in assisting with overcoming these institutional challenges [66]. Tiwari highlighted the importance of planning for non-motorized transport and integrating it with other transport modes in designing urban infrastructure in Indian cities, given the high number of residents that use these forms of transport. The paper indicates that excluding these informal transport modes will lead to sub-optimal development of the total transport system [67]. An overview of the current urban transport development in India emphasized the need for institutional coordination and policy to effectively progress towards low-carbon transport. Global experiences suggest suitable measures to achieve this goal would be promoting public transport infrastructure, improving policy-making and investments in efficient public transport, instituting land use regulations, and land market focused on efficient public transit and implement effective road pricing [68]. Scorcia et al. highlighted the importance of understanding the different implications of spatial patterns on transport patterns [69]. Pojani et al. indicated the flexibility in small- and medium-sized cities for taking different paths towards sustainable urban development, and thereby their potential for transformation [70]. Overall, these papers show the PT challenges of cities in the developing world, with many of these challenges having institutional roots. Further attention is needed in order to align the optimal routes for economic, environmental, and social development, there is potential for an inclusive approach, which in turn should help averse or limit future challenges in linked fields. The development and application of such an approach is a research gap [RG 19].

4. Avenues for Further Research

The objective of this paper was to explore and analyze knowledge gaps in the place of flexibility in the structural spatial development and passenger transport relationship in metropolitan areas in developing countries. The paper reviewed 155 papers and identified the generic need for further research on the SSD-PT relationship, and its economic, environmental, and social impacts. The paper identified 19 research gaps. Based on these research gaps, avenues for further research are discussed below.

- **The need for an integrated approach towards flexibility for decision-making**

From the general SSD-PT relationship, both the dynamic and complex nature of this relationship indicate the dependence on many variables and has many unknowns [RG 1]. The different topics that influence this SSD-PT relationship are often approached in silos (stand-alone) in the existing literature [RG 4, 5, and 11]. The way forward from here is the development of a system dynamics model to simulate the existing dependencies, their levels of influence between variables, and their development (changes in dependencies and influence) over time [RG 2], in order to achieve an integrated approach. The application of this model requires data on the broad development of the urban area, in order to develop scenarios for development paths. Based on the model and the required data, the key focus areas for high-impact flexibility can be identified through a sensitivity analysis, together with assessment methods developed for on the economic [RG 9], environmental [RG 10], social [RG 12], and combined impacts. This can then be applied for the development of a method to optimize the application of flexibility in the SSD-PT relation, which in turn can be applied in decision-making in policy and practice.

- **The need for valuation of flexibility**

Flexibility needs to be approached from the SSD and the PT point of view, where the level of ability to cope with change can differ strongly between SSD and PT [RG 6 and 8]. The understanding of decision-making in adaptiveness and the flexibility towards adaptiveness of SSD or PT needs to be further researched, especially option values to assess whether investing in flexibility is worth it or not [RG 3, 7, 13, 16, and 17]. This requires the development of a valuation method. Suggested initial steps are empirical research on how these option values relate and weigh in decision-making, and how this can be optimally applied. Based on these findings, a systems-approach for valuing flexibility can be set up.

- **The need for a better understanding of the development of flexibility over time**

Flexibility in future urban area development options is not, or in a very limited way, being taken into account in the valuation of current options, which can lead to sub-optimal long-term developments due to the selection of less beneficial short-term options (which can be perceived as optimal from the decision-makers' current perspective) [RG 15 and 17]. This underlines the importance of further research on this topic, especially on the questions of how to measure and how to value flexibility. This requires empirical research to collect data points, and subsequent development of a method to apply this flexibility value. In order to remain flexible in development and policy, further research on the role of adaptiveness and flexibility is needed here from a policy point of view [RG 14]. This can be done by developing the system dynamics model and valuation methods as described above, and making the assessment of different policy impacts on the development of flexibility. Overall, this can help to give a clear picture of the level of success of different policy measures.

- **The role of flexibility in developing countries**

For urban areas in developing countries, these do not necessarily need to follow the development paths as seen in cities in developed countries. Special focus should be given to the link between flexibility, institutional development, and pro-poor approaches. The way forward is the development of the model and methods as described above, and specifying the application to local context by applying empirical studies [RG 18 and 19]. This in turn can benefit policy-makers and urban planners, to help them build an urban area for today and tomorrow.

In conclusion, with increasing complexity of decision-making in the development of metropolitan areas and subsequent sub-optimal decision-making, the development of strongly negative long-term consequences impends. Therefore, there is urgency to build a better understanding of the dynamics between these areas and the potential of assessing, valuing, and handling optimized flexibility options, especially in developing countries where strong urban growth takes place. This understanding can help with determining development paths which can be optimal in both the short and long term, which in turn could bring us closer to having our cake and eating it.

Author Contributions: Author contributions include (and are not limited to): Conceptualization, T.S. and R.P.; methodology, B.W. and R.P.; validation, R.P., B.W. and T.S.; formal analysis, R.P.; investigation, R.P.; writing—original draft preparation, R.P.; writing—review and editing, R.P., B.W. and T.S.; visualization, R.P.; supervision B.W. and T.S.; All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: We want to thank the reviewers for their valuable contribution to this paper.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

List of the 153 reviewed papers

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