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Urban Form and Sustainable Mobility Choices - Analyzing Energy Use and Carbon Emissions from Transportation in Typical Swedish Neighborhoods

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Abstract

Many Swedish municipalities have ambitious goals to cut carbon emissions from transportation, but the urban form is a major obstacle. The lack of mobility choices in many Swedish neighborhoods and cities designed for automobiles hinders the possibilities to shift towards more sustainable travel alternatives. Urban designers and planners can help with redesigning these neighborhoods and creating urban forms that encourage walking, cycling and increased use of public transportation if policy is morphologically informed about the environmental performance and carbon implications of transportation systems in existing and newly planned neighborhoods. This paper proposes a model to assess the effect of urban form on sustainable mobility choices by analyzing typical Swedish neighborhoods. It firstly present a model of the typical Swedish city and later it analyzes the sustainable mobility choices as a set of urban form and accessibility factors commonly used in urban planning and design practices. Swedish typomorphology has a long tradition and the typomorphological urban model is based on previous conceptualizations by Swedish morphologists as Greger Paulsson, Björn Linn, Carl-Johan Engström and Johan Rådberg. The mobility choices model that is used to assess the buildings in the typical neighborhoods produces heat maps and visually informs about the integration with walking, cycling, public transportation and private car, modal shares, carbon emissions and transportation energy use. This information can (potentially) trigger urban transformation or redesign to better integrate sustainable travel alternatives in these neighborhoods and contribute to more sustainable cities. In the ongoing pandemics and lockdowns the possibilities to walk and cycle are increasingly appreciated.

Keyword: *urban form, sustainable mobility, neighborhood type, urban typology, Sweden.*

Introduction

Urban transportation today is a major cause for accelerating climate change. Many Swedish municipalities have ambitious goals to cut carbon emissions from transportation, but many neighborhoods were designed for the private automobile and they lack possibilities to walk, cycle and use public transportation. The urban form hinders the possibilities to shift towards more sustainable travel alternatives. Urban designers and planners can help with redesigning these neighborhoods and creating urban forms that encourage walking, cycling and increased use of public transportation if they are informed about the environmental performance and carbon implications of transportation systems in existing and newly planned neighborhoods.

This paper proposes a model to assess the effect of urban form on sustainable mobility choices by analyzing typical Swedish neighborhoods. It starts by presenting a model of the typical Swedish city and later it summarizes the sustainable mobility choices analyses from a report (see Stojanovski, 2020) on Urban Mobility Certificates (UMC). The mobility choices model (Stojanovski, 2019a; 2019b) is used to assess and certify the buildings in the typical neighborhoods produces heat maps and visually informs about the integration with walking, cycling, public transportation and private car, modal shares, carbon emissions and transportation energy use. This information taken in a context of Swedish urbanization can (potentially) trigger urban transformation or redesign to better integrate sustainable travel alternatives in these neighborhoods and contribute to more sustainable cities.

Background

The background describes an intersection of typo-morphology and a method to analyze the effect of urban form on mobility choices.

Typo-morphology is a branch of urban morphology that seeks to understand cities and their evolution through types and typological processes. Types are abstractions about urban forms (e.g. apartment block), the representative exemplar or prototype. Typo-morphologists investigate the physical form of cities and processes of formation and transformation by abstracting urban elements and types or urban patterns. There is a long tradition of Swedish typomorphology (see Abarkan, 2009; 2013; Stojanovski 2019a) established by Greger Paulsson, Elias Cornell, Björn Linn, Carl-Johan Engström and Johan Rådberg. Greger Paulsson (1950) introduced the concept of idealtype. Idealtypes are abstractions (often become words and narratives about dream houses and dream mobilities in culture, e.g., "villastad" or neighborhod with villas) that describe the historical process and social construction of idea into building/neighborhood type and family/social class stereotype. Urban typologies have been developed according: 1) architecture styles (Björk et al., 1983; 2003; 2009); 2) planning paradigm (Rådberg, 1988; Rådberg and Friberg, 1996); and 3) social and economic development epochs (Engström et al., 1988). Many municipalities (such as Stockholm and Malmö) use typologies (building types, urban development, city characteristics or city types) in comprehensive and detailed plans (e.g., SSBK, 1997; MSBK, 2001).

The Urban Mobility Certificates (UMCs) or transportdeklarationer is Swedish is a method that analyzes a set of urban form and accessibility factors commonly in planning practices to visually inform modal shares of walking, cycling, public transportation and private car, carbon emissions and transportation energy use from buildings and neighborhoods (Stojanovski, 2019b; 2019c; 2020a). The theoretical framework behind Urban Mobility Certificates (UMCs) derives from typomorphology. Urban morphologists dissect elements of the urban form at various resolutions and describe interactions between urban form elements in a morphological structure (Conzen, 1960; Moudon, 1994; 1997; Kropf, 1996; 2009; 2011; 2014; 2018). The UMC method emphasizes a set of urban form factors including buildings, their façades and commercial frontages, sidewalks, driving lanes, public transportation infrastructures, strips of greenery, and so on. These factors e.g., density, building heights, building setbacks, street widths, parking standards etc. are commonly used in planning and urban design practices.

Methodology

The methodology section starts with analytical methods from typo-morphology that create the background for the application of UMCs in Swedish cities. In the second subsection it shortly describes the mobility choices model or the Urban Mobility Certificates (UMCs) that is described in detail by Stojanovski (2019a; 2019b; 2020a).

Typo-morphological methods

Typologies can be created by finding similarities in urban forms or pattern matching, by following the historical emergence, variation and multiplication of a prototype (of a building, street, neighborhood and so on) or by selecting representative examples (Southworth, 2005). Figure 1A shows the process of selecting representative example (or prototype) and following the variations. Furthermore, it is possible to abstract a fictional example of urban pattern by looking at variations of one neighborhood type (Figure 1B). This idealized abstraction can be used to recognize urban forms.

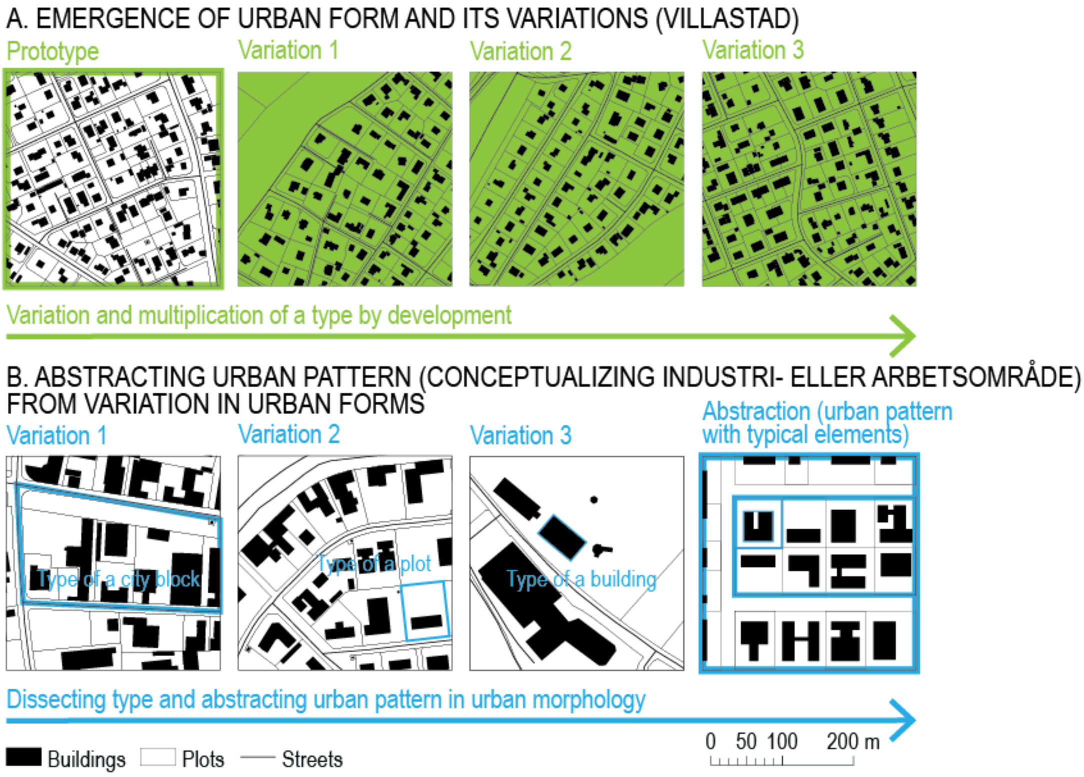

Figure 1. Methods of abstracting urban patterns of neighborhoods: A) seeking prototypes and variations; of B) creating abstraction as ideal pattern that does not exist in reality (typical for Swedish urban morphology)

Urban Mobility Certificates (UMCs) method

The methodology for the UMCs builds upon theories from urban morphology, environmental perception and sustainable indicators. Figure 2 shows the steps in the mobility choice model that assesses environmental preconditions to walk, cycle, use public transportation and drive. Based on this assessment it estimates modal shares and calculate energy use and carbon emissions from transportation.

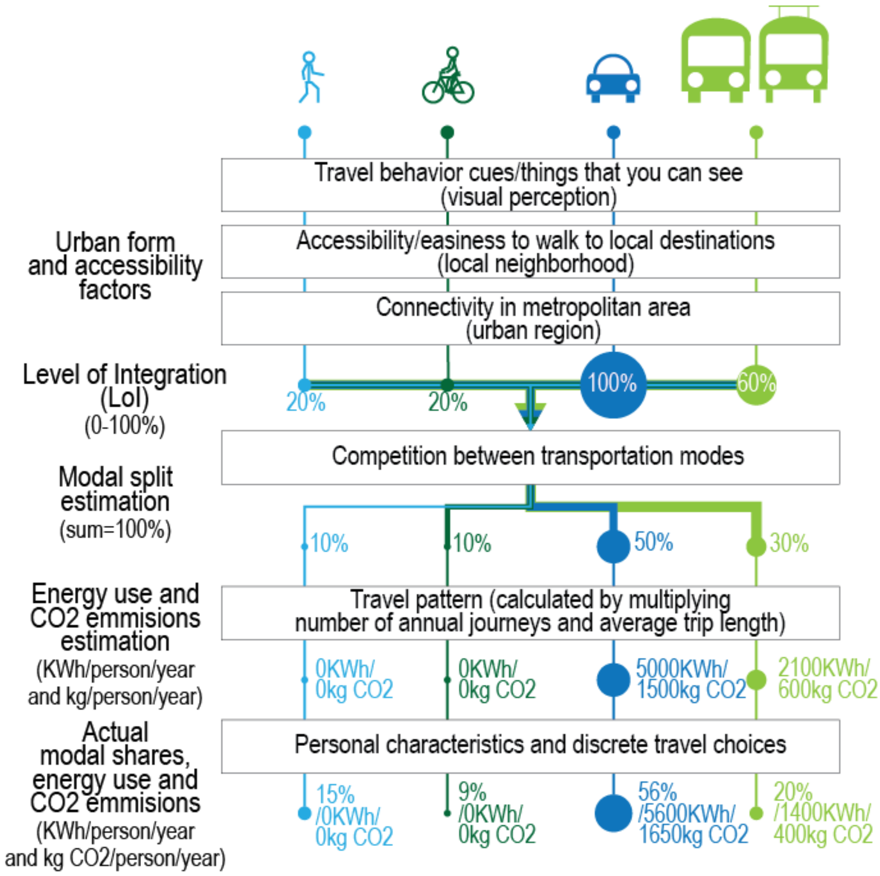

Figure 2. *Methodology of structuring and weighing urban form and accessibility factors to estimate the modal shares, energy use and carbon emissions.*

The model comprises of a set of weighed urban form factors that measure Level of Integrations (LoIs) with walking, cycling, public transportation and private car. The LoIs illustrate preconditions to travel embedded in the urban form and they vary in complexity. A private automobile needs parking space at the destination and a quick access to an expressway. These two crucial factors give 100% integration. Walking, cycling and public transportation require a very complex combination of urban form and accessibility factors. The integration with public transportation includes more than ten weighed factors (including the factors for walking). If the private automobile has 100% integration, while public transportation is 60 % and walking and cycling are 20%, the modal shares will be 50%, 30 % and 10% accordingly. The estimated 50% of sustainable transportation would lower the parking norm. Based on the LoIs for the transportation modes (0–100%) as precondition to travel, the model calculates modal shares proportionally. Better preconditions to travel with particular transportation modes means better integration with the buildings and that would arguably result in higher modal shares for that transportation mode. Table 1 lists the urban form and accessibility factors with weights for different factors organized by scale (viewshed/visual proximity, walkshed/neighborhood and regional access).

Table 1. Integration with transportation modes (as a set of weighed urban form and accessibility factors).

Urban form and accessibility factors	Walking	Cycling	Public transportation	Private car	Scale
Sidewalk design and continuity	(3) 5[1]				Viewshed
Street segment length/city block width/intersection density	(7) 15				Viewshed
Speed limit	(3) 5[1]				Viewshed
Bike infrastructures (racks, parking and cycling lanes)		(3) 20			Viewshed
Bus line/busway/tramway on street			(3) 5		Viewshed
Transit stop/station exit on street			(3) 5		Viewshed
Parking				(9) 60	Viewshed
No visible congestion				(3) 10	Viewshed
Building setbacks	(3) 5[1]				Viewshed
Building height/street width ratio	(3) 5[1]				Viewshed
Building façade activity/openness	(9) 20[1]				Viewshed
Lot/block density (residents and jobs)	(9) 40[2]		(3) 5		Local neighborhood
Neighborhood topography (slope)		(9) 40			Walkshed
Access to everyday activities	(9) 20				Walkshed
Access to event-type activities	(3) 5				Walkshed
Access to a mix of activities	(9) 20				Walkshed
Access to a local transit stop			(9) 30		Walkshed
Access to a regional transit stop			(9) 30		Regional access
Access to an expressway				(5) 30	Regional access
Bikable location		(9) 40			Regional access
			Walking (5) 20		
Sum	(48) 100	(21) 100	(32) 100	(17) 100	

[1] value assigned to street space
[2] value assigned to the built parameter of the city blocks/perimeter within building façades (the values for street spaces and built parameters city blocks are averaged with focal statistics in 100m radius)
[3] D-variables is a term coined by Robert Cervero to describe urban form factors such as Density, Diversity, Design and so on (Cervero, 1989; Cervero & Kockelman. 1997; Ewing & Cervero, 2001; 2010; Cervero et al., 2009)

Figure 3 shows the results of applying the methodology. Firstly, all the urban and accessibility factors are surveyed in Geographic Information Systems (GIS) software (Figure 3A). The methods include geocoding, observations and spatial and network analyses in GIS. Map algebra is used to sum the urban and accessibility factors into LoIs. The modal shares are estimated proportionally. The modal shares in the end are used to estimate the average energy use and carbon emission from transportation. The detailed methodology is described in Stojanovski (2019b; 2019c; 2020a).

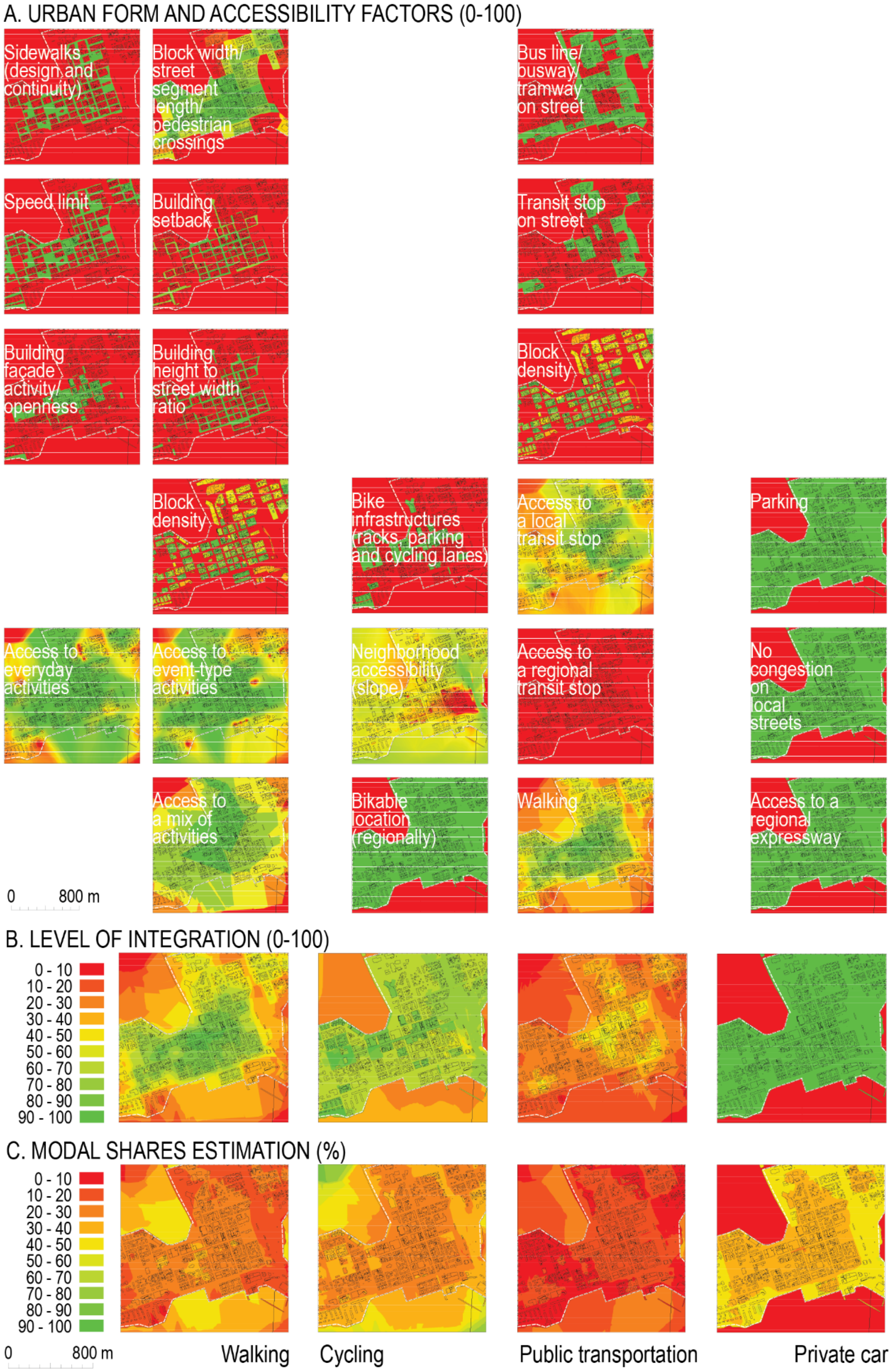

Figure 3. *Heat maps of the urban form and accessibility factors and modal share estimation (Luleå Centrum is the historical, preindustrial core of the city).*

Results and discussions

The result and discussion section starts with describing the Swedish urbanization as typical neighborhoods and concludes with figures illustrating the transportation performance of typical neighborhoods.

Urbanization in Swedish cities

The history of Swedish industrialization and urbanization can be understood through major development cycles and neighborhood types that emerge during building booms. To show the historical expansion of Swedish cities Figure 4 illustrates four major cyclical changes: the preindustrial, industrial, modern and postmodern city. The y-axis shows historical timeline that includes changes in economy and society along with transportation revolutions and the emergence of new technologies. The x-axis indicates distance from the city center with cores and peripheries for each urban development cycle.

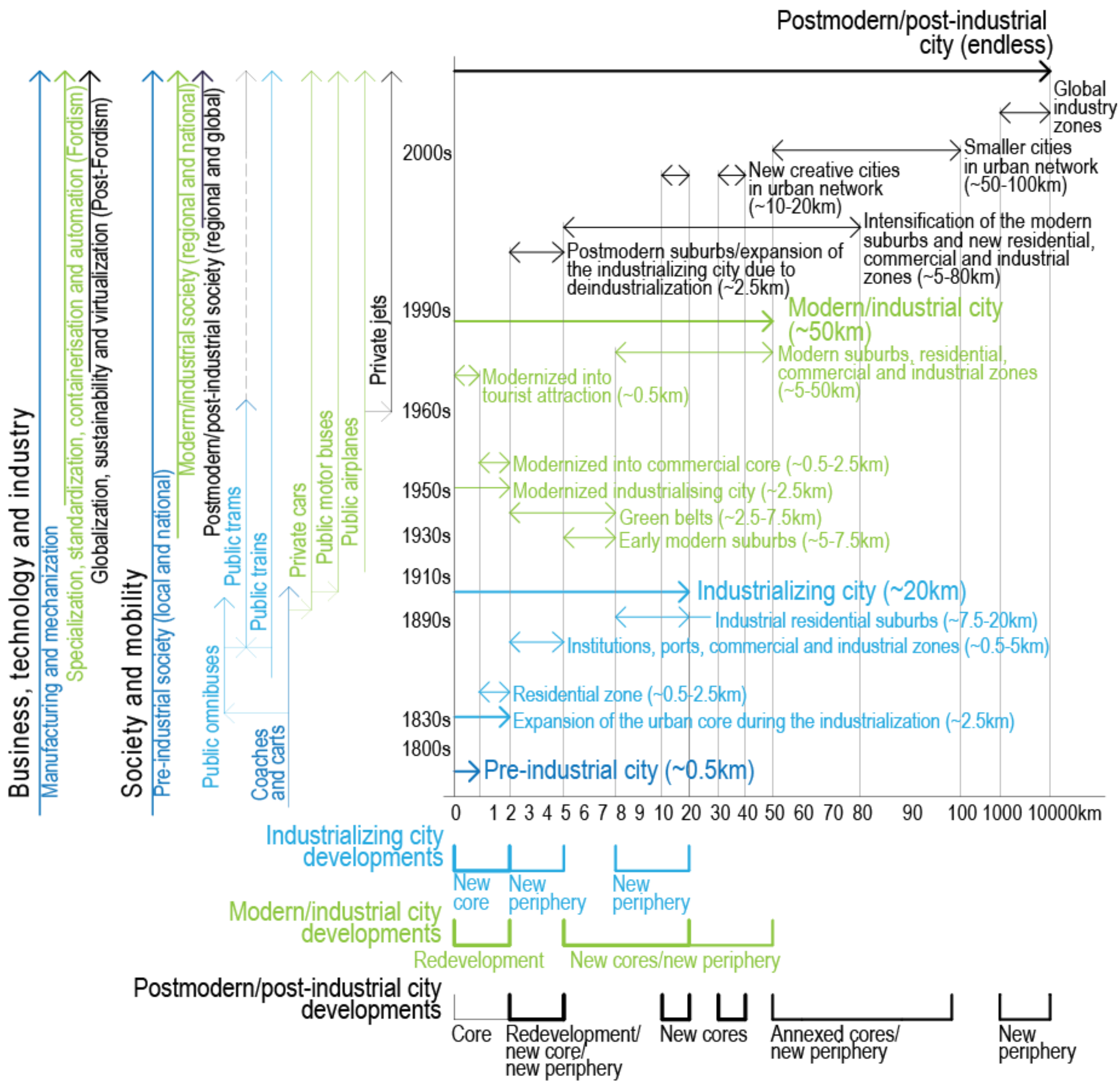

Figure 4. *Cyclical changes and morphogenesis of Swedish cities during periods of industrialization of society, together with the urban cores and peripheries*

Figure 5 presents an urban model of a small and a large Swedish city with typical or representative neighborhoods from different periods. The typical traditional (preindustrial) Swedish city displays organic or rectangular street grids with wooden or stone houses organized in city blocks. The names trästad (wooden city, type 1 on Figure 5) or stenstad (stone city, type 2 on Figure 5) denote these neighborhood types. The medieval cities were surrounded by villages with detached houses scattered organically in the landscape (type 3 on Figure 5). These villages became urbanized with the rapid motorization in the second half of the 20th century. The industrialization produced a very dense urban core, an expansion of the medieval stone city (type 4-5 on Figure 5). At the same time, it created an urban fringe of industrial zones (type 8 on Figure 5), institutional (healthcare, education and so on) and sports complexes (type 9-10 on Figure 5). The trägårdstad or garden city (type 6 on Figure 5) and its residential suburban villastad or neighborhood with villas (type 7 on Figure 5) emerged along the first suburban railways on the end of the 19th century. The modernist movement and the welfare state inspired the biggest building boom in Sweden in the mid-20th century. The experimental early modernist apartment blocks emerged on the edges of the old cores and in the suburbs from the 1930s (type 11 on Figure 24). In the 1950s the functionalist city (type 13-17 on Figure 5), so called ABC-city, mainstreamed. In ABC, A stands for arbetsområde or work areas (office parks and industrial zones), B for bostadsområde or residential areas with apartment blocks (type 14 on Figure 5) or row houses (type 17 on Figure 5) and C for community/town centers (type 13 on Figure 5). In this period, parts of the old cores in the small or large cities were modernized (type 12 on Figure 5) and transformed into office parks serving an entire region. From the 1970s a new type of residential suburbs with single detached houses (type 16 on Figure 5) emerged, followed by external shopping malls and new office parks (type 15 on Figure 5). The trend in the last two decades is to develop new postmodernist sustainable neighborhoods (type 18 on Figure 5) on the industrial fringes of the old cores. At the same time, the predominantly commercial old cores (type 12 on Figure 5) are densified to increase the number of residents.

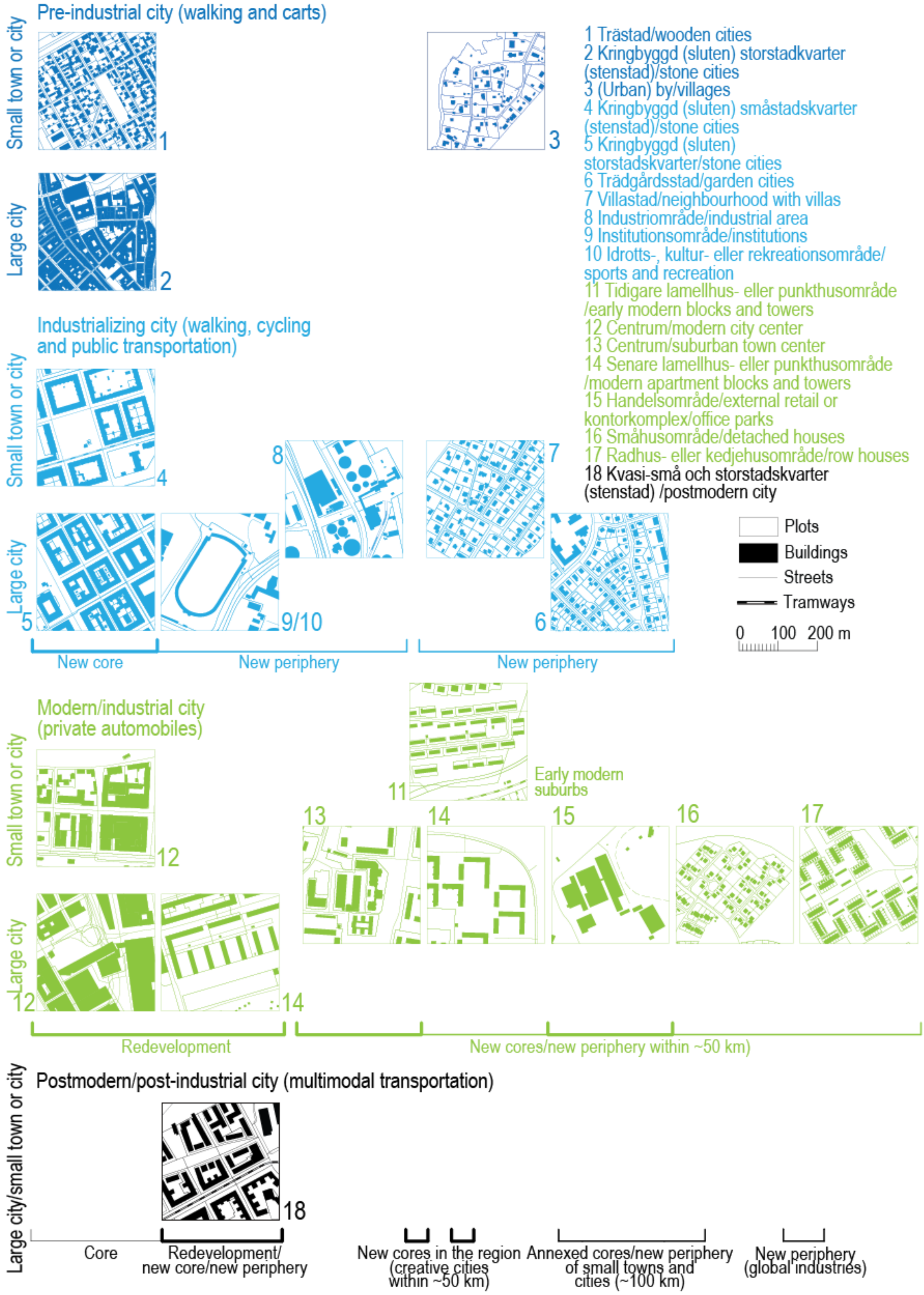

Figure 5. *Cyclical changes and morphogenesis of Swedish cities during periods of industrialization of society, together with the urban cores and peripheries*

Energy use and carbon emissions in typical Swedish neighborhoods

This paper summarizes the results of a report (Stojanovski, 2020a) that analyzed typical Swedish neighborhoods in the cities of Jönköping, Luleå and Stockholm. Figure 6 and Figure 7 illustrate energy use and CO_2 emissions based on the modal share estimation in the typical Swedish neighborhoods from this report. The results show that the very dense urban cores from the industrialization period (type 4 on Figure 5) perform best in terms of transportation energy efficiency and vary from 3000-4500 kWh/person/year (and 400-1200 kg CO2/person/year). These neighborhoods were designed specifically for walking and use of public transportation (Figure 5). The trägårdstad or garden city (type 6 on Figure 5) and its residential suburban villastad or neighborhood with villas (type 7 on Figure 5) in close proximity add 1000 kWh/person/year (plus 200-400 kg CO2/person/year). The commercial cores of the functionalist cities (type 13 on Figure 5) achieve 4500-5500 kWh/person/year, whereas the residential suburbs in the functionalist city (type 14 and type 16 on Figure 5) have the worst transportation energy performance with over 5500-6000 kWh/person/year (1400-2400 kg CO2/person/year) close to the commercial cores and 6000-10000 kWh/person/year (1800-3000 kg CO2/person/year) on the peripheries. These neighborhoods were specifically designed for private mobility and the automobile and it is often impossible to walk or cycle because they are located at longer distances (up to 60 km from the preindustrial and industrial urban cores (type 1-2 and 4-5 on Figure 5). The new postmodernist sustainable neighborhoods (type 18 on Figure 5) achieve 4000-5000 kWh/person/year (600-1400 kg CO2/person/year) as mixed developments. The transportation energy and carbon emission performance will be better than a typical suburb (type 16 om Figure 5), but worse than dense historical core of the city (type 4-5 in Figure 5).

Many Swedish municipalities have ambitious goals to cut carbon emissions from transportation and the results (Figure 6 and Figure 7) show the variation of energy use and carbon emissions from transportation in the typical Swedish neighborhoods. The results show that the urban cores from the preindustrial and industrialization period perform best (400-1200 kg CO2/person/year), but still the goal to achieve zero carbon emission transportation seems like elusive possibility even in the old historical cores that were designed for walking (and where walking dominates the modal shape). The newest sustainable suburbs perform better than the average (1700 kg CO2/person/year in Sweden), but there is still need to offset carbon emission to reach zero. Prospectively there is maybe a need to go into negative carbon emissions to compensate for the industrialization period.

In the end, there is possibility for transformation of neighborhoods from one type to another. Some neighborhoods (type 7-8 on Figure 5) can undergo change into very dense urban cores (type 4 on Figure 5), while the functionalist cities (type 13-17 on Figure 5) need radical changes to improve their transportation energy efficiency.

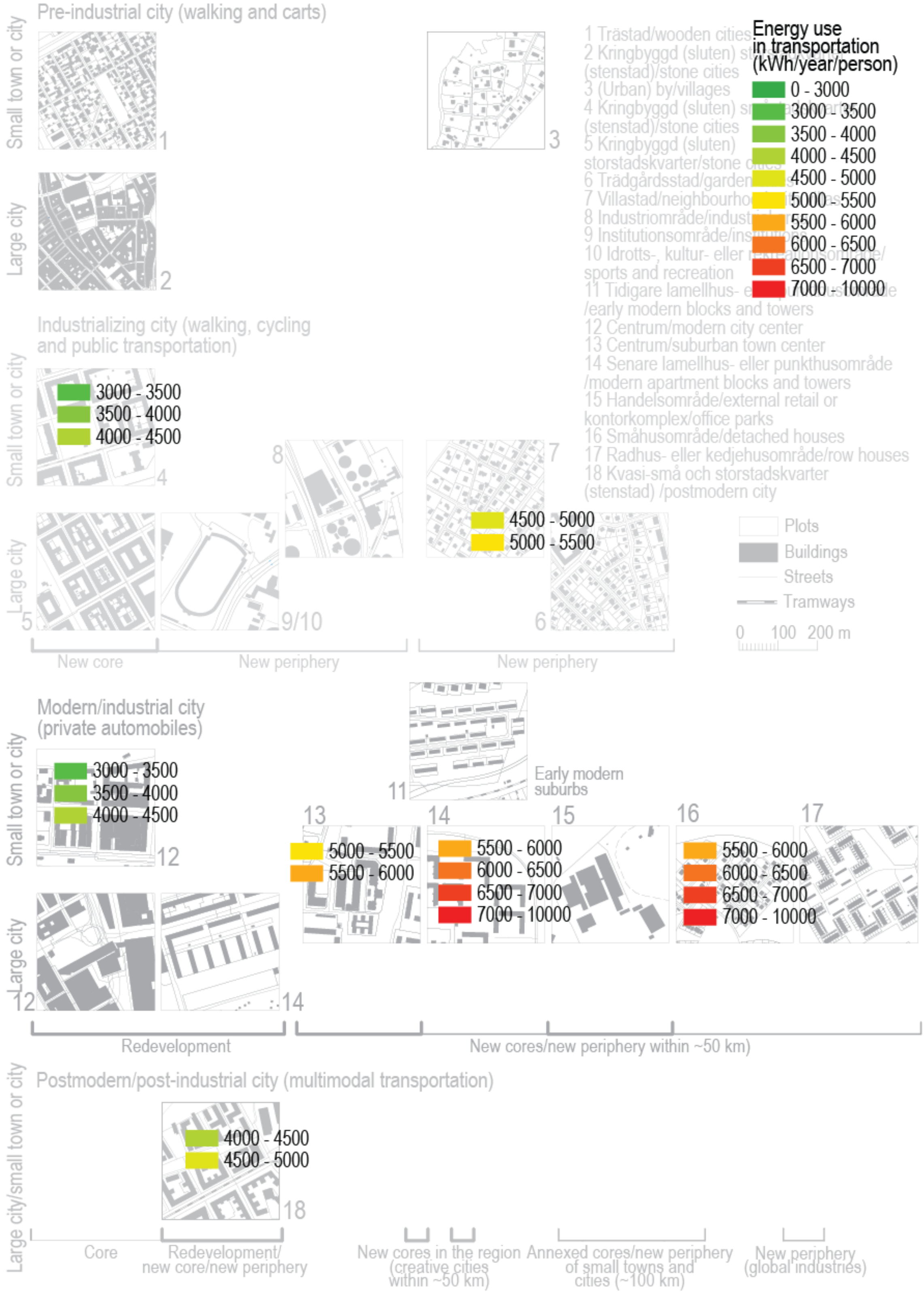

Figure 6. *Transportation energy use in the typical Swedish neighborhoods. Note. An average person living in a 50 m^2 apartment uses 5000-6000 kWh/year for heating and electricity.*

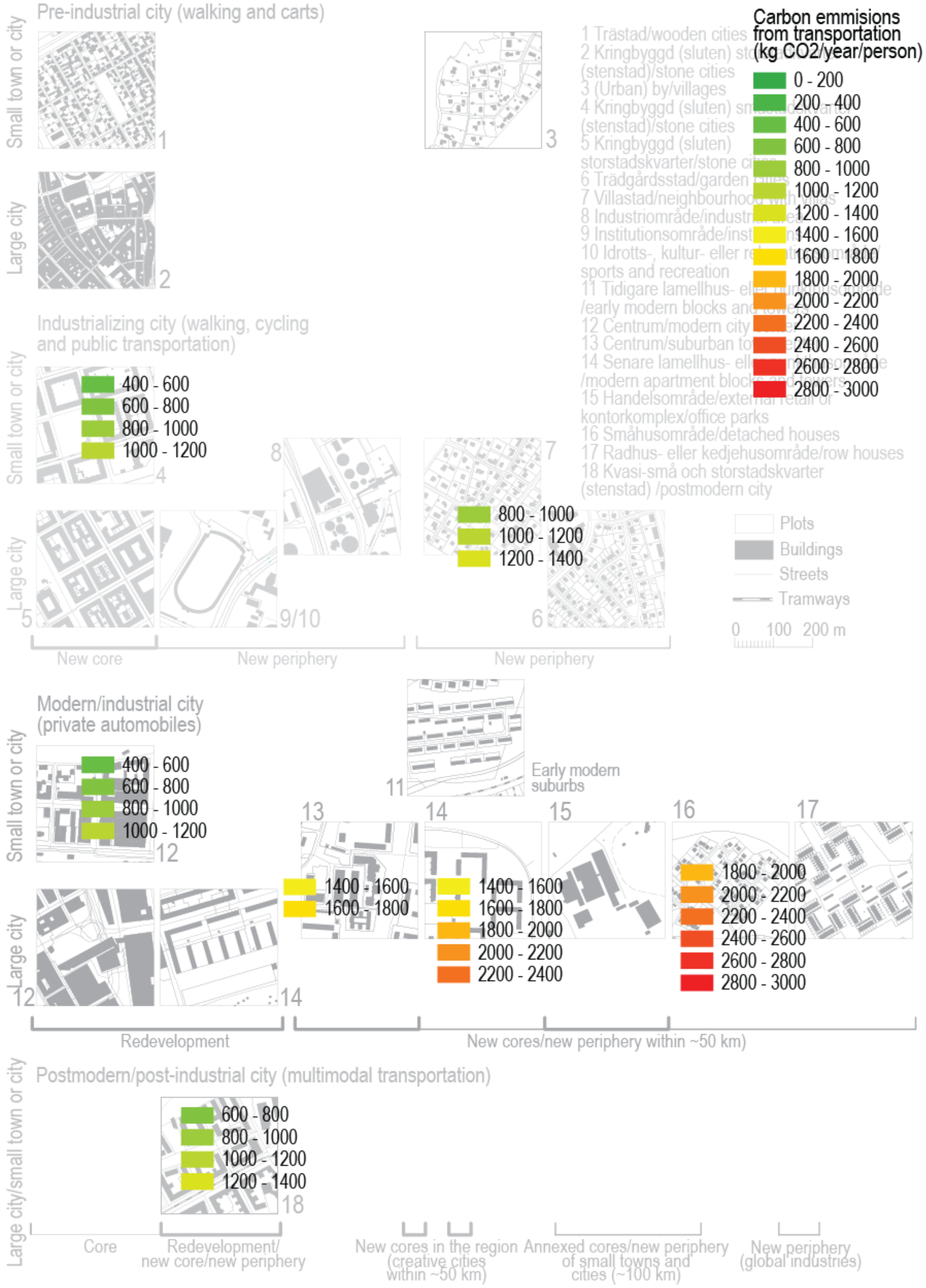

Figure 7. *CO2 emissions from transportation in the typical Swedish neighborhoods. Note. The average CO2 emissions from transportation are 1.7t/ person/year.*

Conclusions

Many Swedish municipalities have ambitious goals to cut carbon emissions from transportation and to achieve these ambitious goals there is a need to get information about the unsustainable neighborhoods. This paper firstly presents a model of a Swedish city with typical neighborhoods and later it presents sustainable mobility choices analyses from a report (see Stojanovski, 2020) on Urban Mobility Certificates (UMC). The results show the variation of energy use carbon emissions from transportation where the the urban cores from the preindustrial and industrialization period perform best. The results show that the newest sustainable suburbs perform better than the average, but the goal to achieve zero carbon emission transportation seems like elusive possibility even in the old historical cores that were designed for walking (and where walking dominates the modal shape).

Urban designers and planners can help with redesigning these typical neighborhoods and creating urban forms that encourage walking, cycling and increased use of public transportation if they are informed about the environmental performance and carbon implications of transportation. They can also use the neighborhood typology to address these problems morphologically as typological transformation from from one type to another. Some neighborhoods can undergo change into very dense urban cores, while the functionalist cities need radical changes to improve their transportation energy efficiency.

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References

1. Abarkan, A. (2009). The study of urban form in Sweden. *Urban Morphology*, 13(2), 121.
2. Abarkan, A. (2013). Typo-morfologi: Metoden och dess tillämpning på bebyggelsesmönster. *The Nordic Journal of Architectural Research*, 13 (1-2).
3. Björk, C., Reppen, L. & Kallstenius, P. (1983). *Så byggdes husen 1880-1980: arkitektur, konstruktion och material i våra flerbostadshus under 100 år* (Stockholm, Statens råd för byggnadsforskning)
4. Björk C., Kallstenius P.and Reppen L., (2003), *Så byggdes husen 1880-2000* (Forskningsrådet Formas, Stockholm)-
5. Björk C., Nordling L. and Reppen L., (2009), *Så byggdes villan: svensk villarkitektur från 1890 till 2010* (Forskningsrådet Formas, Stockholm)
6. Conzen, M. R. G. (1960). Alnwick, Northumberland: a study in town-plan analysis. *Transactions and Papers (Institute of British Geographers)*, (27), iii-122.
7. Engström C.J, Lindqvist A., Lagbo E. och Landahl, G. 1988. *Svensk tätort*. Stockholm: Svenskakommunförbundet.
8. Kropf, K. (1996). Urban tissue and the character of towns. *Urban Design International*, 1(3), 247-263.
9. Kropf, K. (2009). Aspects of urban form. *Urban Morphology*, 13(2), 105-120.
10. Kropf, K. (2011). Morphological investigations: Cutting into the substance of urban form. *Built Environment*, 37(4), 393-408.
11. Kropf, K. (2014). Ambiguity in the definition of built form. *Urban Morphology*, 18 (1), 41-57.

12. Kropf, K. (2018). *Handbook of urban morphology*. (John Wiley & Sons, Chichester).

13. MSBK (Malmö Stadsbyggnadskontoret). (2001) *Översiktsplan för Malmö 2000* (Öp 2020). (MSBK, Malmö).

14. Moudon, (1994). Getting to Know the Built Landscape: Typomorphology. in Franck, K.A. and Franck, K.A. and Schneekloth, L.H. (ed.). *Ordering space: types in architecture and design* (Van Nostrand Reinhold, New York). 289-314.

15. Moudon, A. V. (1997). Urban morphology as an emerging interdisciplinary field. *Urban morphology*, 1(1), 3-10.

16. Paulsson, G. (1950). *Svensk stad*. (Bonnier, Stockholm).

17. Rådberg, J. (1988). *Doktrin och täthet i svenskt stadsbyggande 1875-1975* (Statens råd för byggnadsforskning, Stockholm).

18. Rådberg, J. och Friberg, A. (1996). *Svenska stadstyper: historik, exempel, klassificering* (Kungliga Tekniska högskolan, Stockholm).

19. Southworth, M. (2005b). Reinventing main street: From mall to townscape mall. *Journal of Urban Design*, 10(2):151-170.

20. SSBK (Stockholms Stadsbyggnadskontoret). (1997). *Stockholms byggnadsordning* (SSBK, Stockholm=.

21. Stojanovski, T. (2019a). Swedish Typo-Morphology - Morphological Conceptualizations and Implication for Urban Design. *Iconarp International Journal of Architecture and Planning* 7, 135-157.

22. Stojanovski, T (2019d). Typo-morphology of transportation – Looking at historical development and multimodal futures of Swedish streets and roads. Presented on the 26nd International seminar on urban form, Nicosia, Cyprus.

23. Stojanovski T. (2019b). *Urban Form and Mobility - Analysis and Information to Catalyse Sustainable Development*. (Doctoral Thesis, Stockholm: KTH Royal Institute of Technology).

24. Stojanovski, T. (2019c). Urban Form and Mobility Choices: Informing about Sustainable Travel Alternatives, Carbon Emissions and Energy Use from Transportation in Swedish Neighbourhoods. *Sustainability*, 11(2), 548.

25. Stojanovski T. (2020). *Urban Mobility Certificates (UMCs): Informing mobility choices, carbon emissions and energy use from transportation* (KTH Royal Institute of Technology, Stockholm).