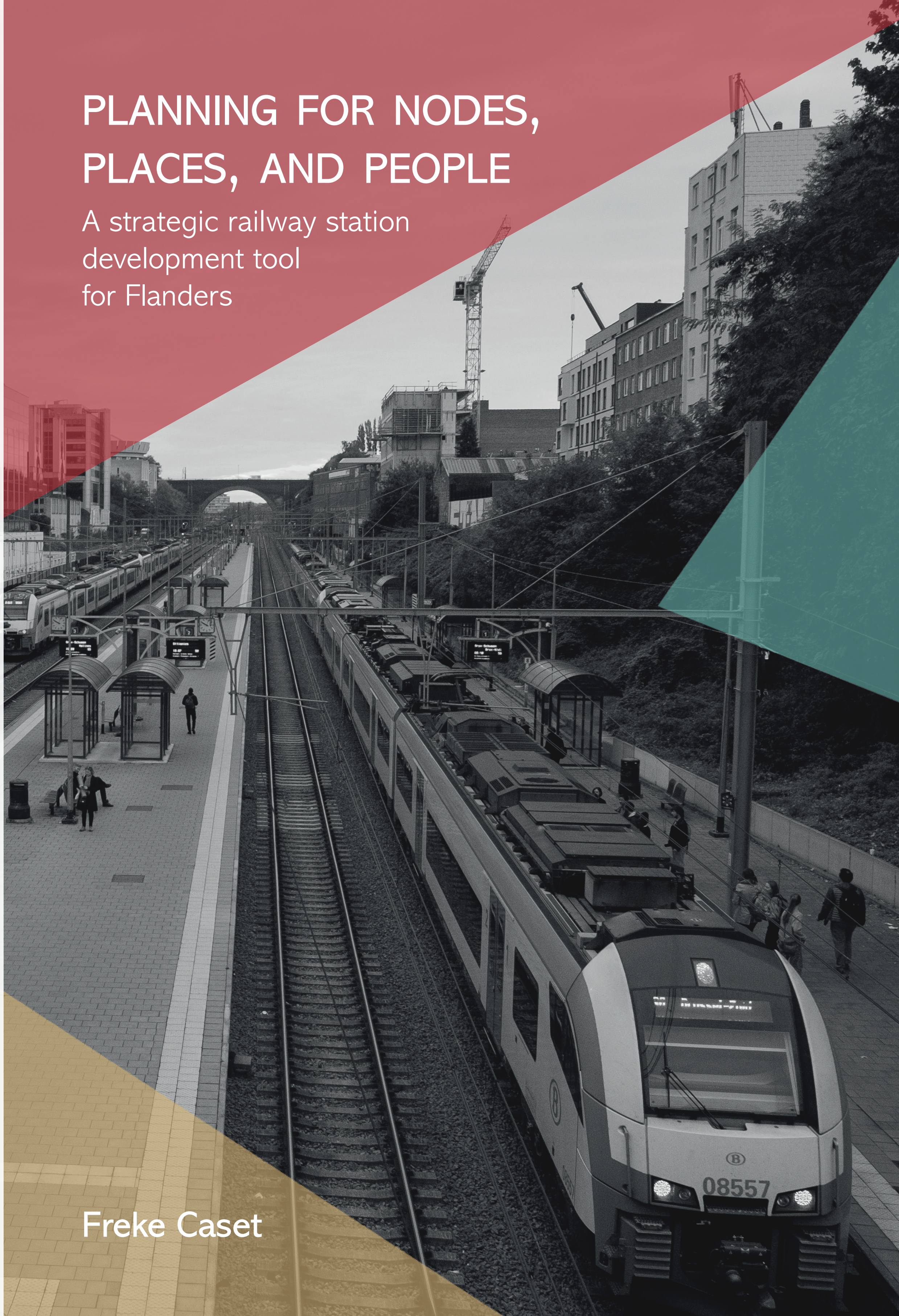


# PLANNING FOR NODES, PLACES, AND PEOPLE

## A strategic railway station development tool for Flanders

Freke Caset

PLANNING FOR NODES, PLACES, AND PEOPLE

Freke Caset

In recent years, the public debate about a future vision for spatial development in Flanders has been alive and at times intense. According to the Flemish Government, the railway network has a key role to play in the transition to more sustainable daily travel patterns in the region, and the urban development strategy of 'transit oriented development' (TOD) or 'knooppuntontwikkeling' is put forward as one of the means to reach this higher goal. Reasoning from the assumption that TOD has the potential to live up to this promise, a series of key questions arise: how, where and what development opportunities can be identified for which railway stations? This dissertation zooms in on the 'how' of this pursuit and examines the suitability of a particular methodological framework in supporting planning debates around railway station (area) development in Flanders: the 'node-place model'. The empirical material that was developed and validated as part of this work ultimately crystallized into an open and interactive webtool coined 'StationsRadar'.

fwo
GHENT UNIVERSITY
VUB VRIJE UNIVERSITEIT BRUSSEL

# Planning for Nodes, Places, and People

## A Strategic Railway Station Development Tool for Flanders

**Freke Caset**

Proefschrift aangeboden tot het behalen van de graad van Doctor in de Wetenschappen: Geografie (UGent) – Doctor in de Wetenschappen (VUB)

Academiejaar 2019 – 2020

UNIVERSITEIT GENT

VRIJE UNIVERSITEIT BRUSSEL

One might be forgiven for thinking that technology
holds all the answers to the travel-versus-environment conflict,
and that society can simply employ more scientists and engineers to develop
environment-friendly ways of maintaining the mobility that it has come to enjoy.

Peter Hughes, 1993

Supervisors

Prof. dr. Ben Derudder

Department of Geography, Ghent University

Prof. dr. Frank Witlox

Department of Geography, Ghent University

Prof. dr. Kobe Boussauw

Department of Geography, Vrije Universiteit Brussel

Members of the Examination Committee

Prof. dr. Veerle Van Eetvelde (Chair)

Department of Geography, Ghent University

Prof. dr. Michael Ryckewaert (Secretary)

Department of Geography, Vrije Universiteit Brussel

Prof. dr. Cathy Macharis

MOBI - Department of Business Technology and Operations, Vrije Universiteit Brussel

Prof. dr. Luca Bertolini

Department of Human Geography, Planning and International Development Studies, University of Amsterdam

Prof. ir. Dirk Lauwers

Department of Mobility and Spatial Planning, Ghent University, and
Research Group for Urban Development, University of Antwerp

Dr. Peter Pelzer

Department of Human Geography and Spatial Planning, Utrecht University

CONTENTS

## ACKNOWLEDGEMENTS

Over the course of these four years, the number of acknowledgeable individuals has proliferated rapidly. In terms of this book, it took a village to produce both the scientific arguments and the empirical support material that it contains. In broader terms, I am thankful for the many people who stimulated, shaped and challenged my efforts in thinking critically, and for those who were supportive in dealing with the many facets that come with navigating the field of academia. In this preface I will try my best to do justice to the myriad of human faces behind all this.

I will start by expressing my excitement over the joint institutional agreement of this dissertation. From the start, I had the pleasure of being part of both the SEG (Social and Economic Geography) team at Ghent University *and* of Cosmopolis at Vrije Universiteit Brussel. Both research groups are not just hosted within two different universities, they are also located within two very different urban settings and they are composed of researchers with the most diverse academic and non-academic pursuits and backgrounds. It has been a delight to get to know all of these wonderful minds, to be part of the stimulating and thought-provoking discussions during the numerous lunch seminars and *urban borrels*, to experience how different academic institutions and cultures thrive quite differently, and to get lost in the quasi weekly train commute to the Brussels metropolis while feeling – quite literally – immersed in my research subject: the Belgian railway system.

As per usual, a special and sincere word of thanks goes out to the supervisors/promotors. I have always used both of these terms interchangeably but it turns out they signify quite different job descriptions. According to the Cambridge English Dictionary, a 'supervisor' translates as 'someone who is in charge of a group of people or an area of work and who makes sure that the work is done correctly and according to the rules', whereas a 'promotor' is defined as 'one that promotes, especially an active supporter or advocate'. In hindsight, both of these distinct yet equally important tasks have been neatly balanced out between Ben Derudder, Kobe Boussauw and Frank Witlox.

Ben has been involved in my academic endeavours since the very start. He supervised my master's dissertation and – in doing so – has played a pivotal role in nourishing my interest for all things urban. Besides an authority in the field of Urban Geography, I consider Ben a truly dedicated scholar and mentor with an uncanny talent to detect illogicalities in thought processes of any kind. His eagle eyes have the ability to spot the tiniest conceptual, methodological and textual flaws. The extent to which I have assimilated any of these skills I owe to his prowess, and I am thankful for his enduring confidence in the things I have been cooking up over the past years.

I want to thank Kobe for his intellectual curiosity and passoniate commitment throughout this entire trajectory. His firmly established academic and practical expertise within the fields of Spatial Planning and Mobility has been crucial to the development of this project in general and to my evolving understanding of both fields in particular. The valuable time and energy he dedicated to and during the workshop series are much appreciated, along with his thoughtful and supportive presence during times of struggle. Kobe gave me confidence by showing confidence in me.

Lastly, I'm grateful to have had Frank on board of this project, as it has benefited greatly from his longstanding expertise in the fields of Economic and Transport Geography, his level-headed strategic advice and his enthusiastic encouragements.

Next, I want to thank the many colleagues who have flavoured and spiced up daily life at the office(s). While this naturally applies to all colleagues past and present at SEG and Cosmopolis, I owe a bit more space to some people in particular.

A big *dankjewel* and *obrigada* to my office mates Jorn Koelemaij and Filipe Teixeira. Thanks for bringing in your worldly views and for challenging mine, for your friendship, for some exciting travel adventures closeby and afar, and for simply co-creating a space to feel at ease (apart perhaps from the bunch of sinister male characters decorating your sides of the office!). Filipe, thanks for venturing with me into this project, for sharing your exquisite technical skills and working your magic, and for tolerating this demanding *tech noob*. Thanks as well to Tom Storme, my first office mate at SEG, whose intermittent wise words of advice still resonate and whose kind personality is such a joy to have around. A major thanks to my dear friend Laura Deruytter who is and has been co-navigating the academic and non-academic realms for quite a while now… Laura embodies all things valuable in an academic environment: intellect, empathy, modesty and bravery. Time and again she inspires. In a similar vein, I want to thank ex-colleagues Michiel van Meeteren and Anna Plyushteva. Both of these extraordinarily inspirational and talented scholars have been role models to me more than they can possibly imagine. To the fellow writing retreaters Laura, Deborah Lambert (Rebekka!), Nina Haerter, Maëlys Waiengnier and Kandice Kreamer Fults: thanks for the much-needed, beautiful, change of scenery during one of the most stressful periods of writing up this book. I am convinced my brain hemisphere balance fully restored thanks to the fruity Margarita's, the hilarious coffee grit/olive oil scrub sessions, early morning yoga and pseudo-athletic frisbee workouts! And finally, I'm thankful for those other colleagues who have become good friends *en route* …

Thanks as well to the faces behind a couple of networks that have been important throughout the past four years: the many dedicated early-career scholars behind AGORA Magazine[1] who work hard to keep the Dutch-Belgian dialogue on socio-spatial issues alive, the people from the STeR* group at VUB for the engaging and enlightening research reflections, and the 'women in academia' for doing such important and excellent work and for fostering my awareness of and sensitivity to issues of gender, race and power.

The past years have also been greatly enriched by various (mostly slow and quite adventurous) travels to conferences, seminars and workshops and by the people whom I have had the pleasure of meeting and exchanging thoughts with. There is one group of dedicated scholars in particular that I would like to thank: the AESOP Transport Laboratory of Thought. Thanks for your hospitality, for shaping and pushing my thinking on all things transport and ethics, for the thought-provoking reflections and for the highly amusing day trips and activities. I vividly remember the beautiful sunset and boat trip in Sweden, the tarot card game at the beach, the nightly capoeira session and fun surf initiation lessons in Costa de Caparica, and the bumpy cargo bicycle ride throughout *De Hoge Veluwe*, … I hope to catch up with all of you sooner or later.

There is one person who I haven't mentioned yet but who has been of substantial importance to the way in which this research has developed. His name is Johan Vanhove and he works for Belgian national railway company NMBS. Johan has tirelessly shared with me his expertise and insights, has enthusiastically shown me around the NMBS headquarters and has helped obtaining official access to an amazing dataset which arguably put large parts of this dissertation on the fast track.

Likewise, many other individuals have contributed, both at the outset of and towards the end of this work: UGent colleague Bart De Wit, UGent and VUB secretaries Helga Vermeulen, Sofie De Winter, Inge Meyskens and Hilde Everaerts, Guy Engelen, Lien Poelmans and Els Verachtert from VITO (*Vlaamse Instelling voor Technologisch Onderzoek*), Hans Tindemans from VRP (*Vlaamse Vereniging voor Ruimte en Planning*), Denis De Bruyne, Bart Wuyts and Erik Van Meensel from NMBS, Tim Scheirs from Veneco, Bart Deceuninck and Anne Boer from the Province of East Flanders, Michael Eeckhout from the Flemish Department of Mobility and Public Works, Stephan Reniers from Regionet Leuven, …

[1] Have a look! http://www.agora-magazine.nl/

To conclude, a few words of gratitude to the people closest to me. Mom and dad, Mieke and Johan, although you were often quite clueless about my geography-related occupations and pursuits over the past (I would say nine) years, your support and encouragements have been unconditional… I look up to both of you in so many ways and I am lucky and proud to call you my parents. Stan, the previous lines equally apply to you big brother! Tom, thanks for bringing joy, laughter and adventure to my soul, for your generous and playful spirit and for simply being. Gerda, I know you are proud, and this book is dedicated to you.

# LIST OF FIGURES

## LIST OF TABLES

# LIST OF ABBREVIATIONS

| | |
|---|---|
| AIC | Akaike information criterion |
| ANOVA | Analyses of variance |
| BCR | Brussels Capital Region |
| BRV | Beleidsplan Ruimte Vlaanderen |
| BTM | Bus tram metro |
| CA | Catchment area |
| CE | Concrete experience |
| CI | Contagion index |
| FAC | Forming of abstract concepts |
| FUR | Functional urban region |
| GIS | Geographical information system |
| GTFS | General feed transit specification |
| GWR | Geographically weighted regression |
| ICO | Intercommunal organization |
| IJI | Interspersion and juxtaposition index |
| MIVB | Maatschappij voor het intercommunaal vervoer te Brussel |
| MPW | Mobility and public works |
| MTS | Metropolitan transport system |
| NMBS | Nationale maatschappij der Belgische spoorwegen |
| NPM | Node-place model |
| NTP | Node train place |
| O&R | Observation & reflection |
| OLS | Ordinary least square |
| OSM | OpenStreetMap |
| PP | People |
| PSS | Planning support system |
| RER | Regional express railway network |
| RMP | Regional mobility plan |
| SEG | Social and Economic Geography |
| SHDI | Shannon diversity index |
| SNAMUTS | Spatial network analysis for multi-modal urban transport systems |
| SSD | Sum of squared differences |
| STIB | Société des Transports Intercommunaux de Bruxelles |
| TNS | Testing in new situations |
| TOD | Transit oriented development |
| VIF | Variance inflation factor |

# CHAPTER 1. INTRODUCTION

## 1.1 This dissertation: Outline and objectives

This dissertation originated from a research proposal for a study commissioned by the Flemish Government. The study, ultimately granted to and conducted by Verachtert et al. (2016), involved a full-scale mapping exercise for the region of Flanders (with the inclusion of the Brussels Capital Region) of relative levels of (1) public transport accessibility and (2) densities of amenities. Both maps served to inform policy-making in terms of the location for strategic areas for future urban compaction and/or higher transit accessibility levels. The objectives of this commissioned study are illustrative of a wider momentum in present-day Flemish policy circles in which concentrated development strategies around public transport hubs (in particular railway stations) are gaining increasing attention. This momentum is informed by wider environmental and socio-economic sustainability goals, such as transitioning to a more sustainable mobility system and safeguarding the accessibility of major urban-economic centres in the region (as communicated through different policy papers, see for example Flemish Government 2017, 2018a and 2018b).

The primary motive for the work presented in this dissertation has its roots in this momentum of *'knooppuntontwikkeling'* or 'transit-oriented development' (TOD) in Flanders. Reasoning from the assumption that TOD indeed has the potential to support a realization of the goals mentioned above, a series of questions arise: how, where and what development opportunities can be identified for which railway stations? Instead of embarking on a full-scale mapping exercise similar to the work of Verachtert et al. (2016), this dissertation marshals a different methodological approach in order to improve our understanding of the TOD potential in Flanders: the 'node-place model' (NPM). This methodology was originally put forward by Bertolini (1999). In its present-day and general interpretation, the NPM is a place-based accessibility instrument that compares transport accessibility levels at multiple locations (usually railway stations in a network) with their proximity to, and intensity of urban developments, in order to identify substandard conditions. The NPM has become one of the leading analytical frameworks to identify differentiated development opportunities for public transport networks.

Against this backdrop, the research presented in this dissertation has a methodological and a theoretical component in that it aims to address a number of longstanding gaps in the NPM literature. At the same time, there is also an empirical and policy-support objective in that the motive to apply and develop this NPM framework is firmly rooted in present-day TOD policy debates in Flanders. The methodological advancements developed in this dissertation resulted in a collection of case-specific empirical support material, most of which has crystallized into a web-based planning support tool coined 'StationRadar'.

In other words, the research agenda addressed in this dissertation oscillates between interventions in the Flemish policy discourse and interventions in the international academic debate on node-place modeling. As a corollary, large parts of this introductory chapter will extensively introduce the reader to both of these contexts: Section 1.2 introduces the empirical case of Flanders and Section 1.3 introduces the reader to and contextualizes this dissertation within the extant academic NPM literature.

Before embarking on both parts, the current Section 1.1 clarifies the structure and the research objectives of this dissertation. Figure 1 provides an overview of the main six building blocks (chapters) of the dissertation. The order in which the chapters have been included reflects the chronology in terms of research execution. The most tangible and operational product of the dissertation consists of the StationRadar planning support tool: a web-based tool intended to support integrated land use and transport strategy-making, with a geographical focus on railway stations in the regions of Flanders and Brussels. The tool can be considered the cornerstone of this dissertation, as Chapters 2 to 4 all feeded into its development (indicated with the dashed arrows in Figure 1) in ways that will be detailed below. Importantly, the tool is not an end in and of itself, but is a means to reach a higher end as will be clarified below.

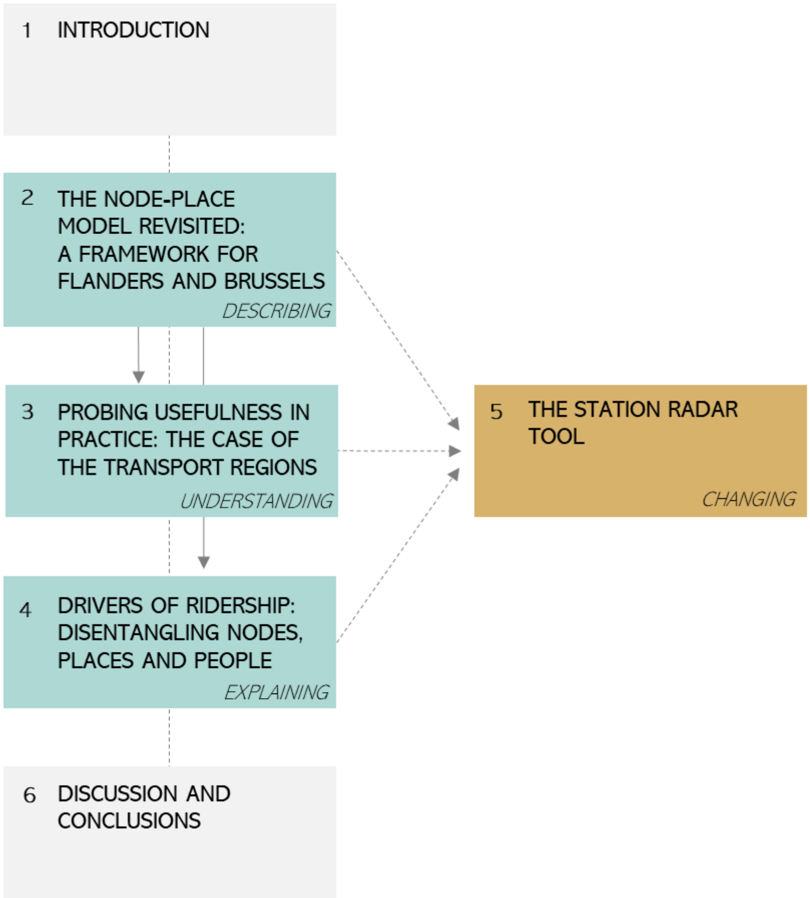



Figure 1: Outline of the dissertation

Each chapter is characterized by an overall research objective (indicated in italics in Figure 1) in line with the classification proposed by Blaikie (2010: 72). These research objectives clarify the types of knowledge that we intended to produce. The dissertation pursues a number of these objectives in sequence, ranging from 'description' (Chapter 2) to 'understanding' (Chapter 3), to 'explaining' (Chapter 4), and 'changing' (Chapter 5). Importantly, Chapters 2 and 4 are of a distinct epistemological nature compared to Chapter 3 in the sense that they draw on the field of spatial science and follow a deductive reasoning, whereas Chapter 3 draws on the field of design science[2] and adopts an abductive[3] approach. These epistemological vantage points derive from the nature of the research questions.

The dissertation is conceived as a monograph. This implies that some of the chapters were compiled by fusing different bits and pieces of co-authored work. As a corollary, the below chapter elaborations will also make clear my personal contributions. As for this introductory chapter, Section 1.2 loosely draws on Caset

[2] We refer to te Brömmelstroet (2010: 14) who characterizes the 'design sciences' in terms of their core mission to "develop knowledge for the design and realisation of artefacts (for instance in engineering or architecture), or for improving the performance of existing entities (for instance in medicine or management). A *'mutandum'* or 'something to change' is their object". In doing so, he draws on the earlier work of, among others, Van Aken (2004) and Schön (1983).

[3] As argued by Dorst (2011), the basic reasoning pattern of productive thinking in the design sciences is abduction. Contrary to induction and deduction, the outcome of this process is conceived in terms of a certain 'value' created for others. The work reported in Chapter 3 of this dissertation fits the 'Abduction-1' type discerned by Dorst (2011, 523): "Here we know both the value we wish to create, and the 'how', a 'working principle' that will help achieve the value we aim for. What is missing is a 'what' (an object, a service, a system), that will give definition to both the problem and the potential solution space within which an answer can be sought".

et al. (2017) and Caset et al. (2019a) and consisted of a joint manuscript preparation in which I took the lead. Section 1.3 is single-authored.

*Chapter 2: The node-place model revisited: A framework for Flanders and Brussels*

The overall aim of the research reported in Chapter 2 consists of applying the node-place model to the regions of Flanders and Brussels, in line with the current developments within a particular group of NPM writings (coined group 'C' in Section 1.3). The chapter is organized around two main sections.

As a first step (Section 2.1), a collaboration was set up with David Vale and Cláudia Viana from the University of Lisbon. The former had been publishing on ways of reconciling the node-place model with common measures of TOD under the banner of an 'extended node-place model' (Vale 2015, 2016 and Vale et al. 2018) (see Section 1.3). Since Vale's aim consisted of comparing a number of European metropolitan areas in terms of NPM outcomes, we opted to take the Brussels Regional Express Railway (RER) network as the empirical case for our study. By drawing on his work and that of Province of North Holland and Deltametropolis Association (2013), we aimed to: (1) systematically map and visualize the accessibility characteristics of all 144 railway stations in the RER zone, (2) verify if an intelligible station typology could be derived from this, and (3) verify to what extent different catchment area sizes (corresponding with different modes of access to stations) would influence these outcomes. This research was published in 'Networks and Spatial Economics' (July, 2018) as part of special issue on the 'Intersections between Urban Studies and Network Science' (see Caset et al. 2018). In terms of author contributions, the three of us were jointly involved in devising the research design and in conducting the data collection process and data analysis. I took the lead in preparing the manuscript.

Building on the experiences of this first empirical analysis, we worked towards a conceptual framework to map and visualize the accessibility features for all 287 railway stations located within the region of Flanders and the Brussels Capital Region, in order to arrive at a strategic railway station development tool (see Section 2.2). This revisited node-place framework crystallized into an extension of the NPM in which a variety of data is reflected about the users of the stations. We coin this the 'people' dimension. In many ways, the motives for such model extension trace back to the early writings on nodes and places, in which the role of the station user was emphasized frequently. Some examples include:

> In a broader connotation accessibility is not just a feature of a transportation node ('how many destinations, within which time and with which ease can be reached *from* an area?', but also of a place of activities ('how many, and how diverse are the activities that can be performed *in* an area?'). A third important component of accessibility is the user, or the question 'by whom'?'.
>
> Bertolini (1999: 201, emphasis in original)

> As a mobility environment a place is jointly identified by the interrelated characteristics of the available transport means, its land-use characteristics, and the characteristics of its users.
>
> Bertolini (2006: 320)

Although these user characteristics were emphasized repeatedly, they did not meaningfully crystallize into model operationalizations during the previous decades of node-place modeling research. Besides the inclusion of ridership data in some of the models (which reflects a part of this user- or people-based perspective), or studies that look into the socio-economic and demographic characteristics of the people residing in the station areas (assuming these are (potential) station users), to the best of our knowledge no efforts have been made to genuinely incorporate this important aspect of a station's accessibility profile as part of a node-place model testbed.

Besides this proposed methodological contribution, we suggest strategies to improve the analytical strength of some conventional node and place indicators, and strategies to include the temporal dimension of railway station accessibility. Together with the 'people' extension, the motive behind the latter methodological pursuit is informed by the work of Geurs (2006, see also Geurs and van Wee 2004) who put forward a conceptual accessibility framework. In this framework four components of accessibility are distinguished that are ideally accounted for when conducting accessibility analyses: the 'transport', 'land use', 'individual' and 'temporal' components. Drawing on this revisited node-place framework, two station typologies were produced for both the node-place and the people based data. We also aimed to consolidate our empirical findings into a well-structured polar graph visualization in order to later feed into the StationRadar planning support tool (beta version). In order to demonstrate what these results could mean for planning practice, a section in which the outcomes are interpreted for five station cases is worked out.

Section 2.2. is based on an article that was published in the 'Journal of Transport and Land Use' (Caset et al. 2019a). In terms of author contributions, I collected and analyzed the data whereas colleague Filipe Teixeira visualized the polar graphs. I devised the research design whereas the manuscript was prepared jointly with my supervisors. In terms of acknowledgements, we would like to thank both NMBS and VITO for their provision of data in the context of this research.

As indicated in Figure 1, the empirical analyses conducted in the above all serve *descriptive* research purposes given that a detailed account is provided of the accessibility characteristics of these railway stations, and associations and regularities are interpreted and discussed. Afterwards, the outcomes of the analyses conducted as part of Section 2.2 directly feeded into the StationRadar tool.

*Chapter 3: Probing usefulness in practice: The case of the transport regions*

The 'people' part in the title of this dissertation does not only pertain to an explicit empirical focus on the *users* of the stations (captured by means of the conceptual framework extension), but also to an explicit consideration of the 'node- and place-based actors' (Bertolini 2008) who are involved in current *planning processes* dealing with development opportunities for railway stations in Flanders. Similar to the 'people' framework extension, this research endeavour can be traced back to the early writings about nodes and places, in which a number of critical reflections were made:

> While the terminology [nodes and places] is often evocative, the analysis stops short of the level of articulation that would be needed to translate it into effective intervention tools. Crucial questions remain unanswered: How can the heterogenous process-spaces of a specific station-place be identified? And how can they be integrated in its development? In order to answer these questions, an exploration of the connections of the complexities of the object (places and networks) with those of the (development) process appears to be needed.
>
> Bertolini (1997: 5)

In a similar vein, Bertolini (1996b: 135) stated: "outstanding is the need to direct more attention towards the process, promoting communication among all the participants and involving the local and other interests affected". A short contribution written by Cornelissen and Groenendijk in 1999 also emphasized the importance of taking into account 'the actors with diverging interests' (broadly defined and ranging from station users to project developers and public transport operators), besides aspects of 'node' and 'place'. A couple of years later, at the end of their overview article, Peek et al. (2006: 459) put forward a research agenda for the next generation of node-place models. In doing so, they emphasize the need for in-practice and multi-stakeholder model validations:

> Whether and how they [node-place models] helped enhance coordination between stakeholders and develop integrated strategies should be the main focus of future model validation exercises. (...) The focus of the next generation of node-place models should be on the synergy between the *actors* involved in the (re)development process (...) The challenge seems to lie in the development of models that focus on the question of how to nourish collaboration in order to develop a station area in such a way that it leads to added-value to participants in the process.
>
> Peek et al (2006: 459, emphasis in original)

Investigations of the role that the node-place model may fulfill in establishing such meaningful collaboration thus seemed to be of crucial importance to Peek et al. (2006). However, during the decade following this key publication, node-place modeling concepts, assumptions and outcomes have rarely been subjected to validation in close dialogue with the intended end users of the conducted analyses and developed tools. This is surprising, since the majority of studies touch upon the interface between planning practice and planning research, and foreground, or at least hint towards, the usefulness of their empirical outcomes for (a variety of) stakeholders involved in station (area) (re)development processes.

In order to help bridge this gap between NPM research and practice, Chapter 3 is organized around the following three main sections. Section 3.1 reports on an experiential research strategy that is organized around a series of workshops in which a beta-version of the StationRadar tool was put to the test. More specifically, by drawing on the concepts of 'usefulness', 'usability' and 'utility' of planning support systems (Pelzer 2017), we aimed to validate StationRadar in the context of three 'transport regions' (see Section 1.2 for more information about these partnerships): Ghent, Aalst and Leuven. Data collection methods included focus groups, participatory observation and Likert-scale surveys. This section draws together the findings of the experiential learning process and illustrates to what extent and in which way StationRadar has the potential to become a useful tool to stakeholders involved in the transport regions.

This research crystallized into a conference paper (see Caset et al. 2019b). In terms of author contributions, I devised the research design and collected the data together with Kobe Boussauw. Filipe Teixeira developed the StationRadar beta version. I prepared the manuscript with feedback from my supervisors. In terms of acknowledgements, we want to thank everyone who participated in and co-organised the workshops, in particular Johan Vanhove, Tim Scheirs and the people from Veneco, Stephan Reniers, Anne Boer, Michael Eeckhout, Bart Deceuninck, Charlotte Rosseel and Silke Lemant. Thanks as well to Tom Storme and Koos Fransen for assisting the first workshop, and to Peter Pelzer for taking the time to reflect on the chaotic stream of thoughts at the roots of this research project.

This conference paper nonetheless stopped short of the level of articulation needed to comprehend the *utility* potential of StationRadar. For this reason, Section 3.2 examines in more detail the fit between the planning tasks at hand and the tool, by drawing on and revisiting the conceptual framework proposed by Pelzer (2017). A series of post-workshop expert interviews were organized which revealed how – besides aspects of utility – aspects of 'process' (pertaining to the organization of the transport region) and of 'context' (the wider political-institutional and planning-cultural context) need to be factored in when aiming to understand the usefulness of StationRadar in the specific planning context of the transport region. This Section 3.2 is single-authored.

A final Section 3.3 zooms in on one of the workshop cases that were discussed for the transport region of Aalst. The selected case revolves around three stations in the Dender valley (stations Aalst, Denderleeuw and Ninove), located west of the Brussels Capital Region. This section serves the purpose of (1) illustrating how – at particular moments – the radar diagrams succeeded in structuring a multi-stakeholder dialogue based on the empirical 'common ground' provided by the radar diagrams, and of (2) highlighting some of the main issues and sentiments that (seem to) play a role in debates revolving around railway station (re)development in the Dender valley, in order to elicit possible clues for future development scenarios. The conceptualization of this section took place in close dialogue with Kobe Boussauw while this section is single-authored.

The overall research objective of this chapter is thus to deepen our understanding of the perceived usefulness of a planning support tool that draws on node-place modeling assumptions and concepts. The prescriptive questions of 'what works?' and 'why does it work?' play a central role in this research endeavour. Given the qualitative and intensive research strategy adopted, the objective classifies as 'understanding' according to Blaikie's (2010) typology.

*Chapter 4: Drivers of ridership: Disentangling nodes, places and people*

A fourth chapter aims to explore and subsequently explain the causal relations between the 'node', 'place' and 'people' dimensions that were incorporated in the conceptual framework developed in Chapter 2 and that were validated in Chapter 3.

We draw on the observation that the vast majority of NPM applications discerned in the 'C' group (see Section 1.3) share the assumption that planning for railway station development will result in increased ridership hence in more sustainable travel behavior. Surprisingly however, within the node-place modeling literature analyses of the importance of node and place indicators in explaining ridership remain thin on the ground. A literature review revealed how few studies elaborate on the correlations between ridership and the node-place indicators (see Zemp et al. 2011, Falconer et al. 2016 and Caset et al. forthcoming). Some studies also incorporate ridership as one of the node indicators to arrive at classifications of stations (see Reusser et al. 2008, Monajem and Nosratian 2015, Singh et al. 2017 and Kim et al. 2018) or as a means of validating the empirical node-place classifications found (see Higgins and Kanarouglou 2016). However, to the best of our knowledge there is only one study that has used node-place indicators as a means of explaining ridership determinants (Olaru et al. 2019).

Clearly, the broader literature on TOD and related planning strategies such as the compact city, traditional town planning or new urbanism, contains appraisals of the impact of TOD measures on travel demand. Some key references in this respect are: Handy (2005) who reviewed the available evidence in terms of 'new urbanism design strategies' on travel behavior and demand, and Ewing and Cervero (2010) who conducted a meta-analysis of the built environment-travel literature. More recently, Stevens (2017) conducted the first ever meta-regression analysis of a large collection of built-environment/travel studies. The NPM literature has nonetheless not taken up this pursuit, nor has it inferred findings from this body of research to feed into node-place modeling applications.

This relative lack of analytical cross-fertilization between the NPM literature and the one explaining passenger numbers and characteristics is somewhat surprising given the substantial body of literature addressing the challenge of explaining ridership and forecasting at railway stations. The relative lack of integration is particularly unfortunate given the limitations of most rail ridership models when used to predict demand. The incorporation of node-place variables in demand forecasting models has the potential to (at least partially) overcome this problem by allowing to examine the effect of a much wider range of exogenous impacts on rail trips. Likewise, transferring techniques from rail ridership models to NPM applications may improve the analytical strength of the latter framework, as it introduces knowledge about the likely success of particular node or place interventions in terms of impacting rail ridership.

Against this backdrop, the research presented in this fourth chapter has a double objective. First, there is a methodological objective in that we aim to add to the body of literature in which the explanatory power of node-place modeling indicators in terms of ridership is examined. Second, there is an empirical and related policy-support objective in that we apply the model to the case of Flanders and explore how the findings could be incorporated in the StationRadar tool.

The chapter is structured into one comprehensive Section 4.1. This research crystallized into a journal article for the 'Journal of Transport Geography' and was submitted September 2019. In terms of author contributions, I devised the research design jointly with Simon Blainey from the University of Southampton. The data was collected and analyzed by myself and I took the lead in preparing the manuscript with support from Simon Blainey and my supervisors. In terms of acknowledgements, we would like to thank NMBS for their provision of data in the context of this research. Thanks as well to Ben Waterson from the University of Southampton who gave helpful feedback during the modeling process.

In summary, the overall research objective of this chapter is to explain the differences in ridership totals for the different railway stations in Flanders by examining the explanatory power of the different variables. Given the quantitative and extensive research strategy adopted, the objective classifies as 'explanation' according to Blaikie's (2010) typology. The difference with the previous chapter that is focused on 'understanding' pertains to the way in which intelligibility is achieved. As clarified by Blaikie (2010: 75, emphasis in original): "*Explanations* identify *causes* of events or regularities, the factors or mechanisms that produce them, and *understanding* is provided by the *reasons* or accounts social actors give for their actions".

*Chapter 5: The StationRadar tool*

The main objective of the fifth chapter is to introduce the reader to the most recent version of the StationRadar tool, which can be consulted at http://stationsradar.ugent.be.

We clarify and illustrate the tool and its functionalities by means of screenshots and examples. We also elaborate on the history and the development process of the tool as well as the challenges we faced. We conclude with an outlook in terms of tool maintenance and preservation of data quality.

As indicated in Figure 1, the research objective underpinning the dissemination of the StationRadar tool in the shape of an open webtool corresponds to 'changing'. The type of change aspired in the context of this research requires open dissemination of knowledge and data, freely available for everyone to consult and build on[4]. Importantly, the viability of this objective could only be established after the workshops were finished. Only then a proper assessment could be made about the extent to which the tool might actually fulfill a meaningful role or not (this relates to the earlier statement that the tool was never envisioned as an end in itself at the outset of this dissertation). Blaikie (2010: 78) argues in this regard that "change can only be achieved with confidence if the actions taken are based on those that a well-established explanation or understanding would suggest". In our case, the tool validation process generated the insights required to confirm the tool's future potential as a planning support tool, hence to further develop it and include it as a central part of this dissertation. Therefore, this dissertation entails the joint objective of increasing knowledge about the literature gaps described above, and of changing certain aspects of the world. The tool describes a present reality and will hopefully facilitate the process of actually changing this reality into a new one that moves a step closer towards more sustainable mobility outcomes.

[4] Besides the open dissemination of the tool we published the R code pertaining to the radar diagrams on GitHub (see Chapter 5). We support the ideological tenets of the open source software movement, in terms of norms, values and beliefs (see Stewart and Gosain 2006 and Ven and Verelst 2008).

The StationRadar tool originated from a joint and intensive collaboration with colleague Filipe Teixeira who is the main designer and the coder of this tool. Without Filipe's enduring engagement and technical support, StationRadar would not have existed.

*Chapter 6: Discussion and conclusions*

Chapter 6 summarizes the key take-away points of the dissertation and critically reflects on avenues for further research. The chapter is structured in three sections according to type of scientific contribution aimed for: methodology (Section 6.1), concepts and theory (6.2) and empirical output and policy support (6.3). This chapter is single-authored.

## 1.2 A sustainable land use development and transport challenge: The case of Flanders

### 1.2.1 The 'seeds of total urbanization'

> Then suddenly, below us: a patchwork sewn together by a madman, pieced together from God knows what garbage, and on top of that, thrown down with great contempt by an enraged giant, carelessly, just to be done with it: the contents of scores of block sets. In between, a tangle of roads and streets, lenghtwise and crosswise in all directions, seemingly only listening to the law of the fear of emptiness that, we were taught, also informed the compositions of the greatest painters of the little country there below us.
>
> Braem (1968: 19, own translation)

With a great deal of verve, prominent architect and urbanist Renaat Braem ridiculed the Flemish post-war 'spatial chaos' and the apparent absence of urban planning in his influential pamphlet 'The most ugly country in the world' (1968). Although published more than half a century ago, his animated description of a bird's eye view on the Belgian territory could have easily been written today. Since the publication of Braem's lament, the suburban sprawl-like morphology of Flanders (the northern and Dutch-speaking half of the country), or the 'patchwork randomly sewed together' as Braem sneeringly framed it, has become even more pronounced in today's landscape. This fragmented spatial organization has been captured by means of various metaphors and concepts. The 'nebular city' (*'nevelstad'* in Dutch) is commonly used in this regard (Smets 1994 and 1995, Ryckewaert 2002, Dehaene and Loopmans 2003, de Vries 2014), referring to the drop-like nebula of small to very small villages and interspersed suburban zones on a short distance from one another. Albrechts (1999: 594) speaks of "a diffuse nebula of scattered destinations linked only by a car ride". References to the 'raster city' (Boudry et al. 2003), the 'horizontal city' (Viganò 2013) or the 'isotropic' city reminiscent of a diffuse landscape without contrasts (see Ryckewaert 2002) have also been made. Although similar neologisms have been applied to other Western-European regions[5], van Meeteren (2016: 177) draws attention to the unique set of circumstances that have shaped urbanization in the Belgian case: "while such morphology might convey the impression of homogeneity, the regularity of the nebula on the map hides a turbulent history that strongly shapes Belgium's contemporary culture, politics and economy".

This spatial idiosyncrasy thus has deep cultural antecedents and strong socio-economic roots (De Meulder et al. 1999, Kesteloot 2003, De Decker 2011). While the starting point of Belgium's scattered settlement structure can be traced back to the Middle Ages, the 'seeds of total urbanization' were sown towards the end of 19th century (De Meulder et al. 1999: 81). Societal changes resulting from the development of the – what is now called – Walloon industrial axis (the rise of socialist movements and secularization) warned the powers that were. As argued by Voets and De Rynck (2008: 462): "Catholics, constituting the then-main political family in Belgium, were not keen on importing what they considered to be 'unholy' urban features to the countryside. They also feared losing their dominant political position, as socialists and liberals were successfully gaining political power in cities". New policy tools were implemented to geographically spread the industrializing labour force away from the unhealthy, 'bad' and politically dangerous cities, giving rise to profound anti-urban political and cultural convictions (Kesteloot 2003, De Decker 2011, Meeus et al. 2013) that still shape contemporary culture, politics and economic policies (Baeten et al. 1999, Voets and De Rynck 2008, van Meeteren 2016).

[5] For example, the term *'Netzstadt'* introduced in Switzerland by Oswald and Baccini (2003), or the term *'Città diffusa'* introduced in Italy by Indovina (1990) and pertaining to the Veneto region.

A particularly important policy tool was the instalment and construction of dense and extensive rail- and tramways of local and regional lines[6], accompanied by a system of exceptionally cheap railway season-tickets for employees, which "allowed the working class to commute between land and labour; that is between their homes with gardens in the healthy countryside and factories in cities or coal mines" (De Block and Polasky 2011: 312, referring to the work of British sociologist Rowntree[7]). Or as Boussauw et al. (2013: 1516) put it: "employees could be part of the new industrial society, without necessarily having to move to the city where they could fall prey to social movements such as socialism and fall off Christian values and norms". As such, commuting became an institutionalized Belgian practice[8], stimulated by a motivation to industrialize the country with a minimum of metropolization (Boussauw and Witlox 2011). Or, as De Meulder et al. (1999: 83) argue: "The finely meshed railway and tramway network was an efficient political device for countering the urban expansion that typified industrialization in neighbouring countries". In this way, the proletariat could be conveniently shipped in from the countryside by train or tram on a daily basis, and this in tune with the state of the economy. Other policy interventions stimulated individual and affordable ownership of new houses that were mainly intended for the working population, such as the first Belgian Housing Act (*'Loi sur les Habitations Ouvrières'*, 1889) and the establishment of the National Society for Small-scale Land Ownership, 1936). Public utilities on the countryside were made more affordable as well. This interplay between housing policy and the systematic politics of mass rail transport had severe and paradoxical consequences for the urbanization of Belgium: "By inhibiting migration to the cities, the problems of density and congestion that beset such cities as London, Manchester and Berlin could be prevented. The provincial town remained the norm. In the absence of typically metropolitan problems, Belgium never really worked out a real urban policy for itself (including town planning)" (De Meulder et al. 1999: 86). One major consequence of this, as De Block and Polasky (2011: 313) point out, is that "whereas European metropolises such as Paris exponentially increased at the expense of villages or cities with a population up to 50,000, in Belgium only the municipalities with a population of less than 2000 decreased in the second half of the nineteenth century". The growth of cities was thus averted in favour of the urbanization of the countryside (see also Bruggeman 2019).

The post-war period was characterized by the expansion of the welfare state, which was coupled with a Keynesian policy of large-scale building programmes (Ryckewaert 2002). Extensive motorway networks were quickly realized with complementary 'express' roads and ring-roads around the major cities. Together with the democratization of car ownership, the De Taeye act (1948) directly stimulating owner-occupied housing, and the overall circle of wealth creation instigating mass consumption of household products which further facilitated independent housing on the countryside, unleashed a further irreversible housing proliferation process (De Meulder et al. 1999). As a result, suburban, low-density neighbourhoods with suitable car accessibility emerged scattered around the Flemish region, facilitated by weak spatial planning policies (De Vos and Witlox 2013). In this respect, Albrechts (1999: 588) speaks of "a permissive spatial policy which resulted in a relatively continuous deterioration of the environment: e.g. a massive expansion of building activity across the country, an increasing ribbon development, unplanned industrialization and a

[6] In 1885, the Belgian national vicinal tramway company *('Nationale Maatschappij voor Buurtspoorwegen')* was established, with the objective of connecting smaller towns to the national rail network by tram or local rail lines.

[7] As pointed out by De Block and Polasky (2011), in 1911 British sociologist Benjamin Seebohm Rowntree stated in his book 'Land and Labour: Lessons from Belgium' that Belgium had gone further than any country in supplying its working class with gardens.

[8] The following notable comparison was made by Dickinson (1957: 531) for the case of Belgium: "Commutation developed in the latter half of the nineteenth century, through the special facilities afforded by the state railroads, and the latest census (1947) revealed that 40 per cent of the employed worked in places outside the communes in which they lived! This compares with 15.2 per cent for the Netherlands, 13 per cent for Switzerland, and 15.3 per cent for North Rhine-Westphalia, with its great nexus of urban centers grouped around the Ruhr. It [Belgian commute] is certainly the highest degree of labor mobility in the world".

general fragmentation of both green zones and agricultural areas. In fact, neither policy makers nor the political administration had adequate instruments at their disposal to prevent this deterioration".

### 1.2.2 Urbanization in Flanders today: An inventory

The appropriation of space endures to this day at an average rate of six hectares per day[9] (Poelmans and Engelen 2014, Vermeiren et al. 2019). A recent study nominated Flanders as the 'sprawl champion of Europe' with 95 percent of the Flemish population living in areas that qualify as 'urban sprawl' (Vermeiren et al. 2018 and 2019). The sprawl typology map resulting from this study is displayed in Figure 2a. Incidentally, this spatial representation renders a striking blueprint of the nebular city metaphor described above. On the basis of this typology, Vermeiren et al. (2019) recently calculated the societal costs of urban sprawl for the domains of *infrastructure* (the costs pertaining to the construction and maintenance of roads, public utilities and lightening), *mobility* (the internal and external costs per kilometre travelled per transport mode, drawing on travel behavior data per travel mode) and *ecosystem services* (in terms of food production, wood harvesting, water supply, carbon storage, air quality, recreation, noise reduction and visual pleasure of green areas).

The results of these calculations are sobering, as the societal costs of these respective domains are invariably much higher – a factor 7 (infrastructure), 2 (mobility) and 4,5 (ecosystem services) – for the 'sprawled' areas than for the areas classifying as 'urban core'. The factor 2 impact of a sprawled urban morphology on the societal costs of mobility should not surprise. While the region of Flanders has a well-developed and dense railway network offering intercity services as well as a well-developed local urban public transport systems allowing for intracity services, the Flemish public transport system does not sufficiently cater to medium distance trips that do not take place within or between cities (Verhetsel et al. 2007, VRP 2016). Inevitably, the diffuse urbanization pattern visualized in Figure 2a inhibits the implementation of such a system, which de facto hinges on individual motorized transport (Blondia and De Deyn 2012, Fransen et al. 2015). This evolution is worsened by ever increasing distances between homes, jobs and daily facilities and is a major source of dispersed traffic and road congestion today (Boussauw et al. 2011). This has been demonstrated empirically for the case of Flanders by Boussauw and Witlox (2011), who used a regression model to forecast regional variations in mobility production (in terms of the daily kilometrage per person) based on characteristics of spatial proximity at the residential location (controlling for socio-economic variables) by drawing on a region-wide travel behavior dataset. Figure 2b illustrates the spatial visualization of the best fit model at the scale of the census ward. The values represent the expected amount of daily generated kilometres per inhabitant, and illustrate how the urban areas (in particular the historical city centres and a number of 19th – century neighbourhoods) yield the lowest values, while rural areas generally have the highest values. Importantly, differences in spatial resolution aside, both of the maps depicted in Figure 2 mirror each other remarkably well, which seems to corroborate the often asserted association between the sustainability of the travel behavior of a Flemish citizen and residential location[10].

[9] As calculated for the period of 2005 to 2015 by Poelmans and Engelen (2014).

[10] To what extent residential location actually influences travel behavior, travel attitudes or lifestyles, or the other way around, is food for ongoing debate in Flanders. According to Van Acker et al. (2014), there is a significant direct effect of the residential neighbourhood on car availability. However, effects are small compared to the influence of other, more subjective, variables such as stage of life and travel (mode) attitude, the latter referring to travel-related selfselection.

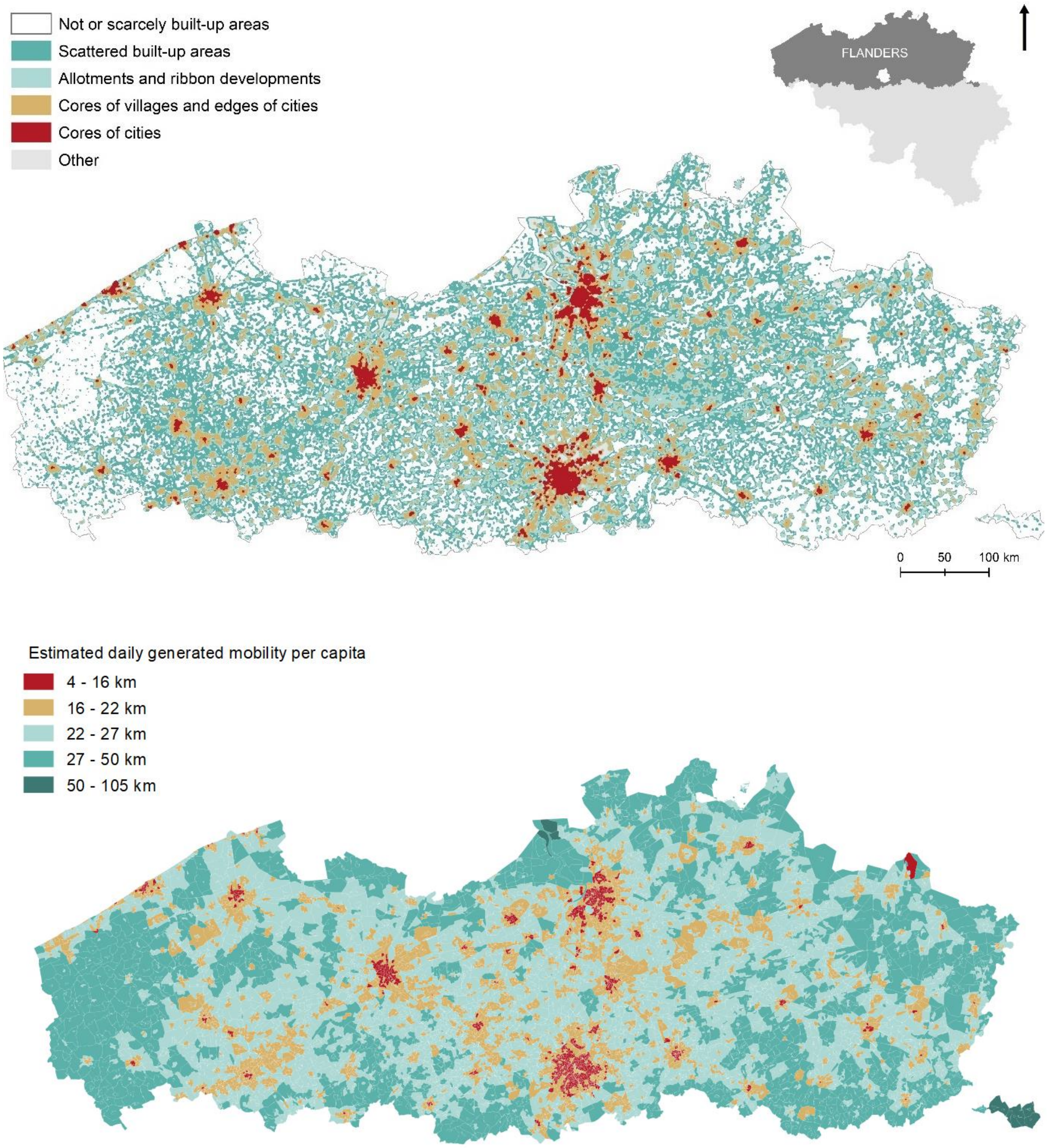



Figure 2: a) Sprawl typology map of Flanders (after Vermeiren et al. 2019: 15),
b) Spatial distribution of the estimated daily generated mobility per capita (after Boussauw and Witlox 2011: 940)

Car dependence in Flanders is also reflected by some of the recent figures in Van Eenoo et al. (2019): the car fleet in Flanders has expanded at a rate of 25% between 2000 and 2018, and vehicle kilometres travelled increased by 6% between 2007 and 2016. An important stimulus for this trend is the continous and substantive fiscal government support for the Belgian company car regime (see May et al. 2019). As explained by te Boveldt (2019), this regime is a resultant of the long Belgian tradition of home-work travel subsidies and it is increasingly criticised (see also Vanoutrive et al. 2010 and May et al. 2019).

The current mode share rates in Belgium and its expected evolution were recently studied by the Federal Planning Bureau and the Federal Public Service for Mobility and Transport (see Vandresse et al. 2012). As summarized in Figure 3, in 2008 cars covered about 81% of total kilometers travelled (both carpooling and single person vehicle), whereas the train accounted for 7% of distances travelled. The latter number comprises 11% for home-work purposes and 5% for all 'other motives'. It is clear from Figure 3 that the dominance of the car in Belgium is expected to continue until at least 2030, and that the role of the train (or any means of public transport) is not expected to rise significantly. A slight increase in railway ridership is predicted, and this due to an increase in road congestion which would give rise to a small modal shift from road traffic to train, metro and walking / cycling types of transport. The proportions for bus and tram travel, however, are likely to decrease due to this expected increased road congestion (for more details see Vandresse et al. 2012).

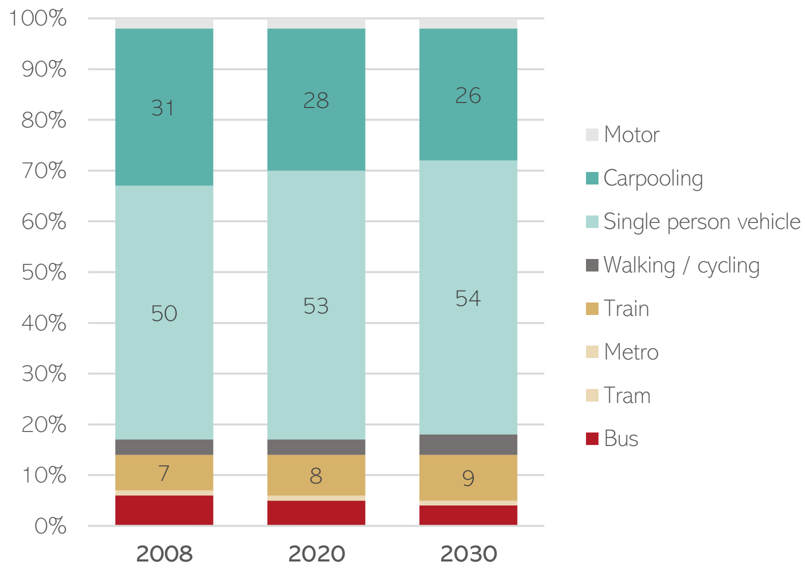



Figure 3: Proportion of the different transport modes in terms of km travelled in Belgium for all travel motives (after Vandresse et al. 2012, 43)

As a consequence of the above observations, today a critical mass of people to organize a well-functioning public transport system is located at only a small number of strategic places (Verhetsel and Vanelslander 2010, van Meeteren et al. 2015, VRP 2016). Additionally, policy levers in the policy realms of spatial planning and mobility are fragmented across various political-administrative levels, often hindering effective integration and coordination (De Vos and Witlox 2013, Boussauw and Boelens 2015).

### 1.2.3 Flanders in 2050: From nebular city to compact city?

> In 2050, every citizen of Flanders can travel easily each day. We will have organised our space in such a way that the need to travel is reduced. More Flemish citizens can travel in a sustainable manner. They will take the bicycle or train to commute and leave the car in the garage more often.
>
> Flemish Government (2017: 23)

Against the backdrop of the longstanding challenges outlined in the above section, the Department of Environment of the Flemish Government recently put forward an ambitious outlook on the future development of the built (and unbuilt) environment in Flanders by 2050. The quote above is taken from one of the preparatory documents for the new Spatial Policy Plan Flanders or *'Beleidsplan Ruimte Vlaanderen'* (hereafter BRV). Twenty years after the installment of the first comprehensive Spatial Structure

Plan for Flanders or *'Ruimtelijk Structuurplan Vlaanderen'* (RSV)[11], the BRV puts forward a renewed mid- to long-term vision in an overdue effort to halt the unguided sprawl and to curb the daily absorption of open space. The intake limit is set to 3 hectares per day by 2025 and 0 hectares by 2040[12]. In May 2012, a BRV Green Paper was released, followed by a BRV White Paper in November 2016. The BRV strategic vision was recently approved by the Flemish Government (2018b), but the six thematic policy frameworks underpinning it were not approved during the previous legislature (2014 – 2019). These policy frameworks contain operational objectives on the mid-long term and concretize the operationalization of the strategic vision.

A major policy change in the BRV concerns the principles that determine the strategic areas for future urban development. Whereas the RSV put forward a comprehensive growth strategy in which 'urban' and 'rural' areas were installed with prohibitive regulations and a targeted supply policy of residential and commercial development (de Olde 2018a), the BRV more explicitly adheres to a compact growth model (van de Weijer 2016) in which future developments are to be concentrated at those places with a sufficiently high 'node value' or *'knooppuntwaarde'*, and/or a sufficiently high level of amenities. In other words, the potential for the allocation of additional urban development is determined by (1) the extent to which a location is accessible by public transport, and (2) the extent to which jobs, residences and amenities are present (Flemish Government 2017).

Importantly, the railway network is attributed a prominent role in the BRV, as it is considered to be the "spatial backbone for future development"[13]. According to the White Paper BRV, "the railway network is the public transport system with the highest potential to transport many people with a minimal impact on health and a minimal use of space", and "the (re)development of urban centres therefore needs to take place in the vicinity of stations within the rail network" (Flemish Government 2016: 72, own translation). Although the RSV also pointed towards the strategic relevance of railway stations as places for concentrated development, the strategic BRV vision does take a much more explicit approach:

> We will build new houses and workplaces within a radius of 1000 meters from public transport nodes. We will aim for densities of at least 30%. Station neighborhoods and other places that are connected to the railway or bus network or cycling infrastructure will be well developed, with many facilities and beautiful layouts. We will always put new houses within walking or cycling distance from basic facilities. That way, everyone will have a shop, a family doctor, primary school and child care right in the neighborhood. Regional facilities – such as hospitals, swimming pools, administrative centres and secondary schools – will be easily accessible by public transport.
>
> Flemish Government (2017: 23)

In addition to an environmental sustainability motivation, this pronounced focus on the railway network draws on a flanking policy goal of increasing agglomeration economies in the Flemish polycentric region. As is evident from the BRV strategic vision, the regional government of Flanders engages itself to develop a 'metropolis Flanders', or as Boussauw et al. (2018: 8) put it: an urbanized region that "ought to be large

[11] For an extensive and insider perspective on the establishment of structure planning in Flanders we refer to Albrechts (1999).

[12] This policy goal has been popularized in newspapers under the banner of *'betonstop'* or 'concrete stop'. Although the term does not appear in the Green nor in the White Paper for the BRV, the term has become fashionable in Flemish media outlets. An interesting read on the origins of the controversial metaphor is provided by de Olde (2018b).

[13] Interestingly, this is not the first time that public transport is envisioned as the impetus for spurring economic development in Belgium. As argued by De Block and Polasky (2011: 316), "(e)ver since Belgium won its independence in 1830, politicians and engineers have considered the railway network as a vital instrument for defining, constructing and regulating the modern nationstate. As one of the first national projects of the government, the 'iron road' disseminated strong concepts on socio-economic and spatial development that set the tone for future infrastructure planning in Belgium (...)The engineers of the state conceived the new technology as the cultural and political centre of both Belgium and Europe. The system was even compared to a main street, as the railway would unite the great centres of intelligence and industry into one giant city".

and efficient enough to position itself successfully in the urban economic network of the north-western European delta". In order to make this happen, it is acknowledged that high levels of both external and internal connectivity are paramount for meeting this objective. Given the high levels of road congestion, especially in and around some of the largest economic centers of Brussels and Antwerp, the impetus for focusing on the railway network as an alternative, congestion-free, mode of transportation gained traction. In fact, a 'strong spatial backbone for the knowledge economy' is one of the central pillars of the recently approved BRV strategic vision (Flemish Government 2018b).

One of the six thematic policy papers mentioned above specifically deals with this 'spatial backbone'[14]. A central objective of this spatial backbone paper is to designate strategic public transport nodes which have the highest potential for the allocation of additional urban development. This potential is determined by (1) the extent to which a location is accessible by public transport, and (2) the extent to which jobs, residents and amenities are present. As indicated in Section 1.1, both criteria have recently been operationalized by Verachtert et al. (2016) as part of a study commissioned by the Flemish Government. Drawing on the results of this study, the policy paper puts forward a conceptual typology of railway stations for passenger transport[15] in which four types are distinguished: 'international nodes', 'metropolitan nodes', 'urban-regional nodes', and 'rural-regional nodes'. Figure 4 (bottom) incorporates an overview of these types of nodes and the kind of spatial development potential that is envisioned as communicated by Flemish Government (2018b).

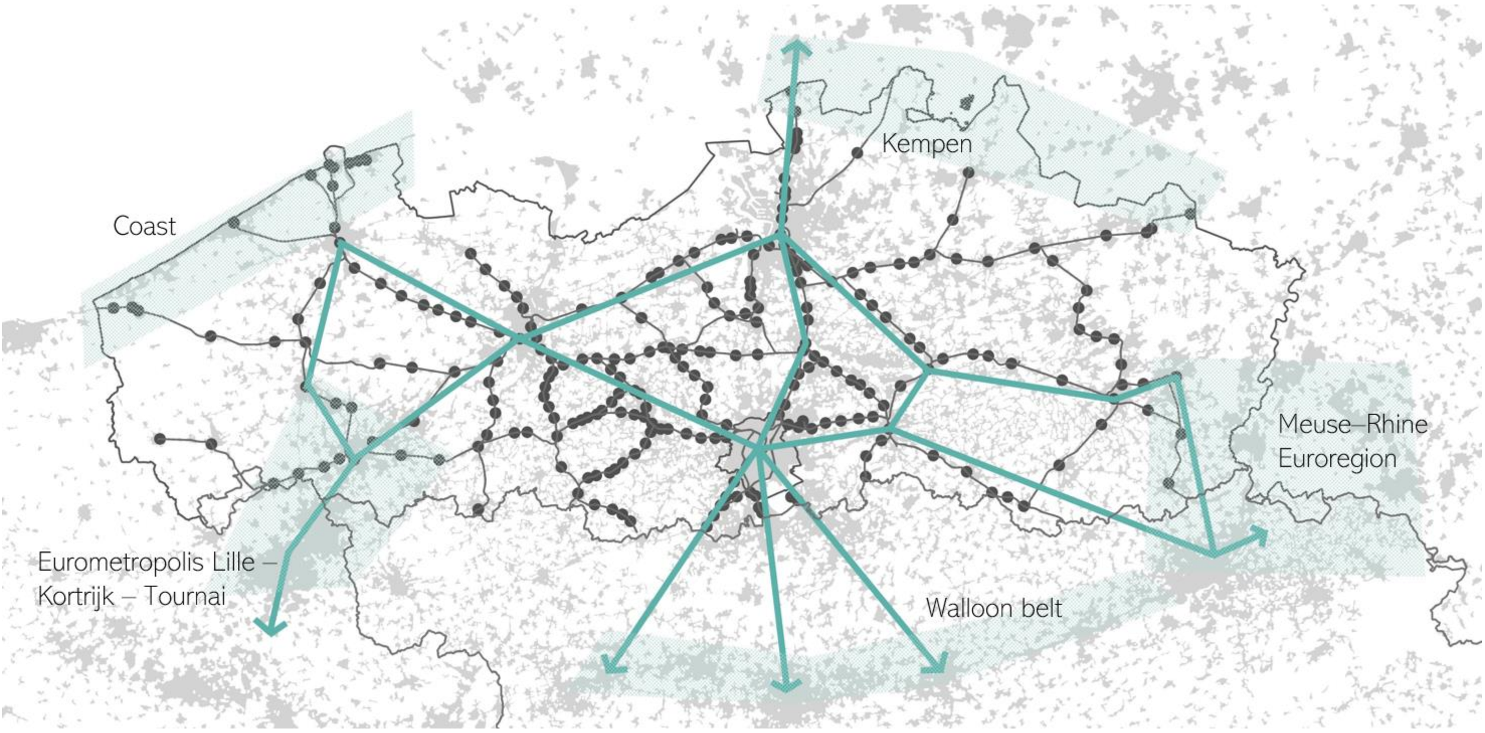
The first two types are defined based on lower thresholds with respect to the two development criteria mentioned. The Flemish Government (2018b: 26, own translation) states that "the international and metropolitan public transport nodes with a high node value and degree of amenities, that form a strategic location for the consolidation of the spatial backbone, will be developed more". According to the policy paper, the largest railway stations that are located within the central and strongly urbanized part of Flanders and the urbanized corridors in the directions of Bruges and the Eurometropolis Kortrijk – Lille – Tournai and the Meuse-Rhine Euroregion classify as one of both types. The policy paper refers to van Meeteren et al. (2015) when arguing that these 'strategic metropolitan regions' constitute a coherent metropolitan labour and consumer market with a strong presence of internationally competitive knowledge-oriented economic activities. As a corollary, the railway network connecting these international and metropolitan nodes is coined the 'metropolitan transport system' (hereafter MTS) (Flemish Government 2018b). A sketch of what this MTS could look like is provided in Figure 4 (top), which draws on a tentative list of international and metropolitan nodes provided in the policy paper and on a sketch included in a recent presentation by the Department of Environment[16].

According to the Flemish Government (2018b), additional strategic railway nodes need to be identified along the corridors in between the metropolitan and international nodes, both in urban and rural areas. This objective translates into the two other railway station types mentioned: the 'urban-regional' and 'rural-regional' nodes. Importantly, guidelines with respect to the identification of these nodes remain opaque.

[14] As a consequence of the political undecidedness about these policy frameworks during the previous legislature of the Flemish Government (2014 – 2019), at the moment of writing it is uncertain to what extent these will be recuperated during the current legislature. We draw here on a draft version of the framework created June 2017.

[15] This typology was also officially communicated (see Flemish Government, 2018b).

[16] At a recent railway station event (June 2019), the Department of Environment presented a slideshow that featured a 'loop system' railway network, in which metro-like frequencies are envisioned for the loop connecting Ghent – Antwerp – Mechelen – Brussels. Tangential lines radiate outwards towards the other main urbanized areas in Belgium. The presentation can be retreived from: https://spryg.com/be/events/stationsgebieden/achtergrond/presentaties (accessed August 2019).




| TYPE | DESCRIPTION | SPATIAL DEVELOPMENT PERSPECTIVE |
|---|---|---|
| **INTERNATIONAL NODES ('Internationale knooppunten')** | Nodes that are excellently accessible internationally (for example: Brussels Airport and high-speed railway stations) | Mixed environments with high efficiency, potentially taking the shape of a metropolitan core area ( *'hefboomplek'* ). In particular there should be space for international amenities, international presence of the knowledge economy and metropolitan lifestyles. |
| **METROPOLITAN NODES ('Metropolitane knooppunten')** | Multi-modal nodes that are excellently accessible from the entire region of Flanders and adjacent areas, such as railway stations of the large cities. These nodes serve as gateways to areas with an urban character. | Mixed environments with high efficiency, potentially taking the shape of a metropolitan core area ( *'hefboomplek'* ). In particular there should be space for metropolitan amenities, investment in knowledge-intensive economic sectors and metropolitan lifestyles. |
| **URBAN-REGIONAL NODES ('Stedelijk-regionale knooppunten')** | Nodes that are easily accessible from the urban regions by means of public transport and cycling infrastructure, such as the many (smaller) railway stations and the tram and metro stops that connect the different urbanized cores in the region with the metropolitan nodes. | Mixed environments with sufficient efficiency (housing, employment, amenities, …). The urban cores receive sufficient development opportunities. |
| **RURAL-REGIONAL NODES ('Landelijk-regionale knooppunten')** | Nodes that are easily accessible from the rural regions by means of (public) transport and cycling infrastructure such as the small railway stations and bus stops that connect the urbanized cores in the region. | Mixed environments with tailored efficiency (housing, employment, amenities, …). The urban cores receive tailored development opportunities. |

Figure 4: Top: Indicative sketch of the 'metropolitan transport system' (interpretation by authors), Bottom: BRV typology of nodes for passenger transport (Flemish Government 2018b: 43 – 35, own translation)

The 'spatial backbone' policy paper indicates that the exact definition and operationalization of these two types of regional nodes will be outsourced to the 'supralocal level', and that a further differentiation of these types of nodes should be worked out on this scale. However, since only the BRV strategic vision was approved by the Flemish Government (July 2018), there is currently no such thing as a BRV and the Department of Environment currently does not have a mandate to implement these strategic principles in practice. The situation today is that no political choices have been made regarding this thematic policy framework (and therefore regarding the designation of strategic nodes), and that no decision has been made on *how* to arrive at these choices[17].

[17] Conveyed through personal communication with the Department of Environment (July 2019).

### 1.2.4 Operationalizing the integration between transport and land use: The 'basic accessibility' principle and the transport region

The Department of Mobility and Public Works of the Flemish Government nonetheless received permission from the Flemish Parliament to start working 'in the field' by means of supralocal partnerships coined 'transport regions'. The objective of these new regional partnerships (15 in total) is to stimulate cooperation between municipalities, public transport operators, the Flemish Government and other stakeholders on the organization and coordination of public (but also road and water) transport in the region, and this in line with the principles outlined in the decree 'basic accessibility' (Flemish Government 2018a).

Today, the 'basic accessibility' concept is the dominant principle in the Flemish mobility policy and it is considered a 'game changer' (VRP 2019) due to the now joint collaboration between the Flemish Government, local governments and other stakeholders at this new regional scale. It furthermore signals a paradigm shift from a supply-driven to a demand-driven public transport system, in which the accessibility to destinations of societal importance is prioritized. A hierarchical four-layer public transport system is envisioned, in which the railway network functions as the backbone, followed by, respectively, the 'core network' (a fixed network of high-capacity bus and tram lines connecting large residential areas and attraction poles), the 'supplementary network' (a feeder network of bus lines connecting smaller settlements) and 'customized transport' catering to individual and instantaneous mobility demands. Key to this multilayered public transport system, is the concept of *'combimobiliteit'* or multimodal mobility, which implies a modal shift towards more sustainable transport modes such as walking, cycling and public transport. The Department of Mobility and Public Works aims to bundle these sustainable transport modes and the networks they are part of at strategically chosen points called *'mobipunten'* or mobipoints [18], with the aim of catering for qualitative transfers between transport modes.

As stipulated in the decree, each transport region has to prepare an 'integrated regional mobility plan', in which a strategic vision and an operational plan for the organization of public (but also road and water) transport in the region is formulated for a time horizon of 2030 (and preferably 2050). Although the Department of Environment has no official decision power in the transport region and is assigned an advisory role only, officials of both the department of Mobility and Public Works (MPW) and of Environment emphasise that coordination with the domain of spatial planning is crucial, something that is also specified in the decree. As a corollary, a cooperation agreement between both departments was recently established (July 2019). The main task of the Department of Environment is to safeguard that the decisions that are taken within the transport regions are in line with the spatial principles put forward in the BRV strategic vision. In other words, no binding decisions will be taken with respect to (classifications of) strategic nodes in these regions. In turn, experiences and insights will be gathered that will feed back into the current and ongoing BRV preparations. Figure 5 schematizes the institutional landscape pertaining to the transport regions.

While each transport region has some flexibility to organize its functioning, there should always be an administrative and a political leg of the transport region council. The latter is responsible for the decision-making process and usually consists of the municipal mayors (or aldermen), one chairman of the Department of Mobility and one political chairman of one of the involved municipalities.

[18] It is important to point at the difference in semantics between the concept of *'mobipunten'* or mobipoints (put forward by the Department of Mobility and Public Works) and *'knooppunten'* or nodes (put forward by the Department of Environment). The former is defined as a place where a transfer between different or the same mode(s) can be made, while the latter refers to a railway station area. Therefore, a mobipoint is not necessarily a node, while each node (a railway stations) is a mobipoint.

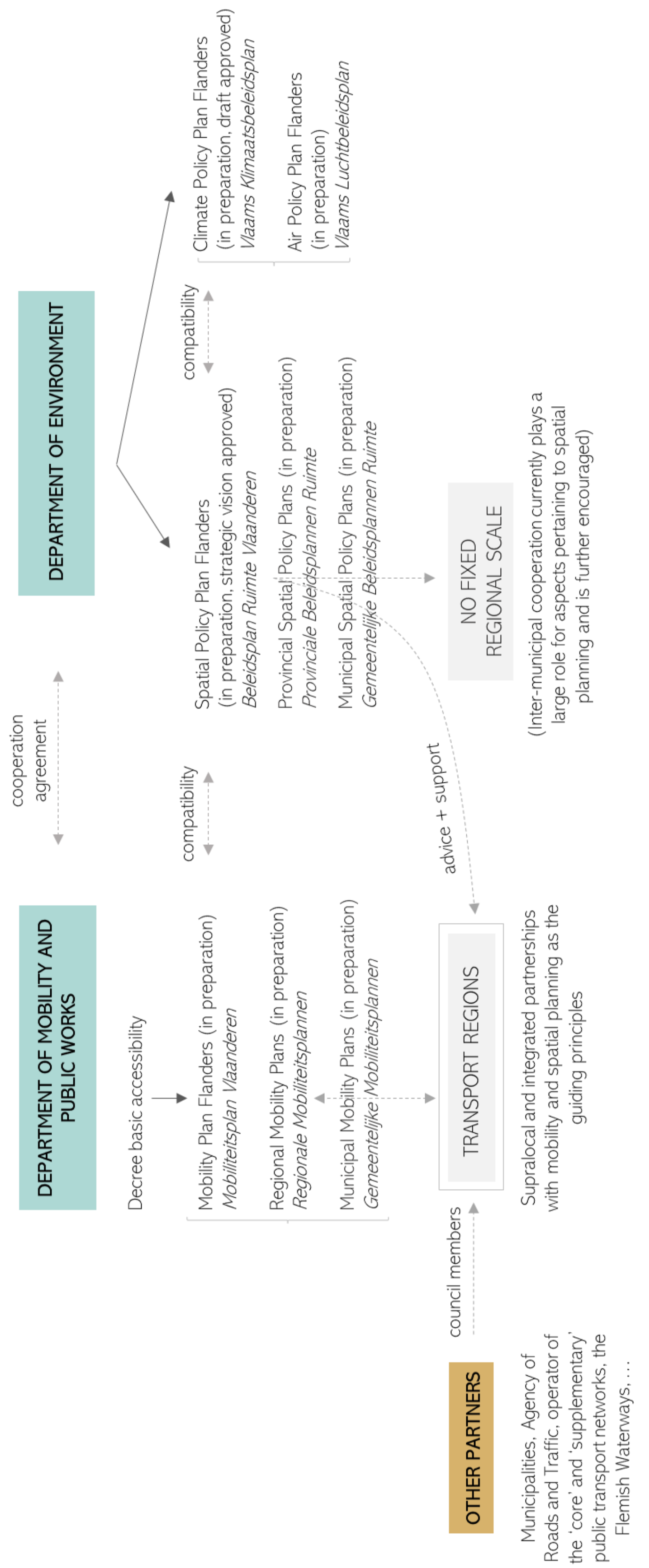



Figure 5: Institutional landscape of the transport regions (source: authors)

The administrative leg should at least host one representative of each municipality in the region, the department of Mobility and Public Works, the Agency of Roads and Traffic, the operator of the 'core' and 'supplementary' public transport network, and the Flemish Waterways. The coordinating role of the department of Mobility and Public Works is of key importance, and additional stakeholders (such as the national railway company NMBS, the department of Environment, the Provincial Government and intercommunal organizations) can also take part in the council.

In summary, the wider goal of the transport region thus consists of integrating the fields of transport and spatial planning in Flanders at the supralocal scale.

## 1.3 Identifying development potential for railway stations: The node-place model

### 1.3.1 Thinking 'nodes' and 'places': A synopsis

The literature on railway stations as 'nodes' and as 'places' is mainly European-based and can be traced back to the mid 1990s, when Luca Bertolini (architect and spatial planner by training) published his doctoral dissertation presenting a cross-national study on the redevelopment of railway stations in Europe (Bertolini 1995). Since then, writings on railway stations and their ambivalent character as "nodes of networks" and "places in the city" (Bertolini 1996a: 330) have proliferated both geographically as well as substantively. In order to situate this dissertation within this research literature, this section will discuss some general trends in the literature on the basis of the schematic overview provided in Figure 6. This overview aims to structure the scholarly[19] node-place literature according to the year of publication (vertical axis) and the theoretical substantiation that lies on the basis of its writing (horizontal axis). As for the latter, two major theoretical foundations can be discerned: writings on the 'network city' and the 'compact city'. Both are discussed at length below but may require some preliminary framing. With 'the network city' we broadly refer to theories revolving around the 'network society' (among others Castells 1996). Broadly speaking, these writings focus on the new social and spatial patterns that have emerged over the past four to five decades, and on their repercussions in terms of interpretations of 'the urban'. The 'compact city' in turn refers to theories about sustainable urban development that are based on conceptions of a walkable, bikeable and a transit-oriented city (among others Breheny 1992, Calthorpe 1993, Jenks et al. 1996).

Based on these groups of theories and on the timeline provided in Figure 6, we distinguish three main groups of writings that deal with railway stations as 'nodes' and 'places'. We label these 'A', 'B' and 'C'. Importantly, as with all classifications the risk of simplification is high, and different frames cannot be neatly identified. Thus, the classification presented here rests entirely on our interpretation and, although we thoroughly screened the academic literature, no exhaustiveness is claimed in terms of the sources cited. Before discussing these groups in more depth, we briefly summarize their main properties. The 'network city' paradigm is at the roots of the writings categorized as 'A'. The majority of this work is of a theoretical nature and is illustrated by means of a select number of empirical cases. Importantly, the notion of the 'development potential' of a station (area) is predominantly conceived as the extent to which physical human interaction at and around railway stations might materialize. While the motivation for station area (re)development of the 'A' group revolves around the consumption of the human interaction potential of station locations to achieve broader economic and social objectives, the 'B' group of writings starts from a problem statement that centers around a need for more integrated transport and land use development efforts in line with the tenets of the compact city paradigm. Importantly, and in contrast to group 'C', these contributions largely adopt the same model conceptualization and operationalization as the one that was initially proposed by Bertolini (1999). Moreover, contrary to group 'A' these contributions are mostly of analytical nature and consist of applications of the node-place model in empirical cases. The 'C' group also includes analytical contributions, but is characterized by a reinterpretation of the 'place' dimension in terms of conceptualization and measurement. This group of writings strongly engages with the empirical literature on compact cities (and related notions such as TOD, smart growth and new urbanism). This merging of

[19] We acknowledge that academic platforms do not provide the sole source for tracking the history of node-place modeling applications, as a sizeable number of consultants and think-tanks have conducted node-place analyses as well (see for example Buck Consultants International 2003). For reasons of clarity we nonetheless limit the list in Figure 6 to the scholarly literature, except for Province of North Holland and Deltametropolis Association (2013) which we consider a key reference, as it is frequently cited in the academic literature.

both literatures gave rise to new sets of indicators and dimensions with the aim of measuring aspects of density and diversity, but also of design (such as the 'walkability' and 'bikeability' of the built environment).

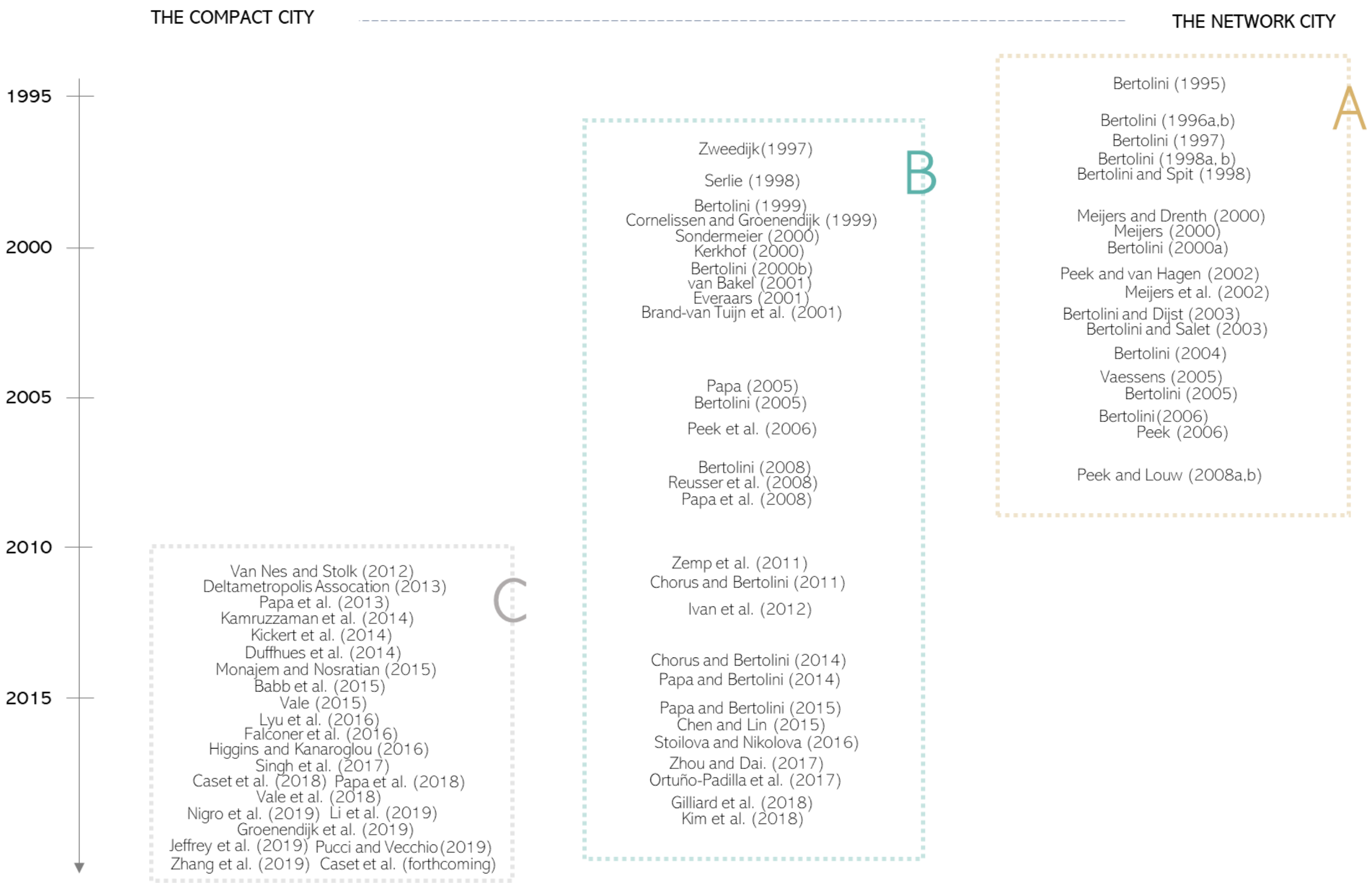



Figure 6: Classification of the node-place modeling literature (interpretation by authors)

*A. New planning tasks in the face of an increasingly mobile and 'networked' urban society*

A first group of writings directly builds on the work of Bertolini (1995) and the publications following immediately after that. Bertolini (1996a) and (1996b) are respectively titled 'nodes and places: complexities of railway station redevelopment ' and 'knots in the net: on the redevelopment of railway stations and their surroundings'. Both titles hint at the context in which this line of reasoning was originally developed: a context firmly embedded within the fields of planning theory and urban design.

Bertolini's starting point is the observation that European station area (re)development projects were strongly on the rise. He investigated this trend in the light of a number of then widely documented societal developments revolving around the vantage point that society had become increasingly mobile and gradually less dependent on urban physical and administrative boundaries. More specifically, as a consequence of developments in transport and communication infrastructure, the activity space of individuals had grown significantly, their transport patterns had become more complex and cities seemed to continue on paths of spatial decentralization processes. In order to grasp what was happening, Bertolini (1996a: 332), having worked at the Politecnico de Torino, appealed to the typical southern European network approach to spatial analysis, which was developing around emerging insights about 'network geography'[20], 'network cities' and the 'network society':

> New social and spatial patterns are emerging, calling for interpretations of the urban phenomenon. Some of the most fruitful attempts to explain these transformations revolve around the relationship between the local and the global dimensions. In the contemporary metropolis the two are simultaneously and contradictorily present. The application to station areas of conceptual frameworks such as those proposed by Castells (1989) and Dematteis (1988) is intriguing. Central to these analyses is the tension between a space of global connections (the 'space of flows' in Castells; the 'geography of networks' in Dematteis) and a space of local disconnections (the 'space of places' in Castells; the 'geography of areas' in Dematteis). In and around railway stations this tension, almost literally, materializes. On one hand, stations offer a (potential) connection to several of the material and immaterial flows that create value in the current 'informational' (Castells, 1989) mode of development. Stations are (or may become) important nodes in both transport and non-transport (e.g. business, consumption) networks. The connection to ever denser, faster and further reaching transportation systems, as well as the development there of office complexes and shopping centers are materializations of this global dimension of station locations. On the other hand, stations identify a 'place', a both permanently and temporarily inhabited area of the city, a dense and diverse conglomeration of uses and forms accumulated through time, that may or may not share in the life of the node. The mixture of housing, small business premises and informal public spaces of the station's neighborhood are an expression of this local dimension. Between node and place spirals of both growth and decline may develop.

Within this "emerging, multi-centred geography", Bertolini (1996b: 130) argued that railway stations could, at least potentially, fulfill an increasingly important role as "favoured anchors for the metropolitan activity nodes in the making" or as "nodes in the network city". In a later publication, Bertolini and Dijst (2003: 31) coined these anchor points 'mobility environments'[21] and described them as those locations "where many different people can come, but also one where many different people can do many different things: it is an accessible *node*, but also an accessible *place*" (emphasis in original)[22]. Importantly, the reference to 'different people' in the previous quote is purposeful, because Bertolini's quest for understanding the role of railway stations coincided with a quest for an increased understanding of the meaning of 'urbanity' in the context of a highly mobile society. Drawing on the work of, among others, Martinotti (1993) who wrote about the social complexity of the metropolis, and Hajer (1996) who elaborated on the idea of 'heterotopia' in relation to public space (in turn drawing on the work of philosopher Foucault), Bertolini argued that fostering urbanity (should) mean(s)[23] creating positive conditions for economic and socio-cultural diversity and exchange between the "diverse array of 'residents', 'commuters', 'city users' and 'metropolitan businessmen' present" at and around stations (Bertolini 1996a: 332). In other words, "the liveliness and long-term social and economic viability of the urban place the station identifies also rest on the plurality of its dimensions, on the variety of uses and people it is able to contain. The problem could be

---

[20] As pointed out by Bertolini (1997: 3): "These analysts have tried to develop a conceptual framework to focus *at the same time* on the transportation node and on the portion of the territory it is embedded in. Such an approach requires the 'superimposition of a *node* and an *area* reading' (Morandi and Moretti 1996: 115)" (emphasis in original). Other scholars who extensively reflected on and applied the network paradigm to transport interchanges are Boelens and de Herder (1994) and Pucci (1996).

[21] Other transport interchanges such as airports, motorway service areas and pedestrian or bicycle nodes are also discussed.

[22] As pointed out by Bertolini (1997), this unique ambivalence of stations had been raised before, albeit in other terms by, among others, Amar (1989) who introduced the concept of 'motion-places' or *'lieux-mouvements'* to conceptualize the ambiguity of stations as geographical entities. Peny (1990), Ollivro (1996) and Sander (1996) as well, reflected on the functioning of stations within both networks and cities.

[23] At certain points, Bertolini's work indeed reads as a plea. For example: "The city is increasingly spatially discontinuous, it emerges and disappears at different times, and some of its functions are being transferred to virtual networks, such as the Internet. It is in all these different spatial, temporal and virtual dimensions that the urban must be sought today" (Bertolini 2000a: 460). In the same breath he expresses a critique of Augé's (1995) anthropological interpretation of spaces as transit as 'nonplaces': "But are nonplaces, and particularly railway stations, indeed void of relations, history, identity? (…) Even for those just passing through there is in stations always a degree, or sometimes a possibility, of placeness. At the very least they have to share a physical space with people that can be very different from them (one of the few places where this still happens)" (Bertolini 2000a: 465).

defined as one of ‘coexistence of differences’ if not, as it may be argued with a bit of idealism, of ‘integrating diversity’” (Bertolini 1996b: 134)[24]. A crucial feature of Bertolini’s conceptualization of the station as a ‘place in the city’ therefore consists of its potential for ‘physical human interaction’ as captured by the ‘intensity and diversity of human activities’ present in the station area. Drawing on this work, Meijers (2000) and Meijers et al. (2002) theorized about this meeting potential and about a way to quantitatively and qualitatively capture the extent to which meaningful interaction actually takes place.

Bertolini’s engaged stance towards promoting the plurality of station area users arguably resonated with his engagement with a particular strand of research in planning theoretical debates. These debates revolved around the argument that planning is essentially a communicative endeavour that should involve multiple interacting actors (see among others Forester 1989, Healey 1992, 1997 and Innes 1995)[25], and that there should be greater attention to the process and the context dimensions of planning (among others Hall 1988). These lines of reasoning assume the crisis of instrumental rationality, and, in the case of planning the ‘rational comprehensive decision-making model’. In turn, emphasis is put on ‘how things really happen’ to move beyond that crisis (Bertolini 1997). In this regard, Bertolini (1996b: 134 – 135) makes a plea for more inter-disciplinary, inter-organizational and collaborative efforts: “If lively and diverse urban fabrics are to be achieved (that is, urban fabrics that contain contradictory and ambiguous mixtures of users, forms and populations), the many voices of both the existing and future reality of the station and its surroundings must have a place in the planning and implementation process (…) Outstanding is the need to direct more attention towards the process, promoting communication among all the participants, and involving the local and other interests affected”.

To summarize, the purported advent of the ‘network society’ and its repercussions for the fields of urban planning and design lies at the root of a range of writings on stations as nodes and places. The majority of this work is of theoretical nature and is illustrated by means of a select number of empirical station cases. Importantly, the notion of the ‘development potential’ of a station (area) is predominantly conceived as the extent to which physical human interaction at and around railway stations might materialize. Issues pertaining to sustainable development were not at the core of this early thinking about nodes and places, although Bertolini (2000a: 461) does briefly touch upon the sustainability impact of railway station development when stating that “(t)his [human interaction] potential could be realised in a relatively sustainable way, as it could allow the clustering of trips and a more efficient use of land”. Meijers (2000: 7) also dedicates a short paragraph to the alleged benefits of efficient “and as a consequence also sustainable” trips organized around a networked public transport infrastructure.

*B. Analytical explorations to stimulate integrated transport and land use efforts at stations*

While the motivation for station area (re)development of the previous group of writings revolves around the consumption of the human interaction potential of station locations to achieve broader economic and social objectives (Bertolini 1998b), the group of writings discussed here more explicitly starts from the perspective of the environmental sustainability of public transport-oriented development planning strategies. For example, Bertolini’s (1999: 199) article starts by asking “(h)ow to acknowledge the merits of urban decentralization and cope with the challenges of its unsustainability?”. He replies by stating that “a promising approach is public transport-oriented development at the scale of the region”. In doing so, he

[24] In order to invigorate his view, Bertolini refers to a number of scholars such as Sennett (1990) and Soja (1991) who had argued that the ability to integrate difference is an essential ingredient of the urban environment.

[25] For a recent review of and commentary on collaborative planning theory we refer to Goodspeed (2016).

refers to the work of TOD pioneer[26] Calthorpe (1993), Breheny and Rookwood (1993), Owens (1992) and Hall and Ward (1998). Similarly, in a 2006 overview article describing a decade of node-place modeling in The Netherlands (written by Peek, Bertolini and De Jonge), the introductory chapter states that "first and foremost" there are "mounting concerns about the sustainability of 'sprawling' and 'car-dependent' urbanization patterns" and "the integrated development of railway networks and land around the nodes of those networks is seen as a way towards a more public transport and non-motorized modes oriented, concentrated urbanization pattern". This shift in emphasis resonates with the evolution of discourses underpinning railway station (re)development projects in Europe as extensively described in Bertolini et al. (2012). Besides 'TOD', other labels exist that describe parallel planning and design movements such as new urbanism and smart growth in North America[27], and compact city and 'multifunctional land use' in Europe (Dieleman and Wegener 2004).

In order to stimulate integrated transport and land use development efforts such as TOD, Bertolini (1999: 199) introduces the 'node-place model' as "an analytical tool to help identify the potential for public transport-oriented urban-regional development". The model was operationalized in the context of two master theses (Zweedijk 1997 and Serlie 1998) at Utrecht University for the case of the Amsterdam and Utrecht agglomerations. It takes the shape of a simple x (place) and y (node) diagram (Figure 7), in which different node and place indicators are translated into a node and a place index by means of multi-criteria analysis[28].

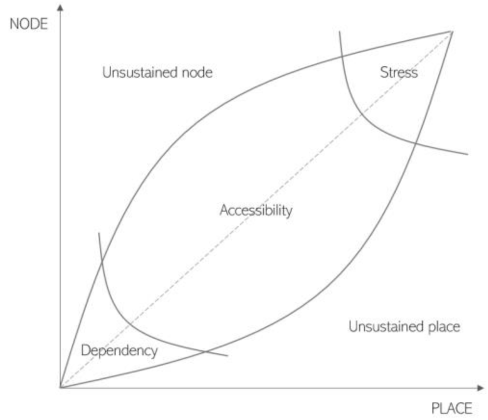



Figure 7: The node-place model (after Bertolini 1999: 202)

[26] Calthorpe (1993: 15) was the first to make reference to 'transit oriented developments'. The concept was proposed in his seminal work 'The next American metropolis: ecology, community and the American dream', in which he aimed "to map out a new direction for growth in the American Metropolis". In doing so, he borrowed from many traditions and theories: "from the romantic environmentalism of Ruskin to the City Beautiful Movement, from the medieval urbanism of Sitte to the Garden Cities of Europe, from streetcar suburbs to the traditional towns of America, and from the theories of Jane Jacobs to those of Leon Krier" (page 15). He stated the concept to be "a search for a paradigm that combines the utopian ideal of an integrated and heterogeneous community with the realities of our time – the imperatives of ecology, affordability, equity, technology, and the relentless force of intertia". The movement thus called for a rethinking of the American suburb and for alternatives to automobile-generated urban sprawl.

[27] As explained by Chapple and Loukaitous-Sideris (2019: 15): "While these three movements [new urbanism, TOD and smart growth] have some interrelated goals and aspirations, the defining characteristic of the TOD movement is that it pursues development around a transit station".

[28] The node index combines accessibility by rail (number of directions served, daily frequency of services, amount of stations within 45 minutes of travel), by bus, tram and underground (number of directions, daily frequency), by car (distance from the closest motorway access, parking capacity) and by bicycle (number of freestanding bicycle paths, parking capacity). The place index includes the number of residents in the area, the number of workers per each of four economic clusters (1: retail, hotel and catering, 2: education, health and culture, 3: administration and services, 4: industry and distribution) and the degree of functional mix. The latter was defined as the degree to which different user types (1: residents, 2: workers in the secondary sector and 3: workers in the service sector) are present in the station area, using an entropy index (see Serlie 1998, Bertolini 1999).

The node index is conceived as the "*potential* for physical human interaction", and is operationalized as the transport technical accessibility of a station location (Bertolini 1999: 201, emphasis in original). The place index, in turn, is conceived of as the "degree of actual *realization* of the potential for physical human interaction" and is operationalized as the intensity and the diversity of activities in the station area (Ibid.). The station area is defined as "the surface included within a 'walkable radius' of 700 meters from the main pedestrian entrance to the public transportation node" (Bertolini 1999: 202)[29].

Thus, importantly, although the predominant scope in which the NPM is framed here is of different nature than that of the 'A' group of writings, the fundamental driver behind the original node-place model depicted in Figure 7 still revolves around the impetus of increasing the potential for human interaction: "the realisation of the potential for physical human interaction at and around public transportation nodes is the essence of the strategy for public transport-oriented development envisaged here" (Bertolini 1999: 201).

Four ideal-typical situations were distinguished in the diagram. Bertolini (1999: 201) explains:

> Along the middle diagonal line are areas where the node and place are equally strong. At the top of the line are areas 'under stress'. Here the intensity and diversity of transportation flows and urban activities is maximal. This indicates that the potential for physical human interaction is highest (strong node) and that is has been realised (strong place). However, these are also locations where the great concentrations of flows and activities mean that there is an equally great chance of conflicts between multiple, extensive claims on a limited space. The property development ideal of maximal intensity of land use and the transport development ideal of maximal flexibility for infrastructure adaptation and expansion have to find here a difficult synthesis. At the bottom of the middle line is a second ideal-typical situation, represented by the 'dependent' areas. The struggle for space is here minimal, but the demand for transportation services from area residents, workers and other users and the demand for urban activities from travellers are both so low that supply can be held in place only by the intervention of factors other than accessibility. Finally, two 'unbalanced' situations can be identified. On one side – at the top left of the diagram – these are the 'unsustained' nodes, areas where transportation facilities are relatively much more developed than urban activities. On the other side – at the bottom right of the diagram – these are the 'unsustained places', where the opposite is true.

According to Bertolini (1998b, 1999, 2000b), the diagram should come with a dynamic interpretation, in that a perspective on movements within the diagram is needed to properly assess (re)development opportunities. He formulates the assumption that "in the long term and provided that no 'disturbing' factors intervene" all stations will be situated across the middle line of the diagram (Bertolini 1999: 203). Interestingly, in these early writings the argumentation underpinning this equilibrium assumption leans strongly on the normative socio-cultural conceptualization of station areas as described in Section 'A': "an accessible node (a location that 'can be reached' in a certain degree) needs an equally accessible place (a location where 'something can be done' to a corresponding degree), and the other way around. The assumption is also connected with the plea that the potential for physical human interaction of the station area (…) be realised through a proportionally intense and diverse concentration of urban activities" (Bertolini 1999: 203). This is relevant, because in later NPM publications there seems to be a shift towards an argumentation for the equilibrium assumption that directly draws on theories revolving around the interaction effects between transport and urban form. For example, Bertolini (2008: 37) states that "the model freely builds on elaborations of the 'transport land use feedback cycle'". In doing so, he refers to the

[29] Interestingly, Bertolini and Spit (1998: 12) put forward a more nuanced working definition of the station area as a place. They discern four possible types of station area delimitations (the walkable radius, one that takes into account the functional-historical elements, a topographic approach and one that fits the development perimeter of particular (re)development plans), to arrive at a definition that entails a combination of these approaches. The station as a 'place in the city' is defined as "All the built and open spaces, together with the activities they host, contained within the perimeter designed by a 'walkable radius' centred on the railway station building, as amended to take account of case-specific physical-psychological, functional-historical and development features". Presumably, in order to arrive at a systematic analysis of larger sets of stations (as was done in Zweedijk 1997, Serlie 1998 and Bertolini 1999), these nuances were dropped.

work of Manheim (1974), Hanson (1995), Wegener and Fürst (1999) and Meyer and Miller (2001). In Bertolini (2005) as well, a paragraph is dedicated to theories discussing the complex relationship between transport and land use developments, after which it is concluded that "the node-place model introduced by the author (Bertolini 1999) offers a framework to further penetrate this dynamic. The basic idea underlying the model is that – in line with the feedback cycle – (...)". This is a noteworthy shift in theoretical substantiation in Bertolini's thinking about nodes and places (and their mutual relationship): from a planning theoretical and urban design framework towards a framework with a more pronounced transport geographical orientation.

At the turn of the millennium, different node-place models were deployed and applied to cases both within and outside of The Netherlands, mainly with the purpose of categorizing stations to generate typologies (Peek et al. 2006). Some examples include Reusser et al. (2008) who applied the (slightly modified) NPM to all Swiss stations in order to arrive at a classification of stations 'for sustainable transitions', Zemp et al. (2011) who extended the work of Reusser et al. (2008) and Chorus and Bertolini (2011, 2014) who applied the NPM to railway stations in Tokyo.

To summarize, this second group of writings about stations as nodes and places starts from a problem statement that centers around a need for more integrated transport and land use development efforts in line with TOD. Importantly, and in contrast to group 'C', these contributions largely adopt the same model operationalization as the one proposed in Bertolini (1999), which is built on indicators that emanated from a need to capture the physical human interaction potential and realization at station(s) (areas). Moreover, contrary to group 'A' these contributions are mostly of analytical nature and consist of applications of the NPM in empirical cases.

*C. 'Places' as compact, mixed-use and walkable entities*

As suggested at the end of the previous paragraph, a third group of writings is characterized by a shift in the conceptualization and operationalization of the 'place' dimension in the node-place model. Whereas the conventional place indicators capturing aspects of 'density' and 'diversity' (see Bertolini 1999 and others) did not emanate from theories about the causal relationships between transport and land use effects, the opposite is true for the 'C' group of writings. These publications collectively distinguish themselves due to their engagement with empirical literature examining the effects of the built environment on travel behavior. Besides a number of frequently cited contributions[30], a key framework often referred to is that of the 'D' variables, first proposed by Cervero and Kockelman (1997) and expanded by Ewing and Cervero (2010). The D's stand for: density of activities, diversity of land use, design of the urban fabric (in terms of pedestrian orientation), destination accessibility or regional accessibility, distance to transit and demographics. Be it under the banner of TOD, new urbanism, the compact city, smart growth or traditional town planning, the contention underpinning these urban design philosophies is that travel demand can be shaped by intervening in the built environment. Whereas in Europe, the concept of the 'compact city' emerged as a "visionary quest for a model of sustainable urban development based on a city tailor-made for pedestrians and cyclists, with a relatively high density, a high degree of functional mix and efficient public transport" (Boussauw et al. 2012: 688), in North America, the 'new urbanism' concept can be considered the counterpart of the compact city model, as an alternative to the typically American, extensive form of

[30] See Belzer and Autler (2002) who propose a set of six TOD performance criteria, Schlossberg and Brown (2004) who investigated the performance of a range of walkability indicators across TOD sites in Portland, Dittmar and Poticha (2004) who developed a TOD typology, Evans and Pratt (2007) who aimed to quantify 'TOD-ness', Center for Transit-Oriented Development (2010) and Atkinson-Palombo and Kuby (2011) who developed a TOD station typology for light-rail transit in Phoenix.

suburbanization. Encouraging trips over short distances and creating spatial conditions that stimulate walking, cycling and using public transport are the key *Leitmotifs* of these planning paradigms.

This shift in conceptualization and operationalization has recently also been observed within the node-place literature by Nigro et al. (2019: 111) who argue that "in recent years, studies about the node-place model and TOD in general tend to focus more on the aspect of the design of urban areas around stations". Different attempts at measuring these aspects have been made. A number of studies consist of NPM applications in which indicators measuring the design of the built environment are incorporated besides indicators measuring the density and diversity of the built environment. For example, Kamruzzaman et al. (2014: 60) included the indicators 'intersection density' and 'cul-de-sac density' as part of a design dimension, and argue that "the derived place indicators neatly fall into the 3D's of Cervero and Kockelman (1997)". In a similar vein, the works of Vale (2015), Lyu et al. (2016), Caset et al. (2018), Vale et al. (2018), Jeffrey et al. (2019), Zhang et al. (2019) and Caset et al. (forthcoming) extend the node-place model by incorporating design indicators as a proxy for the extent to which a station area is 'walkable' in terms of physical features. As Vale (2015: 71) argues, by including measures of "walkability friendliness", "we want to increase the usefulness of the node-place model as a TOD planning tool". Province of North Holland and Deltametropolis Association (2013) as well, extended the model by building on the earlier work of Balz et al. (2006) and Balz and Schrijnen (2009) and developed a 'butterfly model' in which the 'distance to transit' variable (Ewing and Cervero 2010) was incorporated. Other characteristics of the built environment were included as part of a node-place modeling exercise by van Nes and Stolk (2012) and Monajem and Nosratian (2015), who deployed network analysis techniques by means of the Space Syntax approach to investigate the spatial configuration of the street network, hence capturing to what extent the station area is conducive to sustainable travel modes such as walking. Other work incorporated 'quality of place' indicators (Babb et al. 2015), extended the model with an 'experience' dimension giving rise to a node-place-experience model (Groenendijk et al. 2019) or applied the node-place model in a criminological research setting in order to detect crime-generating and crime-attracting characteristics at railway stations (Irvin-Erickson and La Vigne 2015). Caset et al. (forthcoming) in turn added a 'people' dimension reflecting characteristics of the station users (see Chapter 2).

Interestingly, operationalizations of the node dimension do not vary substantially in comparison with the 'B' group of writings. The operationalization of the original Bertolini (1999) model (see footnote 25) that is composed of measurements of the accessibility by public transport, by car and by bike is adopted in the majority of articles. There are some exceptions such as Papa et al. (2013), Caset et al. (2018), Zhang et al. (2019) and Caset et al. (forthcoming), who adopt network centrality measures to calculate public transport accessibility, or Nigro et al. (2019) who calculate different node (and place) values according to the feeder mode considered.

To summarize, this third group of writings on stations as nodes and places is above all characterized by a reinterpretation of the 'place' dimension in terms of conceptualization and measurement. This reinterpretation seems to have occurred rather 'naturally' as, increasingly, the Bertolini (1999) model was framed and positioned by many scholars as building on the transport and land use feedback cycle. Since much of the empirical literature on compact cities, TOD and the like centers on the same question - how do transport and land use interact? – it may not surprise that at a certain point both literatures broadly merged, giving rise to new sets of indicators that were intended to measure aspects of density and diversity, but also of design.

Back in 2006, Peek et al. already mentioned that "the determination of the place aspect is less obvious" and that "a diversity of variables is used" (page 457). They argued that, due to the "plurality of processes" there is "room for more than one view of the problem" (Ibid.). This seems particularly relevant today given the broad range of ways in which the NPM has been applied, extended and reinterpreted. Not only did models evolve in terms of the operationalization of node and place indicators, they also transformed into 'extended' models with entirely new building blocks according to 'the view of the problem' as Peek et al. (2006) mentioned. Interestingly, the observation that the vast majority of analytical NPMs is captured within groups B and C (in comparison to the theoretical reflections in group A), seems to resonate with the observation made by van Nes and Stolk (2012: 6) who noted that "the concepts used in the network city approach (…) tend to be rather abstract. It is difficult to apply these concepts into concrete research projects as well as strategic planning and urban design projects". Blondia (2014) also argued in a different but nonetheless relevant context that, although the theories put forward by sociologists such as Castells allowed to synthesize and understand large societal changes, there were no concrete suggestions formulated as to how the urbanized territory should be specifically shaped in order to live up to this changed context. Perhaps the compact city literature, which more narrowly focuses on sustainable urban development, provided more tangible clues for the analytical approach that is inherent to a quantitative perspective on 'measuring' nodes and places.

### 1.3.2 Classifying stations and visualizing performance: An overview

The node-place modeling work that was conducted as part of this dissertation positions itself within the 'C' group of writings. This is because – given the empirical and policy-support objectives of this dissertation – the motivation behind an application of the model in the Flemish context originates from a compact city perspective (see Section 1.2.3). As a corollary, the conceptualization and operationalization of our developed framework is adapted in line with the most current developments within both the TOD and the NPM literature. In terms of data analysis and communication of results, the work presented in this dissertation specifically builds on the type of NPM applications which serve the purposes of: (1) generating station *typologies* or *classifications*, and (2) *visualizing the performance* of stations on the different node and place criteria in order to allow *visual comparisons* between stations. We will now expand on both of these aspects.

In terms of station typologies, most of the contributions listed within groups 'B' and 'C' are characterized by some kind of classification of the stations and their surroundings into types with similar land use and transport characteristics. As stated in Higgins and Kanarouglou (2016) and Pucci and Vecchio (2019), the recent literature demonstrates an emerging interest in such empirically informed typologies as tools for informing policy prescription and evaluation. By quantifying relevant characteristics of stations and their areas in terms of land use and transport, clustering techniques may distill more or less homogeneous station categories which may enhance their planning, design and operational activities in many ways (Kamruzzaman et al. 2014). In other words, station typologies may enable comparisons and performance assessments within and between each station class and they enable the identification of successful benchmarks or can highlight tailored needs for action (Zemp et al. 2011, Kamruzzaman et al. 2014, Papa et al. 2018). The identification of similarities within each station type further allows policy makers and planners to design common sets of strategies in terms of desired density, land use mix, transit system functioning or other, by supplementing the quantitative analysis with their tacit knowledge (Reusser et al. 2008). Or, based on such evaluations, "the problem space can be defined" (Reusser et al. 2008: 201). The recent NPM literature includes a series of studies in which operational classifications of stations have been worked out. We refer to Higgins and Kanaroglou (2016) for a comprehensive overview structured around 'normative' (qualitatively informed types of TOD) and 'positive' (quantitatively informed empirical and systematic) approaches.

In terms of visualizing performance, a number of NPM applications listed in Figure 6 have incorporated visual renderings of station-specific performance levels. These visualizations generally take the shape of polar graphs in which the performance of stations for a set of criteria is plotted along scaled axes with a common origin. A chronologic overview of polar graph-like renderings is provided in Figure 8. Although we thoroughly screened the literature, we do not claim to provide an exhaustive overview[31]. To the best of our knowledge, the earliest rendering of a visualized *'knooppuntprofiel'* or 'station profile' has been coined the 'amoebe' method or model and was developed and applied by NS Railconstruct. Although we could not get hold of an original publication, reference is made to NS Railconstruct in a publication by Iris Consulting (2001), who applied the amoebe model to the Belgian case of station Antwerp-Luchtbal in order to identify its development opportunities. The method does not appear to directly refer to to the node-place modeling literature, but nonetheless discerns some node- and place-like features captured respectively under the dimensions of *'verkeers- en vervoersaspect'* or 'transport' aspects (capturing 'the extent to which the station functions as a node in the transport system') and *'ruimtelijk aspect'* or 'spatial' aspects (capturing 'the degree of impact on the structuring of the neighbouring urban parts'). The two other dimensions aim to capture 'the extent to which the immediate environment generates origin and destination flows and caters for investment and economic activities' ('economic' aspect) and 'the extent to which social values are realized' ('social' aspect). The arrows in the example provided in Figure 8 (upper left corner) indicate where the development potential for this station would be situated. Other early examples include the 'hourglass model' developed by Brand-van Tuijn et al. (2001), and the graphs by Boelens et al. (2005) summarizing station environments in terms of the activities taking place for the context of the Stedenbaan project in The Netherlands. The latter does not appear to draw on node-place modeling tenets.

Some more recent and well-known examples which were derived from the node-place model and which originated in the Dutch context include: the 'kite model' (Stadsregio Arnhem Nijmegen 2011), the 'node-place diagram' (Atelier Zuidvleugel 2006) and the 'butterfly model' (Province of North Holland and Deltametropolis Association 2013)[32]. The former was developed as an elaboration of the node-place model (Bekink 2017) and comprises five dimensions. Alongside some typical node- and place- like features, a dimension was added that combines transit ridership and the presence of services at the station (waiting rooms, shops, etc.). An 'ambition' dimension was also added, aiming to reflect the degree of ambitions of the municipality, the complementarity between the land use developments plans and their actual realizations, land ownership by the municipality and the sufficiency of funds to (re)develop (Bekink 2017). The 'node-place diagram' was designed by Atelier Zuidvleugel (2006) and "remodeled" the node-place model "into a diagram" (Bekink 2017: 67). It disaggregates the binary node and place division from the cartesian diagram into four axes. Lastly, the 'butterfly model' disaggregates the visual representation even further, arriving at a visual rendering with six axes, reminiscent of the wings of a butterfly. The model was developed by the Province of North Holland and Deltametropolis Association (2013) in the context of the 'Make Space!' project. The left 'wing' of the model includes all dimensions 'node-related' and the right wing includes the place dimensions. The former captures the accessibility by bike, public transport and the car while the latter captures the proximity of the station to the urban centre, the 'intensity' of inhabitants, employees and visitors, and the degree of functional mix. The wings have varying colour gradients reflecting the extent to which the station functions as a destination station geared towards employment, an origin station with a predominant residential character or a station functioning as a touristic hub.

[31] For example, while Peek (2006: 159) mentions two sources that have employed *'radardiagrammen'* (or radar diagrams) in the Dutch context, we did not manage to retreive these sources online. These sources are Holland Railconsult and Llewellyn-Davies (2000), and One Architecture (2001).

[32] For an in-depth discussion of these three models we refer to Bekink (2017).

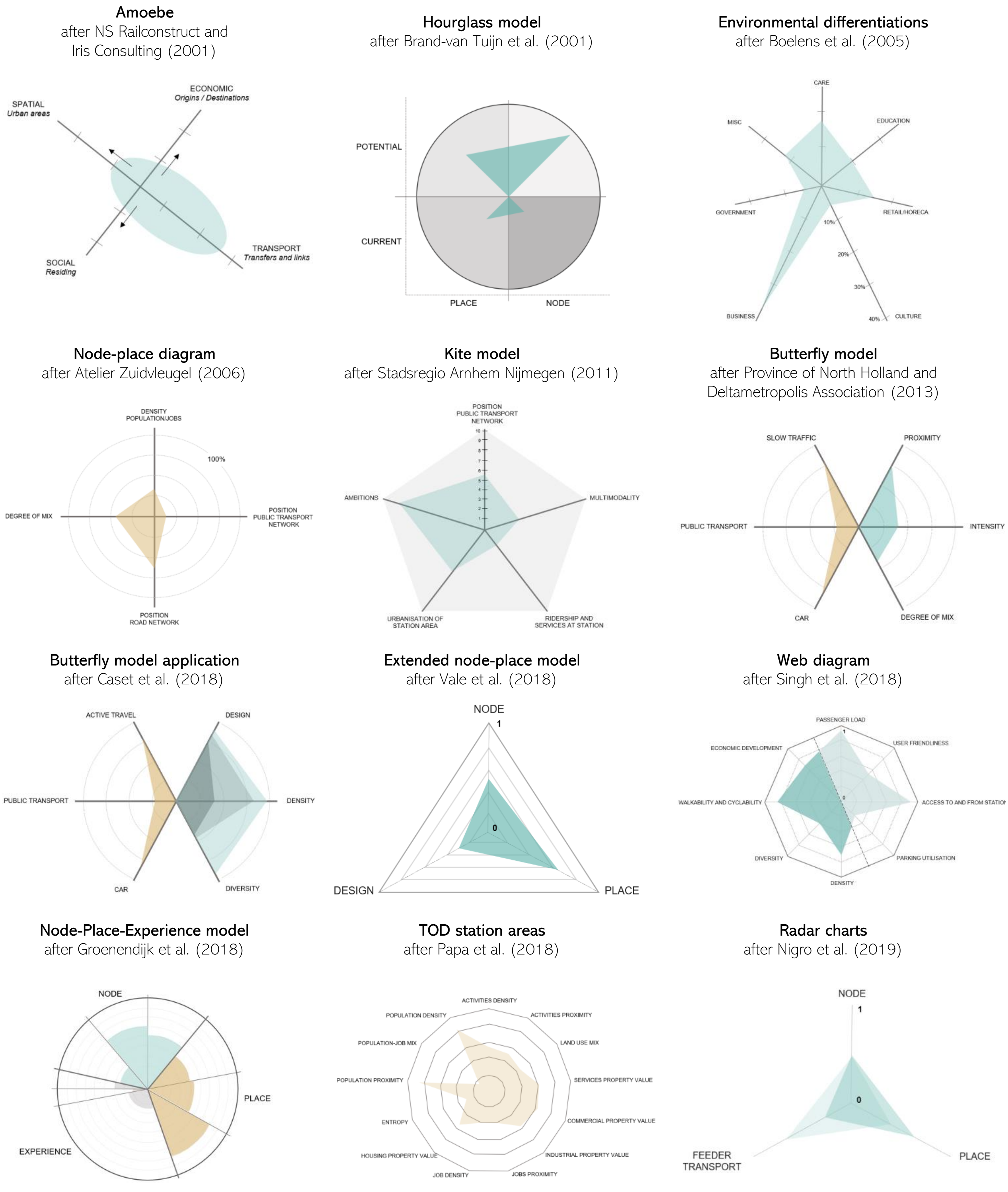



Figure 8: Overview of polar graph-like performance visualizations

Besides these applications, the 'node-place-experience' model (Groenendijk et al. 2018) adds indicators reflecting the traveller's experience at the station in terms of comfort (Wi-Fi, sheltered waiting etc.), ambient elements (type of architecture), and personnel presence. Vale et al. (2018) on the other hand extend the model with a 'design' dimension, in line with the commonly cited 3D's (Cervero and Kockelman 1997) in the TOD literature. The web diagram introduced by Singh et al. (2018) also measures walkability and 'bikeability' of the station area, along with extra dimensions such as 'user-friendliness' (measured by means of e.g. the presence of information displays) and the 'passenger load' or capacity utilization of the transit system. Two other recent examples include the radar diagram visualizations proposed by Papa et al. (2018) and the triangular polar graph introduced by Nigro et al. (2019). Similar to the rendering by Caset et al. (2018), the latter also visualizes the performance effects of different catchment area sizes.

# CHAPTER 2.

# THE NODE-PLACE MODEL REVISITED: A FRAMEWORK FOR FLANDERS AND BRUSSELS

This chapter consists of two main sections, each of which focuses on a different regional scale. The case of Section 2.1 is the Brussels RER network, spanning a region that is coined the 'RER zone' (indicated in Figure 9 below). This trans-regional infrastructure project comprises 144 railway stations. The second section deals with a larger territory and spans the regions of Flanders and Brussels (287 railway stations). Both regions have been subjected to extensive node-place analyses which will be discussed in the current chapter.

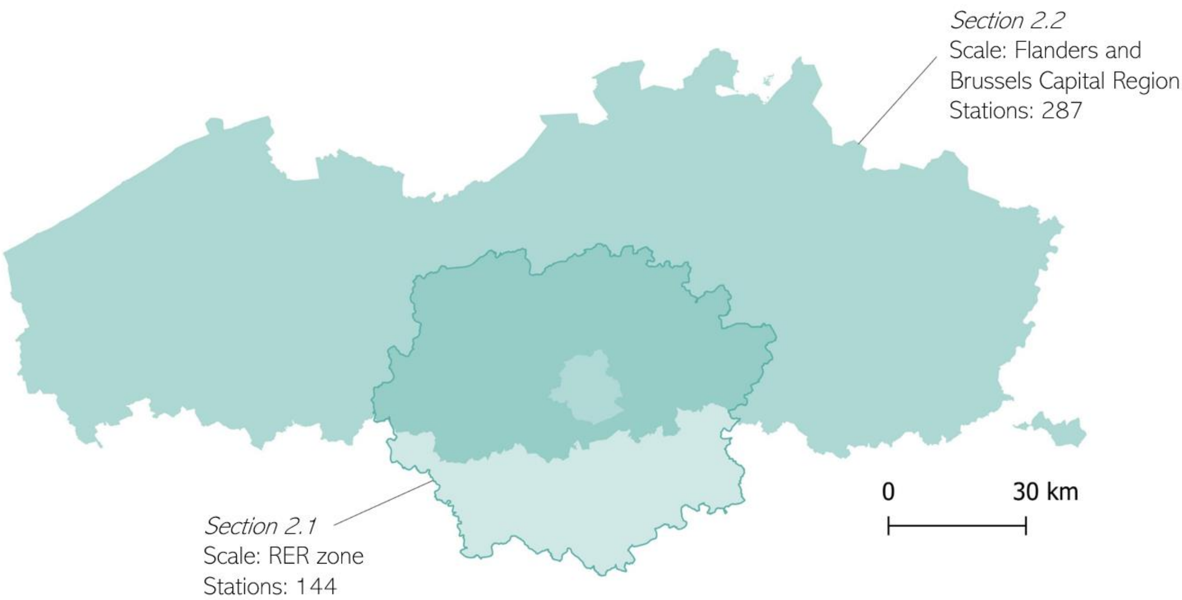



Figure 9: Two scales of analysis

## 2.1 Measuring the accessibility of railway stations in the Brussels regional express network: A node-place modeling approach

### 2.1.1 Introduction

In metropolitan areas around the world, there is a growing interest in a more coordinated approach to the integration of public transport systems and land use developments (Curtis et al. 2009, Tan 2013, Bertolini 2017). Central to this approach is the fundamental question of how to improve land use and urban planning and to strengthen the links with sustainable urban transport, in order to address the environmental and socio-economic challenges that are associated with mobility systems dominated by individual motorized transport (Marshall and Banister 2007). Apart from concepts such as 'smart growth', 'new urbanism' and 'the compact city' (see Section 1.2.1), this 'paradigm shift' from planning for mobility to planning for accessibility (Banister 2008) has crystallized under the banner of 'transit oriented development' (TOD) (originally Calthorpe 1989 and 1993, Bernick 1996, Cervero 1998). TOD is a planning approach with the aim of concentrating urban development around public transport nodes in order to support transit use, and to develop transit systems to connect existing and planned concentrations of development (Curtis et al. 2009). Its dual-purpose strategy is geared towards a high-frequency transit system and a regionally coordinated urban development program focused on the station areas within the transit network (Papa et al. 2013).

Besides creating the conditions for more environmentally sustainable transport, a systematic increase in accessibility for stations within a functional transit network may equally generate socio-economic benefits that derive from urban agglomeration effects and resource efficiency (Boussauw et al. 2016, Spaans and Stead 2016). The importance of the network or regional scale in planning for TOD has often been underscored (Cervero 1998, Cascetta and Pagliara 2008, Chorus 2012, Staricco and Brovarone 2018). The main objective of a "network TOD" strategy (Papa et al. 2013: 2) is the systematic improvement of the accessibility of functionally and hierarchically integrated urban settlements around railway stations in polycentric urban regions. It is argued that this coordinated and hierarchic development of station areas has the potential to create 'synergy' effects between stations of different size and function, as the different functions of nodes in the network can complement each other or enable cooperation (Meijers 2000, Peek 2006, Chorus and Bertolini 2016, Huang 2017). Or, as argued by Higgins and Kanaroglou (2016: 1) the benefits of a networked TOD strategy may be self-reinforcing as "a network of TODs can help to create more opportunities at origins and destinations linked by transit, potentially reducing the need for the private automobile". From a user-perspective, benefits may also emerge as 'network effects' (Mees 2010, Curtis and Scheurer 2016, Curtis 2017), which refers to the potential of transit networks to provide its users with seamless multimodal transfers, integrated ticketing systems and high service frequencies along geographical desire lines. In this way, "the ability of the network as a whole to provide accessibility is superior to that of the sum of its individual components" (Curtis and Scheurer 2016: 8).

Like many other metropolitan areas, the Brussels Capital Region (BCR) faces the problem of an increasingly congested transport system. The BCR hosts the majority of national and European organizations and many companies have their head office there. Given that a large share of daily commuters to the BCR live within the fringe of the BCR (roughly within a radius of 30 km around the capital city) and mainly rely on their car to enter the region (Grosjean and Leloutre 2015), road congestion is an everyday phenomenon and aggravates public health and liveability conditions within and around the BCR (IRIS 2011, Lebrun et al. 2013). Against this backdrop, plans for a Regional Express Railway (RER) project connecting the BCR with its periphery have taken shape over the past decades, aiming to encourage a modal shift from the car to alternative transport modes (Damay 2014). The infrastructure project may best be described as an improved suburban railway service for commuting in, out, and within the BCR, serving an area of approximately 30 km around the capital and increasing speed and frequency at existing railway routes. While realization of the RER was anticipated for 2012, due to budgetary issues and permitting troubles infrastructure completion is now planned for 2031 or later[33].

The development of the RER in turn creates an immense potential for a polycentric and more sustainable urban development of the BCR and its fringe (Dobruszkes and Mwanza 2003, Casabella and Frenay 2009). Unfortunately a strategic urban development plan for the RER zone is lacking. As the three Belgian regions (the BCR, Wallonia and Flanders), which are intersected by the RER network, each have an exclusive responsibility over the policy domains of spatial planning, housing, transport, the environment and regional aspects of economic policy, the visions of the three regions on these matters often differ significantly, and so do the strategic policy plans accompanying them (Casabella and Frenay 2009). Or, as stated by te Boveldt (2019: 3) with respect to the Brussels metropolitan area: "We can argue that the degree of regional autonomy is such that planning across regional borders in Belgium approaches the institutional complexity of planning across national borders elsewhere".

Against the backdrop of this trans-regional infrastructure project and its fragmented institutional and political planning context, the objective of this section is to provide empirical evidence on the land use and transport integration of all RER railway stations in order to support strategic planning processes. More specifically, the research reports on a systematic empirical network analysis of all 144 RER stations in terms of TOD characteristics, by drawing on the node-place modeling literature. In doing so, we aim to integrate network analysis (reflected by the 'node' feature and its indicators measuring network centrality characteristics) and spatial science (reflected by the 'place' feature and its land use characteristics), in line with the concerns raised by Ducruet and Beauguitte (2014) who stress the seminal importance of merging network science and spatial science.

### 2.1.2 The RER network: Connecting the periphery of Brussels

Since its establishment in 1989, the Brussels Capital Region (BCR, Figure 10) is one of the three federated regions besides Wallonia (the French speaking part of Belgium) and Flanders (the Dutch speaking part) within the federal configuration of Belgium. The region contains 19 municipalities, extends over 161 km$^2$ around the city of Brussels and is enclosed within the Flemish region, although its southern part is close to the boundary of Wallonia. While the official limits of Belgium's capital region correspond to the administrative boundary of the BCR, the capital sprawls outwards from these administrative limits both morphologically and functionally. On the basis of the continuity of built-up surfaces, the morphological urban region (MUR) of the BCR was delineated by Thomas et al. (2012)[34] and resulted in an operational agglomeration of 48 municipalities. The influence of the BCR as an international centre of employment nonetheless clearly extends the MUR. Therefore a functional urban region (FUR) was demarcated by OECD (2013, 2016) on the basis of commuting flows. The FUR comprises over 2,5 million inhabitants and mainly stretches towards the South and West of the BCR. Hence, as pointed out by Lebrun and Dobruszkes (2012), the administrative borders and decision-making structures do not coincide with the socio-economic reality of the Brussels metropolitan region.

[33] As indicated by Lallemand (2018), the RER is finished for 62%. The main corridors that are still under work are the L124 and L161 in Wallonia and BCR. L161 will be entirely achieved in 2031 (2024: for Uccle-Moensberg station, 2025 for the Waterloo-Braine-l'Alleud section, 2026 for the Lillois-Nivelles section and 2031 for the De Hoek-Linkebeek section).

[34] The exact borders have been revised several times and the results depend on the criteria and thresholds used (see also Dujardin et al. 2007 and Van Hecke et al. 2007). See also Boussauw and van Meeteren (2018) for a discussion about the demarcation of the Brussels metropolitan area.

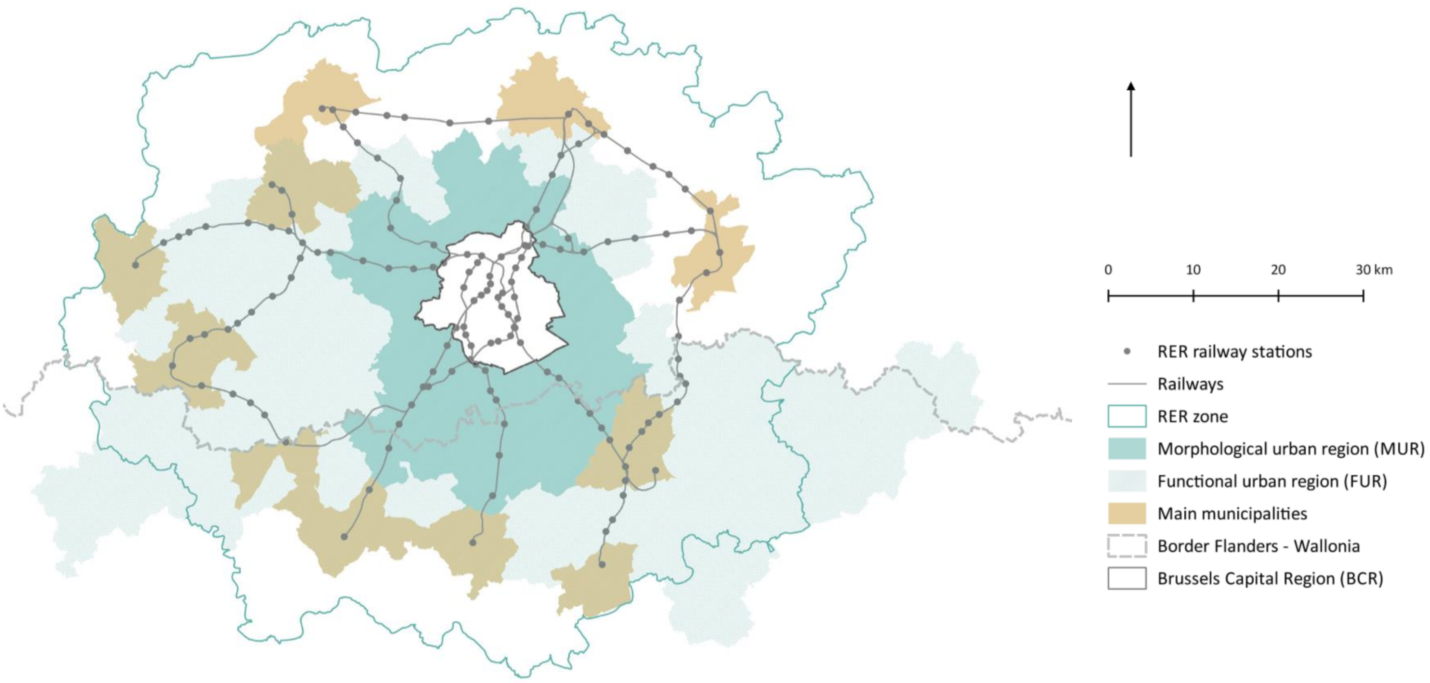



Figure 10: The Brussels metropolitan region, railway network and different demarcations

Of all employment in the BCR, 56% is occupied by commuters living outside of the region (Grosjean and Leloutre 2015), resulting in high numbers of daily commuters. Of these daily commuting flows to the BCR, the car is most frequently used, especially by employees living within a radius of 30 km around the region. This area corresponds to the 'RER zone' (Figure 10), and comprises 135 communities. Within this zone, public transport and bike commuters to the BCR together occupy a trip share of 33% whereas private cars occupy a 66% rate (Grosjean and Leloutre 2015). As a comparison, for BCR commuters living even further away, outside of the RER zone, these numbers are respectively 43 and 57% (Ibid.)[35].

This observation might be explained due the to relatively poor service of public transportation from the periphery (and generally from a distance of 35 km around Brussels) to the capital, resulting in high proportions of people commuting to the BCR by car and alarming rates of daily road congestion, aggravating public health and liveability conditions (Lebrun et al. 2013, da Schio et al. 2018). At the same time, employment within parts of the RER zone has risen fast during the last decade, arguably modifying the overall structure of mobility flows (more outward commute from the BCR and more trips between cities within the RER zone), thereby shaping an increasingly polycentric region centered around the BCR (Lebrun et al. 2013, Hubert et al. 2014). The strenghtening of the railway network in specific urban centers (such as Aalst or Dendermonde) could therefore provide sufficient agglomeration economies which may help to sustain indigenous development and/or encourage inward investment into the region (Casabella and Frenay 2009).

Although ideas hinting at a Brussels suburban railway project had been raised earlier, the first concrete plans for the RER date back to the establishment of the BCR in 1989 (Damay 2014). The project thereafter crystallized within the subsequent regional mobility, or IRIS, plans (1998 and 2011) after which it was

[35] As indicated by Strale (2019), the high proportions of commuters between Brussels and its periphery are a historical heritage resulting from a complex interplay of various societal dynamics – see Section 1.2. In terms of the car commute, the development of major arterial roads within and around Brussels since the 1950s has been a major impetus stirring further car use (Hubert 2008, in Strale 2019).

legally anchored in 2005 with a cooperation agreement between the three different regions and the federal state. This was the first occasion where the three regional governments, since their formation, collaborated jointly with the federal authorities, to reach an agreement on the financing of the project (Vandermotten et al. 2006).

The RER project combines speed, frequency and capacity, and mainly applies to the railway services of the *'Nationale Maatschappij der Belgische Spoorwegen'* (hereafter NMBS), or Belgium's national railway company. Specifically, the project includes the following measures: an increased service frequency with four trains per hour for most RER stations, a duplication of the railway tracks from two to four along the five major railway routes, the reopening of some railway stations and the realization of the Schuman-Josaphat tunnel[36] and the diabolo project[37]. No new independent railway routes were planned. Works have been completed on most railway tracks but constructions on the lines to the Walloon stations of Nivelles and to Ottignies are not yet finished. Parallel to the RER infrastructure project there is no strategic urban development project on the scale of the RER zone. The three regions instead each have an exclusive responsibility over the policy domains of spatial planning, housing, transport, the environment and regional aspects of economic policy, resulting in different regional planning narratives without much attention for trans-regional issues (Casabella and Frenay 2009).

### 2.1.3 Objectives and data

Against the backdrop of this trans-regional infrastructure project and its fragmented institutional and political planning context, the objective of this section is to provide empirical evidence on the land use and transport integration of all RER railway stations in order to inform strategic planning. To this end, three objectives may be discerned: (1) systematically mapping the accessibility of all 144 railway stations by drawing on current developments within the node-place modeling literature, (2) verifying if an intelligible station typology may be derived by means of cluster analysis, and (3) verifying to what extent different catchment area sizes (corresponding with different modes of access) influence the results of the analyses.

The methodology of this section draws on two recent developments within the node-place modeling literature. Both have been introduced in the introductory Section 2.1: the 'butterfly model' developed by the Province of North Holland and Deltametropolis Association (2013) and extensions of the original node-place model with an additional dimension that aims to quantify the design of the built environment (see Vale 2015, Lyu et al. 2016, Vale et al. 2018). This model extension allows to evaluate not only aspects of land use and transport accessibility, but also the ways in which the design of the built environment stimulates walking and cycling conditions to support access to and from the station. In this way, the 'design' dimension which was emphasized earlier by Cervero and Kockelman (1997) is attributed more importance in describing a station's overall accessibility.

Figure 11 illustrates the butterfly model as it is applied in this paper to the Brussels RER network (for full indicator descriptions including metadata and source actuality, see Appendix 2.1.I at the end of this section). The node dimensions are similar to the ones discerned by Province of North Holland and Deltametropolis Association (2013). The 'urban design' dimension mentioned above is included as part of the place wing. As a corollary, the three place dimensions are in line with the original 'three D's' (density, diversity and design) discerned by Cervero and Kockelman (1997) in their research on the link between land use characteristics and travel behavior. Inherent to measuring the place dimensions is the need for a

[36] This is a new direct link between the Brussels-Schuman station (with the European Quarter) and the HalleVilvoorde railway line (towards the North of Brussels), also referred to as the Eastern orbital railway around Brussels.

[37] This is a new line serving Brussels National Airport, via the Brussels-Antwerp connection.

geographical delimitation of a station's neighbourhood. In line with Province of North Holland and Deltametropolis Association we adopted a 1200 m radial buffer to calculate the place indicators. This distance corresponds to about 15 minutes of walking and 5 minutes of cycling. Moreover, according to a study by the NMBS holding (2013) in which the modal split of Belgian train stations in terms of feeder mode travel was examined, walking seems to represent the most important mode for more than half of all (N = 83) examined stations. A 1200 m distance therefore seems justifiable. Figure 11 also provides an overview of the indicators that were collected for each dimension. In order to arrive at a summary score for each dimension, a multi-criteria analysis was applied. In a first step, a unity-based normalization was implemented, assuring all indicator scores ranged between 0 and 100. Importantly, since not all criteria have the same measurement scale it is necessary to divide each indicator score by its average, in order to avoid a disproportionate impact on the dimension score (see also Zweedijk and Serlie 1998). The dimension scores are finally calculated by taking the average value of all indicators the dimension is composed of, assuming equal indicator weights. The operationalization of the indicators is discussed in more detail below.

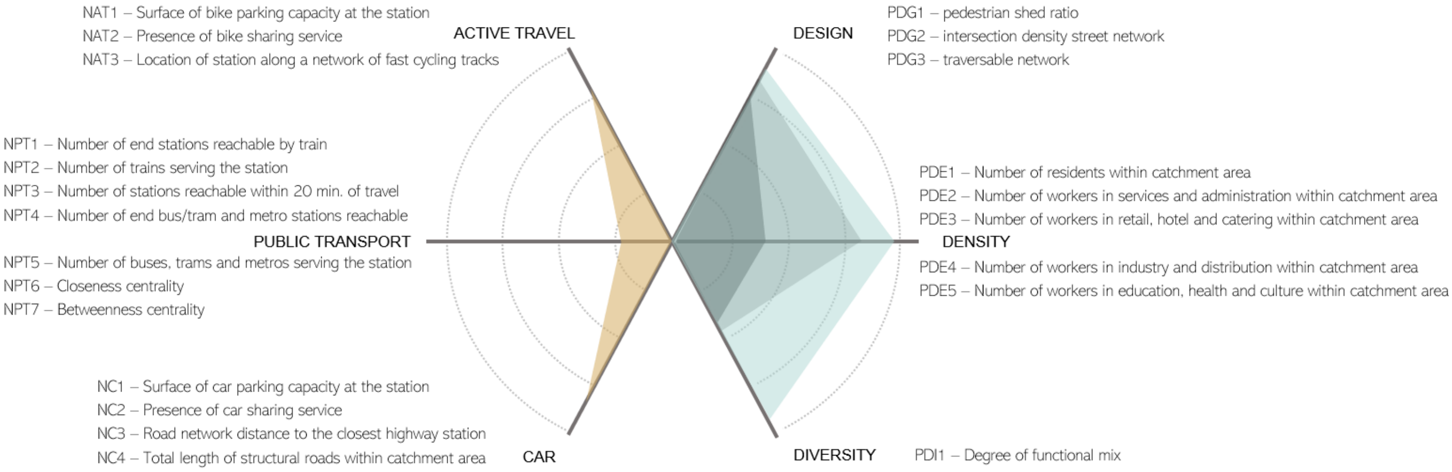



Figure 11: Overview of dimensions and indicators

*Active Travel*

The active travel dimension measures the accessibility to and from the station for 'active' modes of travel (here we include walking and cycling), and largely includes the same indicators as those that were used by Province of North Holland and Deltametropolis Association (2013). NAT1 measures the bike parking capacity (expressed as a surface measure) within the immediate vicinity (a 300 m radius) of the station. The indicator was measured by digitizing the bike parkings using OpenStreetMap (OSM) as a basemap, and by consulting Google Street View, the official website of NMBS and other online sources for the cases in which confusion about the bike parking presence and capacity arose. In case a bike parking includes multiple floors (e.g. the 'bike building' at station Aalst), the surface calculated in GIS was extrapolated in line with an estimated floor ratio. NAT2 is a binary variable indicating the presence of bike sharing facilities at the station. The indicator was created by consulting the Flemish, Brussels and Walloon bike sharing operators' websites. NAT3 is also a binary variable and indicates whether the station is connected to a network of dedicated and fast cycling routes. For Flanders, this network is labeled *'fietssnelwegen'* or 'cycling highways'. The BCR has its own system, the *'RER vélo'*, and for Wallonia the *'RAVel'* and *'véloroutes'* networks were used. Important to note is that NAT3 also includes the routes that are not yet operational.

*Public Transport*

The public transport dimension includes: (1) the original indicators that were used by Bertolini (1999) and much other later studies[38] (NPT1 to NPT5) and (2) two network centrality measures (NPT6 and NPT7) which provide additional insight into each station's 'centrality' within the full RER network. Regarding indicators NPT1 to NPT5, calculations are based on the General Feed Transit Specification[39] (GTFS) data that was obtained from the four different transport providers servicing the RER zone in September 2017. The transport companies are the national railway company NMBS, the Flemish bus and tram company De Lijn, the BCR's bus, tram and metro company MIVB/STIB and the Walloon bus and tram company TEC. International train connections to and from station Bruxelles-Midi (the only station in the RER network with international train connections) were also considered, by consulting the timetables of the operators Thalys and Eurostar. All calculations were conducted with the 'Public Transit Tools' toolbox for ArcGIS[40] for a full regular working day (a Tuesday). Indicators NPT1 and NPT4 indicate the number of end stations reachable by respectively the train service and the other public transport modes present, based on all available routes listed in the GTFS data. NPT2 represents the total number of trains serving the station (stop or start at the station) while NPT5 is the same indicator but then calculated for the other transport modes servicing the station on the same day. Indicator NPT3, measuring the number of stations that can be reached within 20 min of travel by train, required a particular approach due to the sensitivity of the chosen day and time in the calculation of travel times between any two points by public transport. We therefore calculated the indicator every 5 min within the timeslot 7:30 AM – 8:30 AM on the same Tuesday. Afterwards, the average of the different temporal snapshots was calculated for each station. It is important to note that all five indicators were calculated based on the entire Belgian public transport network, and not only based on the RER network.

These five indicators can be supplemented with the type of accessibility indicators categorized as 'network measures' by Curtis and Scheurer (2010). These measures assess a node's 'centrality' across the network expressed in terms of, for example, the average minimum travel time needed to reach all other nodes in the network, or the average minimum number of transfers required to reach all other nodes. As a corollary, two additional indicators (NPT6 or 'closeness centrality' and NPT7 or 'betweenness centrality') were added in line with the work of Curtis and Scheurer (2010) and Curtis and Scheurer (2016). Both indicators were calculated using the 'Urban Network Analysis' toolbox for ArcGIS (see Sevtsuk et al. 2013), and using travel times between stations instead of path length. NPT6 measures 'closeness centrality', defined as the average shortest travel time from a given station to all other stations in the network:

$$NPT6 = \frac{1}{\sum_j \left(d_{[i,j]} \, . \, W_{[j]}\right)} \qquad (1)$$

Where is the origin station, j is the destination station, d[i,j] is the shortest (i.e. fastest) path between d and j, and $W_{[j]}$ is the weight of the destination station (note that in our operationalization all stations were

[38] The majority of the 'B' and 'C' group of writings discerned in Section 1.3.

[39] An increasing number of public transport agencies publish their route and schedule data with the General Transit Feed Specification as the standard, open format (see https://developers.google.com). As explained by Kujala et al. (2018: 2, emphasis in original): "GTFS specifies how to present PT service supply with a series of CSV (comma-separated-values) plain text files constituting a GTFS *feed*. GTFS data is primarily used for PT passenger routing, but it can also be used for research, for instance for modeling PT-provided accessibility".

[40] Available at http://esri.github.io/public-transit-tools.

assigned the same weight). NPT7 measures 'betweenness centrality', defined as the proportion of fastest paths between any two nodes within the network that traverse station i:

$$NPT7 = \sum_{j,k} \frac{n_{jk}[i]}{n_{jk}} \cdot W[j] \tag{2}$$

where i is the origin station, $n_{jk[i]}$ is the number of fastest paths between station j to station k that pass by station i, and $n_{jk}$ is the total number of shortest fastest paths from j to k.

*Car*

The car accessibility of the station was measured using four indicators that are in line with Province of North Holland and Deltametropolis Association (2013). NC1 provides the car parking capacity (expressed as a surface measure) that is present in the immediate vicinity (300 m) of the station. The indicator was measured using OSM data, by consulting Google Street View and by contacting the main parking operators for information on the capacity of the underground parkings. In case a parking area exceeded the 300 m radius, the full parking space was included anyway (e.g. station Dendermonde and station Ternat). In case a parking is clearly oriented towards the station but is not located within the radius, the full area was also included (e.g. the dedicated RER parking near station Louvain-la-Neuve). In case a car parking includes multiple floors, the calculation in GIS was extrapolated in line with an estimated floor ratio. NC2 is a binary variable, indicating the presence of a car-sharing service at the station, and was collected by contacting the main car sharing operators within the three regions. NC3 and NC4 were measured in ArcGIS using OSM data, and indicate the position of the station in the national and regional road network. NC3 indicates the road network distance between the station and its closest highway access, while NC4 provides the total length of 'structural' roads within the station catchment area. The structural roads include the following OSM road categories: 'primary', 'secondary', 'tertiary' and 'residential'.

*Design*

Three 'design' indicators are included. This dimension reflects the extent to which the design of the built environment promotes active ways of travel (walking and cycling) and is in line with earlier work by Vale (2015), Lyu et al. (2016) and Vale et al. (2018) who extended the original node-place model by drawing on the 'walkability' literature (for example Schlossberg and Brown 2004, Ewing and Clemente 2013, Nawrocki et al. 2014, Park et al. 2015). Vale (2015) and Vale et al. (2018) coined this the 'extended node-place model' while Lyu et al. (2016) referred to this additional dimension as the 'oriented' dimension. In this work, we included similar indicators as the ones used in these sources. All indicators were calculated in GIS, using OSM data. PDG1 measures the 'pedestrian shed ratio' of the catchment area. It reveals the actual area that may be covered by walking within a specific walking time from a station instead of walkable circle (15 min. in the case of the 1200 m buffer). It is the ratio of the total area that can be drawn based on the walkable street network from the station, divided by the area of a circle with the same radius. The larger the value, the larger the walkable area around the station. PDG2 provides the number of street network intersections with three or more links in the station area, as it is an indicator of the connectivity of the street network (Handy et al. 2003). The larger the indicator, the more walkable the neighbourhood. PDG3 measures the 'traversable network length' and is related to PDG1, but is not dependent on the algorithm settings used to generate the walkable catchments in GIS (illustrated in Figure 12 for the case of station 'Veltem'). The indicator reflects the total length of the accessible street network.

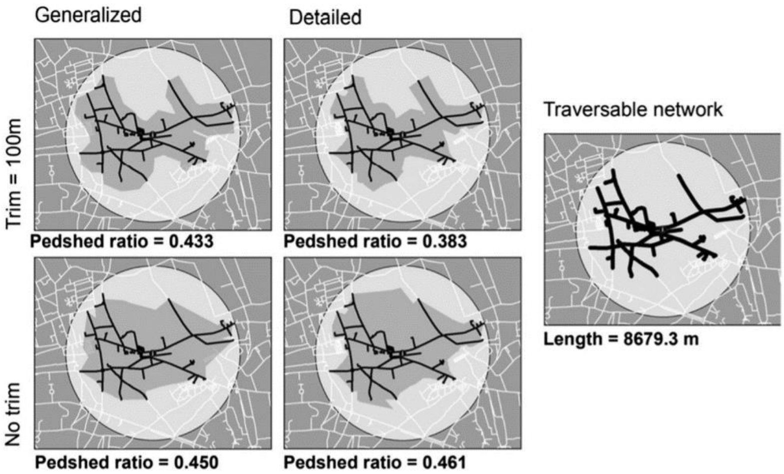



Figure 12: Illustration of pedshed ratios and traversable network length

*Density*

In line with Bertolini (1999) and other studies (for example Reusser et al. 2008, Chorus and Bertolini 2011, Lyu et al. 2016), five density indicators were included. PDE1 measures the number of residents within each catchment area. This data was calculated and provided by Statistics Belgium, on the basis of the geographical coordinates of the official residential addresses in the National Register (situation January 1st 2011). PDE2 to PDE5 provide the number of jobs that are located within the different catchment areas, disaggregated by employment sector. Four employment sectors were used: services and administration, retail hotel and catering, industry and distribution, and education health and culture. Appendix 2.1.II at the end of this section indicates the different subsectors that were included for each sector. All employment data was also calculated and provided by Statistics Belgium, on the basis of the 'Datawarehouse labour market and social protection' of the 'Crossroads Bank for Social Security' (situation January 1st 2011). The officially registered employment addresses were subsequently obtained from the 'Crossroads Bank of Enterpises' and were geocoded. Statistics Belgium also performed an imputation towards the areas with high levels of employment for those jobs with an unknown address but with a known municipality. A limitation of this data is that people who are not registered in the National Register but are working in Belgium, are not included. Furthermore, some jobs may be registered at the location of the 'interim office' or the head office of the company while the actual work takes place elsewhere.

*Diversity*

The diversity dimension is represented by the functional mix indicator used in Bertolini (1999) and others (for example Reusser et al. 2008, Chorus and Bertolini 2011, Lyu et al. 2016, Vale et al. 2018), and indicates the functional mix between the five 'density' indicators PDE1, PDE2, PDE3, PDE4 and PDE5:

$$\mathrm{PDI1} = 1 \quad \frac{\left(\left(\frac{a-b}{d}\right)-\left(\frac{a-c}{d}\right)\right)}{2}$$

$$\text{with} \begin{cases} a = \max\,(\mathrm{PDE1, PDE2, PDE3, PDE4, PDE5}) \\ b = \min\,(\mathrm{PDE1, PDE2, PDE3, PDE4, PDE5}) \\ c = (\mathrm{PDE1 + PDE2 + PDE3 + PDE4 + PDE5})\ /\ 5 \\ d = \mathrm{PDE1 + PDE2 + PDE3 + PDE4 + PDE5} \end{cases} \tag{3}$$

The indicator returns a value of ‘1’ when the number of inhabitants in the catchment area equals the number of employees in each of the four different economic sectors. In this case, the functional mix between all density indicators is maximal. Whenever there are large differences between the totals of the different sectors, the indicator will return low values, indicating a lower functional mix. This measure is disputable for two reasons. First, it does not take into account the spatial mix of the different categories considered (see Hess et al. 2001, Dovey et al. 2018). Second, PDI1 assigns equal weights to the six density indicators while in practice, some of the PDE indicators might prove more instrumental when planning for TOD.

### 2.1.4 Methods

In order to verify if an intelligible empirical station typology may be derived from the collected indicators, a hierarchical cluster analysis is conducted using different clustering methods (minimum distance, maximum distance, between-groups distance, centroid distance and Ward’s method), based on the six node and place dimensions. In order to reduce the probability of a wrong classification of a subject in a cluster (Marôco 2014), a subsequent non-hierarchical k-means cluster analysis is conducted. The results of the cluster analysis will be discussed in Section 2.1.5.

As the indicators included in the place dimension are calculated for the area within a certain spatial threshold, the outcomes of the node-place analyses are to a certain degree affected by the choice for a certain catchment area (CA) size. In order to verify to what extent different CA sizes influence the results of the analysis and the resulting station typology, the place indicators in this research have also been assessed for three other CA sizes. Besides the 1200 m CA size, 700, 800 and 3000 m sizes were selected. The smallest size of 700 m corresponds to most European studies, while the 800 m buffer is adopted in most American and Canadian studies (which either use a quarter mile or a half mile buffer size) (Kamruzzaman et al. 2014). The largest CA size of 3000 m is in in line with bicycle-TOD studies which use large CA sizes in order to represent a 10 min cycling distance, assuming a 18 km/h speed (see Lee et al. 2016). Including this large CA allows to analyze the conduciveness of the urban environment for cycling as a main feeder mode. Importantly, the CAs are not mutually exclusive (buffers may overlap), since the objective of this empirical analysis is to map the *potential* conditions for each station without presuming separated spheres of influence between stations.

As a way of exploring the variability in results for the three place dimensions, Section 2.1.6 will discuss a series of scatterplots in which the place dimension scores for the different CA sizes are visualized for all stations. Besides analyzing this ‘inter-buffer’ variability, Section 4.3 will also report on an ‘inter-cluster’ comparison. To this end, the same k-means clustering method that was applied for the 1200 m CA, is also applied to the other three CA sizes, in order to identify which stations are more sensitive to switch station type according to changes in CA size. The inter-cluster analysis is structured around two common association measures for categorical data: Cramer’s V and the Kappa Index.

### 2.1.5 Results: An empirical typology of RER stations

In order to interpret the dataset, first an exploratory correlation analysis was conducted. Appendix 2.1.III at the end of this section provides the Spearman correlation coefficients with their significance scores. Overall, the correlation analysis indicates that associations are significant and particularly strong between the ‘design’ and the ‘density’ dimensions, between the ‘diversity’ and the ‘density’ dimensions and between the multimodal public transport indicators (NPT4 and NPT5) and most of the ‘density’ and ‘design’ indicators. The remainder of the public transport indicators (NPT1 to NPT3 and the network centrality measures NPT6 and NPT7) do not seem to correlate strongly with other node or place indicators. The 'active travel' indicators correlate only little, except for NAT2 (presence of bike sharing service) which seems to generally coincide with car sharing presence, multimodality of the public transport service, a walkable built environment and higher residential densities. Of the 'car' indicators, correlations are significant and strong between NC4 (the structural roads infrastructure) and all the 'density' and 'design' dimensions.

The different hierarchical clustering methods all resulted in an optimal cluster solution of seven clusters according to a visual analysis of the screeplot and the $R^2$ criterion, but the non-hierarchical k-means clustering method explains the highest proportion of total variance (70.3%). Figure 14 summarizes the main characteristics of the seven resulting station types. For each type, a reference butterfly is portrayed, indicating the average dimension scores and their standard deviations. These summary statistics are also provided in the table included in the Figure, along with some station examples per type. In line with Province of North Holland and Deltametropolis Association (2013), an additional colour grading is introduced for the place 'wing', reflecting the extent to which the station area is geared towards residential densities (red colour), employment (orange) or a mix of both (green). These colour categories were defined based on the ratio of the number of inhabitants to the number of jobs and a lower (average minus stdev) and upper (average plus stdev) boundary. Figure 13 in turn illustrates the geographical distribution of the station types. Below, the seven clusters are discussed in more detail.

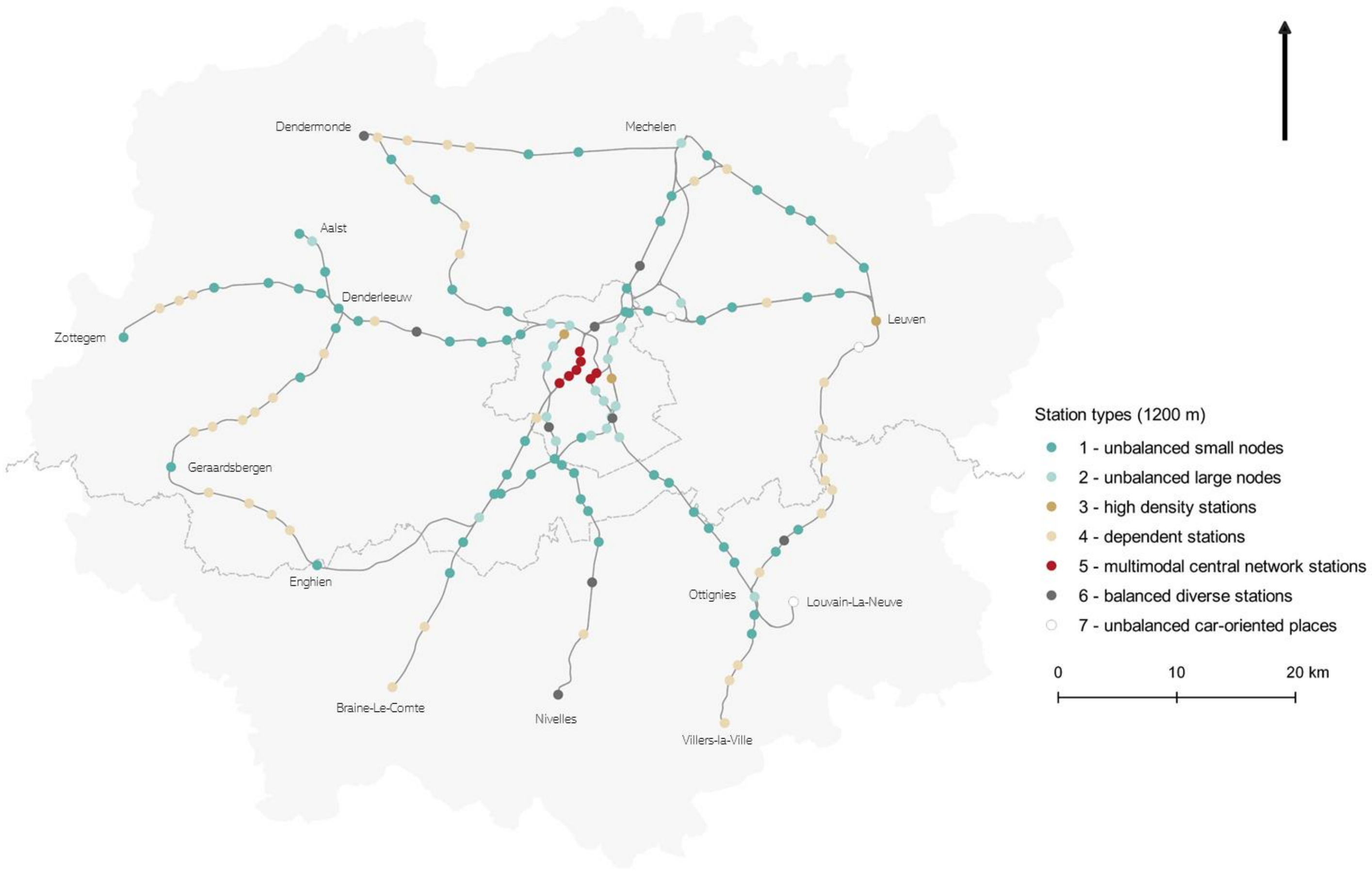
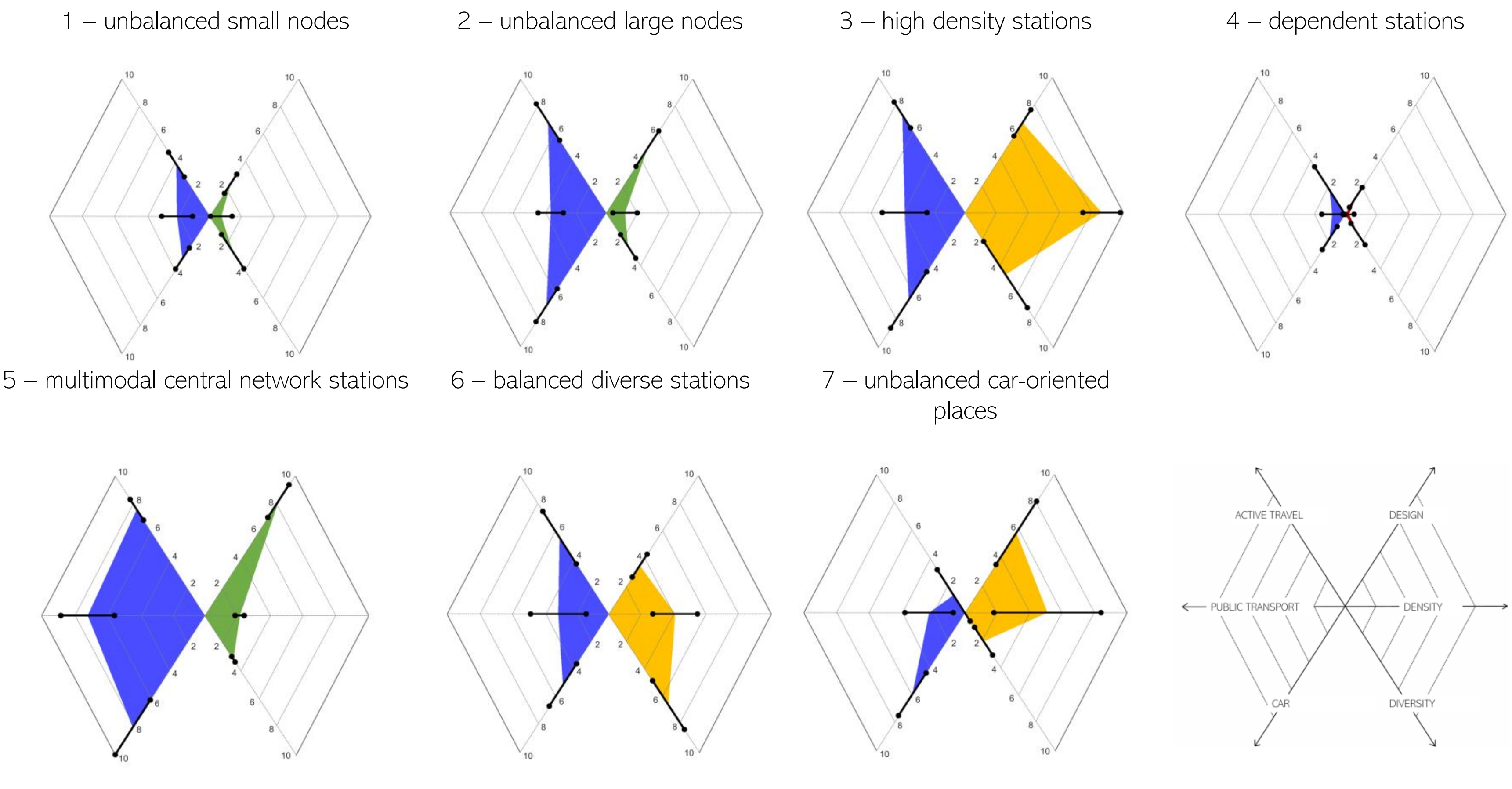



Figure 13: Geographical distribution of the station types




| CLUSTER TYPE | NAT1 | NAT2 | NAT3 | NAT | NPT1 | NPT2 | NPT3 | NPT4 | NPT5 | NPT6 | NPT7 | NPT | NC1 | NC2 | NC3 | NC4 | NC | PDI1 | PDI | PDE1 | PDE2 | PDE3 | PDE4 | PDE5 | PDE | PDG1 | PDG2 | PDG3 | PDG | STATIONS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 (N = 62) | 7 | 6 | 100 | **38** | 13 | 13 | 34 | 14 | 6 | 23 | 53 | **20** | 8 | 2 | 73 | 30 | **31** | 26 | **26** | 10 | 2 | 5 | 2 | 5 | **7** | 38 | 14 | 18 | **24** | Kortenberg, Profondsart, Liedekerke, La Hulpe, … |
| | *9* | *25* | *0* | *9* | *10* | *12* | *18* | *17* | *7* | *16* | *21* | *10* | *9* | *13* | *20* | *10* | *8* | *12* | *12* | *7* | *3* | *6* | *3* | *7* | *7* | *11* | *8* | *6* | *7* | |
| 2 (N = 21) | 13 | 95 | 95 | **68** | 13 | 13 | 47 | 36 | 31 | 35 | 77 | **35** | 15 | 90 | 75 | 59 | **69** | 25 | **25** | 18 | 5 | 9 | 2 | 5 | **12** | 64 | 34 | 42 | **48** | Brussel-West, Halle, Etterbeek, Mechelen, … |
| | *28* | *22* | *22* | *14* | *8* | *9* | *17* | *28* | *20* | *20* | *18* | *8* | *27* | *31* | *11* | *20* | *12* | *9* | *9* | *10* | *6* | *7* | *1* | *4* | *8* | *19* | *11* | *14* | *13* | |
| 3 (N = 3) | 17 | 100 | 100 | **72** | 14 | 14 | 25 | 50 | 45 | 41 | 75 | **38** | 11 | 67 | 76 | 71 | **65** | 46 | **46** | 73 | 73 | 42 | 17 | 77 | **86** | 73 | 65 | 57 | **66** | Thurn en Taxis, Merode and Leuven |
| | *29* | *0* | *0* | *10* | *21* | *21* | *24* | *40* | *11* | *34* | *28* | *14* | *19* | *58* | *4* | *14* | *21* | *25* | *25* | *24* | *33* | *14* | *9* | *21* | *12* | *23* | *24* | *11* | *10* | |
| 4 (N = 39) | 3 | 0 | 49 | **17** | 7 | 6 | 18 | 3 | 1 | 12 | 32 | **8** | 4 | 0 | 47 | 17 | **17** | 15 | **14** | 5 | 1 | 1 | 1 | 1 | **2** | 22 | 6 | 8 | **12** | Buggenhout, Lillois, Sint-Gillis, Hennuyères, … |
| | *4* | *0* | *51* | *17* | *6* | *7* | *12* | *4* | *1* | *9* | *16* | *7* | *4* | *0* | *26* | *8* | *9* | *8* | *8* | *5* | *1* | *1* | *1* | *3* | *3* | *13* | *5* | *6* | *7* | |
| 5 (N = 7) | 28 | 100 | 100 | **76** | 78 | 77 | 87 | 45 | 63 | 26 | 93 | **72** | 39 | 86 | 65 | 87 | **80** | 31 | **31** | 24 | 8 | 29 | 3 | 6 | **21** | 86 | 78 | 77 | **82** | Brussel-Luxembourg, Brussel-Congres, Brussel-Kapellekerk, … |
| | *22* | *0* | *0* | *7* | *35* | *36* | *9* | *23* | *33* | *34* | *4* | *16* | *38* | *38* | *5* | *8* | *20* | *2* | *2* | *3* | *1* | *10* | *1* | *1* | *3* | *9* | *17* | *14* | *12* | |
| 6 (N = 9) | 10 | 56 | 100 | **55** | 16 | 18 | 41 | 42 | 19 | 27 | 58 | **31** | 15 | 44 | 73 | 49 | **51** | 66 | **66** | 35 | 21 | 29 | 15 | 34 | **41** | 49 | 26 | 28 | **35** | Braine-Le-Comte, Watermaal, Ukkel-Stalle, Wavre, … |
| | *12* | *53* | *0* | *19* | *19* | *22* | *28* | *30* | *15* | *24* | *28* | *17* | *13* | *53* | *27* | *14* | *15* | *18* | *18* | *14* | *11* | *14* | *8* | *16* | *14* | *16* | *7* | *8* | *8* | |
| 7 (N = 3) | 5 | 0 | 33 | **13** | 13 | 15 | 31 | 38 | 11 | 14 | 43 | **22** | 10 | 67 | 88 | 42 | **59** | 21 | **21** | 19 | 21 | 44 | 35 | 48 | **51** | 66 | 50 | 53 | **58** | Louvain-La-Neuve, Heverlee and Zaventem |
| | *4* | *0* | *58* | *19* | *19* | *23* | *33* | *20* | *5* | *13* | *28* | *15* | *7* | *58* | *5* | *4* | *16* | *10* | *10* | *3* | *27* | *50* | *57* | *40* | *33* | *8* | *33* | *26* | *23* | |

Figure 14: Overview of RER station types and characteristics

*Cluster 1 – Unbalanced small nodes*

Cluster 1 includes the largest number of stations (N = 62). These stations are mainly located along the radial arms of the RER, outside of the BCR (except for the stations Moensberg, Saint-Job, Sint-Agatha-Berchem, Haren-Sud and Haren). Overall, this station type is characterized by moderate scores on most indicators, low scores on the multimodal public transport indicators (NPT4 and NPT5) and low scores on most density and design indicators. These lower scores point towards a moderate degree of urbanity of these station environments and a low presence of feeder public transport services (bus, tram or metro). The train indicators NPT1 to NPT3 and the network centrality measures NPT6 and, especially, NPT7 however indicate a moderate to good overall railway connectivity of these stations. These stations are also all connected to fast cycling routes, as variable NAT3 has a maximal score. As for the station area orientations towards employment and/or housing (reflected by the colour of the place wing), the majority of stations belong to the mixed category. Only nine stations exhibit a predominant residential character (e.g. stations Huizingen, Ede and Iddergem) and only eight stations exhibit stronger employment characteristics (e.g. stations Haren-Sud, La Hulpe and Aalst-Kerrebroek). Overall, place dimensions feature less prominently than the node features in the butterfly, therefore we opted to label these stations 'unbalanced nodes' (or 'unsustained nodes' as Bertolini (1999) originally labeled this group, see Figure 7). Since these stations are predominantly located in low density areas, this station type was finally labeled 'unbalanced small nodes'.

*Cluster 2 – Unbalanced large nodes*

Cluster 2 is a smaller group (N = 21) and is also characterized by low scores on some of the density dimensions, but clearly exhibits higher scores on the design indicators, indicating a more walkable built environment compared to cluster 1. These stations furthermore score high to very high on all active travel indicators and on both the railway indicators and the multimodal public transport indicators. Car accessibility is also high, with most stations providing car sharing services and much parking capacity. Geographically speaking, these stations are mostly located within the BCR, except for five stations (i.e. stations Aalst, Mechelen, Brussels Airport, Ottignies and Halle). When analyzing the station areas, there are no stations with a predominant residential character, and three stations exhibit pronounced job characteristics (i.e. stations Brussels Airport, Mechelen and Diesdelle). All other stations have mixed environments. We chose to label this station type as 'unbalanced large nodes' because of its higher overall scores for the node features, and its overall metropolitan location.

*Cluster 3 – High density stations*

This cluster includes only the three example stations listed in Figure 14. Two of them are located in the BCR (i.e. Thurn en Taxis and Merode) while the other one is the central station of the city of Leuven. The main aspects distinguishing this cluster from the other ones are the very high scores on all 'density' indicators, especially PDE1 (number of inhabitants) and PDE2 (number of jobs in services and administration), with station Leuven exhibiting the highest score on the density dimension of all RER stations. Although there are some common characteristics (high scores on the 'active travel' and 'design' dimensions), some other characteristics (such as car accessibility, diversity and public transport accessibility) vary considerably more between the three stations. Arguably, although statistically speaking this cluster bears relevance, this station type might prove less meaningful in strategic policy and planning discussions as its internal cohesion across the dimensions is only moderate.

*Cluster 4 – Dependent stations*

Cluster 4 (N = 39) has the lowest scores of all clusters on all indicators. The stations are mainly located at the periphery of the RER network (except for station Forest-Midi), and seem to cluster along the tangential lines connecting Leuven with Ottignies, Denderleeuw with Geraardsbergen, and Geraardsbergen with Braine-Le-Comte. The cluster is particularly characterized by very low scores on the network centrality measures NPT6 and NPT7, indicating respectively that these stations do not have fast services to the other RER stations, and that they are not located at the crossroads of many different railway routes. However, the near-future realization of the ongoing RER works on the tracks towards Nivelles and Ottignies (a deduplication of tracks from two to four allowing increased frequencies and capacities), will likely improve these stations' accessibility and alter the clusters' composition. According to the equilibrium logic underpinning the node-place model, the current weak overall node accessibility nonetheless matches the low scores on the 'density' and 'diversity' dimensions. Most of the stations (N = 21) likely function as origin stations (an assumption based on their predominant residential character), while the other ones are characterized by mixed employment/ residential areas. When situating these stations in the original node-place model (Figure 7), this profile matches the 'dependent stations' category.

*Cluster 5 – Multimodal central network stations*

Cluster 5 is a small cluster comprised of seven stations which are all located closeby at the centre of the Belgian railway network (hence the name of the cluster), in the heart of the BCR. Five stations are located along the important axis connecting the Brussels-North and Brussels-South stations, while the other two stations (Brussels-Luxemburg and Brussels-Congres) are located closeby, across another major rail passage. As a corollary, the cluster is characterized by very high scores on the majority of 'public transport' indicators, but also on the 'active travel' indicators, on most 'car' indicators and on all 'design' indicators. The only dimension featuring less prominently is the 'density' dimension, which may largely be explained by these stations' relatively moderate population densities (PDE1) and moderate to low scores on PDE4 (industry and distribution) and PDE5 (education, health and culture). As a consequence of these lower relative scores on PDE1, PDE4 and PDE5, the 'diversity' dimension features below average. While most stations exhibit 'mixed' neighbourhoods, two stations are more strongly geared towards employment (Brussels Central station and Brussels-Kapellekerk).

*Cluster 6 – Balanced diverse stations*

Cluster 6 is also a small cluster (N = 9). The main feature distinguishing these stations from the other ones are the high scores on the 'diversity' dimension. Besides this, the cluster includes stations with moderate scores on the 'design' dimension and high scores on PDE4 and PDE5. As for the node dimensions, accessibility of the station for active travel modes is above average, together with NPT4. Overall, these stations exhibit balanced butterfly visualizations, with a slight predominance of place features due to high scores on the diversity dimension. The stations are located both within the BCR as in Flanders and Wallonia, and all of their CAs mainly exhibit employment characteristics except for station Schaarbeek.

*Cluster 7 – Unbalanced car-oriented places*

Similar to cluster 3, cluster 7 includes only three stations (Heverlee, Louvain-La-Neuve and Zaventem), with relatively high heterogeneity in characteristics and geography. However, common features are the high scores on NC3 (distance to nearest highway access), PDE3 (jobs in retail, hotel and catering) and PDE4 (jobs in industry and distribution) and the very low scores on the 'active travel' indicators. The station of Louvain-La-Neuve, with its large RER parking (containing more than 2300 parking places) that is seamlessly connected to both the station and the highway, is a good illustration of the strategy adopted by the Walloon government for the main RER stations in the region. Long-distance commuting is encouraged by constructing vast parkings next to its main stations (Casabella and Frenay 2009). Overall, for this station type a similar conclusion as with cluster 3 can be drawn. Although statistically speaking the cluster is relevant, this station type might prove less instrumental in policy discussions focusing on the planning, design and operational functions for these stations, since internal cohesion across the dimensions is rather moderate.

### 2.1.6 Results: Analyzing the impact of catchment area sizes

This section aims to verify to what extent different CA sizes influence the node-place analysis. To this end, two sub-sections are discerned. The first deals with a general comparison of results for the three place dimensions, while the second specifically examines the extent to which different CA sizes influence the station typology discussed in the previous section.

*General results*

As a way of exploring the variability in results for the three place dimensions, Figure 15 illustrates the scatterplots for the 700 m scores (x-axis) opposite the scores for the other 3 CAs (y-axis) for the 'diversity', 'density' and 'design' dimensions. Overall, the 'design' indicators seem to have the most consistent results across CA sizes. When analyzing this dimension more closely, it seems that the pedshed ratio (PDG1) induces most of the variation between the buffer sizes. As for the 'density' dimension, the distributions for the buffer sizes are all positively skewed, with only a small amount of stations having moderate to high levels of density. When varying CA, the 700 and 800 m buffer results appear strongly correlated while the 1200 and especially 3000 m buffers attenuate the association, indicating that relative population and employment densities decrease for most stations when enlarging the buffer. Within this dimension, PDE3, PDE4 and PDE5 induce most of the variation between buffer sizes. The last dimension, 'diversity', exhibits less overall variation between buffer sizes than the 'density' dimension and reveals a general decreasing trend line, although the functional mix of some stations relative to the others varies significantly when changing CA.

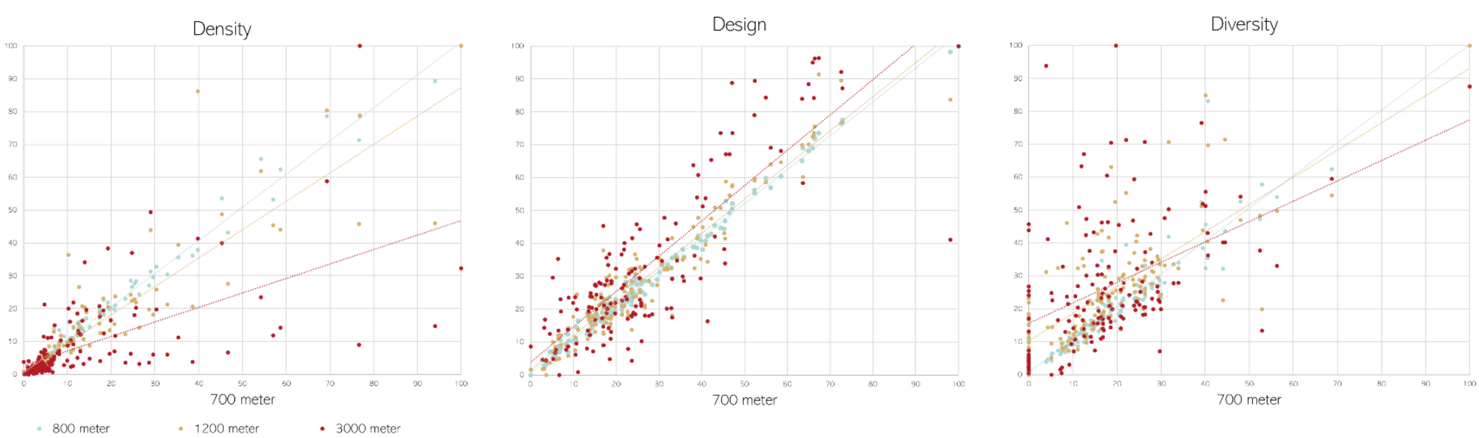



Figure 15: Impact of catchment area size on place dimensions

*The impact on the station typology*

This section examines the impact of different CA sizes on the 1200 m station typology. The same k-means cluster analysis (with k = 7) is conducted for the 700, 800 and 3000 m buffers. These analyses respectively explain 68.4%, 69.3 and 69.3% of the total variance. Appendix 2.1.IV indicates the cluster centers and membership totals for each of the CA sizes. The extent to which the CA size influences the station typology is discussed first by means of comparative statistics (Tables 1 and 2).

Table 1 reports on the assocation between the 1200 m cluster solution (ranked 1 to 7 in line with Figure 14) and the clusters that were generated for the other CA sizes, expressed in terms of the sum of squared differences (SSD) of the 1200 m cluster centers relative to the other CA cluster centers. The results reveal small to moderate differences for most cluster centres, suggesting an inter-cluster comparison for the four CA's is overall appropriate. However, clusters 6 (the 'balanced diverse stations') and 7 (the 'unbalanced car-oriented places') reveal larger differences, which may be explained by the small size of these clusters (1 in the case of the 700 and 800 m clusters and respectively 9 and 4 stations for the 3000 m stations, see Appendix 2.1.IV). These results suggest that the variety in place characteristics captured by the small CAs does not produce both station types that were nonetheless detected within the 1200 m cluster solution. Therefore a smaller cluster solution is most likely required for the 700 and 800 m CAs. As for the 3000 m CA, cluster 7 reveals only little association with the corresponding cluster of the 1200 m CA, equally indicating this cluster type may not be suited to describe the variety in place characteristics for the largest CA.

| | Sum of squared differences | | |
|---|---|---|---|
| CLUSTER (1200 m) | 700 m | 800 m | 3000 m |
| **1** | 450 | 441 | 680 |
| **2** | 55 | 36 | 186 |
| **3** | 574 | 388 | 367 |
| **4** | 219 | 213 | 285 |
| **5** | 176 | 98 | 105 |
| **6** | 5276 | 4833 | 718 |
| **7** | 2984 | 2797 | 2147 |

Table 1: Sum of squared differences between the cluster centers

| | CA size | | | | |
|---|---|---|---|---|---|
| | 700 m | 800 m | 1200 m | 3000 m | |
| 700 m | | *.966* | *.503* | *.620* | *Kappa* |
| 800 m | .989 | | *.529* | *.591* | |
| 1200 m | .753 | .754 | | *.434* | |
| 3000 m | .654 | .648 | .700 | | |
| | Cramer's V | | | | |

Table 2: Measures of association between different catchment area typologies

Table 2 in turn reports on the results of applying two common assocation measures for categorical data (Cramer's V and the Kappa Index), in order to find out how closely the overall cluster solutions for the four CA's are associated. Both measures typically range between 0 and 1, with 1 indicating perfect agreement and 0 indicating a pattern arising by chance. Judging from Table 2, the two smallest CAs (700 and 800 m) reveal very similar values. Therefore the choice between both small buffer sizes is somehow insignificant for the final classification. A similar conclusion was reached in Kamruzzaman et al. (2014) when analyzing outcomes for the small buffer sizes of 600 and 800 m, as the results for both sizes were strongly correlated. In our analysis, only three out of our 144 stations (stations Diegem, Kortenberg, and La Hulpe) were classified differently for both catchment area sizes. In all three cases, these stations switched from the 'dependent stations' (cluster 4) to the 'unbalanced small nodes' (cluster 1), indicating a notable rise in place dimension performance relative to the other RER stations. The differences between the 800 m and 1200 m classifications are more pronounced. In this case, only 94 stations (65.3%) are assigned to the same cluster. The largest difference is given by a group of 40 stations classified as cluster 4 in the 800 m (the 'dependent stations') and as cluster 1 in the 1200 m classification (the 'unbalanced small nodes'). The main areas where these stations seem to cluster are: a group of seven stations near station Denderleeuw, a group of 15 stations just south of the BCR, and 10 stations along the 'triangle' between the BCR, Mechelen and Leuven. The switch from the 'dependent stations' (cluster 4) to the 'unbalanced small nodes' (cluster 1), indicates a notable rise in place dimension performance relative to the other RER stations. Finally, the 3000 m classification is the least similar to the other three. Not only is there a significant difference with the 800 m classification, there is also a pronounced difference with the 1200 m classification. These results suggest that analyses focused on bicycle-TOD may reveal radically different typology outcomes than the typically walking-induced types of TOD in which typically smaller CAs are used.

A second comparative analysis considers all sequences of cluster allocations present in the data, which we designate here as a station's 'DNA' (see Appendix 2.1.V). The 'DNA sequence' of a station indicates the succession of cluster types the station is allocated to when altering CA size from 700 to 3000 m. Some stations are always assigned to the same type regardless of the CA size (for example sequence 'AAAA', 49% of all stations), while other stations are more 'sensitive' to switching type. Figure 16 visualizes the locations of these AAAA stations for the 1200 m basemap, together with two other relevant 'DNA sequences', i.e. AABB and AAAB.

As regards the AAAA sequence, some station types appear largely robust irrespective of the CA used: the 'dependent stations' (cluster 4), the 'multimodal central network stations' (cluster 5) and the 'unbalanced large nodes' (cluster 2). These clusters have place characteristics that are clearly more coherent and distinct as opposed to other stations that shift clusters more easily. These three station types may therefore be especially meaningful to inform strategic discussions dealing with RER network development opportunities, as their node and place characteristics prove well defined and sound across different local scales. In terms of the 'dependent stations', the clustered and geographically robust appearance along some specific corridors in the network (the tangential lines connecting Leuven to Ottignies, Denderleeuw with Geraardsbergen, and Geraardsbergen with Enghien) is noteworthy. Given the pronounced residential character of this station type, these railway corridors may therefore be tentatively labeled as 'residential corridors'. Further research should nonetheless shed more light on the specific dynamics of different types of corridors within the RER network, to better understand the specific needs in terms of the development and coordination they require. After all, a regional approach focusing on railway corridors is generally put forward as the most suitable strategy for a successful coordination of transport and land use changes (Bertolini and Rietveld 2008, Chorus 2012). Besides these co-location patterns of most of the robust 'dependent stations', it is interesting to note that the robust stations of clusters 2 and 5 are predominantly located within the BCR, revealing marked place characteristics between the BCR on the one hand and Flanders and Wallonia on the other hand. The AABB sequence type (9% of all stations) is also relevant as it indicates a clear change in place characteristics relative to the other RER stations between the two smallest buffer sizes and the two larger ones. This information may prove meaningful to stakeholders involved in the planning process as it indicates to which station types certain stations show most resemblance for larger and smaller spheres of influence. On this note, it is interesting to observe that most of the B's in the AABB sequence are either 'unbalanced small nodes' (cluster 1) or 'balanced diverse stations' (cluster 6). As for the former type, all of these stations switched from the 'dependent station' type (cluster 4) to cluster 1 as they are part of the group of 40 stations elaborated on above. As for the latter group, most stations also switched from the 'unbalanced small nodes' type (cluster 1) to cluster 6, indicating a notable change in place dimensions (especially for the 'diversity' dimension as this is the main distinguishing feature of cluster 6, see Figure 14).

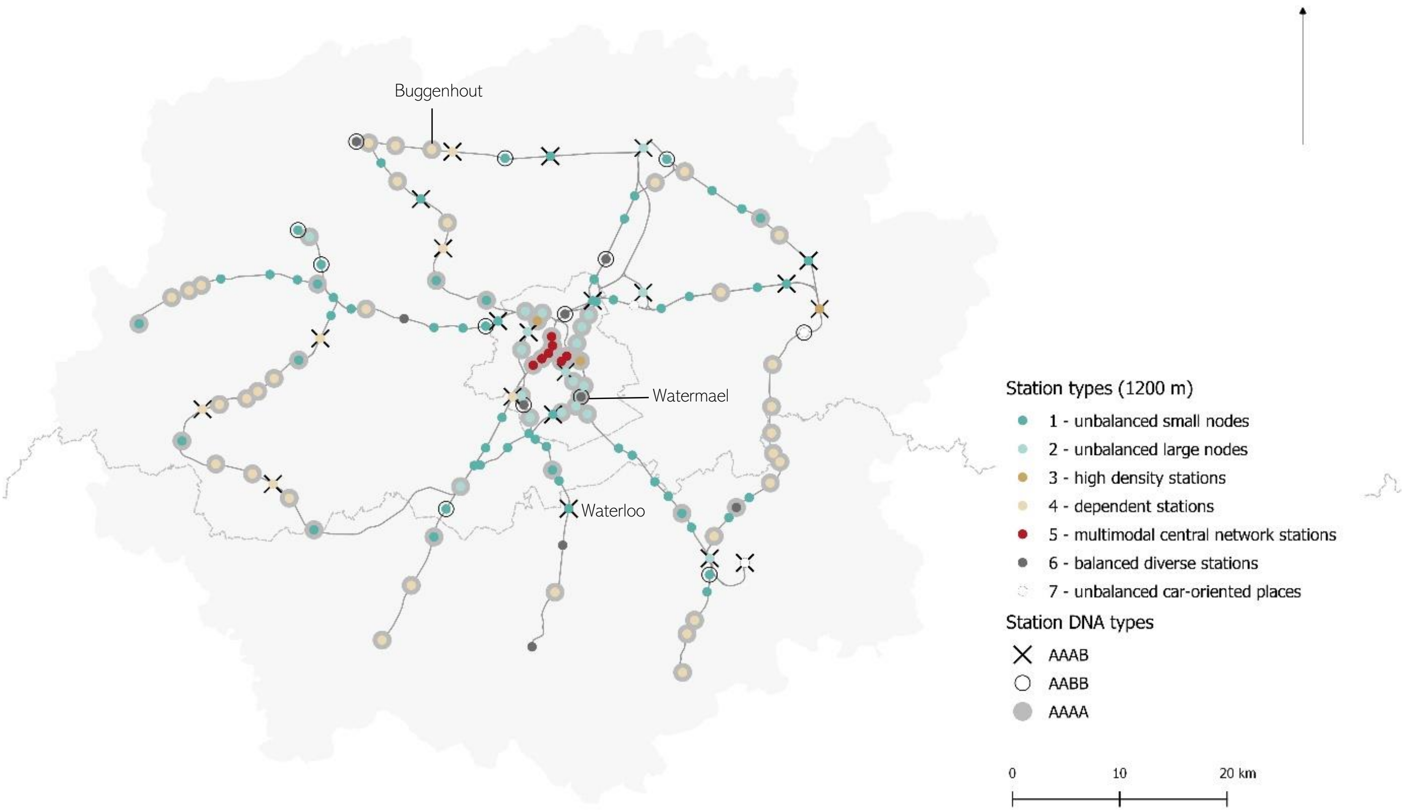



Figure 16: Geographical distribution of three station 'DNA sequences'

By means of example, we illustrate the butterfly visualizations for three stations belonging to different DNA sequence types: station Waterloo (AAAB), Watermael (AABB) and Buggenhout (AAAA) (see Figure 17). The locations of these stations are also indicated in Figure 16.

Station Waterloo changes typologies when extending its catchment area from the smaller walkable buffers to the largest one. The station reclassifies from an 'unbalanced small node' to a 'dependent station'. Stations like Waterloo whose profile alters for the largest 3000 m buffer size (15 % of all stations) are particularly interesting, as these are stations where the promotion of cycling as a feeder mode will inevitably require a different development strategy compared to walking. Station Watermael in turn classifies as a AABB station. The station's place characteristics become more pronounced when extending the buffer size, resulting in a change from an 'unbalanced small node' to a 'balanced diverse station'. Judging from the colour of the place wing, compared to the other stations in the network the Watermael station area is more strongly geared towards employment in the large CA sizes. A last station, Buggenhout, classifies as an AAAA station. This indicates the relative station characteristics are robust when different local scales are applied. It seems that – especially for this type of stations – cluster membership is solid, allowing to draft more robust development scenarios.

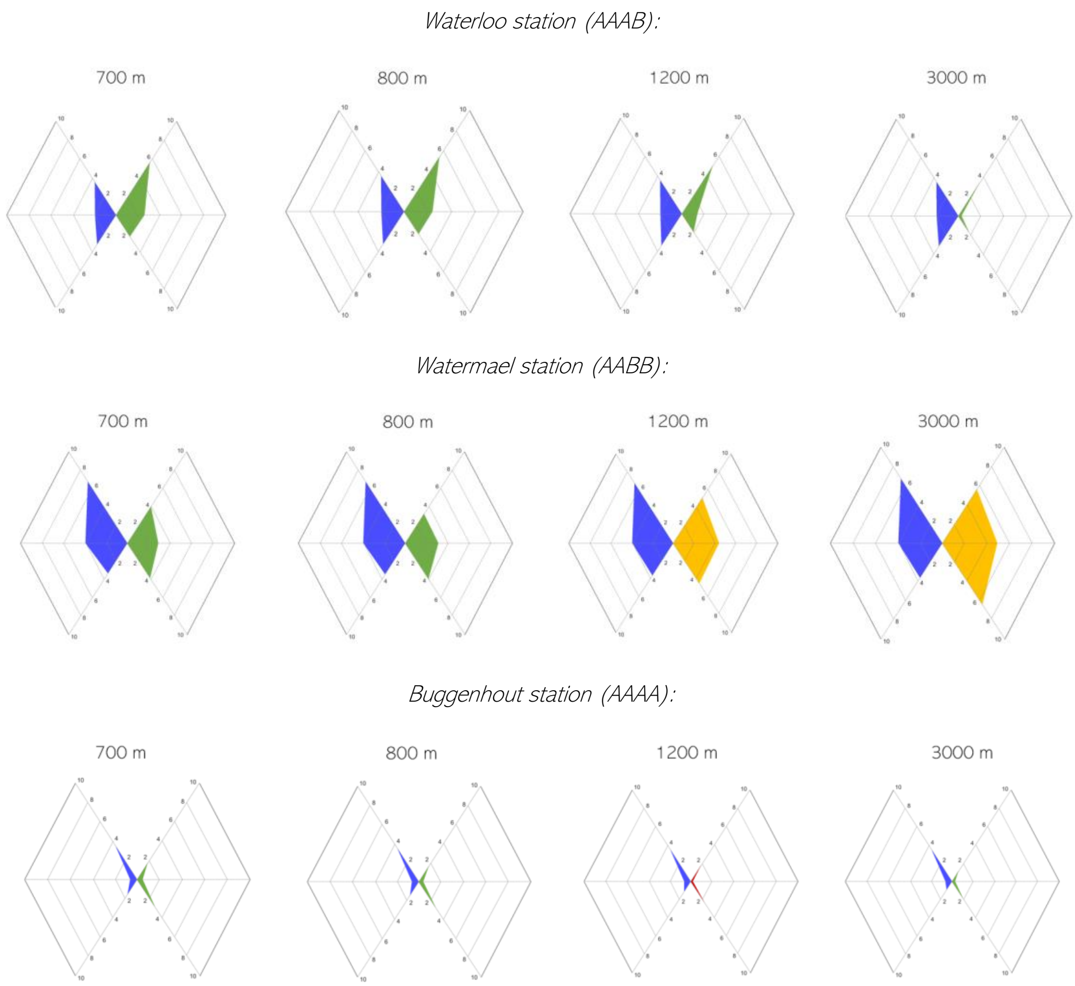



Figure 17: Butterfly visualizations for stations Waterloo, Watermael and Buggenhout

### 2.1.7 Discussion and conclusions

This section reported on a systematic empirical node-place analysis for all 144 railway stations that are part of the Brussels Regional Express Railway (RER) network. A set of node and place characteristics, reflecting different dimensions of the transport and land use accessibility of stations relative to all stations in the network, were measured and collected in line with current developments in both the node-place modeling and the TOD literature. We specifically built on two recent renderings of the original node-place model: the 'butterfly model' developed by Province of North Holland and Deltametropolis Association (2013) and an extension of the node-place model incorporating indicators assessing the design of the built environment. The dimension measuring public transport accessibility was furthermore supplemented with two network centrality measures in line with the type of accessibility indicators categorized as 'network measures' by Curtis and Scheurer (2010).

The strength of the node-place modeling approach is that it makes explicit the relative functioning of nodes within a public transport network. Thus, instead of absolute accessibility levels, relative measures are used in order to detect substandard or distinctive conditions within the overall network. Dalvi and Martin (1976, cited in Handy and Niemeier (1997: 1181) stress the importance of such (changes in) relative accessibility measures linking the study area within its broader context, as "it is often not changes in the absolute accessibility of a zone that are important, but rather the change in the position of the zone vis-à-vis other zones on the 'accessibility scale'. In this case, changes in relative accessibility may be the most relevant analysis". Bertolini (2000b) in this respect argues that the development opportunities of the stations in terms of land use and transport dimensions may only be assessed correctly, when the stations are analyzed for the transport and spatial network(s) in which they are embedded. The model thus provides insights into the comparative accessibility profiles of all stations in the network. In the context of this research, seven such comparative accessibility profiles within the RER network were discerned via hierarchical cluster analysis for the 1200 m CA. While most of these described station types proved well-defined in terms of indicator performance, some types (the 'high density stations' and the 'unbalanced car-oriented places') may prove less meaningful as an input for strategic planning, since the internal cohesion of the node and place characteristics is rather moderate and the cluster size ratios are unfavorable to deduce generic development scenarios. For these cases in particular, expertise and local knowledge from planning practitioners and stakeholders involved are a prerequisite to move forward the quantitative approach taken here.

A sensible next step for the research direction presented in this paper would therefore imply to validate the operational soundness of the accessibility instrument, for example by means of structured workshops with its potential end-users (Papa et al. 2017), and to look for ways to make the tool more interactive, dynamic and web-based in order to improve its communicative strength (a point also raised by Silva et al. 2017 and Büttner et al. 2018). After all, when measuring accessibility, the ultimate objective consists of finding "the right balance between measures that are theoretically and empirically sound and those that are sufficiently plain to be implemented in the strategic transport planning process" (Vega 2012: 412).

In order to increase the empirical strength of the node-place analysis, the place characteristics of three additional CA sizes were assessed. The most frequently used buffer sizes in the literature (700 and 800 m) were adopted, together with a larger buffer of 3000 m in line with the increasing body of TOD literature focusing on (electric) bicycles as feeder modes to railway stations. In order to test the sensitivity of the generated station typology (1200 m) with respect to these different CAs, a k-means clustering analysis was applied. Based on the classifications for the different CAs, three station types appeared largely robust irrespective of CA size: the 'dependent stations' (cluster 4), the 'multimodal central network stations' (cluster 5) and the 'unbalanced large nodes' (cluster 2). These clusters have place and node characteristics that clearly stand out as opposed to other stations that shift clusters more easily, and may hence prove particularly meaningful to inform strategic planning. As regards the other stations which are more prone to changing station types, an analysis of their individual cluster classification sequences (designated here as 'station DNA'), could prove useful in detecting between which CA sizes these switch from one type to the other, as this information indicates to which station profiles certain stations show most resemblance. In future research this analysis could become more refined when data is collected for more CA sizes, in order to approximate a near continuous spatial range with corresponding cluster allocations.

However, the most important challenge for the successful implementation of the large-scale trans-regional RER planning project is likely situated on a political-institutional level rather than on an empirical-analytical level (see also Strale 2019). We will come back to this statement in Section 3.2, but for the specific case of the RER project this has been contended by Schwengler (2019), who built on the quantitative node-place analyses discussed in this section. He conducted 19 expert interviews for three selected railway corridors in the RER network and discusses a number of persistent barriers in terms of institutional fragmentation, budget allocation, socio-cultural differences between the regions and physical barriers. In this regard, the following quote by an interviewed town planning and mobility expert is telling:

> Concerning TOD, there is clearly no common land planning strategy around the different RER stations (…) the stakeholders are not very pressed to solve these issues by taking difficult decisions now. They prefer to pass the bucket to the next generation of decision-makers as the works will be done around 2030.
>
> In: Schwengler (2019: 37)

Although the RER network presents a real chance of improving the wider Brussels mobility system, as well as a real urban planning opportunity, its sustainable land use and transport planning pursuit requires dedicated long-term coordination beyond regional disputes.

## Appendix 2.1.I – Indicators: Description and metadata

| FEATURE | DIMENSION + INDICATORS | DESCRIPTION | SOURCE | YEAR |
|---|---|---|---|---|
| NODE | Active travel | | | |
| | NAT1 | Surface of bike parking capacity at the station ($m^2$) | OSM, Google Steet View + online sources | 2017 |
| | NAT2 | Presence of bike sharing service (yes/no) | Websites of bike sharing operators | |
| | NAT3 | Location of station along a network of fast cyling tracks (yes/no) | Websites of the regional cycling networks | |
| | Public transport | | | |
| | NPT1 | Number of end stations reachable by train | GTFS data provided by NMBS | |
| | NPT2 | Number of trains serving the station (arrival and departure) | GTFS data provided by NMBS | |
| | NPT3 | Number of stations reachable within 20 minutes of travel | GTFS data provided by NMBS | |
| | NPT4 | Number of end bus/tram and metro stations reachable by the respective public transport modes | GTFS data provided by TEC, De Lijn and MIVB/STIB | |
| | NPT5 | Number of buses, trams and metros serving the stations (arrival and departure) | GTFS data provided by TEC, De Lijn and MIVB/STIB | |
| | NPT6 | Closeness centrality: the average shortest travel time from a given station to all other RER stations | GTFS data provided by NMBS | |
| | NPT7 | Betweenness centrality: the proportion of fastest paths between any two nodes within the RER network that stop at the station | GTFS data provided by NMBS | |
| | Car | | | |
| | NC1 | Surface of car parking capacity at the station ($m^2$) | OSM, Google Steet View + online sources | |
| | NC2 | Presence of car sharing service (yes/no) | Websites of car sharing operators | |
| | NC3 | Road network distance to the closest highway access (m) | OSM | |
| | NC4 | Total length of structural roads within catchment area (m) | OSM | |
| PLACE | Design | | | |
| | PDG1 | Pedestrian shed ratio of catchment area | OSM | 2017 |
| | PDG2 | Number of street network intersections with 3 or more links in the catchment area | OSM | |
| | PDG3 | Traversable network length (m) | OSM | |
| | Density | | | |
| | PDE1 | Number of residents within catchment area | Statistics Belgium | 2011 |
| | PDE2 | Number of workers in services and administration within catchment area | Statistics Belgium | |
| | PDE3 | Number of workers in retail, hotel and catering within catchment area | Statistics Belgium | |
| | PDE4 | Number of workers in industry and distribution within catchment area | Statistics Belgium | |
| | PDE5 | Number of workers in education, health and culture within catchment area | Statistics Belgium | |
| | Diversity | | | |
| | PDI1 | Degree of functional mix | Calculated based on data provided by Statistics Belgium | 2011 |

*Appendix 2.1.II – Four aggregated economic sectors and their sub-sectors*

**Services and administration**
Information and communication
Financial activities
Exploitation of and trade in intangible heritage
Free professions and scientific and technical activities
Administrative and supporting services
Public governance and defence
Mandatory social insurances
Other services
Extraterritorial organizations

**Retail, hotel and catering**
Wholesale and retail
Repair of cars and motorcycles
Supply of accommodation and meals

**Industry and distribution**
Agriculture, forestry and fishery
Construction industry
Exploitation of minerals
Industry
Production and distribution of electricity, gas, steam and cooled air
Distribution of water, waste and sanitation
Transport and logistics

**Education, health and culture**
Education
Health care and societal services
Art, entertainment and recreation

*Appendix 2.1.III - Indicators: Correlations between indicators*

| | NAT1 | NAT2 | NAT3 | NAT | NPT1 | NPT2 | NPT3 | NPT4 | NPT5 | NPT6 | NPT7 | NPT | NC1 | NC2 | NC3 | NC4 | NC | PDI | PDE1 | PDE2 | PDE3 | PDE4 | PDE5 | PDE | PDG1 | PDG2 | PDG3 | PDG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NAT1 | 1.000 | 0.057 | .167* | .520** | .347** | .299** | 0.111 | .276** | .167* | -0.029 | -0.107 | 0.126 | .700** | 0.100 | -0.040 | 0.015 | 0.096 | 0.023 | .176* | 0.111 | 0.151 | 0.092 | 0.123 | 0.163 | 0.055 | 0.112 | 0.090 | 0.104 |
| NAT2 | 0.057 | 1.000 | .223** | .769** | .207* | .256** | .401** | .524** | .655** | .282** | .558** | .633** | 0.080 | .728** | -0.024 | .697** | .633** | .392** | .616** | .595** | .580** | .445** | .496** | .566** | .622** | .676** | .687** | .692** |
| NAT3 | .167* | .223** | 1.000 | .598** | .261** | .281** | .364** | .217** | .304** | .190* | .333** | .391** | 0.035 | 0.108 | 0.138 | .327** | .264** | .176* | .264** | .257** | .365** | .326** | .186* | .277** | .335** | .255** | .347** | .340** |
| NAT | .520** | .769** | .598** | 1.000 | .370** | .390** | .438** | .543** | .617** | .256** | .450** | .617** | .359** | .555** | -0.006 | .575** | .543** | .335** | .588** | .539** | .571** | .456** | .449** | .542** | .570** | .583** | .621** | .627** |
| NPT1 | .347** | .207* | .261** | .370** | 1.000 | .929** | .762** | .209* | .240** | .228** | .343** | .633** | .377** | .176* | 0.102 | .283** | .322** | 0.122 | .233** | .269** | .291** | .209* | .170* | .253** | 0.138 | .334** | .245** | .237** |
| NPT2 | .299** | .256** | .281** | .390** | .929** | 1.000 | .847** | .213* | .270** | .302** | .482** | .730** | .341** | .204* | .230** | .396** | .438** | .170* | .300** | .340** | .351** | .255** | .218** | .313** | .206* | .409** | .316** | .316** |
| NPT3 | 0.111 | .401** | .364** | .438** | .762** | .847** | 1.000 | .208* | .372** | .318** | .625** | .780** | 0.131 | .318** | .270** | .470** | .506** | .165* | .266** | .341** | .354** | .242** | .191* | .292** | .274** | .461** | .365** | .371** |
| NPT4 | .276** | .524** | .217** | .543** | .209* | .213* | .208* | 1.000 | .870** | 0.133 | .295** | .554** | .343** | .511** | .194* | .551** | .603** | .462** | .650** | .629** | .618** | .542** | .615** | .646** | .571** | .626** | .675** | .658** |
| NPT5 | .167* | .655** | .304** | .617** | .240** | .270** | .372** | .870** | 1.000 | .174* | .525** | .677** | .175* | .609** | .232** | .683** | .697** | .439** | .649** | .623** | .643** | .552** | .569** | .635** | .654** | .732** | .754** | .749** |
| NPT6 | -0.029 | .282** | .190* | .256** | .228** | .302** | .318** | 0.133 | .174* | 1.000 | .515** | .551** | 0.094 | 0.154 | .218** | .264** | .315** | 0.155 | .190* | .226** | 0.161 | 0.066 | .171* | .165* | .194* | .254** | .230** | .243** |
| NPT7 | -0.107 | .558** | .333** | .450** | .343** | .482** | .625** | .295** | .525** | .515** | 1.000 | .841** | -0.030 | .437** | .415** | .651** | .682** | .243** | .399** | .403** | .447** | .358** | .279** | .386** | .470** | .605** | .529** | .550** |
| NPT | 0.126 | .633** | .391** | .617** | .633** | .730** | .780** | .554** | .677** | .551** | .841** | 1.000 | .213* | .526** | .375** | .713** | .764** | .341** | .551** | .584** | .600** | .458** | .443** | .554** | .538** | .725** | .650** | .660** |
| NC1 | .700** | 0.080 | 0.035 | .359** | .377** | .341** | 0.131 | .343** | .175* | 0.094 | -0.030 | .213* | 1.000 | .178* | 0.009 | 0.133 | .277** | 0.150 | .291** | .259** | .243** | 0.164 | .254** | .272** | 0.087 | .188* | 0.154 | 0.153 |
| NC2 | 0.100 | .728** | 0.108 | .555** | .176* | .204* | .318** | .511** | .609** | 0.154 | .437** | .526** | .178* | 1.000 | 0.099 | .588** | .736** | .258** | .509** | .508** | .482** | .350** | .443** | .498** | .509** | .626** | .597** | .601** |
| NC3 | -0.040 | -0.024 | 0.138 | -0.006 | 0.102 | .230** | .270** | .194* | .232** | .218** | .415** | .375** | 0.009 | 0.099 | 1.000 | .246** | .575** | 0.133 | 0.151 | .177* | .267** | .228** | 0.126 | .206* | 0.150 | .309** | .236** | .242** |
| NC4 | 0.015 | .697** | .327** | .575** | .283** | .396** | .470** | .551** | .683** | .264** | .651** | .713** | 0.133 | .588** | .246** | 1.000 | .806** | .490** | .773** | .742** | .736** | .592** | .655** | .734** | .752** | .800** | .839** | .833** |
| NC | 0.096 | .633** | .264** | .543** | .322** | .438** | .506** | .603** | .697** | .315** | .682** | .764** | .277** | .736** | .575** | .806** | 1.000 | .408** | .663** | .664** | .677** | .523** | .559** | .658** | .625** | .771** | .739** | .742** |
| PDI | 0.023 | .392** | .176* | .335** | 0.122 | .170* | .165* | .462** | .439** | 0.155 | .243** | .341** | 0.150 | .258** | 0.133 | .490** | .408** | 1.000 | .682** | .757** | .708** | .699** | .816** | .728** | .442** | .525** | .539** | .520** |
| PDE1 | .176* | .616** | .264** | .588** | .233** | .300** | .266** | .650** | .649** | .190* | .399** | .551** | .291** | .509** | 0.151 | .773** | .663** | .682** | 1.000 | .907** | .896** | .835** | .901** | .960** | .750** | .746** | .816** | .810** |
| PDE2 | 0.111 | .595** | .257** | .539** | .269** | .340** | .341** | .629** | .623** | .226** | .403** | .584** | .259** | .508** | .177* | .742** | .664** | .757** | .907** | 1.000 | .918** | .809** | .915** | .946** | .702** | .736** | .786** | .776** |
| PDE3 | 0.151 | .580** | .365** | .571** | .291** | .351** | .354** | .618** | .643** | 0.161 | .447** | .600** | .243** | .482** | .267** | .736** | .677** | .708** | .896** | .918** | 1.000 | .909** | .853** | .961** | .692** | .763** | .780** | .776** |
| PDE4 | 0.092 | .445** | .326** | .456** | .209* | .255** | .242** | .542** | .552** | 0.066 | .358** | .458** | 0.164 | .350** | .228** | .592** | .523** | .699** | .835** | .809** | .909** | 1.000 | .808** | .905** | .560** | .616** | .639** | .623** |
| PDE5 | 0.123 | .496** | .186* | .449** | .170* | .218** | .191* | .615** | .569** | .171* | .279** | .443** | .254** | .443** | 0.126 | .655** | .559** | .816** | .901** | .915** | .853** | .808** | 1.000 | .939** | .610** | .667** | .711** | .694** |
| PDE | 0.163 | .566** | .277** | .542** | .253** | .313** | .292** | .646** | .635** | .165* | .386** | .554** | .272** | .498** | .206* | .734** | .658** | .728** | .960** | .946** | .961** | .905** | .939** | 1.000 | .707** | .748** | .791** | .782** |
| PDG1 | 0.055 | .622** | .335** | .570** | 0.138 | .206* | .274** | .571** | .654** | .194* | .470** | .538** | 0.087 | .509** | 0.150 | .752** | .625** | .442** | .750** | .702** | .692** | .560** | .610** | .707** | 1.000 | .706** | .932** | .944** |
| PDG2 | 0.112 | .676** | .255** | .583** | .334** | .409** | .461** | .626** | .732** | .254** | .605** | .725** | .188* | .626** | .309** | .800** | .771** | .525** | .746** | .736** | .763** | .616** | .667** | .748** | .706** | 1.000 | .879** | .885** |
| PDG3 | 0.090 | .687** | .347** | .621** | .245** | .316** | .365** | .675** | .754** | .230** | .529** | .650** | 0.154 | .597** | .236** | .839** | .739** | .539** | .816** | .786** | .780** | .639** | .711** | .791** | .932** | .879** | 1.000 | .991** |
| PDG | 0.104 | .692** | .340** | .627** | .237** | .316** | .371** | .658** | .749** | .243** | .550** | .660** | 0.153 | .601** | .242** | .833** | .742** | .520** | .810** | .776** | .776** | .623** | .694** | .782** | .944** | .885** | .991** | 1.000 |

* = Correlation is significant at the 0.05 level (2-tailed)

** = Correlation is significant at the 0.01 level (2-tailed)

## *Appendix 2.1.IV – Cluster centre values and number of cases*

**Cluster centers (700 m)**

| Dimension | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Active travel | 45 | 67 | 73 | 26 | 75 | 34 | 1 |
| Public transport | 23 | 37 | 38 | 14 | 71 | 16 | 9 |
| Car | 35 | 69 | 65 | 25 | 78 | 76 | 68 |
| Diversity | 33 | 21 | 34 | 11 | 22 | 100 | 4 |
| Density | 24 | 11 | 75 | 4 | 20 | 94 | 77 |
| Design | 26 | 41 | 48 | 16 | 71 | 43 | 98 |
| *Number of cases* | *26* | *22* | *4* | *83* | *7* | *1* | *1* |

**Cluster centers (800 m)**

| Dimension | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Active travel | 43 | 67 | 73 | 26 | 75 | 34 | 1 |
| Public transport | 24 | 37 | 38 | 13 | 71 | 16 | 9 |
| Car | 35 | 71 | 68 | 25 | 81 | 77 | 71 |
| Diversity | 33 | 21 | 34 | 11 | 23 | 100 | 4 |
| Density | 23 | 12 | 80 | 4 | 23 | 98 | 71 |
| Design | 29 | 44 | 51 | 16 | 76 | 35 | 98 |
| *Number of cases* | *29* | *22* | *4* | *80* | *7* | *1* | *1* |

**Cluster centers (1200 m)**

| Dimension | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Active travel | 37 | 67 | 72 | 17 | 75 | 55 | 12 |
| Public transport | 20 | 35 | 38 | 7 | 71 | 31 | 22 |
| Car | 30 | 69 | 64 | 17 | 80 | 51 | 59 |
| Diversity | 25 | 25 | 46 | 14 | 31 | 65 | 20 |
| Density | 7 | 12 | 86 | 2 | 21 | 40 | 50 |
| Design | 23 | 47 | 66 | 12 | 81 | 43 | 57 |
| *Number of cases* | *62* | *21* | *3* | *39* | *7* | *9* | *3* |

**Cluster centers (3000 m)**

| Dimension | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Active travel | 34 | 70 | 66 | 27 | 76 | 68 | 28 |
| Public transport | 15 | 35 | 30 | 15 | 69 | 36 | 24 |
| Car | 27 | 64 | 60 | 24 | 83 | 60 | 75 |
| Diversity | 50 | 21 | 44 | 15 | 26 | 60 | 27 |
| Density | 8 | 10 | 79 | 3 | 20 | 29 | 7 |
| Design | 22 | 59 | 80 | 20 | 90 | 51 | 30 |
| *Number of cases* | *28* | *17* | *2* | *76* | *8* | *9* | *4* |

## *Appendix 2.1.V – Summary table of all station 'DNA sequences'*

| Station DNA | Frequency | % | Station DNA sequence | Sequence (%) |
|---|---|---|---|---|
| 4444 | 33 | 23 | AAAA | 49 |
| 2222 | 16 | 11 | AAAA | |
| 1111 | 11 | 8 | AAAA | |
| 5555 | 7 | 5 | AAAA | |
| 3333 | 2 | 1 | AAAA | |
| 6666 | 1 | 1 | AAAA | |
| 4414 | 33 | 23 | AABA | 25 |
| 1161 | 3 | 2 | AABA | |
| 1114 | 6 | 4 | AAAB | 15 |
| 4441 | 6 | 4 | AAAB | |
| 2226 | 3 | 2 | AAAB | |
| 2227 | 2 | 1 | AAAB | |
| 1112 | 1 | 1 | AAAB | |
| 1117 | 1 | 1 | AAAB | |
| 3335 | 1 | 1 | AAAB | |
| 7771 | 1 | 1 | AAAB | |
| 4411 | 7 | 5 | AABB | 9 |
| 1166 | 3 | 2 | AABB | |
| 2266 | 1 | 1 | AABB | |
| 3366 | 1 | 1 | AABB | |
| 4477 | 1 | 1 | AABB | |
| 4114 | 3 | 2 | ABBA | 2 |
| 1174 | 1 | 1 | AABC | 1 |

## 2.2 Planning for nodes, places, and people in Flanders and Brussels: The development of an empirical railway station assessment framework for strategic decision-making

### 2.2.1 Introduction

Against the backdrop of the quest to identify strategic railway stations and their differentiated development opportunities as outlined in Section 1.2.3, the objective of this section is to conceptualize, operationalize and analyze a more comprehensive set of empirical parameters that may prove relevant. This main objective has a twofold character. First, there is a methodological objective in that we aim to further develop the type of node-place models classified within the 'C' group which explicitly seek to incorporate indicators from the current TOD literature. As stated in Section 1.1, we specifically pay attention to the following considerations: (1) incorporating information about the people who make use of the station, reflecting the actual demand for accessibility to and from each railway station, (2) improving the analytical strength of some conventional node and place indicators, (3) including temporal variations in public transport accessibility in the model and (4) consolidating all of this information into a well-structured polar graph visualization. In addition to these methodological refinements to the literature, there is also, second, an empirical and related policy-support objective in that we apply the model to the case of Flanders and Brussels, and this in the broad spirit of the approved BRV strategic vision detailed in Section 1.2.3.

The remainder of this section is structured as follows. The specific research objectives are described in Section 2.2.2 and this along with a detailed account of our methodology. Section 2.2.3 then reports on the main findings, while 2.2.4 aims to deepen our insights into the practical relevance of the results by discussing a selection of exemplary cases. The conclusion section reviews the key findings and reflects on avenues for further research.

### 2.2.2 Methodology

*A. A modified framework for Flanders and Brussels*

In light of the policy-support objective detailed in Section 1.2.3, a strategic railway station assessment framework for the case of Flanders and Brussels requires a combined focus on transport and land use accessibility. As stated by Flemish Government (2017), the potential for the allocation of additional urban development is determined by (1) the extent to which a location is accessible by public transport, and (2) the extent to which jobs, residences and amenities are present.

The node-place model provides a framework that allows to capture both of these strategic principles. The node value aims to reflect a station's level of transport accessibility, whereas a place value adds the necessary spatial information to the accessibility equation. Geurs and van Wee (2004: 128) define accessibility as "the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s)". When applying this definition to the node-place model framework, these 'activities or destinations' are assumed to be located either within a station's area (often defined as a walkable buffer) or within the station area of the other stations that are part of the analysis. According to Geurs' (2006) overview of accessibility measures, the node-place model would classify as a 'location-based accessibility measure' because it quantifies accessibility traits *of* a particular location[41]. This approach thus analyses "accessibility at locations, typically on a macro

[41] Besides location-based measures, Geurs and van Wee (2004) discern infrastructure-based, person-based and utility-based measures.

level. The measures describe the level of accessibility to spatially distributed activities, such as the number of jobs within 30 minutes of travel time from origin locations" (Ibid. p. 24). A further specification can be made in that the vast majority of node-place models adopt a cumulative opportunity approach, indicating that there is a fixed, predefined time (or distance) limit (contrary to gravity-based measures)[42]. As explained by Handy and Niemeier (1997: 1177), these cumulative opportunity approaches weigh all potential opportunities within the cutoff time equally, regardless of differences in travel time. Therefore "this type of measure emphasizes the number of potential destinations or opportunities rather than their distance. This type of measure gives some sense of the range of choice available to residents".

In summary, drawing on the overview of accessibility measures, perspectives and components by Geurs (2006), most node-place models currently incorporate two accessibility components: the transportation and the land use components. However, the notion of accessibility to and from railway stations arguably extends well beyond these two characteristics, since the accessibility of railway stations is also related to temporal constraints[43] and individual needs and capabilities of its users. Therefore, in line with Geurs' (2006) framework, we contend that the temporal and the individual components of accessibility also require integration within the node-place model. In general, and for the case of location-based accessibility measures, temporal constraints relate to differences in travel time and cost depending on time of the day or day of the week, whereas the individual component accounts for stratifications of the population under scrutiny (such as age or income groups) (Ibid.). For the case of railway stations, the temporal component arguably relates to the transport component (i.e. temporal variations in public or other transport services). The individual component however requires a new type of user- or demand-specific information which may improve particular insights about a station's functioning in the railway network.

We assume that the consideration of all four accessibility components in a node-place framework may render a more comprehensive, nuanced and therefore rich account of a station's level of accessibility. The conceptual framework that resulted from these considerations takes the shape of a radar diagram and is illustrated in Figure 18. Below, the structure of the diagram is explained, after which the operationalization of the dimensions and indicators is detailed. In the process, we will also discuss how we aim to improve the analytical strength of certain indicators.

The upper half of the radar diagram includes the conventional dimensions used in node-place analyses. Instead of aggregating all transport modes in the 'node value' of the station (as is usually done in NPM studies), we opted to separate the train accessibility in the field 'train', and the feeder mode accessibility (by car, bike and public transport) in the field called 'node'. The 'place' field captures the standard TOD dimensions of 'density', 'diversity' and 'design', based on a walkable network buffer of 1200 m (generally corresponding to 15 minutes of walking).

The lower half of the diagram presents a demand-side perspective by visualizing data about the users of the station. Three fields are discerned: effort, ridership and motivation. The first field captures how far people live from their station of origin, and therefore relates to the *'effort'* it takes for people to reach the station. This 'effort' field is related to the 'node' field in that opportunities to reach a particular station by car or by public transport (reflected by the node dimensions) are arguably more important when most people live far away from their origin station, while for example the bike parking capacity of a station is

[42] Some interesting methods to tackle this 'all-or-nothing-approach' were provided by Gútierrez et al. (2011) and Marti et al. (2018). The former work introduced a distance-decay weighting of the station area's demographic variables. The latter evaluated proximity to transit by means of density distributions, under the assumption that the areas closest to the station should have higher densities than those located further away. Their method provides a more nuanced picture of the developments within the chosen distance threshold compared to the approach taken in many other TOD studies.

[43] Others have highlighted the importance of considering a temporal factor in measures of accessibility as well (for example Burns 1979 and Kitamura and Kermanshah 1984, as cited in Handy and Niemeier 1997).

likely to be more instrumental when most people live closer to the station. The second field, *'ridership'*, reflects the frequency of passengers boarding on a regular working day (the actual ridership) and the extent to which the station functions as an origin or as a destination station. As with the relation between the 'effort' and 'node' fields, the performance on the 'ridership' field can be fitted against that of the opposite 'train' field (thus linking supply and demand). In a similar vein, the last field, *'motivation'*, relates to the 'place' field, as it illustrates the dominant motives (education, work or other) of people who travel to their station of destination.

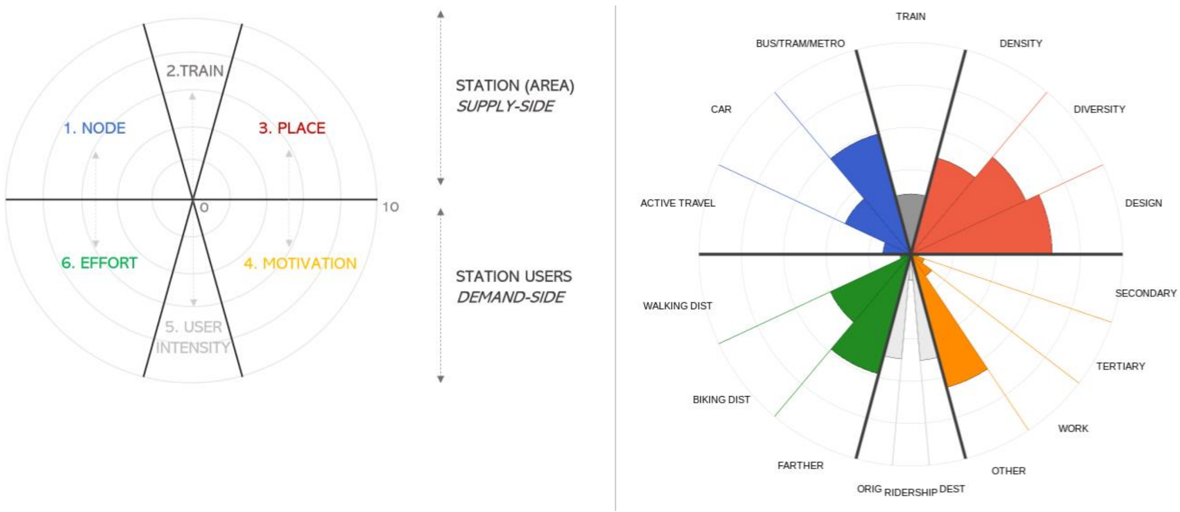



Figure 18: A station area assessment model for Flanders and Brussels: overall structure (left) and dimensions (right)

As a corollary, besides exploring the balance between 'node' and 'place' (the main assumption underpinning the standard node-place model), the balance between 'supply' and (revealed) 'demand' may arguably reveal more insights into a station's functioning on a regional scale.

Each indicator is unity-based normalized to vary between 0 and 10. Then, for each dimension, a multi-criteria analysis is conducted in which all normalized indicator scores are summarized and again normalized per dimension. The visualized scale thus always varies between 0 and 10, and there will always be at least one station scoring 0 and another scoring 10 for a certain dimension or indicator. A descriptive code is given to each indicator detailing its field (N for node, including the train indicators, P for place, and PP for people), followed by its dimension (CA for car, AT for active travel etc.) and an indicator code (freq for frequency etc.), along with the percentage of missing values (MV). Calculations are done for all railway stations with a weekday service in Flanders and Brussels (N = 287).

### *B. Operationalization*

#### <u>The node dimension</u>

Both the active travel and the car dimensions focus on the parking capacity for these feeder modes, discerning between free and toll parking services. Total car parking capacity was used to calculate the dimension scores, assigning equal weights for free and toll parking services.

In order to calculate the accessibility to and from the railway station by public transport, the stops considered very close to the station (within a 300 m walkable network distance from all possible station exits) were filtered from publicly available GTFS (General Transit Feed Specification) data using R statistical programming and R studio. For these selected bus, tram and metro stops, two indicators were measured and afterwards grouped (summarized) per railway station, resulting in the indicators listed in Table 3. By drawing on frequently updated GTFS data, this method allows to easily update and calculate these indicators for different time windows. In this research, a typical Tuesday is selected for the calculation of the B/T/M (Bus/Tram/Metro) indicators.

| Code | Indicator description | Source (year) | MV(%) |
|---|---|---|---|
| ACTIVE TRAVEL | | | |
| N_AT_park_f | Number of free bike parking places | NMBS (2018) | 0 |
| N_AT_park_p | Number of paying bike parking places | | 0 |
| CAR | | | |
| N_CA_park_f | Number of free car parking places | NMBS (2018) | 4 |
| N_CA_park_p | Number of paying car parking places | | 4 |
| BUS/TRAM/METRO | | | |
| N_BTM_freq | Frequency of B/T/M departures on a day-basis | Based on GTFS data by De Lijn, TEC and MIVB/STIB (June 2018) | 0 |
| N_BTM_rout | Number of unique B/T/M routes to and from the station on a day-basis | | 0 |

Table 3: Indicators of the node dimension

The train dimension

The first four indicators (Table 4) analyze characteristics of the railway service at the station (as is usually done in node-place analyses). However, over the last decade, more advanced accessibility indicators for public transport networks have been developed which assess the position (or 'centrality') of a station from a network perspective. Different methods exist to calculate these type of 'network measures' (Curtis and Scheurer 2010). Some scholars (for example Papa et al. 2013, Caset et al. 2018) employed the open source Urban Network Analysis toolbox for ArcGIS (see Sevtsuk and Mekonnen 2012) to calculate these measures, whereas Curtis and Scheurer (2010, 2016) developed a series of multimodal public transport centrality measures as part of the SNAMUTS decision tool. As some of these latter measures were previously operationalized for the Flemish and Brussels railway network (see Verachtert et al. 2016), we opted to take the same approach. We operationalized the SNAMUTS 'closeness centrality' (equation 1) and 'degree centrality' (equation 2) measures (see Curtis and Scheurer 2016, p. 304). Centrality was measured relative to all Belgian stations and the foreign stations included in the GTFS dataset (those on the railway lines towards Lille, Amsterdam, Maastricht, Aachen, and Luxembourg). In order to enhance the interpretation of the indicators for the users of the tool (and to avoid possible confusion with the standard language used in classic network analysis (see Newman 2010)), we renamed the indicators into 'travel time centrality' and 'transfer centrality', respectively. The travel time centrality indicator calculates the minimum cumulative impediment (Lmin, ij) between station i and all other stations j in the network (with N = all railway stations), in terms of travel time (t) and service frequency (f):

$$\text{travel time centrality}_i = \sum_{j=1,\, j \neq i}^{N} \frac{L_{min,ij}}{N-1} \tag{1}$$

with: impediment value of route segment between stations i and j = 4 x $\sqrt{\frac{t_{ij}}{f_{ij}}}$

The transfer centrality indicator calculates centrality for a station i in terms of the average minimum number of transfers (p) required to reach all other stations j in the network:

$$\text{transfer centrality}_i = \sum_{j=1,\, j \neq i}^{N} \frac{p_{min,ij}}{N-1} \tag{2}$$

Similar to the B/T/M indicators, drawing on GTFS data allows to easily update and calculate these indicators for different time windows. Again, Tuesday is selected for the calculation of these indicators.

| Code | Indicator description | Source (year) | MV (%) |
|---|---|---|---|
| TRAIN | | | |
| N_TR_freq_tue | Frequency of departures on a day-basis on Tuesdays | Based on GTFS | 0 |
| N_TR_freq_sat | Frequency of departures on a day-basis on Saturdays | data by NMBS | 0 |
| N_TR_freq_off | Frequency of departures off-peak (between 10 and 11 AM, Tuesdays) | (June 2018) | 0 |
| N_TR_amp | Amplitude between the earliest departure/arrival and latest departure/arrival (Tuesday) | | 0 |
| N_TR_ttcentr | Travel time centrality | | 0 |
| N_TR_trcentr | Transfer centrality | | 0 |

Table 4: Indicators of the train dimension

<u>The place dimension</u>

In order to calculate the place dimensions, the extent of 'the place' needs to be defined. As pointed out by Bertolini and Spit (1998: 12), "any delimitation of the station as place is destined to be somewhat arbitrary", as the influence of a station may go far beyond its immediate surroundings. Conversely, entities located nearby may have no apparent relationship with the station. As this paper draws on empirical assessment models which focus on the walkable area of stations, we delineate 'place' as the accessible area covered by a walkable street network distance of 1200 meter (roughly 15 minutes walking).

First, the 'Density' dimension refers to the concentration of jobs, residents and amenities. Its contribution to the walkability of a transit-oriented neighborhood is detailed in Cervero and Kockelman (1997). The rationale is that density provides the potential to reduce distances between people and the places they need to access. There are a variety of analytical approaches to measure density (for a recent overview see Dovey and Pafka 2018a). Here we adopt the most commonly used measures of population density (residents/hectare and jobs/hectare) along with three measures reflecting the density of amenities (basic amenities/hectare, regional amenities/hectare and metropolitan amenities/hectare)[44].

Second, 'Diversity' or land use mix is a key ingredient of walkability (Dovey and Pafka 2018b). In the node-place modeling literature, this dimension is often operationalized by employing the entropy measure used by Zweedijk and Serlie (1998), the dissimilarity index introduced by Cervero and Kockelman (1997), the MXI (Mixed-use Index) proposed by van den Hoek (2008), or other types of functional mix measures (such as the 'Mixed-ness Index' applied by Singh et al. 2017). While these measures capture 'functional' land use mix, they do not capture the spatial configuration of the land use types (a critique that was already raised by Hess et al. back in 2001). Given this, we draw on the work of Hess et al. (2001) in which a landscape ecology approach to measuring 'patch' diversity is applied within the context of transport and land use interaction studies. Using the Fragstats software (see McGarigal and Marks 1995), two indicators are measured, which reflect the functional and the spatial diversity of land use types within each station's precinct: the Shannon's Diversity Index (SHDI, equation 3) and the Contagion Index (CI, equation 4).

$$\mathrm{SHDI} = -\sum_{i=1}^{m} (P_i \,.\, \ln P_i) \tag{3}$$

[44] The difference between the three types of amenities is specified in Verachtert et al. (2016). In general terms, basic amenities are those considered necessary to organize daily life (a kindergarten, a pharmacy, a general practitioner). Regional amenities are assumed to have a larger catchment, serving different urban areas in the region (a shopping mall, a cultural centre, offices), while metropolitan amenities have the largest catchment (touristic attractions, a university). Based on the coordinates of the individual amenity locations, distance decay functions were applied (depending on the assumed amenity catchment size) and rescaled to a raster with 100 x 100 m cells.

with: i the type of land use, and Pi the proportion of land use type i present within the station's precinct. SHDI increases as the number of different land use types increases and/or the proportional distribution of area among types becomes more equitable. CI measures both the land use 'interspersion' (the spatial intermixing of raster cells with different types of land use) and its 'dispersion' (the spatial distribution of a land use type with respect to the station precinct), at the level of individual raster cells. Higher CI values may point to precincts with a few large and contiguous land use patches, whereas lower values generally characterize precincts with many small and dispersed land use patches. CI, detailed mathematically below, represents the observed level of contagion as a percentage of the maximum, given the total number of land use types[45]:

$$CI = 1 + \frac{\sum_{i=1}^{m} \sum_{k=1}^{m} \left( p_i \frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}} \, . \ln(p_i) \, \frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}} \right)}{2 \ln(m)} \, . \, 100 \tag{4}$$

Equally crucial here is the way in which the land use types, functioning as proxies for walking trip origins and destinations, are defined. The approach to land use categorization adopted here draws on the triangular model of functional mix in which urban functions are divided into just three primary categories of housing, work and amenities (see van den Hoek (2008), van Nes et al. (2012) and Dovey and Pafka (2018b)). We draw on land use data on a 10 meter raster scale containing 39 land use types, which we assigned to the three categories. The raw data was provided by VITO (*'Vlaams Instituut voor Technologisch Onderzoek'*) and stems from an integrated spatial model coined *'RuimteModel'* (for more detail see White et al. 2015).

The third 'D', design, is added to the station assessment model. This design dimension aims to measure the ways in which walkable and bikeable access is mediated by the urban morphology of public space and by the built environment. As regards walkable access, in line with Pafka and Dovey (2018), two key approaches are applied: walkable catchments and permeability.

| Code | Indicator description | Source (year) | MV(%) |
|---|---|---|---|
| DENSITY | | | |
| P_DE_res | Summarized residential densities for all raster cells in the station's precinct | VITO (see Verachtert et al. 2016) | 0 |
| P_DE_job | Summarized job densities for all raster cells in the station's precinct | | 0 |
| P_DE_bas | Summarized basic amenity densities for all raster cells in the station's precinct | | 0 |
| P_DE_reg | Summarized regional amenity densities for all raster cells in the station's precinct | | 0 |
| P_DE_met | Summarized metropolitan amenity densities for all raster cells in the station's precinct | | 0 |
| DIVERSITY | | | |
| P_DI_shan | Shannon Diversity Index for all raster cells in the station's precinct | Based on VITO (2013) | 0 |
| P_DI_CI | Contagion Index for all raster cells in the station's precinct | | 0 |
| DESIGN | | | |
| P_DG_IC | Interface catchment: total length of street segments flanked by buildings in the station's precinct | Based on OSM (2018) | 0 |
| P_DG_perm | Permeability defined as the ratio of the number of street segments and street intersections in the station's precinct | | 0 |
| P_DG_netw | Network length of walkable and bikeable street infrastructure in the station's precinct | Based on OSM (2018) and Verachtert et al. (2016) | 0 |

Table 5: Indicators of the place dimension

[45] More specifically, CI consists of the sum, over land use types, of the product of two probabilities: the probability that a randomly chosen raster cells belongs to type I (estimated by the proportional abundance of type i), and the conditional probability that given a cell is of type I, one of its neighbouring cells belongs to type j (estimated by the proportional abundance of type i adjacencies involving type j) (see McGarigal and Marks 1995).

The first indicator measures the 'catchment' of a station, not in terms of its walkable surface (or 'Pedshed', which is frequently used in node-place modelling studies), but in terms of 'how much' it gives access to. In line with Pafka and Dovey (2018), we focus on the extent of public/private interface within the station's walkable precinct as a proxy measure for how much is actually 'caught'. More specifically, this 'interface catchment' (IC) is calculated by summarizing the length of all walkable street segments (the public realm) that are also flanked by buildings (the private realm). The second indicator, permeability, measures the extent to which the urban morphology is permeated by publicly accessible space (see also Marshall 2005) by means of mapping the total number of street crossings per station area (see also Ryan and Frank 2009). This measure relates to the ease of movement through an urban area as well as the multiplicity of route choices between any pair of points. Both indicators are complemented by a third one mapping the walkable and bikeable street networks within a station's precinct.

The motivation, ridership and effort dimensions

The data for these three dimensions was provided by the Belgian national railway company NMBS and is based on a comprehensive analysis of origin-destination season ticket pairs. As for the effort field, NMBS calculated the percentage of people living within a certain Euclidean distance from their origin station: walking distance (closer than 900m), biking distance (between 900 and 3000m) and a farther distance (> 3000m). The second field, ridership, is structured around three dimensions: origin (the estimated percentage of people using the station as their origin station), ridership (the frequency of passengers boarding trains on a regular working day), and destination (the estimated percentage of people using the station as destination station). We emphasize that both origin and destination do not reflect quantities of travellers (ridership), but specify the proportion of tickets for which the station functions as an origin or a destination station. Thirdly, the motivation field informs us about the (assumed) motivation of people traveling to a particular station. Four categories (dimensions) were discerned: secondary education, tertiary education, work and other. The first three dimensions draw on season ticket data and were categorized by NMBS based on age groups (respectively <19 years old, [19 – 25] and > 25). The latter dimension 'other' reflects individual ticket sale figures.

| Code | Indicator description | Source (year) | MV (%) |
|---|---|---|---|
| MOTIVATION | | | |
| PP_MOT_sec | % of people using the station as destination station for secondary education purposes | NMBS (2018) | 20 |
| PP_MOT_tert | % of people using the station as destination station for tertiary education purposes | | 20 |
| PP_MOT_work | % of people using the station as destination station for work purposes | | 20 |
| PP_MOT_other | % of people using the station as destination station for other purposes | | 20 |
| RIDERHIP | | | |
| PP_RID_orig | % of people using the station as an origin station | NMBS (2017 and 2018) | 0 |
| PP_RID_rid | The frequency of passengers boarding trains on a working day | | 0 |
| PP_RID_dest | % of people using the station as a destination station | | 0 |
| EFFORT | | | |
| PP_EFF_walk | % of people using the station as origin station who live within a Euclidean walking distance (< 900 m) | NMBS (2018) | 21 |
| PP_EFF_bike | % of people using the station as origin station who live within a Euclidean biking distance (900 – 3000 m) | | 21 |
| PP_EFF_far | % of people using the station as origin station who live farther (> 3000 m) | | 21 |

Table 6: Indicators of the motivation, ridership and effort fields

*C. Analyzing patterns and developing a typology of stations*

Taken together, our framework consists of 32 indicators. Most indicators have no missing values, except for those of the motivation (20%) and effort (21%) fields. This is due to the existence of tariff zones[46], which leaves us with some uncertainty regarding the specific station travelled to and/or from when analyzing sold tickets and passes.

A first step in a series of descriptive analyses consists of a two-sided Spearman correlation analysis. This will shed light on the direction and strength of the relations between the indicators belonging to different dimensions and fields, allowing for a validation of the conceptual model from a statistical point of view. As the proportion of missing values for the motivation and effort fields is fairly high, this correlation analysis is based on a list-wise deletion of missing values, resulting in a subset of 221 stations. Drawing on these descriptive statistics, a procedure to estimate the missing values in the remainder of the dataset can be set up, in order to develop a typology of stations inclusive of the effort and motivation fields. The procedure used is a multiple imputation (MI) algorithm and is conducted in SPSS. Since the values are missing in a non-random way, the monotone MI procedure is used. The 'pooled' result (the average of the imputed values over 5 runs) is retained as a basis for the following analyses.

Second, in order to verify to what extent the demand-side indicators add meaning to the findings of a conventional node-place type of classification, we conduct two cluster analyses. The first one only includes the supply-side accessibility fields (node, train and place), while the second one focuses on the demand-side fields. Both cluster analyses draw on an a priori exploratory factor analysis in order to generate a classification based on uncorrelated variables.

### 2.2.3 Findings

*A. Correlation analysis*

When analyzing the direction and strength of correlations between the indicators (see Appendix 2.2.I at the end of this section), the following insights emerge. First, the overall logic of the model seems justified: indicators belonging to the same field generally correlate strongly with each other and exhibit similar patterns with respect to the other fields. The decision to separate the train accessibility indicators from those of the feeder modes (bus, tram and metro) also seems justified, as correlations are clearly contained within both dimensions (e.g. the bus indicators have strong mutual correlations but exhibit weak correlations with the train indicators and vice versa). Furthermore, the assumed associations between the node and effort fields, the train and ridership fields, and the place and motivation fields seem supported by these findings. First, there is a clear positive relation between the distance people live from their station and the supply of car parking (and to a lesser extent bike parking) facilities and feeder public transport mode accessibility. Second, the ridership indicator is strongly positively correlated with most of the train indicators, especially with the frequency indicators. Third, the motivational factors, and in particular the secondary education profile, are generally significantly and strongly positively correlated with the place indicators. The ridership indicator 'destination' is furthermore strongly positively correlated with all motivation indicators, justifying its location on the right hand side of the ridership dimension in Figure 18.

On the indicator-level the following findings are noteworthy. The three design indicators are very strongly correlated (>.936). It seems that the extent of the public-private interface, the permeability of the street

[46] There are 12 tariff zones in Flanders and Brussels: Aalst, Antwerp, Bruges, Brussels, Denderleeuw, Dendermonde, Ghent, Halle, Hasselt, Knokke, Leuven and Mechelen.

network and the total length of walking and cycling infrastructure to a large extent contain similar information about station area walkability. Further research could therefore look into alternative ways to assess walkable and bikeable access to stations mediated specifically by the built environment[47]. In a similar vein, the two diversity indicators are very strongly correlated, indicating the intended differences in functional and spatial land use diversity are not sufficiently captured. More experimentation with alternative Fragstats measures (and parameters) or alternative software packages is therefore a sensible next step. Furthermore, the two centrality indicators do not correlate strongly with other indicators, which suggests that both contain specific information about the network structure that is not covered by the other train indicators. Travel time centrality in particular does not exhibit any strong correlations, whilst transfer centrality is quite strongly correlated with the other train indicators.

A final reflection concerns the ridership indicator. Although it is beyond the scope of this section to investigate the determinants of transit patronage in Flanders and Brussels (see Chapter 4), the correlation patterns do allow to explore some preliminary relations. Ridership is strongly correlated with (most indicators of) all other fields. Especially (free) car and bike parking supply, feeder public transport services, the design dimension, both educational motivations and the size of the catchment area are strongly related. Also, transfer centrality seems more important in explaining ridership than the travel time and frequency based centrality measure. Chapter 4 of this dissertation will explore these ridership determinants in more detail.

*B. Factor and cluster analysis*

In this section the results of two cluster analyses are discussed: a first one based on the supply-side accessibility characteristics (node, train, place) and a second one based on the demand-side accessibility characteristics (people). Clustering based on the full set of indicators did not result in an intelligible typology, hence the separate analyses discussed in two subsections.

<u>A typology for nodes and places</u>

The factor analysis (orthogonal, varimax rotation) results in four interpretable factors (see Appendix 2.2.IIa) with an eigenvalue larger than 1 and explaining 81% of total variance. Factor 1 has strong loadings for nearly all place indicators, factor 2 for the train frequency indicators, factor 3 for most of the node indicators and the train amplitude and factor 4 for both centrality measures. Based on these factors, a Two Step cluster analysis (log-likelihood distance criterion and BIC clustering criterion) is conducted resulting in five interpretable groups of stations (see Figure 19). Brief descriptions for all station types are also provided in Figure 19.

The majority of stations in Flanders and Brussels classify as rural stations (very low scores on all place indicators) with weak bus and tram accessibility levels and weak railway accessibility in terms of frequency (on average 64 departing trains per Tuesday), but favourable in terms of network centrality. In other words, based on the actual NMBS timetables, these smaller stations with low public transport service frequencies are nonetheless located on the most important railway lines connecting the largest cities in Flanders, giving them robust and strategic potential in terms of future urban developments. Although most of these stations are located along the MTS spatial backbone sketched in Chapter 1 (Figure 2), the stations located both in

[47] The inclusion of measures of street network integration or connectivity as proposed by Pafka and Dovey (2018) may be a sensible addition here. The work by van Nes and Stolk (2012) and Liu et al. (2015) in which the spatial configuration of the local street network in railway precincts is assessed using Space Syntax analysis may prove instrumental. The open soruce 'Urban Networks Analysis' toolbox for ArcGIS (Sevstuk and Mekonnen 2012) arguably also provides an interesting basis to refine centrality analyses of street networks with respect to railway stations (see for example Sun et al. 2016).

the Western part and the Eastern part of Flanders exhibit a distinct typology. In these areas, types 2 and 4 are more abundant. Type 4 is characterized by very low bus and tram accessibility levels, and the lowest railway accessibility in terms of frequencies, amplitude and centrality. These stations are not at all or only weakly connected to the Walloon and foreign stations that are part of the network analysis. The level of 'urbanity' of type 4 is nonetheless stronger than the type 1 stations which, from the perspective of a node-place equilibrium, arguably leads to a development scenario prioritizing higher railway accessibility in the network. The type 2 stations, in turn, are all located in urbanized areas and – in contrast with the previous two types - exhibit sizable levels of bus and tram accessibility and have by far the highest car parking supply. Their railway-based accessibility is moderate, except for the service amplitude which is sizable in most cases. Geographically speaking this type is scattered, but there are nonetheless some clusters in and around the large cities of Kortrijk and Antwerp. The Brussels Capital Region is in turn predominantly characterized by stations of type 3. The main features of this type, differentiating it from the Flemish stations, are its very high scores on all place indicators and (mainly travel time) centrality measures. However, given the metropolitan context, the very low scores for the (mainly bike) parking facilities are striking. And finally, two of the three most important railway stations in the Belgian railway network (Brussels South and Brussels North) along with the main stations of the largest cities in Flanders, classify as type 5. The main distinctive factors are the very high frequencies and (mainly transfer) centrality scores and the very high bus, tram and metro accessibility levels.

<u>A user-based typology</u>

The factor analysis (orthogonal, varimax rotation) results in 4 factors (see Appendix 2.2.IIb) with an eigenvalue of 1 and explaining 78% of total variance. Factor 1 has strong positive loadings for destination, and the work and leisure motivations, while factor 2 strongly loads on the tertiary (and to a lesser extent secondary) education motivation and moderately loads on ridership. The third and fourth factor both cover the effort dimension, therefore only the third factor is retained. It loads strongly on large catchment areas where most people live further than a 3000 m radial buffer. The first three factors together explain 70% of total variance. Based on these factors, a Two Step cluster analysis (log-likelihood distance criterion and BIC clustering criterion) is conducted resulting in six interpretable groups of stations (see Figure 20).

The majority of stations in Flanders and Brussels classify as strong origin stations with semi large catchment areas (type 2). These stations are abundant across the region and are often located one after another along certain corridors in between the larger stations. The western and eastern parts of Flanders nonetheless mainly exhibit station types 1 and 3. The first type is quite similar to type 2 but is characterized by large catchment areas. Unsurprisingly, these stations are often located quite far from their neighboring stations, arguably explaining their larger catchments. Type 3 stations in turn have the largest catchment areas and are also characterized by strong leisure motivations (high destination motivations in terms of individual ticket sales).

These are mainly destination stations and are located nearly exclusively in the periphery of the network, i.e. along and near the coast line in the West and at the end of some rail corridors in the East. The stations with the smallest catchment areas (type 5, strong origin stations) are in turn mainly located along some corridors in the centre of the network. Finally, the station types with the least number of stations are types 4 and 6. The type 4 stations are mixed origin/destination stations with a strong educational motivation and high to very high ridership. They are located at the cornerstones of the MTS sketched in Figure 4 and across the Brussels Capital Region. The strongest destination stations (type 6) are also mainly found in the urban regions of Brussels and Antwerp. The classifications of those stations located in the tariff zones should nonetheless be interpreted with prudence, as most of the people-based indicator scores (except for those part of the 'ridership' field) are based on the imputation estimates described above.

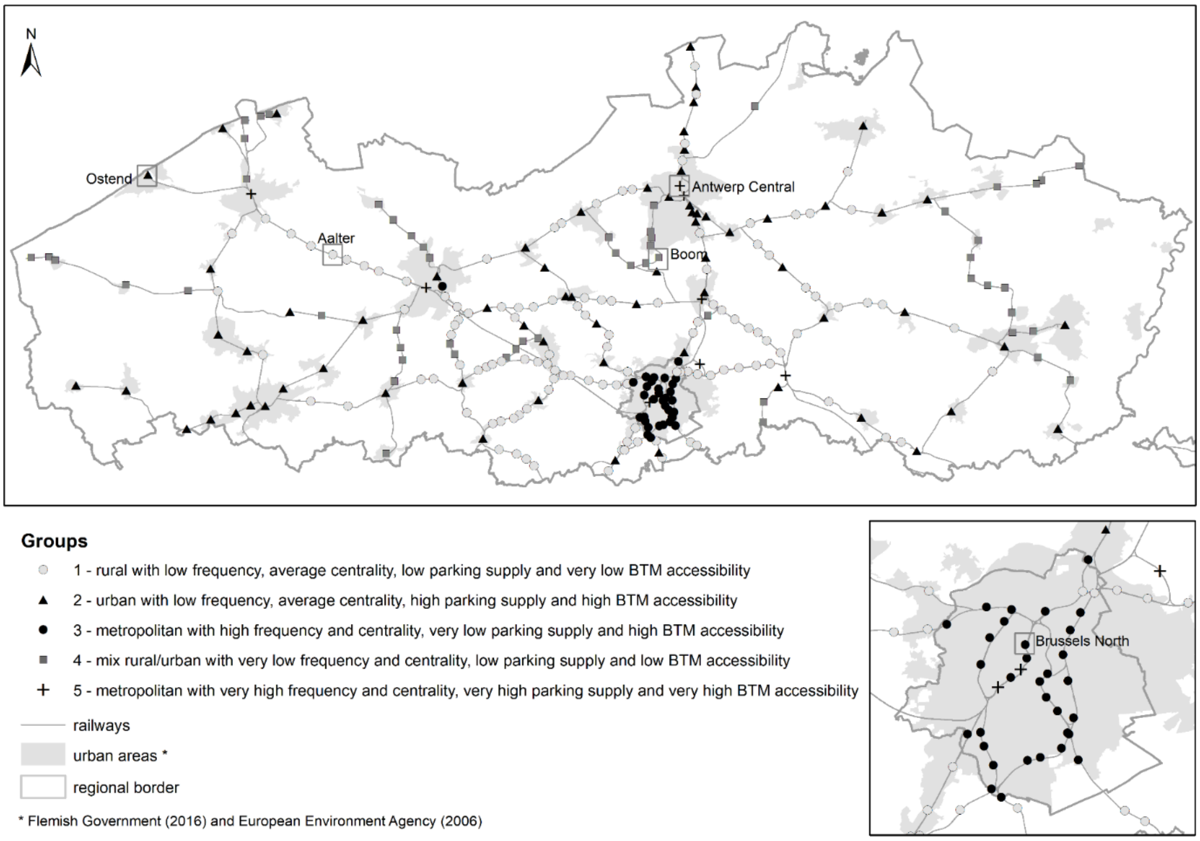



Figure 19: Typology of stations based on node, train and place dimensions

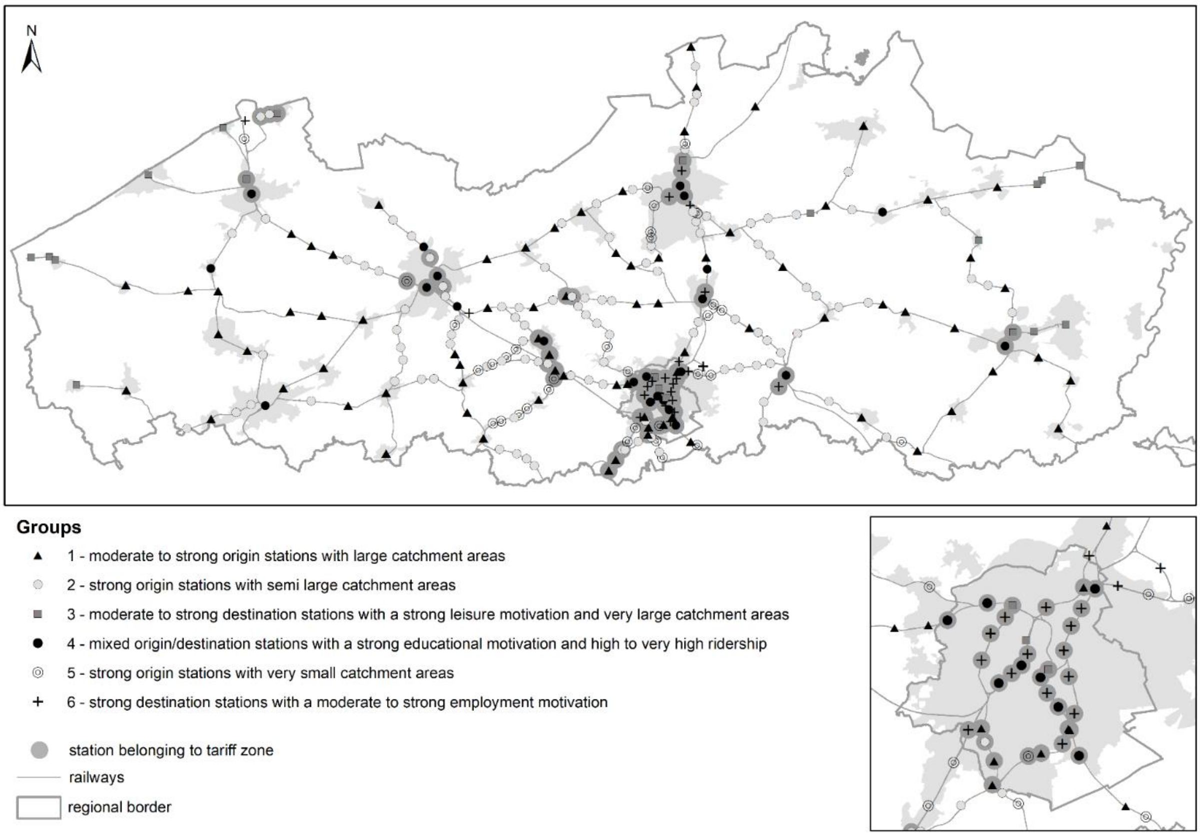



Figure 20: User-based typology of stations

*C. Blending typologies*

Figure 21 illustrates by means of a cross-table how the stations are sorted across both typologies ('NTP' = Node, Train and Place, 'PP' = People), and visualizes a radar diagram for each of the cluster intersections. The dimensions in these diagrams are calculated as averages of the underlying indicators, and afterwards the dimension scores were rescaled to vary between 0 and 10 for each of the intersections. Figure 21 illustrates how the majority of railway stations in Flanders and Brussels classify within a limited number of cluster intersections. A clear example is the general overlap between the rural stations (type 1 in NTP) and the moderate to strong origin stations (1, 2 and 5 in PP). Likewise, the urban stations of type 2 in NTP are most often also moderate to strong origin stations with semi large to large catchments (types 1 and 2 in PP). A similar observation holds for the type 4 stations (NTP), while a distinct pattern is true for the metropolitan stations of type 3 in NTP, which classify predominantly as strong destination stations in the PP typology. The metropolitan stations of type 5 in NTP exclusively classify as the mixed origin/destination stations of type 4.

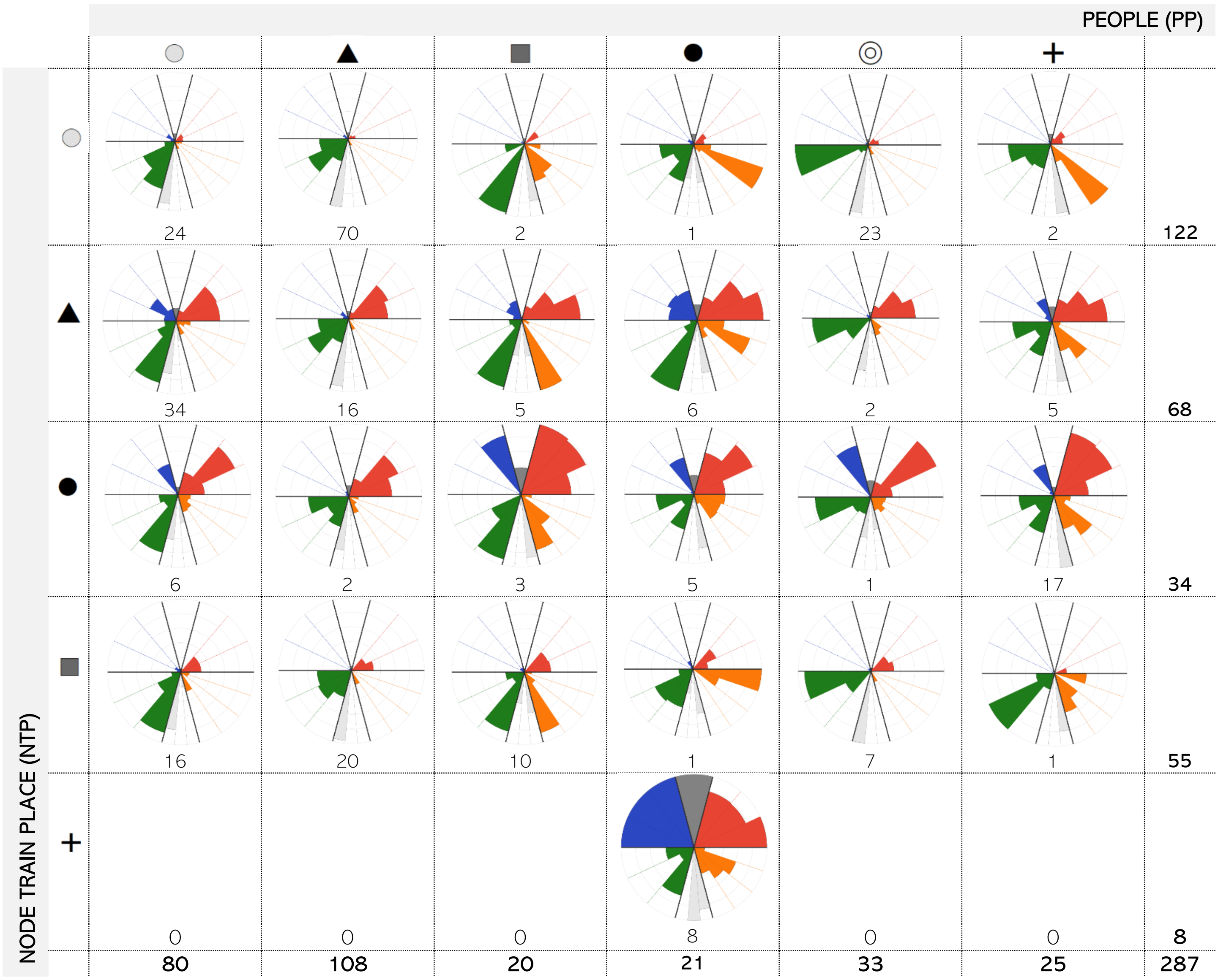



Figure 21: Cross-table of cluster intersections with averaged radar diagrams

These strong cluster intersections may not surprise given the earlier demonstrated correlations between the supply- and demand-side fields in the model. The confrontation of both typologies nonetheless allows for a more nuanced and differentiated account of a station's functioning in the Flemish and Brussels railway network when compared to a standard node-place typology, given that each NTP category diversifies into a range of distinct PP categories and vice versa. This comparative framework furthermore allows to identify stations that fit into unexpected or underrepresented 'boxes' within Figure 21.

### 2.2.4 Practical application to five cases

In order to clarify what the station-specific results of these analyses may mean for planning practice, in this section we will discuss the characteristics of five railway stations, each of which is exemplary for one cluster derived from the NTP typology (see Figure 19 in which the five stations have been designated and Figure 21 indicating their cluster membership for both typologies). We will also explain the position of the station at hand within the PP typology, and relate our findings to the objectives of urban planning policies in Flanders and Brussels. The scores of each station on the model dimensions and on the individual indicators are visualized per case in Figure 22.

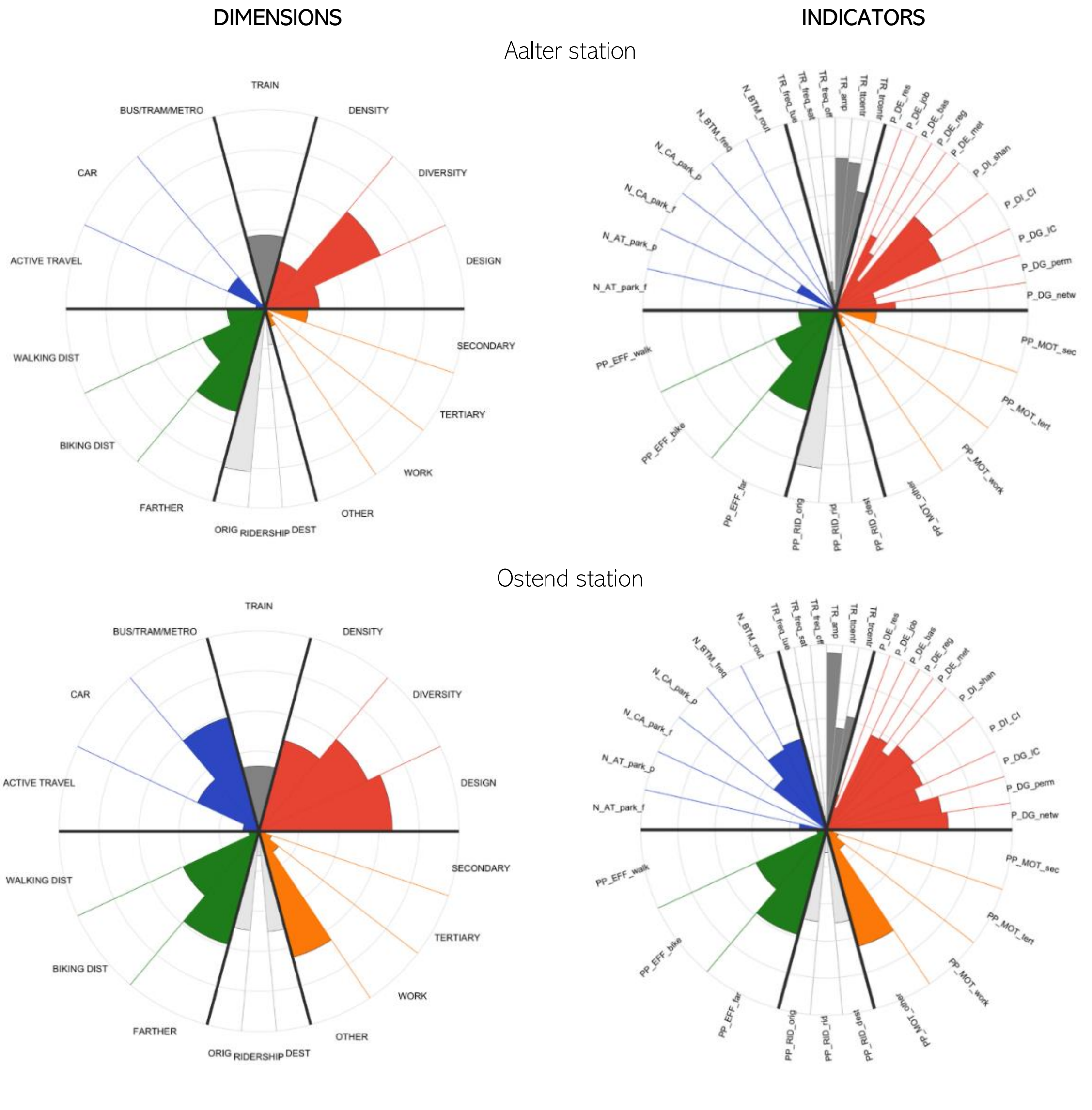
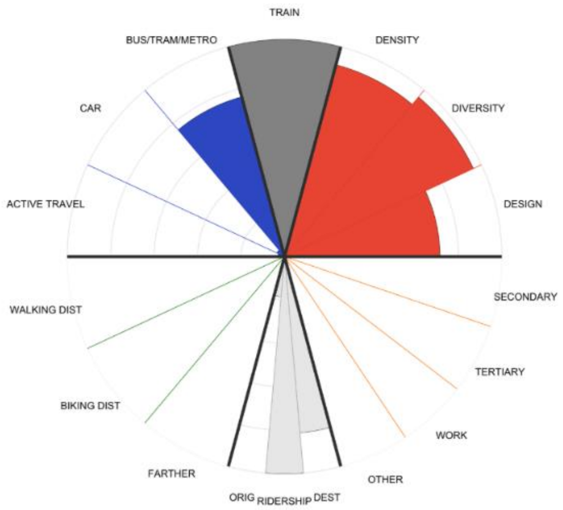
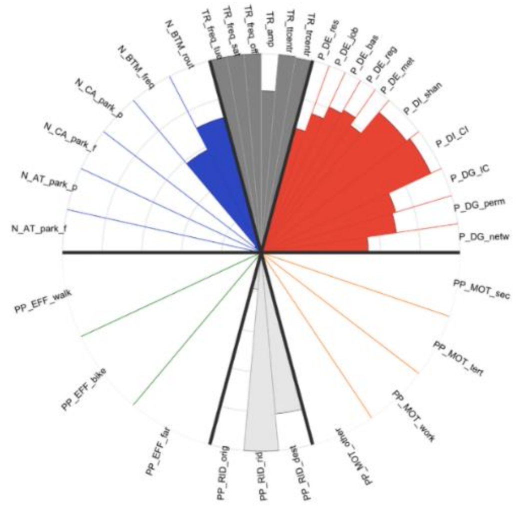



Figure 22: Radar diagrams for five stations

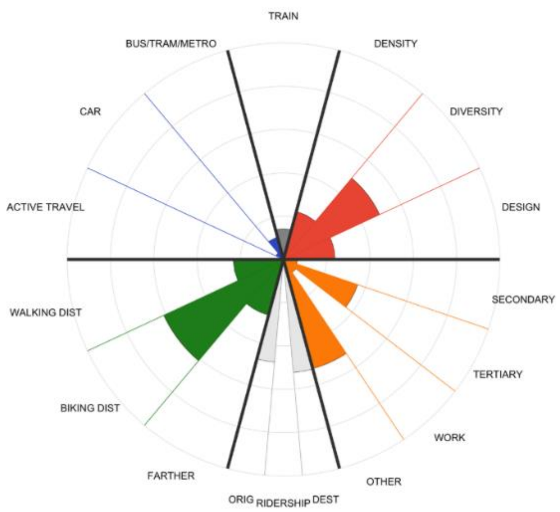
**DIMENSIONS** **INDICATORS**

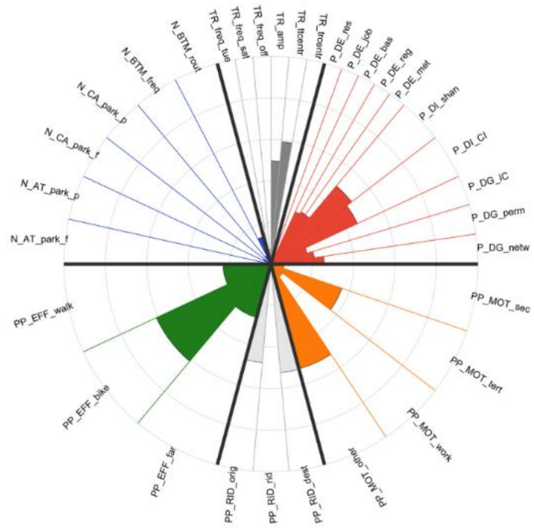
Brussels North station



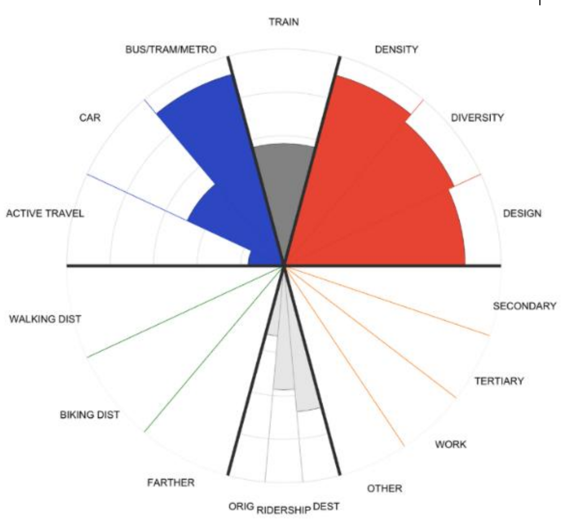




Boom station




Antwerp Central station



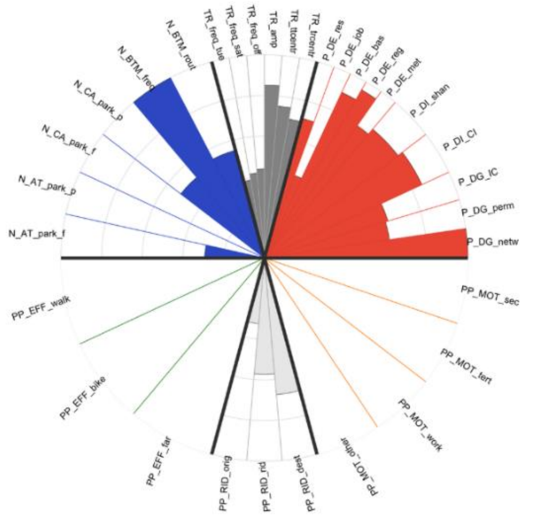




Figure 22: Radar diagrams for five stations

*A. Aalter station*

As indicated in Figure 19, Aalter station is located halfway between the larger cities of Bruges and Ghent. The strong growth of the municipality of Aalter since the 1970s, is a typical consequence of the suburbanization trend of that era, which was initially fuelled by the smooth access of Aalter to the nearby motorway E40, but which is currently also complemented with reasonable access to the railway network. Judging from Figure 20, Aalter is a predominant origin station with a large catchment area where most people live farther than 3 km away from the station. The motivations to reach Aalter station as a destination station are very limited, with the exception of a small proportion of season tickets used for (presumably) secondary education purposes. Although the number of daily passengers boarding (over 2,000) is quite sizable compared to the size of the municipality (more than 20,000 inhabitants), the ridership indicator scores very low when compared to the other stations in the network. Combined, these characteristics fit the station's classification as a type 1 station in the PP typology.

As most station users are living far from the station, from a sustainable mobility perspective one could expect a well-developed public transport service connecting the station with its hinterland. Judging from Figure 22, however, feeder public transport accessibility is very weak. There are two bus stops near the station serving two lines which together offer 41 bus departures on a working day. According to additional statistics, the modal share of public transport trips to and from the railway station is only 6% (NMBS 2013). While the low density, suburban-style, catchment area of Aalter station – revealed by the place indicators in Figure 22 – may hamper a more efficient development of feeder bus lines, this apparent mismatch may prove instrumental when discussing the potential for increased sustainable transport accessibility of the station. Due to its low density walkable area (especially in terms of jobs and residents), Aalter station classifies as a rural station in the NTP typology. The station's walkable precinct nonetheless exhibits a notable functional and spatial diversity of the functions living, working and visiting. The station furthermore classifies as a station with low train frequencies, but with an average centrality in the network. The amplitude of the station is nonetheless favourable, along with its travel time (and to a lesser extent transfer) centrality. The latter observation may be explained by the bi-hourly direct service to Brussels (contrary to the neighbouring local stations on the same railway line).

Policywise, Aalter is selected as an 'economic node' but not as an 'urban area', which limits development options. From a combination of contextual properties and results of the cluster analyses and Figure 22, we derive that the opportunities offered by this station can be valorised through densification of residential use in the immediate vicinity of the station and, at a later stage, such development could be supported by an increase in bus and train supply.

*B. Ostend Station*

Ostend station is the western terminus of the railway that used to be an important link on the international London-Brussels-Cologne route, until the opening of the Chunnel in 1994. Currently, the 'regional urban area' of Ostend (over 71,000 inhabitants) no longer has a ferry connection, and the timetable of trains departing from this terminus is adapted to domestic traffic, which includes an important flow of long-distance commuters. According to the NTP typology, this station can be described as 'urban with low frequency, average centrality, high parking supply and high BTM accessibility'. This can be explained by, among other things, its location in a regional urban area, its status as a terminus, and its importance as a hub for regional public transport, the backbone of which is the coastal light railway. Although most train indicators score weak or moderate, the amplitude is very high.

According to the PP typology, Ostend station is a ‘moderate to strong destination station with a strong leisure motivation and very large catchment area’. This description seems to align with the accessibility profile provided in Figure 22, although the station in fact exhibits a quasi perfect balance between an origin (long-distance commuters) and a destination (presence of the beach as a tourist attraction and sizable presence of regional and metropolitan amenities) character. The remote location of Ostend station in the national rail network may furthermore explain its large catchment area. The station’s ridership on a Tuesday is about 7,600, which is significant but pales in comparison to the Brussels main stations (with over 61,000 boarding passengers). Given the status of Ostend as a regional urban area, strengthening the current concentration of a mixed residential, professional, educational and recreational environment here would be an obvious policy option. The immediate vicinity of the station, which is located next to the currently underused seaport, is hardly developed and may well be suitable for compaction.

*C. Brussels North station*

Brussels North station is one of the three major stations of the Brussels north-south corridor, the busiest railway line in Belgium receiving around 1,200 trains per working day. The station is located centrally in the Brussels metropolitan area, which includes the Brussels Capital Region comprising 1.2 million inhabitants, and is situated between a modernist office district and a densely populated residential area. Judging from Figure 22, the train frequencies are maximal, both off-peak and in the weekend. Besides the amplitude indicator, all train indicators exhibit maximal scores. The place dimensions also score very high, except for the design indicators. Especially the network length of walk and bike paths receive mediocre scores in spite of the station being one of the most important railway hubs in the network. In a similar vein, the bike parking capacity of Brussels North is remarkably low and car parking at the station is also scarce. Furthermore, the station is an important hub in the Brussels tram and bus network, as well as in the Flemish regional public transport system, while virtually all trains serving the national airport call at this station. These characteristics align with the NTP type ‘metropolitan with high frequency and centrality, very low parking supply and high BTM accessibility’.

From a user-based perspective, there is no information available for the effort and motivation dimensions as Brussels North is part of the Brussels tariff zone. From the other available NMBS data we can nonetheless derive that the station is a clear destination station and that it has a maximal ridership compared to the other stations in the network. It is the busiest station in the country on working days, with over 61,000 passengers boarding here. Given the station’s embedding in the metropolitan area and its pronounced role as a destination station (and transfer node), policy objectives could arguably focus on the further reinforcement of the functional mix of the wider station precinct through the development of additional housing.

*D. Boom station*

Boom station is located in the ‘small urban area’ of Boom-Rumst (about 18,000 inhabitants). Judging from Figure 22, all node, train and place dimensions score moderate to low. The station classifies as 'mix rural/urban with very low frequency and centrality, low-parking supply and low B/T/M accessibility'. Despite the central location in the Flemish metropolitan core area, the station is poorly connected to the Belgian rail network, offering no significant connections to Brussels or other cities apart from Antwerp, which is especially reflected in a very low transfer centrality score, and a moderate travel time centrality score. Boom station is furthermore located next to a business park, in a location that is relatively isolated from the city centre because of an expressway that locally cuts through the built environment and significantly decreases the size of the walkable station area (in turn affecting the design indicators).

According to the PP typology, Boom classifies as a 'moderate to strong origin station with large catchment area'. Figure 22 nonetheless reveals a mixed origin-destination profile and a semilarge catchment area. The motivations associated with its destination character are 'other' (presumably leisure activities linked to the large nature recreational park nearby), and 'tertiary education'. The latter motivation is related to the presence of several post-secondary specialization grades offered by the Provincial Technical School, which is located close by the station. Finally, ridership is extremely low (about 230 people on a Tuesday). Given its location in a 'small urban area' in the Flemish metropolitan core area, and its current extremely low ridership, we derive that the potential offered by this station can only be realized if the quality of train supply would increase, its transfer centrality would improve, and if the station precinct would be made more attractive. Compaction objectives appear therefore less urgent.

*E. Antwerp central station*

Antwerp Central station is embedded in the 'metropolitan area' of Antwerp, which includes the city of Antwerp (over 520,000 inhabitants). The station belongs to the cluster 'metropolitan with very high frequency and centrality, very high parking supply and very high BTM accessibility'. The station has recently been part of a large-scale urban renewal project, whichincluded the expansion of the station into a hub of high-speed rail traffic towards the Netherlands (reflected in its high scores on the centrality indicators). The station is very centrally located in the urban fabric, and is embedded in a strongly mixed and high density residential area (reflected by the place indicators). The recent developments have added an office district and a large parking garage to the project (reflected by the notable score on the paying car parking supply), and the station also functions as a hub of urban public transport (tram, premetro and bus) (reflected by the high B/T/M scores).

From a user-based perspective, there is no information available for the effort and motivation dimensions (Antwerp Central station is part of the Antwerp tariff zone). We can nonetheless derive that the station is predominantly a destination and that it has a high ridership (35,000 passengers boarding on weekdays, making it the fifth busiest station of Belgium). Moreover, the station building is an architectural showpiece and a tourist attraction, which was in 2014 named 'the most beautiful station in the world' by the British-American news site Mashable. The large capacity that the station has acquired since the renovation in 2007 allows for a gradual growth of activities and residences in the station precinct, in the longer term to be combined with a rise in the supply of train services.

### 2.2.5 Discussion and conclusions

This section had two related objectives. First, we aimed to methodologically contribute to the literature on empirical station assessment models drawing on node-place modeling principles. We suggested and implemented strategies to improve the analytical strength of some standard node and place measures, took some precursory steps to broaden the model with temporal variability in accessibility and, most notably, complemented the standard supply-side accessibility information with a demand-side perspective focusing on the station users. These differentiated accessibility perspectives were structured along several fields and dimensions of a radar diagram, in line with their hypothesized reciprocal relations. In this way, station accessibility profiles are generated summarizing a variety of empirically collected information for all railway stations in the Flemish and Brussels railway network. Based on a discussion of some concrete examples, we illustrated how these radar diagrams may provide insights and reveal detailed knowledge about station-specific accessibility dynamics, some of which are not captured in standard node-place analyses.

Second, we interpreted the findings of the empirical analyses of Flanders and Brussels in the broad spirit of the recently approved BRV strategic vision (Flemish Government 2018b, see section also 1.1.3). To this end, we used our empirical findings to produce two groupings of stations, the first one based on a standard node-place analysis and a second one drawing on the user-based data acquired from NMBS. We demonstrated and discussed how both typologies intersect geographically, and how they may each provide unique information about the functioning of stations within the Flemish and Brussels railway network. By doing so, our research serves as a refinement of the conceptual typology of strategic railway stations put forward in the BRV strategic vision and the 'spatial backbone' operational framework. Additionally, our analysis is comprehensive in that it includes all railway stations in both regions, allowing to deduce meaningful observations for those stations that fall outside the scope of the BRV typology (most attention is focused on the 'metropolitan' and the 'international' nodes).

We nonetheless point out that the radar diagrams developed in this paper may lose their informative capacity when used in isolation from cartographic material and/or when absolute figures underpin the relative scores in the diagrams. As this station assessment model is intended to help developing a 'useful' (see Pelzer 2017) planning support system (PSS), we presume that additional maps that serve to clarify and increase the interpretation of specific indicator scores, as well as additional tables detailing the absolute figures behind the relative scores will be crucial. After all, several studies dealing with interdisciplinary communication processes facilitated by PSS (see Geertman and Stillwell 2009, Pelzer and Geertman 2014, Papa et al. 2017) stress the importance of spatial visualizations and of transparency in data and methods to render results more easily understandable and relevant for the end users of the tool. In these earlier studies, the added value of node-place analyses as perceived by their intended end users is nonetheless rarely evaluated; to the best of our knowledge, there are no such studies with the exception of Gilliard et al. (2018), who critically validated a node-place model application in a design studio setting with urban design students. This observation has a broader significance, as few planning support instruments commonly discussed in the literature are explicitly validated by their intended users (te Brömmelstroet 2010, Straatemeier et al. 2010, Pelzer et al. 2014, see also Bertolini 2017). This lack of cross-fertilization between the output of applied academic research and actual planning instruments hampers the integration of scientific and practical knowledge (Balducci and Bertolini 2007).

In order to help bridge the gap between planning research and planning practice, a next step in this research will therefore consist of a qualitative validation of the usefulness of this model in the Flemish context. Given the growing importance of the urban-regional governance level in integrating transport and land use in Flanders, a sensible strategy would be to focus on the recently (2018) established 'transport regions'. The objective of these new regional partnerships (15 in total) is to stimulate cooperation between municipalities, public transport operators, the Flemish Government and other stakeholders around the organization and coordination of public transport in the region, and this in close cooperation with spatial interventions. A validation of the model in this context should inform us about the extent to which particular building blocks of the model require modification to better fit the needs of its end users. It might turn out that our concern with the pursuit of rigour (or 'soundness', see Bertolini et al. 2005) in the operationalization of certain indicators, proves less directional for the future development of our planning support tool. In this way, the frequently raised contention that PSS developers should seek for an effective balance between scientific rigour and practical relevance (see among others Papa et al. 2016 and Silva and Larsson 2018) may be put to the test.

*Appendix 2.2.I – Indicator correlations based on list-wise deletion of missing values (N = 221). Significant correlations higher than 0.5 are greyed out.*

| | N_CA_Park_f | N_CA_Park_p | N_AT_Park_f | N_AT_Park_p | N_BTM_freq | N_BTM_rout | N_TR_freq_tue | N_TR_freq_sat | N_TR_freq_off | N_TR_amp | N_TR_ttcentr | N_TR_trcentr | P_DE_res | P_DE_job | P_DE_bas | P_DE_reg | P_DE_met | P_DI_shan | P_DI_CI | P_DG_IC | P_DG_perm | P_DG_netw |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N_CA_Park_f | 1.000 | 0.084 | .608** | .144* | .362** | .465** | .443** | .425** | .381** | .323** | 0.038 | .230** | .373** | .337** | .390** | .274** | 0.133 | .415** | .433** | .357** | .337** | .394** |
| N_CA_Park_p | 0.084 | 1.000 | .302** | .282** | .369** | .372** | .191** | .148* | .180** | 0.084 | -0.040 | .173** | .415** | .370** | .386** | .390** | .272** | .294** | .327** | .401** | .391** | .409** |
| N_AT_Park_f | .608** | .302** | 1.000 | .237** | .371** | .487** | .433** | .496** | .371** | .351** | -0.072 | .194** | .531** | .451** | .517** | .418** | .214** | .516** | .542** | .546** | .510** | .530** |
| N_AT_Park_p | .144* | .282** | .237** | 1.000 | .286** | .301** | .168* | .196** | .175** | .169* | 0.000 | 0.118 | .268** | .298** | .255** | .282** | .201** | .230** | .235** | .277** | .278** | .285** |
| N_BTM_freq | .362** | .369** | .371** | .286** | 1.000 | .906** | .315** | .291** | .369** | 0.062 | -0.028 | 0.125 | .599** | .712** | .537** | .562** | .438** | .576** | .580** | .587** | .593** | .628** |
| N_BTM_rout | .465** | .372** | .487** | .301** | .906** | 1.000 | .317** | .275** | .334** | 0.098 | -0.112 | 0.129 | .566** | .647** | .515** | .481** | .337** | .556** | .564** | .581** | .577** | .606** |
| N_TR_freq_tue | .443** | .191** | .433** | .168* | .315** | .317** | 1.000 | .715** | .920** | .485** | .412** | .529** | .338** | .254** | .302** | .274** | .306** | .300** | .309** | .260** | .268** | .328** |
| N_TR_freq_sat | .425** | .148* | .496** | .196** | .291** | .275** | .715** | 1.000 | .700** | .606** | .330** | .626** | .390** | .308** | .382** | .374** | .339** | .349** | .362** | .358** | .372** | .393** |
| N_TR_freq_off | .381** | .180** | .371** | .175** | .369** | .334** | .920** | .700** | 1.000 | .432** | .413** | .515** | .382** | .333** | .346** | .350** | .370** | .343** | .346** | .298** | .312** | .368** |
| N_TR_amp | .323** | 0.084 | .351** | .169* | 0.062 | 0.098 | .485** | .606** | .432** | 1.000 | .259** | .636** | .158* | 0.040 | .176** | .141* | .143* | 0.098 | 0.117 | 0.114 | 0.109 | .135* |
| N_TR_ttcentr | 0.038 | -0.040 | -0.072 | 0.000 | -0.028 | -0.112 | .412** | .330** | .413** | .259** | 1.000 | .493** | -0.108 | -0.110 | -.135* | -0.114 | 0.083 | -0.081 | -0.099 | -.206** | -.202** | -.135* |
| N_TR_trcentr | .230** | .173** | .194** | 0.118 | 0.125 | 0.129 | .529** | .626** | .515** | .636** | .493** | 1.000 | 0.120 | .142* | 0.097 | 0.099 | .153* | .160* | .149* | 0.089 | 0.097 | 0.127 |
| P_DE_res | .373** | .415** | .531** | .268** | .599** | .566** | .338** | .390** | .382** | .158* | -0.108 | 0.120 | 1.000 | .782** | .925** | .855** | .655** | .819** | .869** | .921** | .899** | .947** |
| P_DE_job | .337** | .370** | .451** | .298** | .712** | .647** | .254** | .308** | .333** | 0.040 | -0.110 | .142* | .782** | 1.000 | .729** | .736** | .569** | .804** | .803** | .782** | .779** | .788** |
| P_DE_bas | .390** | .386** | .517** | .255** | .537** | .515** | .302** | .382** | .346** | .176** | -.135* | 0.097 | .925** | .729** | 1.000 | .896** | .666** | .788** | .830** | .897** | .883** | .927** |
| P_DE_reg | .274** | .390** | .418** | .282** | .562** | .481** | .274** | .374** | .350** | .141* | -0.114 | 0.099 | .855** | .736** | .896** | 1.000 | .796** | .746** | .773** | .809** | .825** | .861** |
| P_DE_met | 0.133 | .272** | .214** | .201** | .438** | .337** | .306** | .339** | .370** | .143* | 0.083 | .153* | .655** | .569** | .666** | .796** | 1.000 | .540** | .550** | .571** | .625** | .665** |
| P_DI_shan | .415** | .294** | .516** | .230** | .576** | .556** | .300** | .349** | .343** | 0.098 | -0.081 | .160* | .819** | .804** | .788** | .746** | .540** | 1.000 | .989** | .819** | .811** | .827** |
| P_DI_CI | .433** | .327** | .542** | .235** | .580** | .564** | .309** | .362** | .346** | 0.117 | -0.099 | .149* | .869** | .803** | .830** | .773** | .550** | .989** | 1.000 | .858** | .841** | .862** |
| P_DG_IC | .357** | .401** | .546** | .277** | .587** | .581** | .260** | .358** | .298** | 0.114 | -.206** | 0.089 | .921** | .782** | .897** | .809** | .571** | .819** | .858** | 1.000 | .974** | .936** |
| P_DG_perm | .337** | .391** | .510** | .278** | .593** | .577** | .268** | .372** | .312** | 0.109 | -.202** | 0.097 | .899** | .779** | .883** | .825** | .625** | .811** | .841** | .974** | 1.000 | .941** |
| P_DG_netw | .394** | .409** | .530** | .285** | .628** | .606** | .328** | .393** | .368** | .135* | -.135* | 0.127 | .947** | .788** | .927** | .861** | .665** | .827** | .862** | .936** | .941** | 1.000 |
| PP_MOT_sec | .426** | .337** | .536** | .218** | .545** | .571** | .278** | .318** | .280** | .203** | -.157* | .143* | .576** | .615** | .552** | .511** | .309** | .574** | .590** | .615** | .619** | .595** |
| PP_MOT_tert | .403** | .473** | .497** | .345** | .525** | .587** | .354** | .349** | .361** | .242** | -0.067 | .249** | .474** | .544** | .438** | .437** | .303** | .431** | .453** | .486** | .482** | .482** |
| PP_MOT_work | 0.098 | .205** | .204** | .150* | .528** | .436** | .197** | .264** | .307** | 0.024 | 0.044 | .181** | .457** | .697** | .402** | .497** | .494** | .566** | .522** | .459** | .497** | .498** |
| PP_MOT_other | -0.011 | 0.067 | 0.097 | 0.085 | .350** | .300** | -0.095 | 0.083 | 0.020 | -0.041 | -.332** | -0.037 | .331** | .481** | .319** | .420** | .357** | .405** | .378** | .354** | .402** | .385** |
| PP_RID_orig | -.175** | -.280** | -.280** | -.198** | -.600** | -.528** | -.168* | -.265** | -.282** | -0.047 | .141* | -.152* | -.515** | -.772** | -.474** | -.561** | -.490** | -.607** | -.576** | -.543** | -.583** | -.563** |
| PP_RID_rid | .668** | .412** | .749** | .291** | .569** | .635** | .603** | .582** | .539** | .408** | 0.084 | .425** | .605** | .566** | .564** | .468** | .326** | .567** | .595** | .627** | .608** | .630** |
| PP_RID_dest | .175** | .280** | .280** | .198** | .600** | .528** | .168* | .265** | .282** | 0.047 | -.141* | .152* | .515** | .772** | .474** | .561** | .490** | .607** | .576** | .543** | .583** | .563** |
| PP_EFF_walk | -.411** | -.224** | -.459** | -.248** | -.362** | -.428** | -0.068 | -.156* | -0.064 | -0.085 | .269** | -0.056 | -0.072 | -.278** | -0.083 | -0.095 | 0.064 | -.187** | -.174* | -.176** | -.170* | -0.119 |
| PP_EFF_bike | -.213** | -.159* | -0.013 | -.181** | -.303** | -.312** | -0.094 | -0.091 | -0.119 | -0.080 | 0.098 | -0.114 | -.153* | -.264** | -.134* | -.154* | -0.111 | -.214** | -.211** | -.190** | -.205** | -.222** |
| PP_EFF_far | .534** | .258** | .487** | .261** | .491** | .549** | .201** | .226** | .193** | 0.128 | -.247** | 0.118 | .190** | .404** | .195** | .177** | -0.005 | .327** | .316** | .303** | .299** | .270** |

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0.05 level (2-tailed)

| | PP_MOT_sec | PP_MOT_tert | PP_MOT_work | PP_MOT_other | PP_RID_orig | PP_RID_rid | PP_RID_dest | PP_EFF_walk | PP_EFF_bike | PP_EFF_far |
|---|---|---|---|---|---|---|---|---|---|---|
| N_CA_Park_f | .426** | .403** | 0.098 | -0.011 | -.175** | .668** | .175** | -.411** | -.213** | .534** |
| N_CA_Park_p | .337** | .473** | .205** | 0.067 | -.280** | .412** | .280** | -.224** | -.159* | .258** |
| N_AT_Park_f | .536** | .497** | .204** | 0.097 | -.280** | .749** | .280** | -.459** | -0.013 | .487** |
| N_AT_Park_p | .218** | .345** | .150* | 0.085 | -.198** | .291** | .198** | -.248** | -.181** | .261** |
| N_BTM_freq | .545** | .525** | .528** | .350** | -.600** | .569** | .600** | -.362** | -.303** | .491** |
| N_BTM_rout | .571** | .587** | .436** | .300** | -.528** | .635** | .528** | -.428** | -.312** | .549** |
| N_TR_freq_tue | .278** | .354** | .197** | -0.095 | -.168* | .603** | .168* | -0.068 | -0.094 | .201** |
| N_TR_freq_sat | .318** | .349** | .264** | 0.083 | -.265** | .582** | .265** | -.156* | -0.091 | .226** |
| N_TR_freq_off | .280** | .361** | .307** | 0.020 | -.282** | .539** | .282** | -0.064 | -0.119 | .193** |
| N_TR_amp | .203** | .242** | 0.024 | -0.041 | -0.047 | .408** | 0.047 | -0.085 | -0.080 | 0.128 |
| N_TR_ttcentr | -.157* | -0.067 | 0.044 | -.332** | .141* | 0.084 | -.141* | .269** | 0.098 | -.247** |
| N_TR_trcentr | .143* | .249** | .181** | -0.037 | -.152* | .425** | .152* | -0.056 | -0.114 | 0.118 |
| P_DE_res | .576** | .474** | .457** | .331** | -.515** | .605** | .515** | -0.072 | -.153* | .190** |
| P_DE_job | .615** | .544** | .697** | .481** | -.772** | .566** | .772** | -.278** | -.264** | .404** |
| P_DE_bas | .552** | .438** | .402** | .319** | -.474** | .564** | .474** | -0.083 | -.134* | .195** |
| P_DE_reg | .511** | .437** | .497** | .420** | -.561** | .468** | .561** | -0.095 | -.154* | .177** |
| P_DE_met | .309** | .303** | .494** | .357** | -.490** | .326** | .490** | 0.064 | -0.111 | -0.005 |
| P_DI_shan | .574** | .431** | .566** | .405** | -.607** | .567** | .607** | -.187** | -.214** | .327** |
| P_DI_CI | .590** | .453** | .522** | .378** | -.576** | .595** | .576** | -.174* | -.211** | .316** |
| P_DG_IC | .615** | .486** | .459** | .354** | -.543** | .627** | .543** | -.176** | -.190** | .303** |
| P_DG_perm | .619** | .482** | .497** | .402** | -.583** | .608** | .583** | -.170* | -.205** | .299** |
| P_DG_netw | .595** | .482** | .498** | .385** | -.563** | .630** | .563** | -0.119 | -.222** | .270** |
| PP_MOT_sec | *1.000* | .609** | .390** | .232** | -.615** | .650** | .615** | -.364** | -.225** | .453** |
| PP_MOT_tert | .609** | *1.000* | .316** | .176** | -.503** | .615** | .503** | -.427** | -.272** | .480** |
| PP_MOT_work | .390** | .316** | *1.000* | .549** | -.848** | .336** | .848** | -.153* | -.217** | .278** |
| PP_MOT_other | .232** | .176** | .549** | *1.000* | -.704** | 0.072 | .704** | -.166* | -.267** | .259** |
| PP_RID_orig | -.615** | -.503** | -.848** | -.704** | *1.000* | -.413** | -1.000** | .273** | .326** | -.419** |
| PP_RID_rid | .650** | .615** | .336** | 0.072 | -.413** | *1.000* | .413** | -.479** | -.236** | .611** |
| PP_RID_dest | .615** | .503** | .848** | .704** | -1.000** | .413** | *1.000* | -.273** | -.326** | .419** |
| PP_EFF_walk | -.364** | -.427** | -.153* | -.166* | .273** | -.479** | -.273** | *1.000* | 0.011 | -.820** |
| PP_EFF_bike | -.225** | -.272** | -.217** | -.267** | .326** | -.236** | -.326** | 0.011 | *1.000* | -.452** |
| PP_EFF_far | .453** | .480** | .278** | .259** | -.419** | .611** | .419** | -.820** | -.452** | *1.000* |

*Appendix 2.2.II: Output of the factor and cluster analyses for the NTP (a) and PP typologies (b).*

(a)

| | FAC 1 | FAC 2 | FAC 3 | FAC 4 |
|---|---|---|---|---|
| INDICATORS (loadings) | | | | |
| N_AT_park_f | .183 | .268 | .781 | -.055 |
| N_AT_park_p | .122 | .238 | .601 | -.004 |
| N_CA_park_f | .232 | .273 | .784 | .028 |
| N_CA_park_p | .201 | .191 | .675 | .022 |
| N_BTM_freq | .584 | .523 | .220 | .106 |
| N_BTM_rout | .433 | .314 | .687 | -.056 |
| N_TR_freq_tue | .169 | .929 | .227 | .169 |
| N_TR_freq_sat | .152 | .909 | .296 | .147 |
| N_TR_freq_off | .206 | .921 | .204 | .180 |
| N_TR_amp | -.165 | .169 | .660 | .445 |
| N_TR_ttcentr | .143 | .211 | -.136 | .786 |
| N_TR_trcentr | .206 | .224 | .242 | .812 |
| P_DE_bas | .924 | .087 | .197 | .051 |
| P_DE_reg | .921 | .137 | .154 | .081 |
| P_DE_met | .833 | .147 | .087 | .180 |
| P_DE_job | .564 | .422 | -.159 | .248 |
| P_DE_res | .787 | .303 | -.119 | .209 |
| P_DI_shan | .873 | .057 | .116 | .074 |
| P_DI_CI | -.902 | -.080 | -.131 | -.078 |
| P_DG_IC | .914 | .204 | .139 | .028 |
| P_DG_perm | .907 | .191 | .148 | .020 |
| P_DG_netw | .763 | .083 | .465 | -.117 |
| CLUSTERS (cluster centres) | | | | |
| 1 | -.75 | -.15 | -.09 | .49 |
| 2 | .56 | -.32 | .80 | -.07 |
| 3 | 1.62 | .12 | -1.13 | .85 |
| 4 | -.09 | -.02 | -.48 | -1.5 |
| 5 | .55 | 4.22 | 2.26 | -.09 |

(b)

| | FAC 1 | FAC 2 | FAC 3 | *FAC 4* |
|---|---|---|---|---|
| INDICATORS | | | | |
| P_MOT_sec | .350 | .555 | .227 | *-.095* |
| P_MOT_tert | .156 | .759 | .138 | *.121* |
| P_MOT_work | .795 | .286 | -.166 | *.037* |
| P_MOT_other | .711 | -.299 | .213 | *.269* |
| PP_RID_orig | -.895 | -.389 | -.078 | *-.104* |
| PP_RID_rid | .193 | .596 | -.081 | *.165* |
| PP_RID_dest | .895 | .389 | .078 | *.104* |
| PP_EFF_walk | -.026 | -.048 | -.954 | *.184* |
| PP_EFF_bike | -.188 | -.184 | .016 | *-.920* |
| PP_EFF_far | .150 | .167 | .809 | *.472* |
| CLUSTERS (cluster centres) | | | | |
| 1 | -.26 | .16 | .90 | |
| 2 | -.47 | -.35 | -.19 | |
| 3 | 1.44 | -1.39 | 1.14 | |
| 4 | .47 | 2.51 | -.02 | |
| 5 | -.45 | -.30 | -1.78 | |
| 6 | 2.11 | .09 | -.57 | |

# CHAPTER 3.

# PROBING USEFULNESS IN PRACTICE: THE CASE OF THE TRANSPORT REGIONS

This chapter is organized around three main sections. Section 3.1 reports on an experiential research strategy that is structured around a series of workshops in which a beta version of the StationRadar tool was put to the test. A second Section 3.2 examines in more detail the fit between the planning tasks at hand and the tool, by means of a series of post-workshop expert interviews. A final, third, section zooms in on one of the workshop cases in order to provide an account of how StationRadar was used by an interdisciplinary group of stakeholders during the workshop in Aalst. The case revolves around three stations in the Dender valley (Aalst, Denderleeuw and Ninove), located west of the Brussels Capital Region. This section serves the purpose of (1) illustrating how – at particular moments – the radar diagrams succeeded in structuring a multi-stakeholder dialogue based on the empirical 'common ground' provided by the radar diagrams, and of (2) highlighting some of the main issues and sentiments that (seem to) play a role in debates revolving around railway station (re)development in the Dender valley, in order to elicit possible clues for future development scenarios.

## 3.1 What strategies for which railway stations? An experiential approach to the development of a node-place based planning support tool in Flanders

> In the most generic sense, to experiment is to act in order to see what the action leads to. The most fundamental experimental question is, 'What if?'
>
> Schön (1983: 145)

### 3.1.1 Introduction

It is generally acknowledged that a better integration of the transport and land use policy domains is crucial to achieve more sustainable urban mobility outcomes (Meyer and Miller 2001, Marshall and Banister 2007). One of the ways in which this policy integration can be pursued is by means of 'transit oriented development' (TOD). This TOD paradigm refers to several mechanisms that can be implemented to intensify the location and mixing of housing and other activities near urban rail transport in inner cities as well as in metropolitan areas, with the overall objective of promoting transit ridership and other alternatives (walking and cycling) over the use of private cars (Cervero 2009).

A specific part of the academic literature on TOD focuses on identifying the development potential of transit station areas as an outcome of the interplay between transport and land use dimensions. The 'node-place model' is the analytical framework that is predominantly used to map the differentiated development opportunities of station(s) areas(s) (see Section 1.2). The assumption underlying most NPM studies is that a systematic inventory of both characteristics for a particular set of stations (along a corridor or within a region), provides useful knowledge that can subsequently inform evidence-based policy discussions, decision making processes and planning practices.

Based on the review of academic NPM studies detailed in Section 1.2, we deduced the most frequently raised statements with respect to the added value of node-place model applications. According to the reviewed studies, the NPM allows *to identify the development potential of station areas* and *to deduce development strategies* that are *context-sensitive*. The model furthermore allows *to benchmark and compare stations* and draft *more targeted TOD strategies* for groups of stations. According to some studies, these features can *trigger a debate* and *allow for discussions and negotiations* which are based on *transparently derived evidence*. This resonates with the majority of studies indicating that their results should *support further research*, help *shape strategic planning questions*, or help *inform policy prescription*. A limited number of studies also argue that the model can *foster a learning process* between stakeholders. Besides the above, a large share of reviewed studies point towards the potential of the NPM for the *evaluation of TOD policy*, and/or argue that the model can *provide insights* in order to *better understand land use and transport dynamics.*

Given this, it is clear that the NPM literature pursues a broad range of research objectives within both the basic and the applied types of social science (Blaikie 2010). Although the reviewed studies are primarily of a descriptive (and, to a much lesser extent, explanatory[48]) nature, most studies touch upon the interface between research and policy, and foreground, or at least hint towards, the usefulness of their empirical outcomes for (a variety of) stakeholders involved in station area (re)development. The latter reveals a somewhat different mission compared to the 'basic' types of research, as it is oriented towards affecting or changing the practice of planning for TOD (a research objective characteristic for applied research). However, it seems that the change-oriented statements listed above are rarely validated in practice. In which way are node-place analyses exactly useful? For whom, in what way and to what extent? Do they

[48] For example: Irvin-Erickson and La Vigne (2015) and Olaru et al. (2019).

indeed foster meaningful (interdisciplinary) discussions and/or social and interdisciplinary learning between stakeholders? These questions can be cast in another way by referring to Faludi and Waterhout's (2006: 11) discussion of the practice of evidence-based planning: does evidence improve political decision-making about a particular planning issue? Does it generate trust in expertise and does it facilitate the transparency of outcome? How do stakeholders participate and what is the role of indicators in collecting, analyzing and presenting evidence?

In line with the work of Balducci and Bertolini (2007), te Brömmelstroet (2010) and Straatemeier (2019), we argue that in order to address these type of research questions ('What can work?', 'Does it work?' and 'Why does it work?'), academic research needs to engage with practice and submit its findings to explicit testing in new situations in close cooperation with relevant stakeholders. To the best of our knowledge, there exist no such studies within the node-place modeling literature[49], with the notable exceptions[50] of Duffhues et al. (2014) and Kickert et al. (2014). Both papers report on the SPRINTCITY project: a computer-based serious game initiated in 2009 in the Netherlands, with the aim of helping different actors understand factors and the position of other actors in, and potential barriers to TOD. The intervention model of the game is quantified using node-place modeling principles and indicators, and the game is developed and validated through a continuous feedback loop between its players and the developers of the game, thereby repeatedly bridging the two sides of the planning practice and planning research spectrum. This research strategy strongly resonates with the 'experiential research design' methodology advocated by Straatemeier (2019, see also Straatemeier et al. 2010), which focuses on the idea that planning research should go through a number of iterative action-reflection cycles in close collaboration with relevant stakeholders from planning practice, in order to deduce meaningful insights about the underlying mechanisms that determine why particular planning innovations do or do not work[51].

This research endeavour resonates more broadly with the trend towards collaborative, participatory or communicative[52] spatial planning (among others Healey 1992, 1997 and Innes 1995). It also resonates with the widely shared contention within current planning support system debates that, instead of developing ever more advanced tools, more attention should be paid towards the intended tool users and the planning/institutional context and barriers (Klosterman 1997, Geertman 2006, Vonk et al. 2007, te Brömmelstroet 2010, Pelzer and Geertman 2014, Silva et al. 2017, Wulfhorst et al. 2017, Straatemeier 2019).

Against this backdrop, the research presented in this section aims to contribute to the body of literature in which node-place modeling concepts, assumptions and outcomes are explicitly tested and validated in practice. To this end, we apply the experiential research strategy proposed by Straatemeier (2019) to the case of StationRadar tool. We validated the tool in the context of the 'transport region' partnerships in Flanders. We refer to Section 1.1.4 for background information about these partnerships and the integrated transport and land use planning tasks they face. The remainder of this section introduces the tool,

[49] Some of the reviewed NPM studies nonetheless recognise the importance of communicative, participatory, collaborative, or deliberative planning in the process of model development and acknowledge the need for in-practice validation as a prerequisite for successful planning support (for example Reusser et al. 2008 p. 201, Zemp et al. 2011, Cheng et al. 2013, Caset et al. 2018, Nigro et al. 2019). Other studies actively involve experts in the process of model development (see Lyu et al. 2016, Singh et al. 2017, Li et al. 2019), but the role of these experts is limited to a one-off *ex ante* selection of model indicators or the assignment of indicator weights.

[50] The work of Gilliard et al. (2018) is relevant as well, albeit that the NPM is validated by urban design students, and not by actual stakeholders involved in railway station strategy making.

[51] This line of thinking also relates to the work of te Brömmelstroet (2010), who developed a method called 'mediated planning support', in which developers of planning support tools and their end-users engage in structured and iterative dialogues. In the process, the tool is tested, discussed and evaluated in order to refine and increase its usefulness.

[52] As stated by Vigar (2017), while there are differences, particularly in the origins of the theories, communicative approaches are similar to those often labeled deliberative and collaborative.

elaborates on the research questions (3.1.3) and methodology (3.1.4), outlines the main findings (3.1.5) and concludes with an overarching discussion (3.1.6).

### 3.1.2 The StationRadar tool[53]

StationRadar is a web-based tool[54] intended to support integrated land use and transport strategy-making, with a geographical focus on railway stations in the regions of Flanders and Brussels. The tool visualises the outcomes of an earlier extensive NPM study (see Section 2.2) in which a range of 'node', 'place' and 'people' criteria have been assessed for the 287 railway stations in both regions. Figure 23 shows the user interface of the tool with an indication of its main components (boxes A to E), which are briefly discussed below.

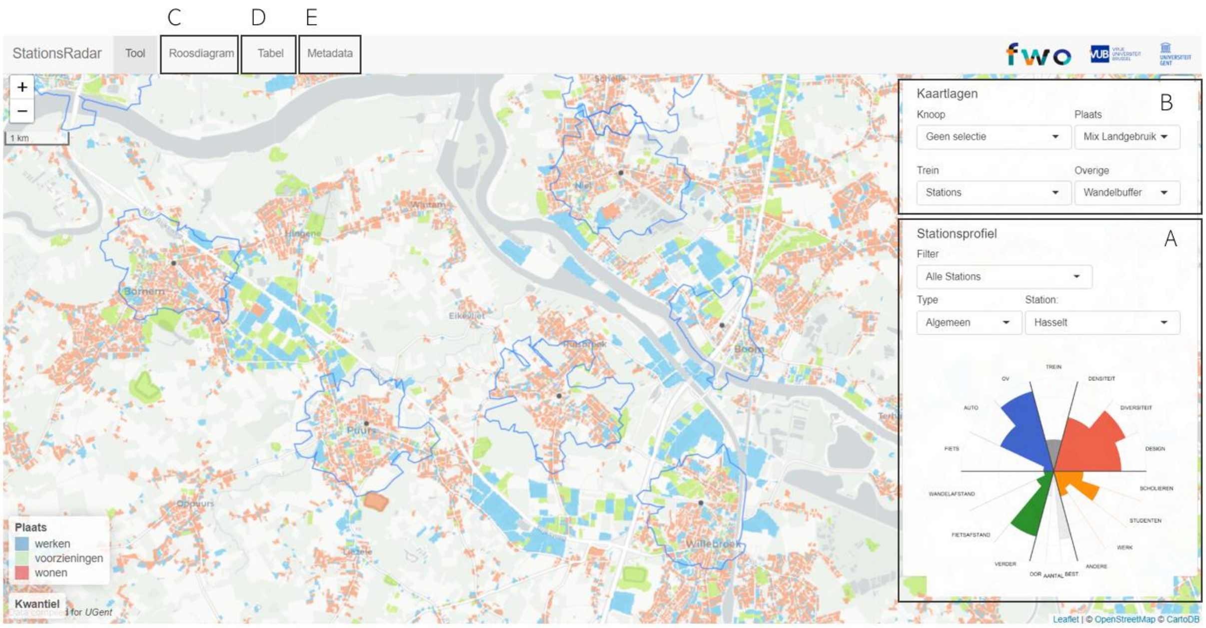



Figure 23: The StationRadar user interface

In line with other NPM studies (see Balz and Schrijnen 2009, Singh et al. 2017, Vale et al. 2018, Caset et al. 2018, Groenendijk et al. 2018 and Nigro et al. 2019), we created visual profiles of station-specific performance levels (box A). Our renderings take the shape of radar diagrams in which relative scores are plotted on scales ranging from 0 to 10. The user of the tool can choose between detailed radar diagrams in which the performance on the individual indicators is shown, or generalised diagrams displaying aggregate scores per 'dimension'. The assumed and often stated (Ibid.), but rarely validated, role of these station profiles lies in the identification of development opportunities by comparing particular stations with each other, and/or by comparing stations within or between their station typology profiles.

In line with earlier work stressing the importance of spatial visualization in collaborative planning support system (PSS) processes (see Andrienko et al. 2007, Pelzer and Geertman 2014), and in order to allow for a better interpretation of the relative scores in the radar diagrams, box B provides the option to display the 'source' maps that are at the basis of the indicator calculations, along with some supplementary maps

[53] All tool descriptions in this section pertain to the 1.0 version that was validated within the context of the workshops. Chapter 5 will elaborate on the 2.0 version which was developed based on the outcomes of the workshops.

[54] The tool is written in R and it uses the Shiny R package to generate the user interface which allows to access a range of R functions such as Leaflet maps and the ggplot2-based radar diagrams.

that might prove useful (e.g. administrative boundaries). Figure 23, for example, displays the land use raster data used that served to calculate the 'diversity' indicators and dimension.

Boxes C to E designate three other tab pages, which all serve to improve the transparency of the tool, a crucial element of a PSS as demonstrated earlier by Vonk (2006), te Brömmelstroet (2010, 2017) and Duffhues et al. (2014). To this end, a tab page is present in which the 'raw' or absolute indicator data are listed for all stations (box D), along with a page detailing the indicator metadata (box E) and a page in which the operationalization and purpose of the indicators is explained in more detail (box C).

### 3.1.3 Research questions

The main research question of this paper is: How useful is the StationRadar tool in the context of the transport region partnership, and how can its usefulness be improved?

In order to make sense of and operationalize the concept of 'usefulness'[55] with respect to PSS, we draw on the conceptual framework developed by Pelzer (2017, see also Pelzer et al. 2014). Building on the work of Nielsen (1993), Pelzer (2017) argues that the usefulness of a PSS is influenced by two main explanatory variables: its 'usability' and its 'utility'. The former has often been the focus of PSS research (for example te Brömmelstroet et al. 2014, Papa et al. 2016, Champlin et al. 2018), and concerns the ease of use of a functionality for the intended end-users (such as its 'transparency', 'user friendliness', 'data quality' or 'communicative value'). 'Utility' on the other hand, concerns the question whether the functionalities of the PSS can live up to the planning task(s) at hand, and whether the PSS fits the phase of the planning process and the scale of the planning issue. Based on this conceptual framework, the main research question can be broken down into two subsidiary questions:

- In what way, and to what extent do the radar diagrams contribute to the usability of the StationRadar tool? What is the role of the maps and the other tool features?

- What is the utility of StationRadar in the context of the transport region partnership?

### 3.1.4 Methodology

In line with the work of Straatemeier et al. (2010)[56], we adopt an experiential research design in which a number of cases are studied in series, in order to allow hypotheses to evolve from one case to the next, and to acquire a deeper understanding of the particular planning context. As stated by Straatemeier (2019: 59), "this methodological philosophy leads to a research process of constantly combining and reflecting on different pieces of knowledge and evidence to try to understand what might be the underlying mechanisms that explain what is happening". This approach directly draws on theories and methods of 'experiential learning' as articulated in the field of education by Kolb and Fry (1975). As explained by Straatemeier (2019: 55), central to this approach is the notion that experiential learning unfolds through "an iterative sequence of interlinked activities, with a continuous shift between reflection and action, the one nurturing the other". The bottom line is the contention that one can only learn the real meaning and value of knowledge by trying and probing it in action, and that learning is a process which closely combines action and thought, experience and conceptualization.

---

[55] A number of other terms are used interchangeably in the literature, such as planning support system 'performance' (te Brömmelstroet 2013), 'effectiveness' (Arciniegas et al. 2013) or 'added value' (Pelzer et al. 2014).

[56] A number of papers revolving around the COST Action TU1002 'Assessing usability of accessibility instruments' (te Brömmelstroet et al. 2014) (see for example te Brömmelstroet et al. 2016, Silva et al. 2017) directly build on this work.

Straatemeier et al. (2010) applied this line of thinking to the fields of planning research and planning practice, and adapted the 'experiential learning cycle' by Kolb and Fry (1975) to fit this new context. The experiential research design should allow connection between the following interlinked activities in a direct and systematic way: 'observation and reflection' (O&R), 'concrete experience' (CE), 'testing in new situations' (TNS) and 'forming of abstract concepts' (FAC). Such a design spiral thus builds on concrete experience (from the side of the practitioners) and aims to gradually enhance the relevance of theoretical improvements (proposed by the academics) for planning practice. As explained by Bertolini (2017: 209), different types of codified knowledge ('abstract concepts') may feed into the cycle such as theories, models or policy transfer. In the case of this research, it is about a combination of both theories (descriptions and explanations about the interaction between transport and land use at transport interchanges as pursued within TOD literature) and a model (the node-place model). Both are subjected to the concrete experience of the stakeholders involved.

Figure 24 illustrates how our research strategy aims to subsequently link three of these loops, by means of workshops in three transport regions. Section 3.1.5 will discuss the different phases of this process.

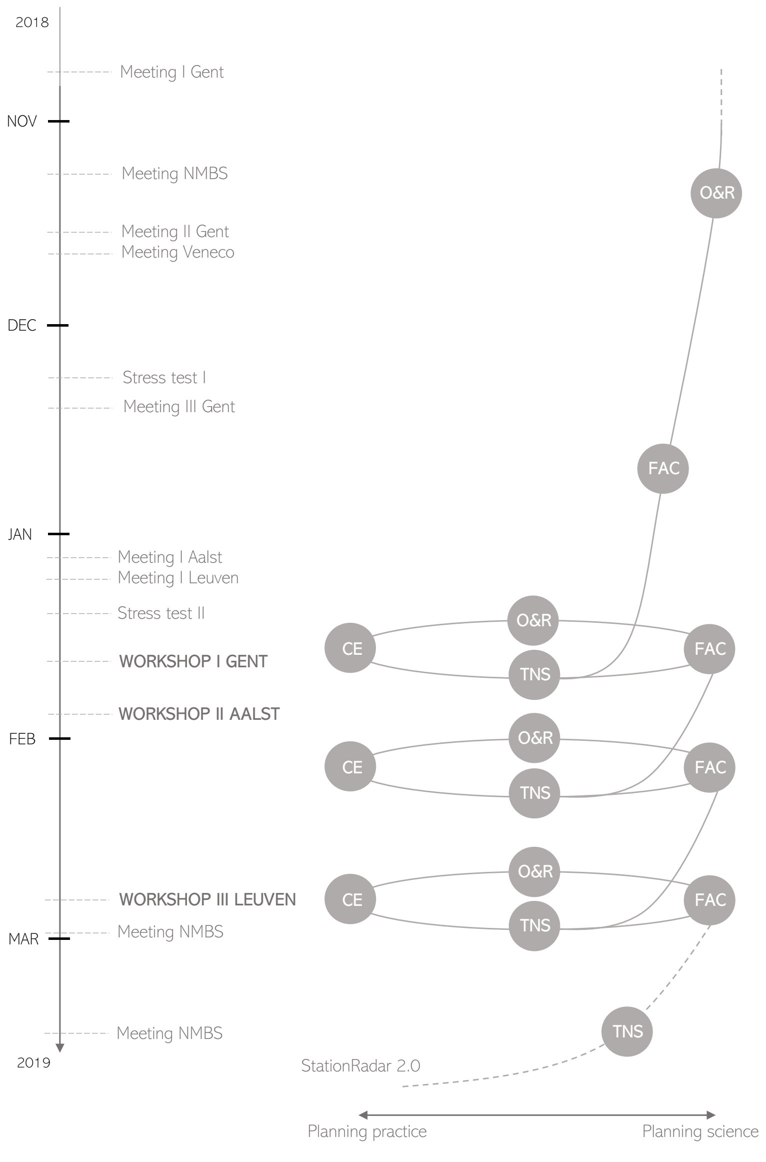



Figure 24: Timeline of workshops and schematised spiralled process (after Straatemeier et al. 2010) (FAC = forming of abstract concepts, TNS = testing in new situations, CE = concrete experience, O&R = observation and reflection)

*A. Workshops and protocol*

As we are not evaluating the usefulness of StationRadar in terms of its effect on the quality of the generated mobility plans (which would arguably require a long-term focus on one particular region), we opted to organise workshops in three *different* transport regions (see Figure 25) with largely similar groups of stakeholders. By doing so, we collect insights from a larger group of stakeholders and are able to deduce to what extent particular findings and recommendations are generalizable across workshops.

Importantly, given the short time span between the workshops (see Figure 24), we were not able to modify the tool after each workshop in line with the participant's recommendations. This has the important repercussion that what *has* evolved experientially as an input for each subsequent workshop are our *hypotheses* about what and why things work, both in terms of the tool usability and utility, but also in terms of the workshop protocol.

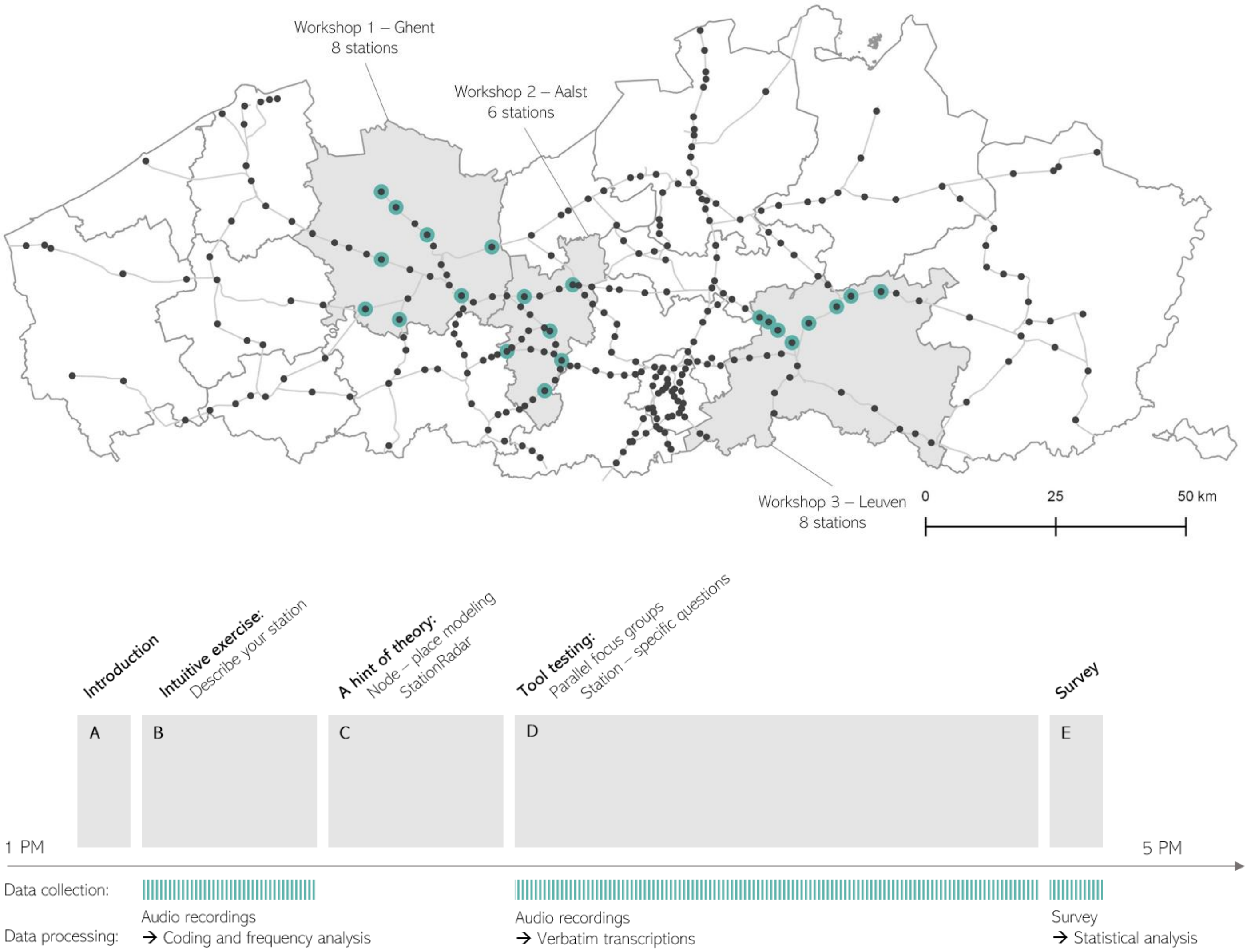



Figure 25: Workshop protocol and selected transport regions with station cases

Our workshop protocol took shape in close dialogue with the local organisers of the first workshop in Ghent. These preparations signaled the start of our experiential learning process, as indicated in Figure 24. The group of local organisers was composed of 4 civil servants from the Provincial Government (1 policy officer for spatial planning, 1 policy officer for mobility and 2 spatial planners of which 1 was specifically trained in setting up participatory workshops) and 1 mobility expert from the intercommunal organization Veneco. The input of these stakeholders was truly valuable in working out the substantive part of the workshops. First of all, given the objective of this research we agreed that the workshop stakeholder composition should closely mimic the composition of the actual transport region council. Second, in order to keep the set-up workable in terms of the number of participants, we decided to make a selection of eight stations in the transport region of Gent (respectively six and eight in the second and third workshop). For each of the workshops, this selection of stations was made by the local organisers and was informed by their own interests in terms of the stations they wanted to have a closer look at, their sense of the willingness of certain municipalities to engage in the workshop and – related to this – their sense of the 'stronghold' individuals in the transport region. Third, we agreed that the 'return on investment' for participating should be high enough, and we therefore prepared summary reports for all participants.

Following the above considerations, we arrived at a workshop protocol consisting of the five main parts labeled A to E in Figure 25.

Introduction. An introduction of the workshop goal and structure, a round-the-table introduction of the participants, and a clarification of how data would be collected and reported (informed consent was requested and obtained from all participants).

Intuitive exercise: describe your station. A round-the-table exercise in which the municipal representatives are invited to briefly describe 'their' station in terms of its accessibility. We asked participants to stick to a description of *three* aspects of their station's accessibility, and briefly presented six possible aspects for them to choose from (feeder mode accessibility, train accessibility, aspects of the station area, aspects of ridership, aspects of the station catchment area and aspects of the people using the station), in line with the radar diagram structure that we showed later on in the workshop. We included this exercise for three reasons. First, it serves as an interactive 'ice-breaker' that introduces the station cases to those not familiar with them. Second, the intuitively sketched station profiles are later on confronted with the empirical radar diagrams, and, third, it allows us to examine the dominant wordings used to describe a station's accessibility, hence the extent to which they are captured by the indicators of the radar diagram. Interventions from us, workshop facilitators, took place whenever participants deviated from the task, or when participants were not clear enough.

A hint of theory. Before moving on to the tool testing in part D, it was essential for participants to become acquainted with the notion of node-place modeling. After introducing the concepts of 'node' and 'place', we explained how the radar diagrams should be interpreted, and how they are incorporated in the StationRadar tool. At the end of this part, participants were invited to explore the tool themselves.

Tool testing. This part is the most important and also the longest part of the workshop. It is conceived of as an actively moderated interactive discussion, organised at two or three interdisciplinary parallel worktables (see Figure 26 for an example worktable setting). Each discussion is structured around a series of station-specific questions which require active tool consultation. For each station, at least four tailored questions were prepared, again in close dialogue with the local workshop organisers. Each question pertains to one of the fields in our radar diagram and addresses a relevant issue regarding the station's development potential. These are some archetypal questions from the first workshop:

- Is it desirable to increase the density of amenities with a supralocal function in the station area?
- Is an expansion of the station's car parking capacity in line with the station's profile?
- The spatial mix of the residential, work and leisure functions is low compared to the other stations. Is it desirable to increase this mix?

- Is it desirable to relocate this station towards a larger urban core in its vicinity?
- Is it desirable to try to cater for more destination flows towards this station? If so, how could this be realised?

In order to address these questions, the participants were asked to consult the radar diagrams and the other functionalities provided by the tool (the maps, the tables, the metadata,...). Importantly, the questions were collectively discussed per worktable, with each of these having at least one facilitator who actively moderated the discussion and made sure that everybody was able to express their opinions. The facilitator also actively steered the discussion in order to zoom in on relevant usefulness statements and to query other's opinions. Hypotheses that evolved over the course of previous workshops were also introduced in the discussion. Part D always concluded with a round-the-table talk in which each participant briefly expressed their feelings with respect to both the workshop and what they had learned (if applicable). Each worktable can therefore be considered to be a focus group.

Survey. At the end of each workshop, participants were asked to complete a survey (which lasted approximately 15 minutes) with Likert-scale statements rated 1 to 5 (from 'strongly disagree' to 'strongly agree'). Space was provided to elaborate on particular statement scores if wanted. The survey composition is further clarified in the next section.

Figure 26: Example worktable setting

*B. Data collection and processing*

Data was collected in the B, D and E parts of each workshop (Figure 25). Both B and D were audio recorded. The accessibility descriptions of B were coded as an input for a frequency analysis in NVivo. The audio recordings of D were transcribed verbatim. The survey (E) Likert scores were processed by means of descriptive statistics in R. The survey design draws on the work of Pelzer (2017) and Champlin et al. (2018) in that it focuses on the following four dimensions: the *participants* and their *background*, the perceived *quality of the workshop process* at the individual and group level (evaluating general satisfaction, insight, communication, shared language, consensus-building and efficiency gains) the *tool usability* (evaluating transparency, credibility, output clarity, focus, level of detail, etc.)and the *tool utility* (evaluating the potential of StationRadar in the context of the transport region). Each workshop was attended and moderated by at least two people of our team[57], who observed, participated and actively stimulated the use of the tool throughout the workshop. Appendix 3.1.I provides a summary sheet of the workshops.

### 3.1.5 Findings

This section starts with a chronologic account of the insights gathered throughout the experiential learning process, from our perspective as academics. We discuss the full process as schematised in Figure 24, and mainly draw on the focus group discussions (part D) to illustrate particular findings by means of citations. Afterwards, we reflect on the results collected in parts B and E.

*A. The StationRadar experiential learning process*

During the preparatory meetings leading to the first workshop, the local organisers expressed a clear interest in the tool. The timing to host an interdisciplinary stakeholder workshop about railway station development potential seemed quite right as the Provincial Government was preparing a new Provincial policy plan in which the principles of transit-oriented development would feature strongly. An academic, and allegedly politically 'neutral', setting in which a sample of crucial stakeholders would be joined under the banner of this new, and quite controversial, theme of TOD, was therefore deemed highly interesting as it would allow our local organisers to 'test the waters' and explore the stance of the different stakeholders with respect to this strategic policy principle. After all, we learned from the Provincial officials how there is some resistance among certain stakeholders concerning the strategy of planning for railway station area development. One of the arguments made is that the railway system is an outdated transport system and that investments need to focus on novel technologies instead. A second reason why the workshop idea was met with enthusiasm, is the abundance of data captured in StationRadar (at the time, our co-organisers were about to start a node-place modeling exercise themselves), and the inclusion of the user-based data captured in the 'people' dimensions of the radar diagram. Thirdly, our co-organisers assumed that the potential of the tool to be useful within the context of the transport region was high; they hypothesised that StationRadar could introduce a *'common ground'* to support supra-local discussions about station development potential, but also expressed the concern that the radar diagrams are *'very mathematical'* which could in turn affect their usefulness.

The above observations and reflections (O&R) initiated the start of the experiential learning process. Although the abstract concepts were formed in the earlier phase of node-place modeling, we slightly readjusted the radar diagrams in line with the feedback received during these preparatory meetings (FAC). After two tool stress-tests with our university colleagues, StationRadar was ready to be tested in the new situation (TNS) of the first workshop in Gent.

At the time of the workshop, the transport region of Ghent had just been established. Prior to the workshop only one informative meeting organised by the Flemish administration had taken place. As a corollary, the members of the transport region council, a large share of our group of participants, had not yet experienced any collective practice or concrete experience (CE). The concrete experience on the basis of which the tool was validated, was therefore mainly stakeholder-specific, instead of it being a collective and cohesive planning practice with well-defined roles and planning tasks.

---

[57] As indicated in Appendix 3.1.I, four team members were present at workshop 1 and two team members were present at workshops 2 and 3. In the former case, the team consisted of a professor of spatial planning and mobility of Vrije Universiteit Brussel, two post-doctoral researchers and myself. The latter two cases included myself and the same professor.

In terms of the quality of the workshop process, main reflections following the first workshop (O&R) were that the tool and the indicators were quite difficult to grasp for those who were not acquainted with node-place model indicators or with TOD in general. As one participant stated: *'Actually we should be able to work with the tool for a longer period of time, let's say a week, in order to give more grounded feedback'*. Due to contractual agreement[58] with the national railway company NMBS, this proposition was not feasible, but we nonetheless came to the conclusion that the workshops should dedicate more time to the 'learning by doing' bit. We therefore decided to allow more individual experimentation with the tool during part C and provide more time for the worktables in D during the next workshops.

In terms of perceived tool usefulness, the main reflections were as follows. First, as hypothesised by our co-organisers, the tool was deemed most relevant for the 'supralocal stakeholders' (the mobility providers, the intercommunal organizations and the Flemish and Provincial Government). A variety of uses on this regional scale were envisioned: to *'better inform regional allocation decisions'*, *'help developing a hierarchy of nodes'*, *'help integrating the different layers and modes of public transport in the region'* and '*function as a communication tool between stakeholders'*. The added value of the tool at the local, municipal, level seemed less evident. Although many participants emphasised the necessity of empirical evidence as an input for local strategy making (the proverb *'meten is weten'*, or *'measuring is knowing'* was frequently used), the evidence conveyed by the radar diagrams was deemed insufficient at this stage, mainly in terms of relevance and level of detail. As one mobility expert stated: *'When I'm asked if we need to increase the bike parking capacity at our railway station, I will certainly not consult the tool for this specific, local, question. No, I will jump on my bike and pass by the station for a couple of months in order to see for myself'*. Most other municipal stakeholders endorsed this view, and also stated that the absolute figures provided in the table were (far) more relevant to them than the relative scores in the radar diagrams. In a similar vein, a civil servant competent for infrastructure argued that '*the influence of the largest stations on the indicator scores of smaller stations is huge and can lead to wrong conclusions. For example, at our station, the diagram indicates there is hardly any bike parking capacity while in fact that way of comparing stations is not very relevant. First of all, our station has no relationship with those large stations and, second, the real question is whether there is still room to park your bike'*. A second, related, reflection concerned the lack of interactivity of the tool and, more specifically, the fact that tool users could not plot radar diagrams as a function of their own desired station selections. This concern arose as some participants thought it made little sense to compare particular stations with other, for example larger or smaller, ones: *'It would make more sense if we could compare stations of a similar size and order'*. Additionally, the tool should allow to plot multiple diagrams next to each other, fostering the ease of visual comparison. Third, we observed and experienced how the NMBS user-based data revealed novel and meaningful insights for the majority of participants (especially to representatives of smaller municipalities who generally lack the resources to frequently update mobility plans and to organise passenger counts or conduct surveys). Unsurprisingly, as we were not allowed to make public the absolute numbers of these user-based data, this prompted some critical comments addressed at the NMBS.

With the above reflections in mind (FAC), we embarked on the second workshop in Aalst (TNS). Contrary to the previous case, the transport region of Aalst was established in 2016 as a pilot project. The concrete experience (CE) of the workshop participants was therefore more developed in terms of being a collective practice. In general, most participants found the idea behind the tool very strong, referring to the integrated approach of mobility and spatial planning and to the *'stimulus'* it could give to *'thinking more regionally'*. Similar to the previous workshop, the difference in perceived usefulness between the local and the regional

[58] For the user-based information included in the radar diagram, the raw data could not be shown in the tool. This protective stance mainly stems from the future liberalization of the Belgian railway sector, which implies that several companies will be allowed to arrange domestic rail travel in Belgium, thus creating a competitive market.

governance scales was quickly raised. However, at one of the worktables an in-depth discussion arose about how the tool's usefulness could be improved for local stakeholders as well, and how this in turn could benefit the transport region's functioning. As a mobility expert explained: *'If the tool would allow for flexible radar diagram comparisons between municipalities, then it might foster inter-municipal dialogues in which certain measures taken and their effectiveness are compared and discussed. For example, if a municipality introduced toll parking at the station, it would be interesting to see, also for neighbouring municipalities, how this affects particular parts of the radar diagram. In this way, the tool could foster a bottom-up, kind of peer-review, dynamic that could reinforce the transport region'.* This statement in turn prompted questions about quality assurance: *'Of course this kind of peer-review dynamic would stand or fall with how frequently the tool would be updated, how recent the data is…'.* Additionally, a series of interesting improvements in terms of diagram visualization were proposed, e.g. the suggestion to visualise the mean or median value for each indicator to immediately get a sense of the distribution of the data hence the exceptionality of your station. Another suggestion was to visualise the absolute number of an indicator score whenever you hover your cursor over that specific piece of the diagram. Or, as one spatial planner proposed: *'It would be great if we could make selections of stations based on one particular theme, such as 'ridership'. In that way, you could easily select stations with similar ridership numbers, plot their radar diagrams and examine how and why they are performing differently'.* These usability statements reveal a similar need for interactivity as was expressed during the first workshop. Another point that had also been raised during the first workshop concerns the difference in expertise and resources between smaller and larger municipalities. As stated by an Alderwoman of Mobility and Public Works: *'The problem is that, and I mainly speak on behalf of the rural municipalities, whenever you have all that information, you need to be able to work with it. You need to have the manpower to get started with it and draw conclusions from it'.* This statement implicitly relates to the perceived complexity of the tool by many participants. As one of our co-organizing mobility experts put it: *'After today's workshop it became clear to me how the tool is of the same level as our transport models or ArcGIS. In other words, you will always need an operator, but that's ok'.*

We concluded that the second workshop led to observations and reflections (O&R) that were largely in line with those of the first workshop, and that the slightly adjusted workshop format now allowed us to sufficiently question and zoom in on the interim hypotheses. We also experienced how some stakeholders (i.e. public transport provider De Lijn and some municipalities) offered to contribute to the tool by providing additional data, which inspired us to rethink the possibilities for tool involvement[59].

With the above in mind, we embarked on the final workshop in Leuven (TNS). Although this transport region had just been established, a large share of participants were experienced in working together on this regional scale (CE) due to their involvement in a project called Regionet Leuven[60]. Similar to the previous workshops, a main observation was that participants requested more flexible station comparisons, and that they stressed the importance of the absolute numbers over the relative scores. Concerning the latter, comments were also made about the normalization of values between 0 (corresponding to the lowest absolute value) and 10 (the highest). As a spatial planner argued: *'It would make more sense to take proportions relative to the highest absolute value. Your point of comparison will distort the results much less, because currently two scores of let's say 546 and 550 will be rescaled to 0 and 10 which distorts proportions severely'.* Along with these suggestions, ideas for additional indicators were proposed such as a 'design for all' indicator (taking into account the accessibility of the station and bus stops for

[59] For example, tool involvement could be improved when users have a possibility to 'flag' that they wish to share additional data. Ofcourse this raises questions in terms of safeguarding data quality and of matching data formats (see also Chapter 5).

[60] Regionet Leuven is a supralocal strategic project comprising the transport region of Leuven. It aims to develop a long term vision for regional development and high-quality public transport and cycling networks.

people with disabilities) and one reflecting the level of road congestion between the station under scrutiny and the most important commuter destinations. At the same time however, other participants questioned the need to further expand the amount of information included and would rather distill the most relevant indicators only. Besides these usability reflections, it became clear how, conceptually, the radar diagram requires a distinct way of thinking that seemed uncommon to many participants. A municipal mobility expert for example asked: *'But why did you opt to compare stations with each other? This diagram totally contrasts with how we are used to look at things. You look completely different at those numbers. We always start by looking at the inflow: how much and how do people get there etc. But these diagrams… It's all so relative'.* A final observation in line with the previous workshops, was the strong interest for the NMBS user-based data. A Provincial policy officer responsible for spatial planning, for example, reflected *'how great it would be if the data about the catchment area sizes could also be visualised spatially, let's say by using rasters so there is no privacy problem. This would be incredibly valuable to better grasp a station's functioning within the transport region'.*

Following the workshops, two additional meetings with NMBS were arranged to communicate our findings and to reflect on the possibilities for disclosing (parts of) the delivered data for public use in an advanced version of StationRadar (2.0). We learned how the user-based data provided by NMBS in the context of this research is only rarely extracted for analytical purposes from the *'enormous pile of data'* the company owns. As one employee argued: *'the mere fact that we have dusted off and tapped into these data as part of your research is very positive'.* The tool was also praised for its accessible user interface in which these and the other data were deemed easily consultable, prompting the idea for a (private) tool spin-off allowing the company to integrate and visualise much more data, such as origin-destination flows. At the time when this section was written, our request in terms of the disclosure of the user-based data was under consideration [ultimately we received the permission to visualize the relative performance in the diagrams, but the absolute data can not be shared]. As an employee stated, *'these data are in fact not that sensitive'* and *'NMBS wants to contribute to the wave of open source applications'* as much as possible. It was also stated how the company wants to collaborate more frequently with universities and research institutes, and how this research is considered a test case.

*B. An intuitive account of a station's accessibility*

The intuitive exercise in part B of the workshop allowed us to examine the dominant wording that was used by the municipal representatives to describe the accessibility of 'their' station, and therefore the extent to which they are captured by the indicators of the radar diagram. We coded the accessibility statements, aggregated them across workshops (N = 22 station descriptions) and analysed how frequently they were used. Figure 27 illustrates the absolute frequencies of the statement codes and the dimensions to which they belong.

As explained above, participants were free to describe three aspects of their station's accessibility, roughly in line with the sixfold structure of the diagram[61]. We intervened whenever participants were not clear enough or deviated from the task. For example, a statement like 'the car accessibility of my station is very good' is insufficiently clear and requires more detail about (in this case) the perceived determinants of car accessibility. As is evident from Figure 27, the vast majority of participants opted to discuss characteristics of feeder mode accessibility (the 'node' dimension), followed by 'place' aspects and 'train' aspects. Aspects pertaining to the lower half of the diagram – intensity of station usage, motivations of the station users and catchment area characteristics – were discussed much less frequently, arguably because a number of

[61] Participants were free to also describe alternative accessibility features that did not fit one of the six options, but nobody opted for this.

participants indicated they had only little insight into these aspects and hence felt less comfortable describing these in front of the group.

On the level of the individual statements, stations were most frequently described in terms of the largest cities they connect to without needing to transfer (coded as 'Train TransferCentrality', 13), the number of car parking spots present at the station ('Car Parking Capacity', 13), and the location of the station with respect to the urbanized area ('Place LocationStation', 13). Examples of statements of the latter are: '*the station is located within a 5 to 10 minutes walk from the city center*' or '*the station is situated at the edge of the city*'. Up next are statements pertaining to the commute and secondary education motivations of the travelers ('Mot Commute', 11 and 'Mot SecondaryEducation', 10), to the size of the catchment area ('Eff SizeCatchmentArea', 10), car parking utilization ('Car ParkingUtilization', 7), train frequency per hour ('Train HourlyFrequency', 7), the kind of environment the station is situated in ('Place StationEnvironmentType', 7) (for example: '*in the middle of the fields*', '*in a very residential environment*', '*in an open landscape*') and the number of boardings on a weekday ('Rid BoardingsWeekday', 7).


Figure 27: Schematic overview of the statement frequencies

On a more general level, some conclusions that can be drawn from this are that, first, most of the statements center around the station feeder modes (the 'node' dimension capturing car, bike and public transport accessibility), with the car featuring most prominently (42 statements, compared to 34 for the bike and 24 for public transport). Second, although 'place' characteristics were frequently discussed, the standard TOD dimensions of 'density', 'diversity' and 'design' (see Cervero and Kockelman 1997) were hardly mentioned or referred to. For example, statements about land use diversity and design of the built environment (walkability) were both mentioned in only 3 out of 22 cases. This could be due to the underrepresentation of spatial planners and urbanists in two out of three workshops. Third, we concluded that some of the frequently mentioned characteristics were not incorporated in StationRadar: parking utilization data, parking quality data, road congestion data, and more 'soft' user-based data about the accessibility of the platforms and safety at and around the station. When combining these observations with our insights from the focus groups, we concluded that some of these characteristics (most notably parking utilization data[62] and road congestion data[63]) are indeed deemed crucial and should find their way into StationRadar 2.0.

*C. Survey results*

The post-workshop survey focused on four dimensions: the background characteristics of the participants, the quality of the process (individual and group), the tool usability and the tool utility. The latter three dimensions will be discussed below, by means of visualizations of the most relevant five-point Likert scale statements and their ratings across the workshops. When relevant, written survey statement replies are also cited, along with the results of one-way analyses of variance (ANOVA). These analyses are used to assess whether there are any statistically significant differences between the means of particular statement scores for the different groups of participants (we tested for age and sex categories, but also for 'organization' and 'background', see Appendix 3.1.I). In total, 43 surveys were completed.

<u>Quality of process</u>

We evaluated the perceived quality of the workshop process at the individual and group level based on 11 statements (some of them are included in Figure 28). At the individual level, the majority of participants expressed positive feelings about the workshop and stated to have required new insights, such as: *'the tool gives a clear insight into the factors that influence the node and place values of a station'* or *'this multidisciplinary approach was new to me'*. Results are more diverging for statements 3 and 4 (Figure 28). As for 3, a large share of the participants stated that the viewpoints of other participants were already sufficiently clear, while others argued that the tool enabled them to better understand the logic of NMBS, or that it helped *'to see things through the lens of other stakeholders'*[64]. As for 4, a majority of participants (strongly) disagreed with the statement or rated it with a 'neutral', which may in part be explained by the recent character of the transport region concept. As two participants stated: *'the division of roles for mobility planning in the region is still very unclear'* and '*there is no coordination of roles yet within the transport region'*. These opinions echo our earlier statement about how the 'concrete experience' within the transport region planning practice had not yet matured at the time of the workshops, which has important repercussions for the inferences made.

[62] At one of the post-workshop meetings with NMBS (see Figure 24) the 'Stations' department of NMBS decided to deliver us all available data in terms of bike and car parking utilization rates.

[63] We are currently still looking for this data at the regional scale of Flanders, and ideally also Brussels.

[64] The results pertaining to statements two to four raise the impression that 'double loop learning' (see originally Argyris and Schön 1973) might have occurred to some extent during the workshops. As explained by Pelzer and Geertman (2014), contrary to 'single loop learning', this type of learning emerges when insights into the way in which other disciplines perceive and address a planning issue increase. When this kind of 'frame reflection' takes place during the course of a specific task (such as the tool testing tasks during part D of the workshop), Schön (1987) speaks of 'reflection-in-action', to indicate that practitioners are "thinking what they are doing while they are doing it".

At the group level, participants stated that the social dynamic at the worktables was constructive, that time was used efficiently, and that there was a shared professional language (statement 5). Drawing on our experience as focus group moderators, we can corroborate the latter as we felt that most participants indeed used and mastered the node-place jargon towards the end of the workshop. Statement 6 in turn has a high proportion of blanks, which might be explained by the fact that some of the station-specific questions or statements were not addressed because the discussion deviated from this task.

Usability

The survey included 22 usability statements, 14 of which specifically focused on the radar diagrams (Figure 29 includes eight of them), and the remaining ones on the StationRadar tool (Figure 29 includes six statements). As statement 7 illustrates, the majority of participants finds these type of visualizations useful, provided that some of the limitations detailed above are tackled. Similarly, most people do not perceive the radar diagrams as being too abstract, *'as long as you fully realise what you are comparing and what the scores really mean'*. Or, as one participant noted: '*For me it's all about the scale of abstraction. It's fine to compare between stations on a regional scale, but on the level of let's say 1 station, a radar diagram is removed too far from reality and in this case, I am more in favour of the combination of multiple tools to approach reality'*. Or: *'In order to make sense of this complex matter, I don't think you can proceed differently than through an abstraction of reality'*. Interestingly, the ANOVA test for statement 7 in terms of the participants organization is statistically significant (between groups, p = .048), indicating how the stakeholders operating on a supra-local scale value the radar diagrams more strongly than the municipal representatives (this is especially the case for mobility provider De Lijn, the intercommunal organizations and both the Flemish and Provincial Governments). These results echo the focus group findings discussed above.

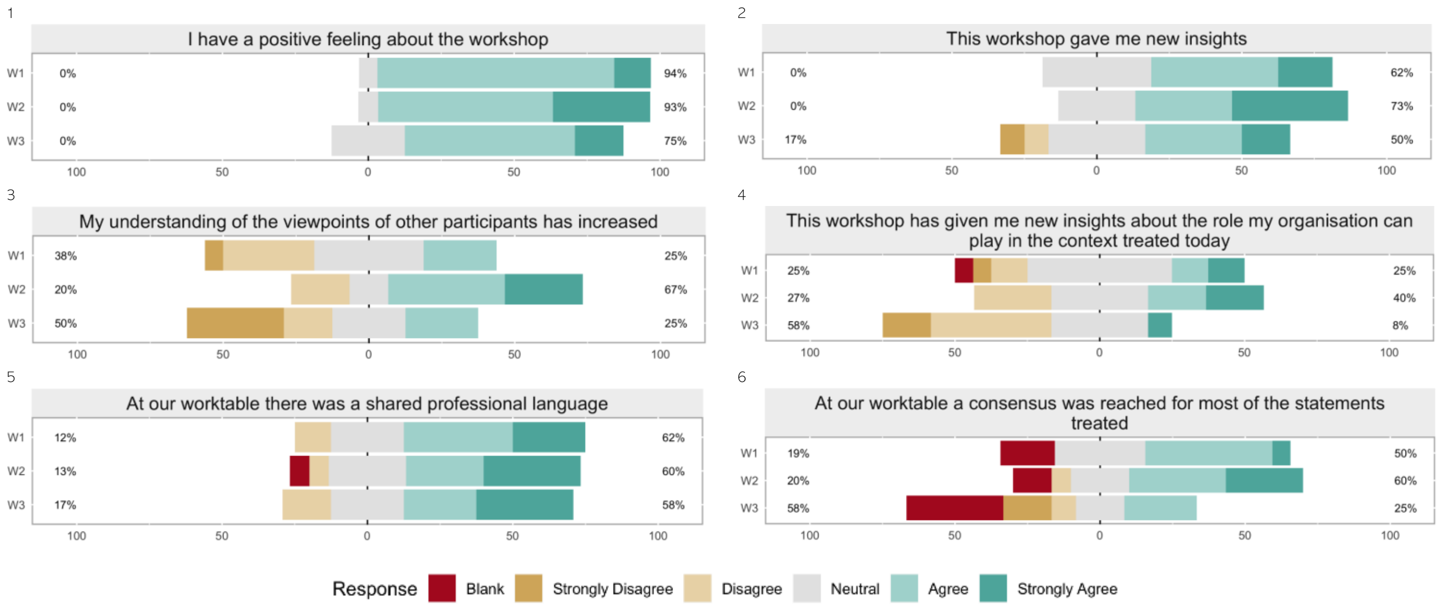



Figure 28: Quality of process - Likert scale statements

As for statements 9 to 12, the results indicate how the workshop set-up did not provide enough time for most people to be able to respond to these statements in a properly informed way – this was also explicitly stated by most participants. Suggestions for extra dimensions and indicators were nonetheless made, and are mostly in line with the ones raised during the focus groups. With respect to the communicative value of the diagrams (statement 13), opinions are divided. Those that do not agree mostly refer to the extensive knowledge required to interpret the diagrams, and therefore argue that it is *'definitely not a quick visualization tool'*. In a similar vein, some also state the communicative value is only tangible for *'professionals'*. Besides that, many participants noted that the communication potential of the generalised diagrams is certainly higher than the detailed diagrams. The latter contention somewhat contradicts with the ratings for statement 14, as it seems that the majority of participants is clearly of the opinion that there are not too many indicators in the diagram.

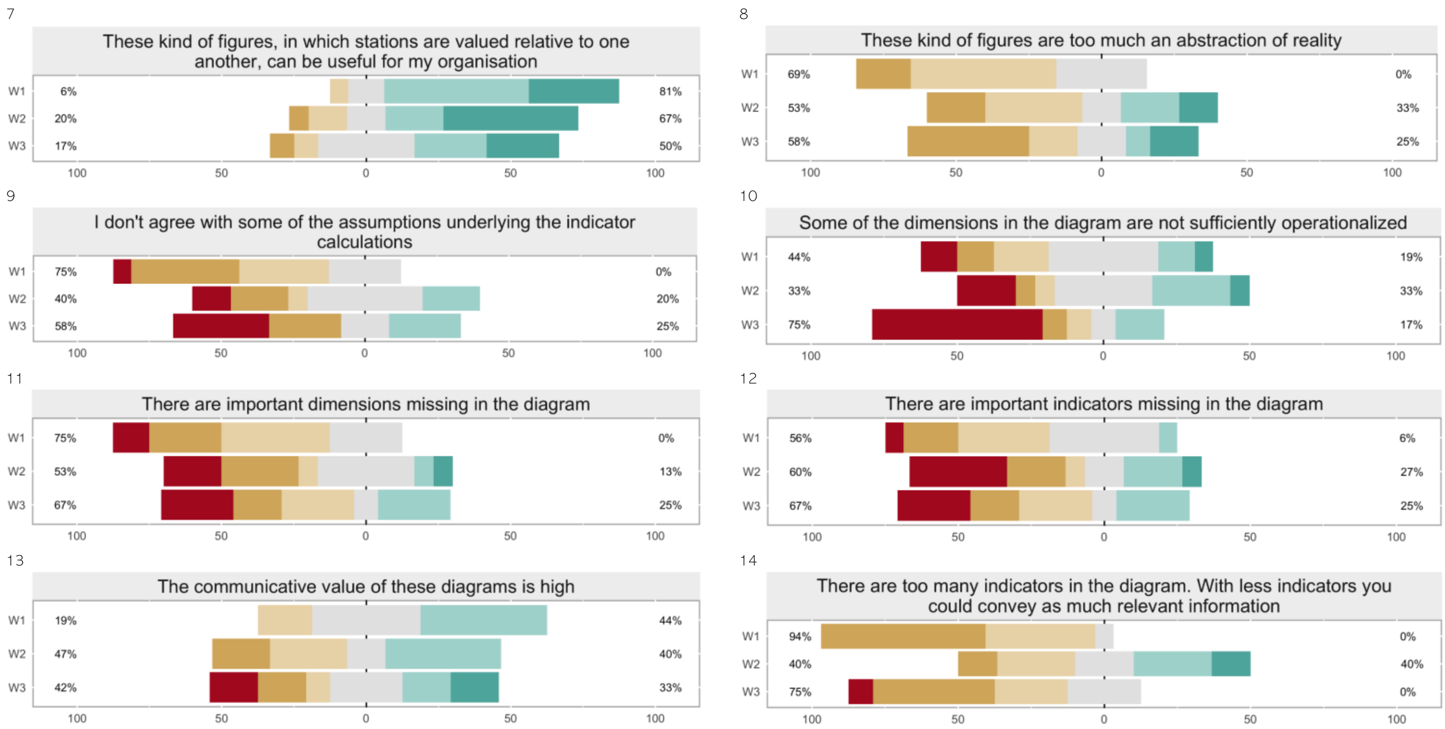



Figure 29: Radar diagram usability - Likert scale statements

Another usability question consisted of asking the respondents to rate each dimension in terms of their importance on a scale from 0 to 5. The results (see Appendix 3.1.II) indicate how, in general, the left and middle sides of the diagram (corresponding to the node, train, effort and user intensity dimensions) are deemed most important, while the right side (place and motivations) receives lower scores. The catchment area dimensions in particular are deemed very important, along with the accessibility of the station by bike and public transport. The motivations of the station users and the place characteristics (especially diversity and design) are deemed less important. However, this general image changes when results are disaggregated according to the participants' backgrounds (mobility or spatial planning). Interestingly, spatial planners tend to value the importance of the place dimensions (density, diversity and design) more strongly than their counterparts, and the accessibility by car is also deemed less important. When running a series of one-way ANOVA tests to discern whether these differences in mean values are statistically different between both groups, only the 'design' dimension returns a significant result ($p = .045$).

These results also expose a mismatch in terms of – on the one hand – the intuitive station descriptions discussed above, which arguably reflect the features of stations that the participants were most familiar with and most comfortable with describing, and – on the other hand – the stated importance of the different dimensions as illustrated in Appendix 3.1.II. Although aspects pertaining to the 'effort', 'ridership' and 'motivation' dimensions were rarely mentioned during the intuitive exercise, they are clearly perceived as being about equally important as the 'node', 'place' and 'train' dimensions. The 'effort' dimensions of 'walking distance' and 'bike distance' in particular, are perceived as very important in both groups (mobility and spatial planning backgrounds).

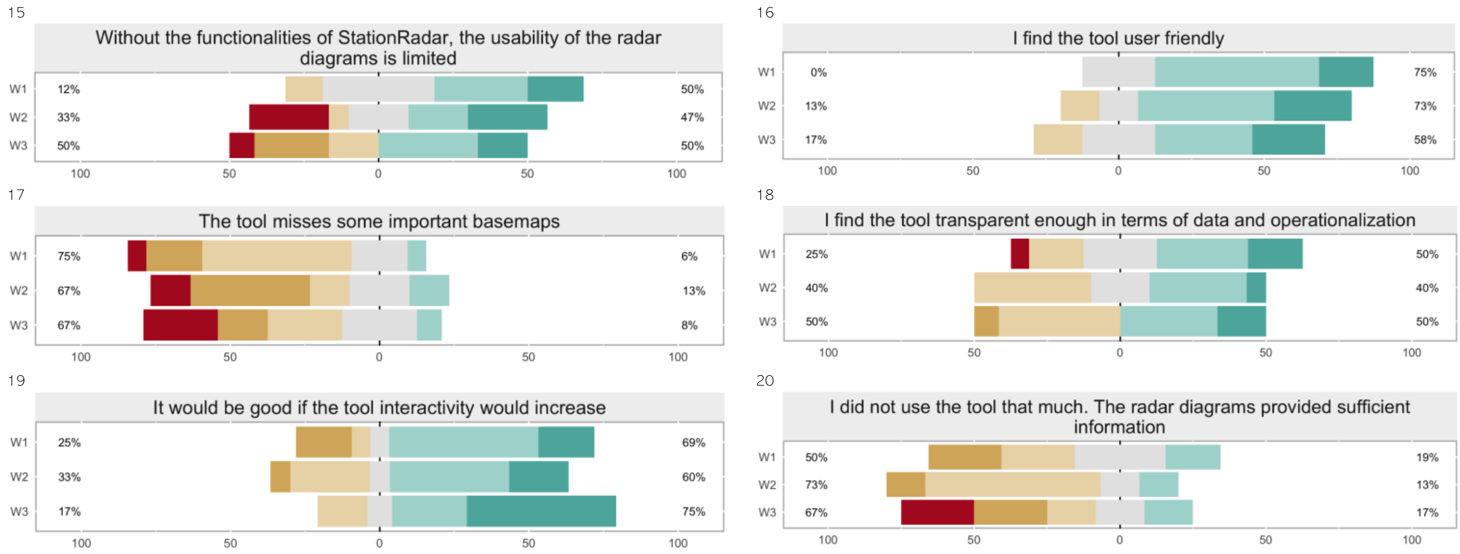



Figure 30: StationRadar usability - Likert scale statements

When moving to an assessment of StationRadar's usability (Figure 30), the following observations can be made. First, most participants consider the embeddedness of the radar diagrams in the tool crucial (as revealed by statements 15 and 20). Second, the majority finds the tool user friendly and does not think important cartographic material is missing. As for the latter, some interesting suggestions were nonetheless made, such as: '*it would be interesting to add a layer visualising the expected demographic growth in the region, and a layer that informs which type of people are living in the station area (age, income, …)*'. Statement 18 in turn reveals how opinions diverge on the perceived transparency of the tool and the statement 19 ratings echo the above mentioned critiques in terms of tool interactivity (mainly in terms of the ability to make tailored station comparisons).

Utility

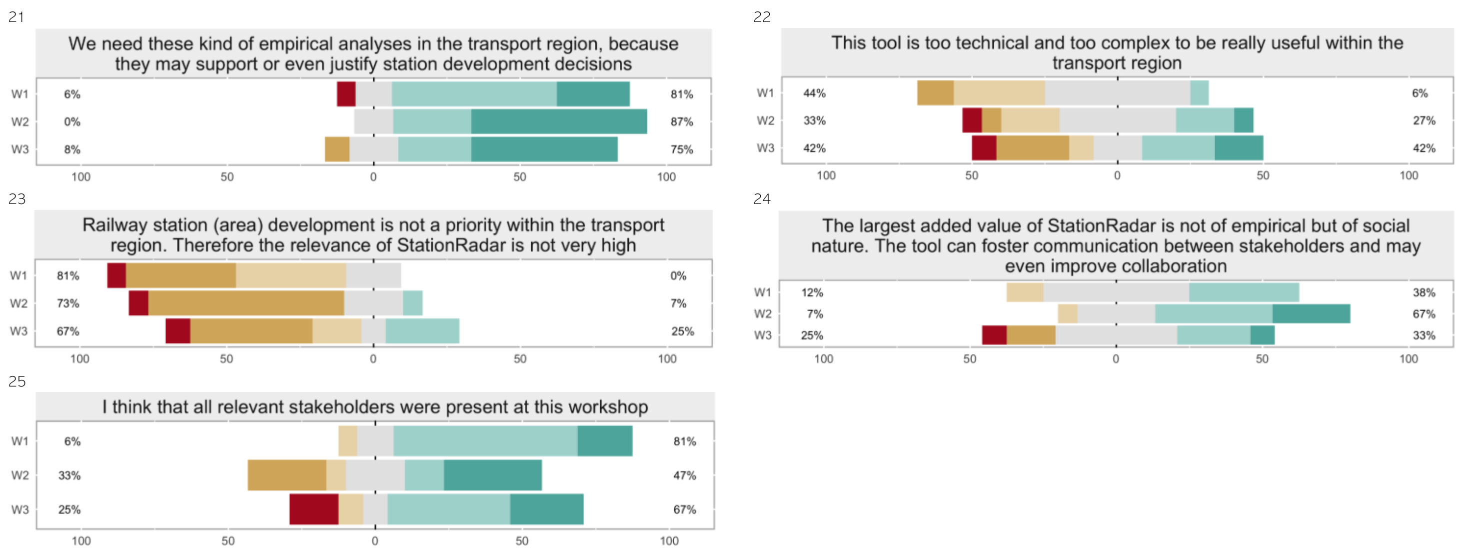



Figure 31: Utility - Likert scale statements

In terms of utility, the survey included five statements. The first examined to what extent these kind of empirical analyses are deemed relevant within the transport region. Judging from Figure 31, the vast majority of participants in all three workshops clearly (and strongly) agree with statement 21, provided that the usability limitations of the radar diagrams are tackled. The number of 'neutral' and 'blank' replies are very small, reflecting a quasi consensus. Statement 24 nonetheless reveals how a significant share of participants consider the tool to be most meaningful in terms of social interaction: communication, discussion and collaboration. Opinions nonetheless diverge. One participant stated that *'this is indeed a very important added value'*, two others noted that *'both aspects are relevant'*, while somebody else considered social interaction as *'a nice side-effect of the tool'*, and another participant hypothesised that *'the tool will not bring stakeholders around the table'*. The latter could be related to the perceived complexity of the tool by a (smaller) part of the participants, as indicated by statement 22, although the majority disagrees that this complexity could hinder its usefulness within the transport region. Written feedback mainly focuses on the usability limitations raised above. Tool utility is moreover determined by the priority given to railway station (area) development in the transport region, and the extent to which this is expected as part of the regional mobility plan (statement 23). In this respect, most participants argue that *'TOD is very important'* and refer both to the decree on basic accessibility (see Section 1.1.4) and the preparations for Flanders' new spatial policy plan in which the railway network is considered the backbone for future spatial development (Flemish Government 2017, 2018b). Others stress that the 'node value' is just one aspect, and that the 'place value' of other non-railway station locations is equally important, or argue that *'there are large areas within the transport region without railway stations or railway line. Important bus stops could or should be added to the tool'*. Another participant argued that *'the main question is how to reduce car traffic in favour of train traffic and other public transport. Therefore, mainly biking and walking from and towards the railway stations needs to be prioritised'*. A final utility statement (25) concerns the stakeholders involved in the planning task. The majority of participants argued that all relevant stakeholders were present at the workshop. Those who disagreed were participants from workshop two where NMBS was not represented, and participants from workshop three where De Lijn was not represented. Other absent stakeholders registered in the surveys are *'Infrabel'*[65], *'policy representatives'*, *'other spatial stakeholders'* and *'representatives of large companies'*.

### 3.1.6 Discussion and conclusions

This section reported on an experiential approach to the development of a node-place based planning support tool in the context of the transport region partnership in Flanders. At the root of this research project was the observation that NPM concepts, assumptions and outcomes are rarely tested and validated in close dialogue with the intended end users of the conducted analyses and developed tools. This is surprising, since the majority of studies touch upon the interface between planning practice and planning research, and foreground, or at least hint towards, the usefulness of their empirical outcomes for (a variety of) stakeholders involved in station (area) development. In order to help bridge this gap between NPM research and practice, we adopted an experiential research strategy and organized a series of workshops in which we put the recently developed, node-place based, StationRadar tool to the test. Arguably, given that participants were subjected to only a small part of one single experiential learning loop (a one-off half-day workshop), interdisciplinary learning effects (if any) on the side of the practitioners were likely very modest. Although the survey gauged for perceived (individual and group) learning effects and the Likert scale ratings returned all in all positive appreciations, the strongest learning effects arguably occurred at the planning research side of the spectrum (i.e. us, workshop moderators and tool developers).

[65] Infrabel is the infrastructure manager of the railways in Belgium.

In the course of the process and in line with a standard experiential design, (usability and utility) hypotheses were continuously revisited and fine-tuned as an input for each successive workshop. In other words, important factors that were raised during the focus groups or during other parts of the workshops were captured and were introduced by the moderators during the subsequent workshops. For example, during the first workshop, a number of participants argued that the added value of the tool would be less evident for the local, municipal organizations. This hypothesis was afterwards introduced during the second and third workshops in order to acquire a deeper understanding of the underlying reasons for this apparent barrier to usefulness.

However, contrary to the seminal work of te Brömmelstroet (2010) and Straatemeier (2019), during the process the tool itself was not modified based on the comments received. The reason for this is that we lacked the capacity to do so within the short timespan in which the workshops were organized. This has an important methodological drawback in that the received feedback is based on assumptions, and is therefore not grounded in actual 'before and after' experimentation. On the other hand however, as the workshop protocol was uniform in all cases, this approach allowed us to aggregate across workshops, yielding a sample size of 45 respondents which was large enough to enable statistical analyses. Moreover, given that the feedback across workshops is mostly consistent, our conclusions are straightforward and consensual.

In terms of usability, we can conclude that StationRadar has the potential to become a functional and helpful tool for different stakeholders in the region, provided that some important limitations are tackled. Regarding interactivity[66], users should be allowed to manually select the stations they want to compare with each other, and the diagrams should be plotted on the fly accordingly. Additionally, interesting ideas were raised to experiment with visualizations of indicator-specific station comparisons. In terms of transparency, it is absolutely crucial to disclose all raw data underpinning the relative scores in the radar diagrams, and in terms of user friendliness, the relative scores need to be weighted in a more intuitive way, i.e. proportional to the highest score in the distribution. Opinions about the perceived communicative value of the diagrams currently diverge, but will arguably converge once the above recommendations are tackled. A final usability remark deals with the level of detail provided by the tool. Compared to earlier NPM research, the radar diagrams can be considered very detailed as more dimensions were added and as all underlying indicators can be displayed. Judging from the survey results, the majority of participants (strongly) appreciated this level of detail. Unfortunately, the workshop set-up did not allow for a more thorough examination of the indicators and their operationalization. A future validation of the indicators as part of StationRadar 2.0 (by means of surveys or another multi actor workshop) is therefore a sensible next step.

The above observations and reflections have a broader significance for the NPM literature, as the practice of developing visual renderings of station-specific performance levels seems to become more prevalent (Balz and Schrijnen 2009, Province of North Holland and Deltametropolis Association 2013, Singh et al. 2017, Vale et al. 2018, Caset et al. 2018, Groenendijk et al. 2018, Nigro et al. 2019) (see also Figure 8). Although each planning context is unique and each NPM analysis originates from a particular problem statement, it may well be the case that certain usability traits in terms of node-place modeling are transferable across cases.

In terms of utility, we believe our findings are less straightforward and consensual at this stage of the research, and will require further examination. Although there seems to be a clear consensus about the need for this type of empirical evidence in the transport region, and about the importance of putting TOD

[66] One way in which we tackled these interactivity recommendations is by scaling the landing page of the project to a Vue.js and D3.js based web app, which allow for more flexibility and interactivity. Recently, we witnessed the emergence of similar webtools such as the Urban Mobility Index (urbanmobilityindex.here.com/) which use JavaScript, react.js/vue.js together with beautiful user interfaces to present often complex data in a simple and reactive way.

on the regional agenda, there is still much uncertainty about the exact role that StationRadar could fulfill within this multi actor setting. Due to the recent character of the transport region partnership and the timing of the workshops at the very start of this planning process, the planning practice to which StationRadar was subjected can be considered 'premature'. Among some of the participants, there was much uncertainty about the subjects that will be prioritised in the region, how (frequently) the meetings will be organised, what is expected from them and what exactly is expected in light of the regional mobility plan. This uncertainty obviously hinders an adequate assessment of StationRadar's utility in the region. A future research step will therefore deal with the organization of additional interviews with representatives from the different supra-local partners, in which we will aim to deepen our understanding of the 'fit' between the tool and the concrete regional planning task(s) at hand (see Section 3.2).

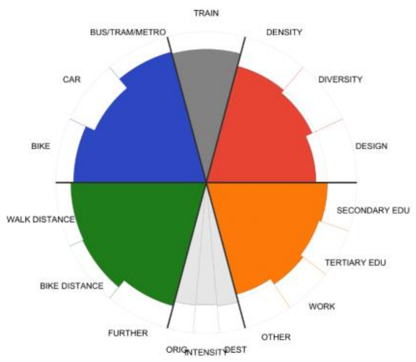
From a valorization point of view, the most noteworthy contribution of this research project arguably consists of the actor-mobilising and data-disclosing potential of the tool. We experienced how different stakeholders spontaneously contacted us with the intention to contribute by delivering data. Besides that, NMBS approved the public dissemination of the radar diagrams in the context of the tool[67]. As such, we hope to somehow fuel the momentum initiated by the transport regions to put sustainable mobility, quite literally, on the map.

[67] Ultimately, permission was not granted by NMBS to display the absolute data underpinning the 'effort', 'motivation' and 'ridership' dimensions in the tool due to the commercially sensitive nature of this data.

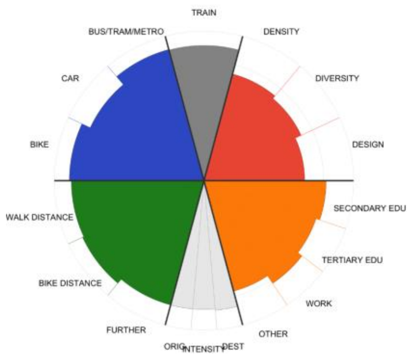
*Appendix 3.1.I – Summary sheet workshops*

| | WORKSHOP GENT<br>17-01-2019 | WORKSHOP AALST<br>25-01-2019 | WORKSHOP LEUVEN<br>21-02-2019 |
|---|---|---|---|
| **Participants** | 16 | 15 | 14 |
| Organization | | | |
| *Municipality* | 7 | 10 | 6 |
| *Intercommunal org.* | 2 | 1 | 1 |
| *Flemish Government* | 2 | 2 | 3 |
| *Provincial Government* | 3 | 0 | 3 |
| *NMBS (railway company)* | 1 | 0 | 1 |
| *De Lijn (bus company)* | 1 | 2 | 0 |
| Background | | | |
| *Mobility* | 10 | 10 | 7 |
| *Spatial planning* | 4 | 3 | 7 |
| *Other* | 2 | 2 | 0 |
| Age category | | | |
| *<30* | 4 | 3 | 2 |
| *31 - 45* | 6 | 5 | 5 |
| *46 - 60* | 5 | 6 | 7 |
| *> 60* | 0 | 1 | 0 |
| Sex | | | |
| *Men* | 11 | 9 | 8 |
| *Women* | 5 | 6 | 6 |
| *Other* | 0 | 0 | 0 |
| **Worktables** | 3 | 2 | 2 |
| **Facilitators** | 4 | 2 | 2 |
| **Station cases** | 8 | 6 | 8 |
| | Eeklo | Wichelen | Haacht |
| | Waarschoot | Dendermonde | Wespelaar-Tildonk |
| | Evergem | Aalst | Hambos |
| | Beervelde | Burst | Wijgmaal |
| | Deinze | Denderleeuw | Wezemaal |
| | Eke-Nazareth | Ninove | Aarschot |
| | Landegem | | Langdorp |
| | Melle | | Testelt |

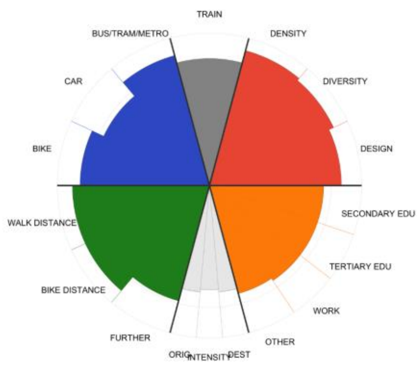
*Appendix 3.1.II – Rated importance of the dimensions (mean values)*



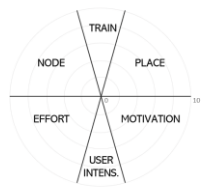

a) All (N = 43)




b) Mobility (N = 27)




c) Spatial planning (N = 14)



## 3.2 Questioning the intersections between ‘task’ and ‘technology’: StationRadar and the case of the transport region[68]

The previous section discussed the added value of StationRadar from the perspective of its perceived usability. Not only did most of the survey questions revolve around that criterion, the design of the focus groups was also mainly catered towards answering questions regarding the tool’s features and functionality. Although we explored the perceived utility of the tool to fit the planning context of the transport region (both in the survey as well as in the focus groups), we did so in general terms. Moreover, as the transport region partnership had just been established, uncertainty about its precise functioning prevailed with many participants. Drawing on the surveys and the focus groups, we were nonetheless able to distill some generic findings and hypotheses. We learned that the empirical evidence presented by StationRadar was perceived highly welcome to the vast majority of stakeholders, that TOD should be high on the regional agenda, and that StationRadar has the potential to facilitate interdisciplinary discussions and collaboration.

These preliminary findings nonetheless stop short of the level of articulation needed to comprehend the potential of the StationRadar planning support tool developed in the context of the transport regions. For this reason, the aim of this section exists of examining in more detail the fit between the planning tasks at hand and the tool[69], by drawing on the conceptual framework explained in Section 3.1.3. In doing so, we aim to answer questions such as ‘What exactly is expected from the transport regions in terms of planning tasks?’, ‘How and where exactly could StationRadar fit into that process?’, ‘Are there potential barriers that may inhibit the implementation of the tool?’. To this end, we conducted a series of clarifying post-workshop expert interviews in which we specifically questioned the respondents on this matter.

The remainder of this section is organized as follows. First, we will zoom in on the construct of ‘utility’ and how we aimed to apply it to this case (Section 3.2.1), followed by a clarification of the research strategy (Section 3.2.2). Afterwards, the findings are discussed in Section 3.2.3, followed by a discussion and conclusion in 3.2.4.

### 3.2.1 Conceptualizing ‘utility’

As clarified in the previous section, PSS usefulness may be considered an outcome of two explanatory variables: usability and utility (see Pelzer et al. 2015 and Pelzer 2017). Within Pelzer’s (Ibid.) framework, the latter is defined as the ‘fit’ between ‘task’ and ‘technology’ and has emerged from the fields of management information systems and group support systems. For example, for the case of information systems, Goodhue and Thompson (1995: 214) developed a ‘task-technology fit model’ and stated that “performance impacts will result from task-technology fit – that is, when a technology provides features and support that ‘fit’ the requirements of the task”. The definition put forward by Dishaw and Strong (1998: 154) is very similar: “The matching of the functional capability of available information technology with the activity demands of the task at hand”. Task-technology fit theory has been applied across different contexts resulting in many different definitions (see Furneaux 2012, Howard and Rose 2018).

Building on this line of reasoning, we arrived at the conceptual framework that is illustrated in Figure 32. On the left hand side – and indicated in gray tones – we illustrate how the tool features (such as the maps and the interactive radar diagrams) may deliver certain support capabilities. Combined, these constitute the

[68] The interview quotes that are reported in this section are own translations from Dutch to English. We have tried to convey the gist of the original fragments as closely as possible.

[69] Importantly, we draw on the 2.0 version of the tool (see Chapter 5), which has some improved features compared to the beta-version that was used in the workshop.

'functional capability of available information technology' as stated in Dishaw and Strong's definition above. Drawing on the work of Geertman and Stillwell (2003) and Klosterman and Pettit (2005), Vonk (2006: 79) distinguished three types of support capabilities – informing, communicating and analyzing:

> The first type of *informing PSS* aims to make planning related knowledge and information accessible and interpretable by the flow of planning related information from an access point or sender towards a user. The second category of *communicating PSS* aims to facilitate communication and discussion between those involved in planning through supporting flow of planning related information between them. These PSS may incorporate informing or analyzing functionality, but the primary aim is always communication support. The third category of *analyzing PSS* aims to facilitate advanced processing of data and information in order to find patterns and underlying processes, and aims to facilitate information modelling for projection, simulation and evaluation.

When applying this categorization to the case of the StationRadar tool, we hypothesize – based on the findings discussed in Section 3.1 – that certain tool features (the tables and the metadata) serve *informative* purposes whereas the maps, the interactive radar diagrams and the additional graphs (see Chapter 5) serve *communicative* purposes. Given that StationRadar does not allow scenario-building, predictive analyses or monitoring functions, we believe the analytical type of support to not be applicable here. Importantly, and divergent from Pelzer's schematic overview (2017: 86), we do not consider these support capabilities as isolated from the tool's perceived usability. Instead, we consider perceived usability as a prerequisite to arrive at certain support capabilities. In other words, we argue that, whether or not the tool features may ultimately deliver these capabilities depends entirely on the perceived[70] usability of these features by the end users of the tool[71]. This conceptual modification has broader repercussions for the ways in which usability and utility relate to one another. Whereas Pelzer (2017) considers both as separated entities, Figure 32 illustrates how – within our conceptualization – utility may be impacted by changes in the tool features. These tool features may in turn be modified based on usability feedback from tool users. The arrow between usability and the tool features points in both directions, as feedback from a usability assessments can lead to improvements in tool features and – possibly – support capabilities whereas, conversely, tool feature modifications can also impact the perceived tool usability. Utility, on the other hand, is conceptualized as a dependent variable only. It is dependent of the support capabilities of the technology and the nature of the planning tasks the tool is supposed to support. The former can only be impacted by intervening on the side of the technology (hence the arrow directing towards that area), whereas the latter – the nature of the planning task – is (usually) static and given.

The right hand side of Figure 32 pertains to the 'task' part of the utility equation. Similar to the other building blocks of the proposed conceptual framework, this construct requires some codification. Drawing on earlier work revolving around planning support tasks of PSS (for example Batty 1995 and Geertman and Stillwell 2009), Pelzer et al. (2015) developed a conceptual framework in which three types of planning tasks are distinguished: 'exploration', 'selection' and 'negotiation'. As explained by Pelzer et al. (2015: 158, emphasis in original):

> *Exploration* concerns the generation of a range of ideas, challenges or alternatives, and is sometimes referred to as divergence. For instance, developing a range of scenarios about how a city will look like in the future. Or using predictions to explore how the future of a city region might evolve. *Selection*, sometimes referred to as convergence, concerns choosing (a set of) assumptions, indicators, etc. Analysis can contribute to this selection process, which ranges from rather detailed tasks in professional settings (e.g., what will be the

[70] Importantly, a tool's usability and utility are ultimately dependent on subjective evaluations of the individuals using the PSS. As explained by Goodhue (1995: 1827, emphasis added): "User evaluations are elicited *beliefs* or *attitudes* about something". Therefore, we framed both as 'perceived usability' and 'perceived utility' in Figure 32 and in the above.

[71] As a corollary, a question mark was inserted between both building blocks in Figure 32. The purported effects of the tool features do not necessarily result in the hoped-for support capabilities.

exact location of a convenience store?) to fundamental decisions taken by politicians (e.g., will a shopping mall be built in this neighbourhood or not?). In the case of PSS the emphasis tends to be on the former. In a planning situation where there is full agreement among the involved stakeholders, exploration and selection tasks suffice. However, this is hardly ever the case as planning often involves conflicting interests. Therefore there is a third task: *negotiation*. Negotiation can be defined as a task in which actors try to reach an agreement through an iterative process, with elements of bargaining and compromising.

Drawing on the conceptual framework illustrated in Figure 32, the purpose of the qualitative work presented in this section is to acquire a deeper understanding of the planning tasks that are expected from the transport region, and to relate these to the (hypothesized) support capabilities of StationRadar in order to better probe StationRadar's utility. The next section will elaborate on the adopted research strategy.

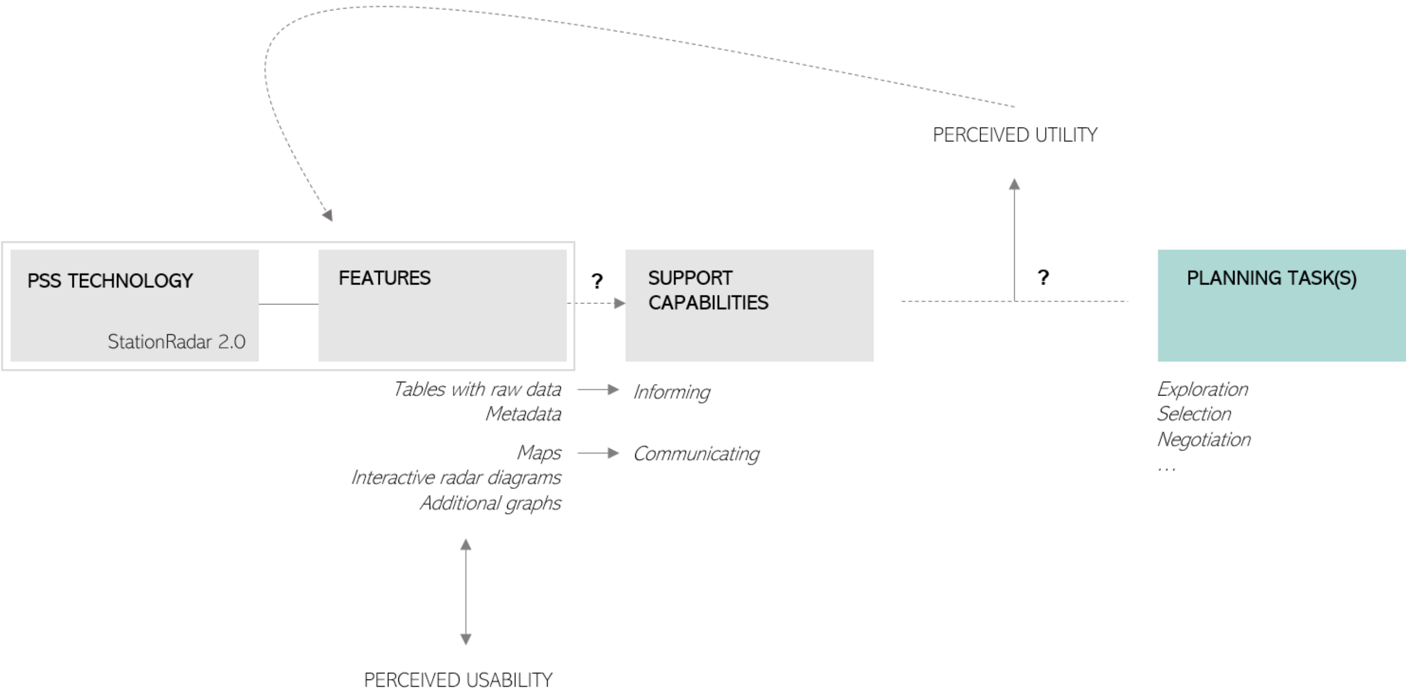



Figure 32: Schematic illustration of conceptual framework

### 3.2.2 Research strategy

We conducted seven follow-up semi-structured expert interviews which served the clarifying purpose of gaining a deeper understanding of the planning tasks at hand within the transport region and the fit with the StationRadar planning tool. To this end, we developed a funnel-style interview protocol that started off with broad, open-ended questions pertaining to the transport region and the nature of its planning tasks, and evolved towards more narrow questions which more specifically zoomed in on the role that StationRadar could fulfill with respect to the tasks outlined earlier on by the interviewee. All interviews were audio-recorded (consent was requested and obtained[72]).

The interviewees were selected for based on their experience. Given the nature of our questions, we particularly aimed for respondents who are either actively involved in one or more transport regions, or who operate on a coordinating level within the departments of Mobility and Public Works or Environment. Table

[72] Any quotes that will follow later on in this section were submitted for consent prior publishing.

7 provides a list of the expert interviews, detailing timing, place, organization and function. Expert 7 was also involved in one of the workshops.

| *Expert* | *Timing and place* | *Organization* | *Function* |
|---|---|---|---|
| **1** | June 17th 2019 (2 h – Brussels) | Flemish Government: Department of Mobility and Public Works | Employee |
| **2** | June 20th 2019 (1,5 h – Mechelen) | Transport consultancy firm active in the transport regions | Project coordinator traffic planning |
| **3** | June 27th 2019 (1,5 h – Ghent) | Flemish Government: Department of Mobility and Public Works | Regional policy officer mobility and chairman of the transport regions of 'Roeselare', 'Oostende' and 'Westhoek' |
| **4** | June 28th 2019 (2 h – Ghent) | Flemish Government: Department of Mobility and Public Works | Coordinator of the transport regions of Flanders |
| **5** | July 2nd 2019 (1,5 h – Brussels) | Flemish Government: Department of Environment | Senior expert strategy |
| **6** | July 2nd 2019 (1,5 h – Brussels) | Flemish Government: Department of Environment | Policy advisor |
| **7** | July 3rd 2019 (1,5 h – Ghent) | Intercommunal organization | Coordinator mobility |

Table 7: Overview of the expert interviews

### 3.2.3 Findings

#### A. The potential for utility

According to the interviewees, the most important planning task the transport region currently faces is the development of the regional mobility plan[73], which was introduced earlier in Section 1.1.4. This plan is a strategic policy plan, structured around four main phases which are inspired by the European SUMP[74] (Sustainable Urban Mobility Plan) directives: inventory and research (phase 1), strategic vision and operational objectives (phase 2), action plan (phase 3) and evaluation and monitoring (phase 4).

Together with the interviewees, these phases were matched against the types of planning tasks that fit our conceptual framework, as indicated in Figure 33 ('RMP' = regional mobility plan). From this perspective, the first phase clearly matches the *exploratory* (diverging) type of planning task. It involves a synthesis of the situation 'as is' in terms of the regional transport flows, attraction poles etc. The second phase fits both the exploratory as well as the *selection* (diverging) phase. The former pertains to the scenario-building and the reflexive exercise in terms of the strategic vision and the operational objectives, while the second pertains to the decisions that are ultimately made in terms of the preferred scenario and the objectives. The action plan (phase 3) resulting from this was also matched with the selection task, as this plan contains the very tangible elements of the RMP in terms of measures, budget allocation, responsibilities etc. As the fourth phase did not neatly classify as one of the three planning tasks, we created the additional category of *'evaluation and monitoring'*. This phase will only take off once the RMP is installed and is as yet not included in the decree nor in the organization model of the transport region. Lastly, the *negotiating* task is also important and overlaps to a certain extent with both the exploratory and (mainly) the selection phases.

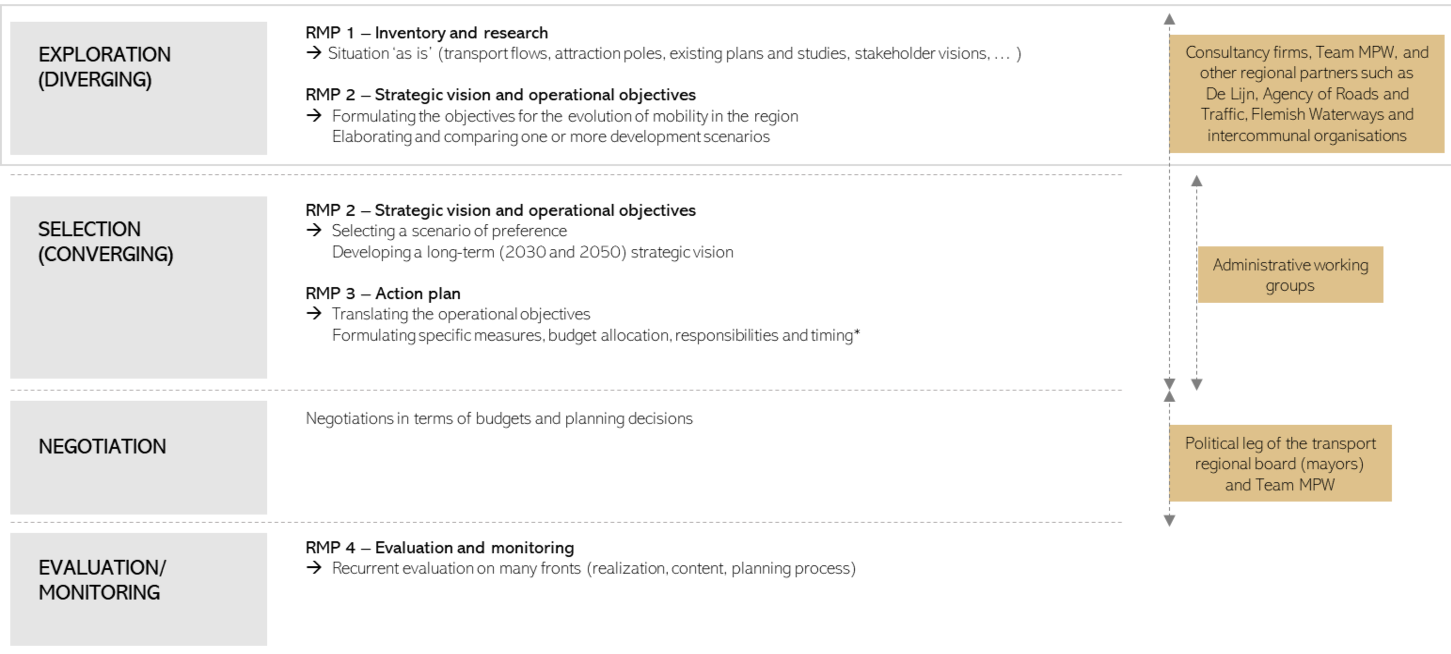
Importantly, different groups of stakeholders are involved in these different tasks. Figure 33 illustrates how the exploratory tasks are (mainly[75]) executed by consultancy firms, coordinated by team Mobility and Public Works (MPW) and in collaboration with some of the regional stakeholders. The deadline to complete this

[73] Besides this, there are a number of more general tasks such as 'the facilitation of combimobility and synchromodality', 'prioritization and monitoring of traffic safety regulations' or 'prioritization and monitoring of unhindered traffic flows'.

[74] For more information we refer to: https://ec.europa.eu/transport/themes/urban/urban_mobility/urban_mobility_actions/sump_en.

[75] Each transport region has some freedom to organize the process as they see fit. The stakeholder constellations described in Figure 5 can therefore more or less deviate from region to region.

task is set on January 2020, but the process will likely take more time according to all interviewees. The consultancy firms have only been selected around June 2019 and will only be able to properly start around September, leading to a tight time budget that will very likely exceed the imposed deadline. The administrative working groups (including the municipal civil servants) are (mainly) responsible for the selection task (in collaboration with the political leg of the regional council) (due in January 2021). The negotiation tasks mainly pertain to the political leg of the transport regional board (each municipality has one vote as well as Team Mobility and Public Works).




* Among other things, the action plan needs to pin down the 'supplementary network' and the 'customized transport' layers of the hierarchical four-layer public transport system as explained in section 1.2.4. Additionally, advice can be given concerning the other two layers (the railway network and the 'core network'). The plan also needs to decide where the 'mobipoints' will be located and which type of facilities will be provided.

Figure 33: Overview of planning tasks in the transport region and actors
(RMP = regional mobility plan, MPW = Mobility and Public Works)

After reflecting on the different planning tasks pertaining to the transport region and after illustrating the functionalities of StationRadar, the respondents were asked to what extent they believe the tool might play a meaningful role (if any). The responses of the interviewees were largely consensual, in that they (1) recognized and emphasized the potential utility of the tool, but (2) hypothesized that this potential is likely limited to the exploratory tasks pertaining to the first and second phases of the regional mobility plan. More specifically, they argued that the tool provides an 'objective basis' that allows to easily compare the most important 'mobipoints' (the railway stations) within a transport region. Therefore, they all agreed the tool should definitely be able to support the inventory phase in which a state of the art regarding transport and land use developments needs to be synthesized. According to expert 2, the fact that the tool is 'out there' for everyone to use, might also support a kind of 'sensitizing' or 'educational' task, in the sense that it might make regional stakeholders more acquainted with TOD planning principles:

> At the moment, there is only little expert knowledge of public transport and the integration with spatial planning, especially in the smaller municipalities. There is also very little recognition that we really need to look further ahead than just three or four years. So, from that perspective this tool could be really interesting. It could support a kind of 'educational' task somewhere on the background.

As StationRadar does not allow for any predictive modeling or scenario-building efforts – hence does not provide any analytical support capability – the interviewees hypothesized that the tool would not be suited to support the selection (converging) planning tasks. For example, as argued by expert 4:

> Unless you factor in some kind of temporal aspect that allows to look at the potential for spatial development, let's say the space for residential expansion areas, the tool will not be able to support the converging tasks. You would need a tool that would say: now your station performs like this, but given these interventions and possibilities, your station will likely perform like this within five years.

Another negative sentiment was shared for the negotiating tasks and specifically pertains to the type of stakeholders involved. As argued by expert 3:

> You can't present such a radar diagram at a regional board meeting with a group of mayors. They have a different logic, they have no time for that and they likely have no interest in listening to a lengthy story about a radar diagram with many different indicators.
>
> StationRadar is useful to consult when used jointly with the civil servants and the consultancy firm, but a political debate on the basis of this, as in: now we will take a decision based on this, … You can't sell that. The gut feeling of many politicians will warrant them. They reason in terms of the consideration: 'I have to be able to explain and motivate this decision to anybody I can bump into on the streets'.

These quotes also illustrate how the background and professional functioning of a potential user is also key in understanding the perceived utility (and usability) of a PSS tool. Vonk (2006: 28) calls this the 'technology-user fit'. StationRadar – a tool requiring a fair dose of background knowledge on TOD and accessibility measures as we experienced during the workshop – therefore mainly seems to add value for the group of civil servants competent for mobility and spatial planning and the regional stakeholders who are acquainted with the matter.

In terms of the final planning task of evaluation and monitoring, the interviewees agreed the tool will likely not serve any supportive function, unless perhaps when the data embedded within the tool is updated on a frequent basis. This would allow to visually compare relative performance between stations or particular indicator ranking scores across different moments in time – a feature that is not present currently.

B. Broader reflections in terms of process and context

Over the course of the interviews, additional elements came to the fore which seem to have a sizeable impact on the usefulness of StationRadar but which are not captured within the conceptual framework outlined in Figure 32. These elements pertain both to (1) the wider *planning process* of which the planning tasks outlined above are a part, and (2) aspects pertaining to the broader political-institutional and planning-cultural conditions that are present – termed *context*. In order to structure these elements, we refer to Bertolini (1997)[76] who put forward a frame of reference in order to make sense of the complexity of railway station (re)development, by distinguishing an 'object' dimension (the station as a node and a place), a 'process' dimension (the 'interactions of social actors associated to these nodes and places') and a 'context' dimension (the 'context of the interactions seen as an evolving set of opportunities and constraints to interacting actors').

[76] See also Bertolini and Spit (1998: 4-5) who articulated this line of reasoning more explicitly using the shape of a 'planning triangle'. Here, 'process variables' are described as "actors, interests and intervening developments" whereas 'context' is described as the "national planning systems, the social and cultural trends of each country, major economic developments, and internationalization processes".

When applying these generically described elements to our empirical case, the planning 'process' would arguably pertain to the functioning and organization of the transport region partnerships, while the 'context' would pertain to broader aspects that are not specific to the transport region, but to political-institutional barriers and to planning-cultural intricacies in Flanders (and Belgium). In Figure 34, the conceptual framework has been expanded in order to take into account these elements. As illustrated in this figure, context may impact both the process in general, and the planning tasks in particular. How these influences may take shape will be demonstrated in the below. We will start by discussing a number of derived opportunities and constraints that pertain to the process of the transport region, followed by a similar account for the context dimension.

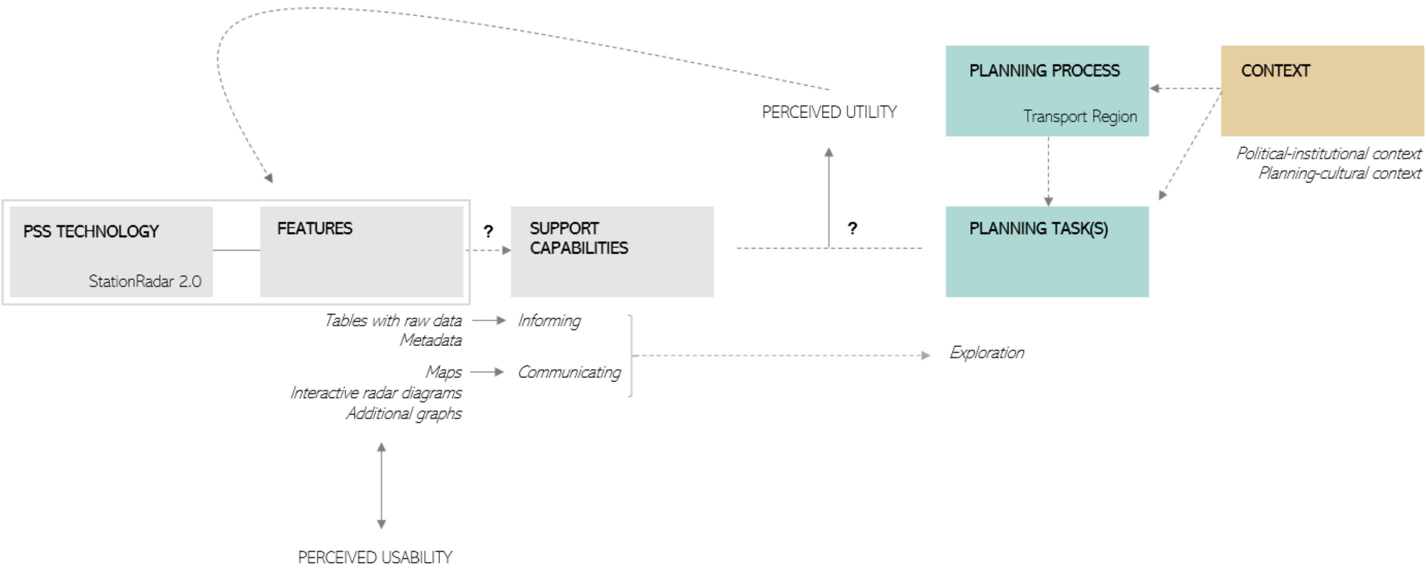



Figure 34: Revised schematic illustration of conceptual framework

<u>The planning process of the transport region</u>

First, a number of opportunities that come with this new type of regional partnerships can be distinguished. These were shared by all interviewees. For example, the increased transparency in terms of decision-making and the spending of budgets was outlined. Expert 2 explains:

> Previously, one municipality did not have insight into the requests about, for example, new public transport services and investments of the other municipalities. Now, everything comes together in one regional board, where all questions are put on the table in a transparent way. It will be a fairer system, because municipalities can make comparisons in an informed way and can come to joint solutions for problems.

Related to this, two other experts (7 and 3) argued that these partnerships bring about a new kind of mindset to the planning process:

> Imagine that a municipality has three railway stations on its territory. Well, the transport region forces these municipalities to look at their stations as part of a wider regional network, and that is a new kind of 'seeing'.

> The good thing about the transport region is that municipalities no longer have to lobby with De Lijn, but with the other colleagues. That is the big shift in mindset brought about by the transport region. The mayor of the town of Ypres will no longer have to call De Lijn with the request to install a new bus line, no, he has to call his fellow mayors.

However, besides these strengths and opportunities, the interviewees also expressed a number of concerns, some of which might impact the usefulness of StationRadar to a great extent. A major first concern revolves around the absence of a dedicated competence for the integration of transport and land use developments in the transport region. As expert 7 stated:

> The regional mobility plan does not require there to be an integrated vision for the railway stations in the region. I would love to see it happening, maybe in terms of some long-term advice every now and then, as in 'It would be good if this station would evolve towards…'. But there is no competence, there is no necessity to effectively figure all of that out. We can only hope that the regional mobility plan will also serve as a basis to shape a sustainable spatial vision. Maybe in that way, we can work a bit on TOD. We could say 'Now we have a better organized plan of the current and future public transport networks on a time horizon of 2030 and ultimately 2050' in the hope that spatial development will follow, since each municipality still has an autonomous competency for the environmental factors.

Related to this sentiment, the same expert stated:

> Spatial planning is something 'long-term'. TOD is something that will ultimately pay off (or not) within twenty years or so. But our mobility policy has to be operational within three to four years. And that is really difficult, how to get both domains integrated and make robust choices.

Given that there is no integrated competency, we learned how the current discussions about railway stations in the transport regions predominantly revolve around the integration of the train service with the feeder public transport network[77], at the expense of spatial discussions. Experts 3 and 7 explain:

> In the transport region, we started from the idea that the railway station service is stable. That it will remain 'as is', and so we concluded that we would mainly look into how the bus network can find a connection with it.
>
> A very important question for the transport region is: 'Are the performance of the train and feeder bus modes in balance with each other?' When it comes to railway stations, most if not all questions will revolve around those transport-related aspects.

Another important concern centers around the rigid nature of the political decision-making process, which might jeopardize the potential for utility in terms of the exploratory tasks discerned above. Expert 7 explains:

> The exploratory phase should be the basis for all that follows, but in practice it often is a political game, a balancing act. In our transport region, 11 municipalities sit around the table, and they all want a piece of the cake. StationRadar should in theory be a good tool to support that first exploratory phase, to maybe objectify certain development choices to be made, but reality will catch up with it. I'm convinced of that. The reality is that these development choices are made on another level. In the sense of, you are facing a very compelling reality, a path-dependency that is still enormous in transport studies. Choices from the past determine around 80 to 90 percent of the choices today. Just look at the bus networks in the transport region. These often trace back to tracks from the mid 19th century. Certain bus lines operational today still drive along the same trajectory of the Belgian national vicinal tramway company. The infrastructure is there, so…
>
> Your tool will definitely tell us that the place value of the largest station in the region should be higher. But, in the final mobility plan, I don't see this reflected immediately, unless perhaps as a long-term recommendation. But well, such a long-term recommendation could have been made a long time ago as well, right? What I'm trying to say is that, in the end, the municipality of that station can, and probably will, still say: 'No, we want to invest in the city center, not in the station area'.

---

[77] This arguably resonates with the findings discussed earlier on in Figure 27, with the vast majority of workshop participants mentioning features pertaining to the station feeder modes.

Besides that, a potential other threat pertains to the geographical constellation of most transport regions (which usually comprise one or two urban cores that are surrounded by suburban of rural municipalities) and its repercussion in terms of political dynamics[78]. Experts 2, 5 and 7 stated that the periphery of the region easily feels left out, resulting in political resentment:

> What I'm fearing a bit in the transport regions is the fact that they are rather small geographical entities that are composed of a central city versus more rural municipalities. Here and there you hear signals hinting at feelings of mistrust.
>
> The question at the periphery of larger cities is: where do you locate the regional nodes? That should be decided jointly by the core city and its periphery, but usually, that relationship is not fantastic. The periphery does not want to have the problems of the city. So, that is not really working out that well.
>
> What I'm experiencing in a couple of transport regions is a clear opposition between city and countryside. Frequently, at board meetings the countryside has already reacted before the first word has been said, with something like 'Not all benefits will be for the city!'. That is not a good evolution as it creates a divide.

Two final concerns relate to the more practical issues of budgetting and timing. In terms of the former, experts 7, 3 and 1 argue:

> It is quite striking that this partnership is just a collective agreement model. The actual execution of what has been decided will not be with the region. For example, it is not the transport region 'Westhoek' that will organize its public transport, it is the Flemish Government that will – in agreement with the transport region – organize public transport. And that is really quite a difference. In other countries there are examples of regional partnerships who are capable of doing that, and where there are cooperation agreements between municipalties and regions. Take the example of Germany with the *Länder*. I can imagine it was politically sensitive to already take that step now, but in my opinion this really has the potential to evolve into something similar like the police zones, but then that step towards a genuine structure has to be taken.
>
> I'm afraid that for the 'customised transport' layer [the lowest of the four-layer hierarchic public transport system envisioned as part of the regional mobility plan, see Section 1.1.4] – there may be too little budget available in the end. The people living in the more rural areas will not sell their houses, whereas public transport accessibility might decrease in these areas. Real estate in the urban cores might in turn get more expensive… There are so many good intentions, but what is being created might actually lead to the opposite effect…
>
> If you really mean well with the transport regions and the objective of sustainable mobility, then you do not organize them in a budget-neutral way, but with an investment budget. You need to have budgets to genuinely invest and construct one or two highly performing bus routes. Currently, that is not possible. Now there's a mere transition from a practice of *'belbussen'*[79]to maybe other types of bus systems, or to more buses in the urban cores instead of in the countryside. That is the situation we are heading towards, but that's it. It's a shift in the means. You could as well say, let's join the transport regions with a climate of investment.

In a similar vein, expert 3 stated:

> If you ask about TOD in the transport region 'Westhoek', they will look at you strangely. They will say 'You know, we barely receive budget to organize public transport in our region, how do you expect us to turn it

---

[78] More detail with respect to this particular 'urban versus suburban' dynamic in light of city-regional governing is provided by Voets and De Rynck (2008). Both scholars frame this dynamic within a longstanding tradition of 'political localism' and party politics. Vanderstraeten et al. (2018: 130) echo this by stating that "a large diversity in the local political landscape in Flanders hinders structural collaboration in regional – intermunicipal – partnerships" (own translation). Besides that, Vanderstraeten et al. (Ibid.) state that municipalities in Flanders are afraid of losing their identity and autonomy in regional partnerships, and that the current fiscal system perpetuates rivalry with neighboring municipalities for (wealthy) residents and industry.

[79] These 'dial-a-bus' services only run on request and do not have a set route or timetable. The bus only stops at the De Lijn stops that are requested in advance from the dial-a-bus switchboard.

> into the spatial backbone for our future development?'. In that region, that will by and large be the political reaction that you get.

In terms of timing, the below issue was raised by expert 7 and endorsed by most interviewees:

> The exploratory phase will be one of the hardest and most challenging tasks on the short term. In principle you should undertake a very broad and intensive study that encompasses all existing networks, nodes, flows etc. I am certain that we will finish this task quite quickly with the consultancy firm, but that we will not do it in-depth. The deadlines are too soon for that. The phase that everyone immediately wants to arrive at is the task of selecting.

<u>Scratching the surface: Exploring some contextual factors at play</u>

Alongside the above aspects, which pertain directly to the scale and organization of the transport regions, there is a second group of political-institutional and planning-cultural contextual factors that directly impact the functioning of the transport region and the planning tasks it faces. As some of these factors were reiterated and stressed during most of the different interviews, we briefly discuss them here. We nonetheless acknowledge that the interview protocol that was designed for this study (with a dominant focus on the task-technology fit) does not allow to draw any comprehensive conclusions pertaining to these contextual factors. Therefore, we emphasize that this subsection only scratches the surface of the matter.

A first major concern is of political-institutional nature and pertains to the high level of compartmentalization between the departments of Mobility and Public Works and that of Environment. Judging from experts 7, 1 and 3 this seems to be maintained due to a system of party politics and to politico-strategic tactics:

> At the time of the first concept note of the Flemish minister regarding the decree of basic accessibility – four years ago – it was clearly stated that mobility and environment should be integrated, that there always had to be a representative of both departments present in the transport region, and that they would use the same regional scale. In each version of that note, from concept letter to circular, these statements have been downplayed. I haven't seen anyone from the Department of Environment at one of the regional board meetings, while this has always been the intention. The compartmentalization of the Flemish administration is so high that… Unless you have one minister for both competencies, nothing will change. Obviously, there are very sensitive political motives behind all that. The story of the transport regions is an exponent of the political party N-VA[80] and is a subtle but probably efficient way to downplay the role of the Provinces. The Department of Environment is still a bastion of CD&V[81], who happens to be the advocate of the Provinces… The request posited in the Flemish Parliament to include the Province – as administrators of the road and bicycle infrastructure – as a permanent member of the regional board, has been voted away by the majority.
>
> Almost everywhere in the decree, the word 'Province' has been deleted. We initially worked it out like that, with the Provinces included, but the first thing they did was delete it again. In fact, the institutional level of the Provinces is being hollowed out.
>
> The dashed line between both departments [referring to Figure 5] is a difficult one, because, the famous notion that everybody knows of, *'verkokering'* (compartmentalization) is still very much a reality.

In their commentary on the difficulties of organising regional cooperation in Flanders, Vanderstraeten et al. (2018: 132, own translation) seem to corroborate the above sentiments:

> The policy visions, but also the projects and the investment budgets of the different Flemish policy domains are often not in tune. When the match is nonetheless found on an administrative level, like between the

---

[80] N-VA or *'Nieuw-Vlaamse Alliantie'* is a Flemish-nationalist and liberal-conservative political party in Flanders and is currently the largest political party.

[81] CD&V or *'Christen-Democratisch en Vlaams'* is a Flemish christian-democratic centrum party, which is currently the third largest in Flanders.

> Departments of Mobility and Public Works and Environment, it is not always there at the political level. For that reason, regional partnerships remain largely sectoral, taking the shape of for example transport regions with paradoxically little movement at the political level. This confuses many local governments in Flanders.

Another example of the impact of politico-strategic motivations was given by expert 4, who elaborated on the establishment of the map with the 15 transport regions:

> The trajectory to arrive at the final map of the transport regions took two years. We started off with 20 transport regions, and we have tried for a long time to arrive at the same regions together with the Department of Environment because they also envisioned regional partnerships in light of the BRV strategic vision. However, this geographical partition was altered many times, in part due to the lobbying of the intercommunal organizations behind the scenes. So, this is definitely a kind of external element that should be factored in if you want to understand the interaction between both policy domains. Most of these intercommunal organizations are very active in both domains, and some even have pieces of land in their possession, which makes it extra difficult to let them take part in the decision-making process.

In terms of planning-cultural factors, the following quotes were raised (expert 1):

> I may be stereotyping here, but our planning system is indeed quite irrational. In other countries, everything is developed at the right place, whereas we plan for a new hospital where the agricultural land is cheapest, and once it's developed, we question how to make the site accessible in a sustainable way. We are not good at this in Flanders, we are not consistent.
>
> Something typically Flemish is that we have a lot of rules for everything, but it's become a sport to avoid them. Politically speaking there is just so much hesitation to develop and execute decrees and implementation orders.

### 3.2.4 Discussion and conclusion

On the one hand, this section has expanded on the main planning tasks which the transport region partnership is currently facing, and has detailed how and to what extent the support capabilities that StationRadar offers may play a role in this. On the other hand, the expert interviews informed us that a number of influential factors need to be accounted for in in the conceptual framework when aiming for a comprehensive understanding of the tool's potential for usefulness.

While being aware of the limited generalizability of this small sample of experts, the latter findings resonate with those of other studies in which the use and usefulness of PSS tools (most of them accessibility instruments) was examined in planning practice (for example Papa et al. 2017, Angiello and Carpentieri 2017, Silva 2017, Silva et al. 2017, Wulfhorst et al. 2017, Larsson and Olsson 2017, Liedtke 2018). According to this body of research, it generally seems that not the instrument itself, but various organizational and institutional factors cause a purported 'implementation gap' of PSSs (see Vonk et al. 2005, Vonk 2006, Geertman 2006). For example, Silva et al. (2017: 143) elucidated two major barriers stemming from their large-scale survey with developers of accessibility-based PSSs and the practitioners testing these: "The marginal and at best ambivalent position of accessibility in the policy agenda (by and large, the focus is still on facilitating mobility) and the lack of institutionalization of AIs [accessibility instruments] (accessibility analysis is not a formal requirement, nor are there accepted procedures to perform it). These two matters seem at the heart of the implementation gap, and it is difficult to see how the gap can be bridged without them being addressed". These studies thus contend that examinations of the usefulness of PSSs need to actively involve these organizational and institutional factors (or what we termed process- and context- factors) as part of the planning case under scrutiny, instead of considering these as a given. This is deemed crucial in order to avoid developing 'pseudo-tools' that have little chance of succeeding in practice. Similar concerns have been raised by Marsden and Reardon (2017: 238) for the field of transportation policy, who point at the "important questions of governance; such as context, power, resources and legitimacy" when developing and validating decision-support tools:

> The substantial lack of engagement with governance issues and debates means that as a field we are artificially, but more importantly, disproportionately generating a science of applied policy making which is unlikely to be utilised because of the distance between it and the realities on the ground.

For the specific case of Belgian planning practice, the importance of process and context have been debated before by (among others) Albrechts (1999: 590-591). He pointed towards a range of factors (reminiscent of those discussed in the above) which "go far in explaining both the image and the functioning of Belgian planning":

> A close examination of decision making in Belgian land use planning, for example, shows that individual landownership, personal interests, adherence to certain social networks, pressure groups and other factors of a petty nature are evidently more important than theoretical constructions when considering certain positions as to the enactment of planning. While such assertions are of interest for revealing the true origins of the built environment, they also emphasize the need for integrating such pragmatic considerations in any theory which aims toward eventual implementation. Theory should, therefore, be rooted in an understanding of the societal as well as individual processes through which the environment is both produced and used. It must, then, include an analysis of the different values and interests of the various groups involved, as well as the interplay of interest and conflicts between them.

In sum, the above has demonstrated that an analysis aimed at understanding the usefulness of a PSS that ignores the broader dimensions of process and context, will inevitably fall short of success. It seems crucial to be mindful of these deeply rooted contextual elements, 'regimes' (Voets and De Rynck 2008) or 'politics of space' (Healey 1997), as these help to explain why certain city-regional initiatiatives such as the transport regions – and certain PSS applications that are catered towards supporting these partnerships – may actually root in practice or not.

In many ways, these outcomes also trace back to Bertolini's (2000a) early plea of 'assimilating' or 'reconnecting' the challenges of station area development 'with a thorough appreciation of both the process and the context dimensions' of planning. As we see it – and as we will elaborate in Chapter 6 – a main challenge for the node-place modeling literature and work is (still) situated exactly here.

### 3.3 Strategies for railway stations in the Dender valley, Flanders: An interdisciplinary dialogue based on node-place modeling concepts[82]

The aim of this section is to provide an account of how StationRadar was used by an interdisciplinary group of stakeholders during one of the workshops. This serves the purposes of (1) illustrating how – at particular moments – the radar diagrams succeeded in structuring a multi-stakeholder dialogue based on the empirical 'common ground' provided by the radar diagrams, and of (2) highlighting some of the main issues and sentiments that (seem to) play a role in debates revolving around railway station (re)development in the Dender valley, in order to elicit possible clues for future development scenarios. We focus here on the workshop that was organized for the transport region of Aalst (see Section 3.1). One of both worktables dealt with the station cases of Aalst, Denderleeuw and Ninove. These stations are located in the Dender valley, in the southwest of the transport region of Aalst (see Figure 35).

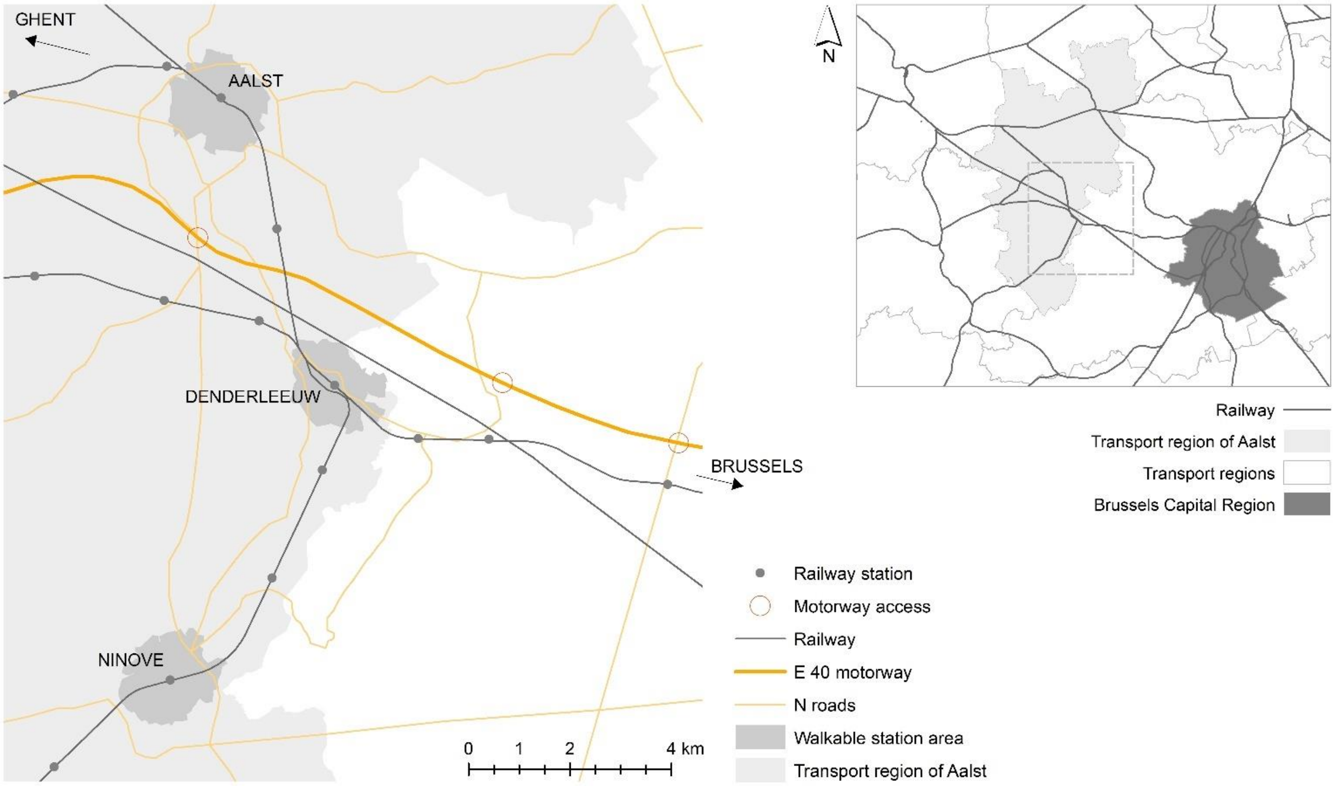



Figure 35: The stations of Aalst, Denderleeuw and Ninove situated in the wider region

The group consisted of the following stakeholders from diverse disciplines or organizational backgrounds: the Department of Mobility and Public Works (MPW) (1 representative), public transport company De Lijn (1 representative), intercommunal organization (ICO) (1 representative), and the municipalities of Ninove (1 mobility officer), Denderleeuw (1 mobility officer, 1 urban civil servant and 1 Alderman competent for spatial planning and mobility) and Aalst (1 spatial planning officer and 1 mobility officer). The session was moderated by a professor of spatial planning and mobility from Vrije Universiteit Brussel.

The remainder of this section is organized as follows. Section 3.3.1 will provide the necessary background information in terms of the station cases and their StationRadar diagrams as they were presented to the

[82] The interview quotes that are reported in this section are own translations from Dutch to English. We have tried to convey the gist of the original fragments as closely as possible.

stakeholders during the workshop. Afterwards, we will discuss our findings, structured around a number of themes that came to the fore during the discussion. A discussion and conclusion (3.3.3) wrap up this section and elaborate more extensively on a series of station area development scenarios.

### 3.3.1 Background: station cases and radar diagrams

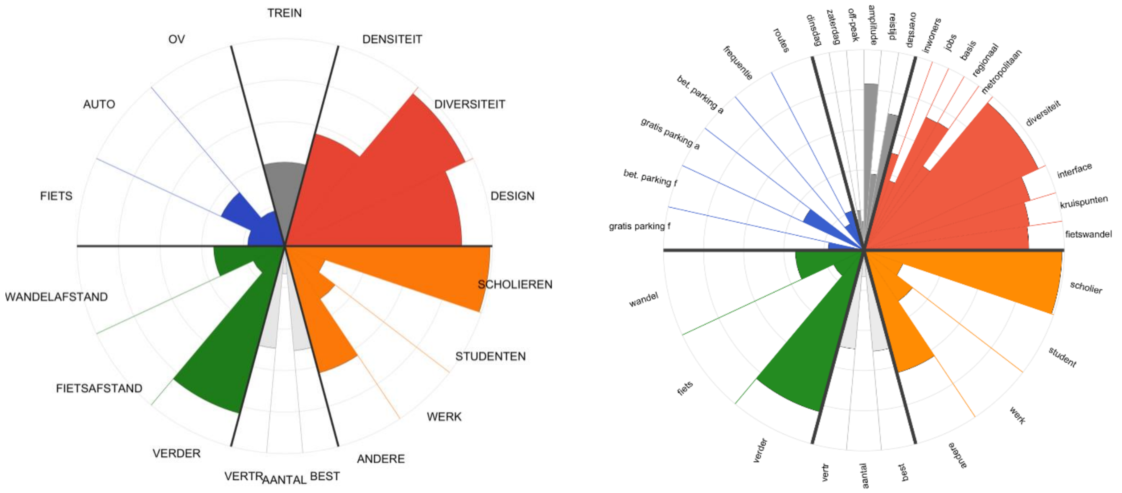
The three municipalities of Aalst, Ninove and Denderleeuw are located in the immediate influence sphere of the Brussels Capital Region. The main stations within their territory are located across the western periphery of the Brussels RER network (see Section 2.1), and receive a large share of commuters who travel to Brussels each day. According to season ticket data (2018) received from NMBS, 64% of rail commuters originating from the Aalst tariff zone travel to Brussels. For Denderleeuw the share is slightly higher (68%) and for Ninove it is around 60%.

The radar diagrams (dimensions on the left and indicators on the right) for these three stations are illustrated in Figure 36. The scores were calculated as explained in Section 2.2, and are based on the 27 stations in the transport region of Aalst. During the workshop, these diagrams were complemented with the raw data behind the relative values, as part of StationRadar. Judging from Figure 36, some general observations are that: the bottom station (Aalst) scores very high overall – especially for the domains of place and motivation –, the middle station (Denderleeuw) has mainly gray and blue tones (which points towards high transport accessibility) in its diagram whereas the opposite holds for the upper station (Ninove), which nonetheless has a well-performing place and motivation field. When exploring these characteristics in more depth, the following observations can be made.

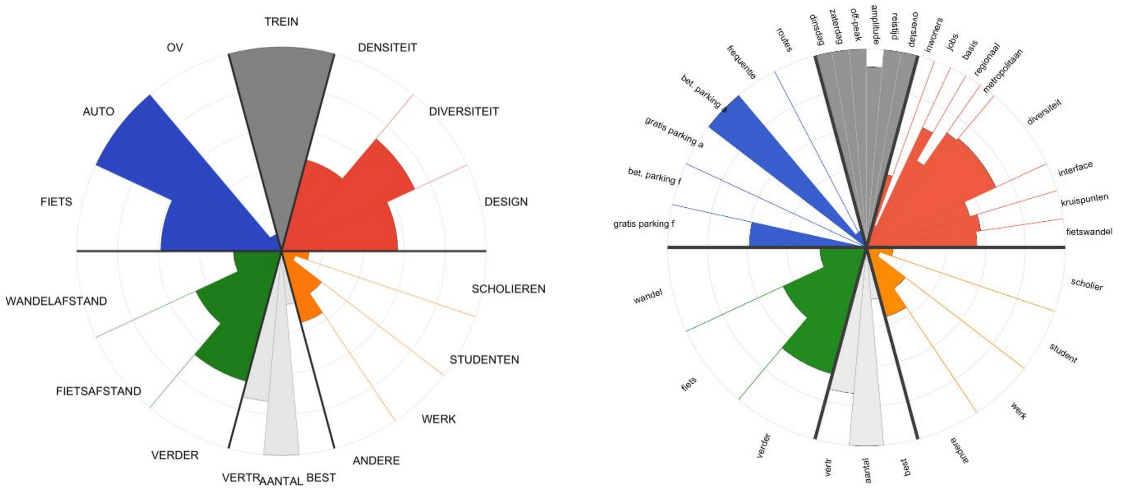
According to the original node-place model (see Figure 7), station Ninove would likely classify as an 'unbalanced place' as there is a clear overweight in place over node performance. In terms of place, the Ninove station area scores remarkably well on the diversity (land use mix) and design (walkability) dimensions, whereas density is rather moderate, especially in terms of inhabitants and jobs. Given this, it may not surprise to see that only a small proportion of people in the transport region commute to the station, as reflected by the motivation dimensions. On the other hand, the secondary education motivation is close to being maximal and individual ticket sales also play a rather important role for Ninove as a destination station. In this respect, the ridership dimension reveals that the station functions as a mixed origin-destination station in the region, with a very limited relative number of passengers on a workday. This low demand for railway accessibility seems to match a low supply of railway accessibility as reflected by the train dimension. The only train indicator scoring very high is the 'amplitude', indicating the station is accessible throughout a large part of the day. Similar to the low train accessibility, feeder mode accessibility is limited. Parking spaces for cars and bikes are small compared to the other stations, and bus services seem limited. A final observation is that the catchment area of this station is large, indicating that the vast majority of season ticket holders regularly boarding this station (a relatively small number, considering the low ridership) reside further than 3 km from the station.

The diagram of station Denderleeuw looks very different, with the highest performances situated within the node, train and ridership dimensions. Of all stations in the transport region, Denderleeuw has the highest train accessibility and – perhaps unsurprisingly – the highest number of passengers per workday. According to the diagram it mainly functions as an origin station, although this statement needs warranting in the sense that the extent to which the station functions as a transfer station is not included in these ridership calculations. Feeder accessibility is also high in terms of bike and car parking facilities; the station has the largest (toll) car parking in the region. Bus services are nonetheless remarkably limited and the catchment area seems medium-sized. On the right hand side of the diagram, we can deduce that place performance is overall moderate (diversity and design) to low (density). The very low density in terms of jobs (and to a lesser extent residents) is remarkable for such a well accessible station, and may arguably be explained by the motivation dimensions which reveal – together with the ridership dimension – that Denderleeuw is not functioning as a destination station.

### Station Ninove




### Station Denderleeuw




### Station Aalst

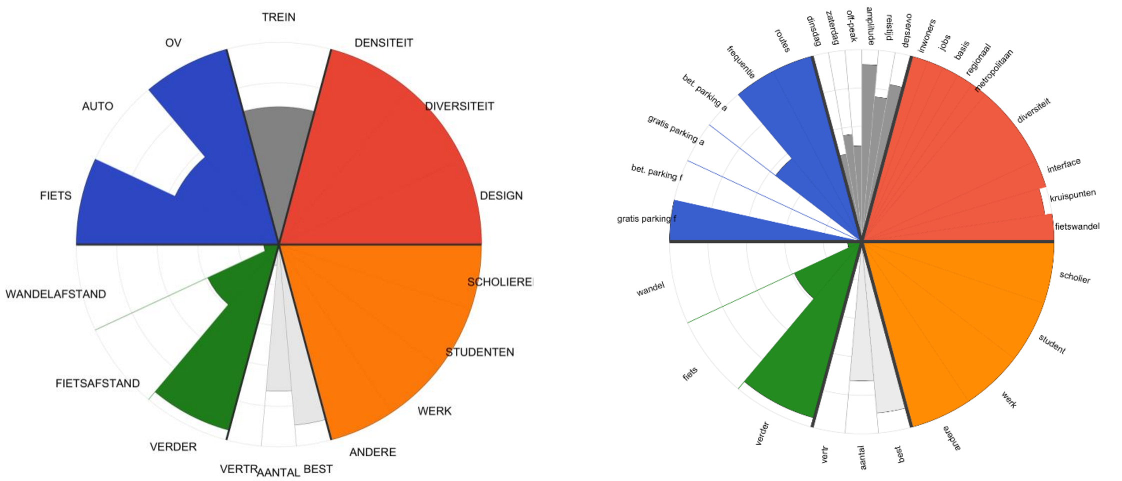



Figure 36: Radar diagrams of the stations of Aalst, Denderleeuw and Ninove as used in the workshop (labels in Dutch)

Station Aalst on the other hand, functions as a clear destination station, with maximal scores on all place and motivation dimensions. Ridership and train accessibility are fairly high. In terms of the latter, frequencies (on a Tuesday, Saturday and off-peak) are rather moderate to low, but the amplitude and centrality measures for the station are high. As for the node dimension, bus accessibility is maximal, together with (free) bike parking facilities, whereas (toll) car parking supply is moderate. Similar to station Ninove, station Aalst has a large catchment area.

### 3.3.2 Points of reflection

#### *A. The role of the train in socio-economic change and contrasting ideas about metropolization*

A first theme that may be deduced in retrospect of the workshop revolves around socio-economic changes due to the presence of the railway station, and the different sentiments of the stakeholders towards these developments. This topic came to the fore when discussing the case of Denderleeuw and – more specifically – its moderate to low performance on the place dimensions. The Alderman responsible for spatial planning and mobility reiterated his concerns which he had raised before during the station introduction round of the workshop. He stressed how his municipality is becoming a 'dormitory town' for low-income families with a migration background, who 'are not planning to invest in the local community'. He argued that the fast railway connection to Brussels plays a major role in this issue:

> The daily life of these residents takes place somewhere else. If you have a chat with the non-Dutch speaking residents in Denderleeuw, they will tell you they don't feel the urge to learn the language, as they only arrive after 6 PM and directly go home. At six in the morning, they are off again to Brussels. They only come here to sleep.
>
> Currently, the station area – let's say a radius of some 500 metres – has an outdated housing stock, little jobs, no offices… The medium-sized companies have abandoned the area and retail has moved as well, to out-of-town locations along the arterial roads. The village centre has zero to offer and the influx of foreigners has caused all bars to fall into the hands of other people. The people from Brussels buy the houses over there, which results in a severe loss of connection with the station area. This is a big challenge.
>
> We try to fix this situation with all instruments available in terms of spatial implementation plans and pre-emption rights, but… It's not enough. Together with NMBS we need to try and give new impulses to the station area, but that will of course cost unbelievable amounts of money.

When the representative of the Department of MPW – also the chairman of the transport region of Aalst – asked how this issue might be resolved, the Alderman argued that it would be of great support to have Denderleeuw officially recognized as a 'core city', similar to Aalst, which would allow for much more subsidies in terms of urban renewal projects.

Interestingly, other stakeholders around the table also pointed out some of the *opportunities* that may come with the strong position of the station in terms of its rail-based access. For example, the representative of the intercommunal organization elaborated on the potential for Denderleeuw to develop a 'new town'-like development around its station:

> Maybe the most important conclusion to make for Denderleeuw is the pronounced imbalance between the origin and destination character of the station, and between the very high node and the low place value. It's mainly an origin hub, while you have the largest train offer in the entire region. So there is also a huge potential as a destination station, which is totally underused today.

> If you look at it from a higher level, the station area of Denderleeuw is the ideal setting to work on TOD. But, that wouldn't be a project specific to Denderleeuw, not even to the transport region. That would be an insanely large project similar to Amsterdam-Zuid. There, they also focused on a station which had high service levels and they just built a new neighborhood around it. It is possible, and actually the station area of Denderleeuw is very big if you look at aerial pictures. The territory that is owned by both NMBS and Infrabel is really large. Imagine if you would build an entirely new neighborhood with apartments and residential towers, perhaps a kind of VAC[83] like the one Ghent has…
>
> Internationally, there are a lot of examples of those kind of projects and Denderleeuw has the space to do that. If it's desirable, that's another question, but the potential is there for sure. If you would invite an international expert and you would show what the station of Denderleeuw has to offer in terms of node value in the train network, then s/he would say: 'This territory is worth millions, what you can develop here is theoretically speaking crazy'. If you look at Denderleeuw's node value, the land values should be skyrocketing.

This urbanist perspective appeared to be novel to the representatives of the Denderleeuw municipality. The Alderman asked the group why – given this purported huge development potential – that scenario had not developed. According to the ICO-representative, that is probably because of the lack of financial incentives and the lack of a regional strategic vision. The Alderman also emphasized that the neighboring station of Liedekerke will receive 'several millions' for a station renewal project while he believes it 'will not have any value' as there is only one type of train passing there: the one in the directions of Brussels and Denderleeuw. "There they will invest while the station area of Denderleeuw – which actually needs it – is left empty-handed".

*B. The quality of train connections in diverse directions: A balancing act*

A second frequently recurring theme revolved around the quality of the stations' train connections. For the case of Ninove, the discussion started when explanations were sought for the station's low performance on the train dimension. As the ICO-representative argued:

> When you think in terms of the standard butterfly model: the butterfly is not balanced. Ninove has a high place value, but a very low node value. You can see it here in the diagram: density and diversity score well, but the entire blue side… The reason for this is quite simple: the historical railway line has a wrong orientation for Ninove… The curve is not towards Brussels, that's the main problem.

Others added that – from Ninove – Brussels can be reached much quicker by car than by public transport. The mobility officer for Ninove argued that "if you miss your train connection to Ninove, especially when traveling back from Brussels, then you easily wait in Denderleeuw for an hour". The ICO-representative subsequently argued that:

> I think we need to solve the problem of Ninove in Denderleeuw. If we succeed to make a smooth connection over there, or to realize a direct train from Ninove to Brussels without a transfer in Denderleeuw…

To this, the mobility officer for Ninove replied that:

> It used to be like that. It used to be a direct line. And then there were a lot of commuters. They just hopped on the train and, well, they were traveling for quite a long time, but they did not make a problem out of it. Now, that transfer in Denderleeuw is the big problem, especially to travel back.

[83] The 'Flemish Administrative Centre' which is located right next to the main station in Ghent. It was the first building that was constructed as part of the new urban district around the station.

Taking the car to Denderleeuw station and hopping on the train was raised as an alternative, but the Alderman of Denderleeuw warned that "there is already a lot of cut-through traffic around Denderleeuw because of that reason, since a lot of commuters from Okene, Ninove and others come to Denderleeuw by car".

For the case of Aalst station, the main issue in terms of the quality of its connections revolves around the speed of particular connections rather than the transfers needed to reach other stations. The mobility officer for Aalst explained:

> There is no fast inter-city connection from Aalst to Ghent, while everything that is going to Brussels… You travel faster from Ghent to Brussels than from Ghent to Aalst. Speed takes off in Denderleeuw! Also, from our region to Ghent it's around 35 minutes by car, whereas it takes an hour by public transport.

The Alderman for Denderleeuw and the ICO-representative respectively added:

> Abroad you don't find things like this. If you look at these lines, for example the line Brussels-Aalst-Ghent, or Ghent-Denderleeuw-Brussels… If you show this abroad, where every few kilometers there is a large station and everything is centralized… But here… Well, it's grown historically of course.
>
> If you look at the map, that's indeed partly due to the many small stations in the region which makes your train traffic slow. But that's a consideration that needs to be made… In fact you could also say: 'Let's give Aalst a decent train connection. Let's arrange a direct train from and to – let's say Zottegem – each hour'. Not that I see it happening immediately, but the infrastructure is there.

According to the MPW-representative and the ICO-representative:

> Yes, from the south there are some possibilities to do that, as there is kind of a provision of travellers from Erpe-Mere and Burst, but that's it. Everything northwards and to the east, that's a white spot for Aalst station. Although, there were some plans to reinstall some of those old lines that have been broken down, and the one from Aalst to Dendermonde is included as a variant. That line could even go all the way up to Sint-Niklaas or Antwerp…
>
> Yes, or we could advocate for another kind of high-quality public transport line. Maybe not rail but light-rail infrastructure. It seems that we never reach this more visionary and 'out of the box' thinking phases of the discussions…

*C. The most desirable location for a regional transit hub*

A third point of reflection revolved around the more holistic relation between the station cases in terms of transit accessibility and the perceived mismatch between their performances across the diagram dimensions. The Alderman for Denderleeuw and the ICO-representative respectively argued that:

> It seems that the link between NMBS and De Lijn is not logic. Judging from the diagram, the ideal node in terms of railway connectivity would be Denderleeuw whereas the ideal node in terms of bus connectivity would be Aalst. That's not logical. Either you have both in Aalst or both in Denderleeuw.
>
> Indeed, the contrast between node and place value is nowhere as visible as between the stations of Denderleeuw and Aalst. Denderleeuw is obviously the network node whereas Aalst is the centrum city. In fact, the station of Denderleeuw should've been located in Aalst. If you would have to draw the network today, you wouldn't draw a node in Denderleeuw. The natural node between Ghent and Brussels is simply Aalst. But it has… for a plethora of historical reasons not evolved like that.

The latter continued reflecting about potential development scenarios:

> You could ask yourself the question: 'What would work best?'. Would it be those three trains per hour from Aalst to Brussels via Denderleeuw, or would it be a high-quality connection between Aalst and Denderleeuw – let's say every five minutes – and then a constant flow of trains from Denderleeuw to Ghent and Brussels that do not have to cross each other? Perhaps the latter would be more efficient, to have no direct trains from Aalst to Brussels, but from Denderleeuw to Brussels and to have a permanent light rail going back and forth between Aalst and Denderleeuw…

Following these reflections, the stakeholders seemed to converge around a 'bi-polar' development scenario for this area of the transport region – a scenario that seemed to be supported by the fact that "both stations are part of the same urban-regional area", as stated by the MPW-representative.

*D. The complexity of integration*

A final theme that often arose during this (and other worktable) discussion concerns the institutional compartmentalization and the lack of integration between regional stakeholders. Some of these aspects resonate with the discussion in the previous section on contextual factors (see Section 3.2.3). A first issue revolved around the low bus accessibility scores in the diagram for Denderleeuw. The Alderman for Denderleeuw and the ICO-representative stated:

> In terms of the weak bus bus service provision at the station, we have been striving for years to improve that. But it's not easy to convince people. In the masterplan for the redevelopment of the station, a large bus hub is envisioned. But, there is so little initiative from the higher governments. The connection to Brussels by train is perfect, but with De Lijn it's a total disaster.
>
> The most striking thing is that there is a rigid Provincial border for De Lijn. They consider anything east from Denderleeuw as the Province of Vlaams-Brabant, hence out of their jurisdiction and that's it.

As the border of the transport region coincides with the Provincial border, similar sentiments were raised with respect to the case of Ninove. The mobility officer for Ninove argued:

> The buses that are operated by De Lijn Vlaams-Brabant do not serve our station. We can't convince De Lijn to provide us with that last kilometer…

The Alderman for Denderleeuw replied:

> Yes, why is that the Provincial border is so difficult to cross? It's only about one bus line that has to be extended for two kilometers, making the loop around Liedekerke church and back. I don't believe it would cost that much? And those kind of loops, I thought that is the essential task of De Lijn? I really think that, both De Lijn and NMBS should at least more actively reflect together with us. It's not because you provide a train connection that the municipality can master the parking problems it generates.

### 3.3.3 Discussion and conclusions

The above points of reflection provided a hint of the dominant topics and different viewpoints that arose during the worktable discussion in order to shed more light on how the tool was able to – at particular moments –structure the interdisciplinary stakeholder dialogue. In terms of the empirical 'common ground' that was given by StationRadar, we conclude that the radar diagrams provided a familiar rendering of the stations' accessibility features to the stakeholders. The radar diagrams seemed to capture and convey the different roles that these stations play within the region in a relatable, understandable and evocative way.

Additionally, drawing on the results of the surveys for this particular group of stakeholders, we can deduce that the interdisciplinary composition of this group was important in acquiring insights and learning. The results of the Likert scale statements pertaining to individual and group learning effects were all in all positive to very positive. For example, statement 3 ('My understanding of the viewpoint of other participants has increased') was rated with an average score of 4. Some written elaborations to this statement were *'Yes, too often we see things through our own perspective and we forget what is important for the other partners involved'*, *'The tool helps to look across our municipal bubble'* and *'Due to the specialization within the group the discussion was very constructive and broad'.* It thus seems that interdisciplinary learning took place to some extent and for some people during this group discussion. It also seems that learning took place both through each other and through the StationRadar tool. However, given that no further systematic analyses of potential learning effects took place during the course of the workshops, these inferences remain assumptions and can only be verified in workshop settings that are truly dedicated to examining these effects [84].

Finally, drawing on the 'points of reflection' discussed in the above we can elicit some potential clues for the future development of these stations in the Dender valley. Three main scenarios may be deduced (see below). The 'A' and 'B' scenarios respectively prioritise investments at the stations of Aalst and Denderleeuw, whereas the 'C' scenario envisions a bi-polar intervention tackling both stations in a comprehensive strategy.

<u>Scenario A</u>:

Create more 'node value' in terms of rail-based accessibility at Aalst station, by shifting part of Denderleeuw's hub role to Aalst. This implies fast and frequent train connections for the line Ghent – Aalst – Brussels. This intervention would likely result in more balanced node/place proportions for both of the Aalst and Denderleeuw stations (all else remaining equal). The former would likely see increased rail-based accessibility performance whereas the latter would likely see a decrease in this domain to levels that are more in tune with Denderleeuw's weak place performance. Likely such intervention would also impact performance for the 'people' dimensions. Morning peak riders would likely make a different trade-off in deciding where to board the train to Brussels, in turn impacting the 'effort', 'ridership' and 'motivation' fields of the diagram.

<u>Scenario B</u>:

Consolidate Denderleeuw's current role as a hub in the railway network and create more 'place value' in Denderleeuw by developing the marshalling yard next to the station. Organize the bus stops at a more strategic place at the backside of the station and increase overall bus accessibility of the station. Reinstall a direct train connection between Ninove and Brussels without a transfer in Denderleeuw. This intervention would likely alter the diagrams of both Denderleeuw and Ninove. The former would likely see an increase in place and bus accessibility performance, whereas the latter would likely experience increased rail-based accessibility performance (and possibly increased ridership performance).

<u>Scenario C</u>:

Implement a bi-polar development strategy by (1) consolidating and expanding Denderleeuw's role as a hub for fast, non-stop and direct trains to both Ghent and Brussels (resembling a metro-like service) and

[84] The work of von Schönfeld et al. (2019a, b) provides inspiration along these lines, as it reports on an analytical approach with the aim of mapping social learning in planning processes, in order to disentangle in a more precise and robust way 'who learns what from whom'.

(2) installing intense (light-)rail connections between Aalst and Denderleeuw. Additionally, improve train frequencies between Ninove and Denderleeuw. Create more 'place value' in Denderleeuw in order to capitalize on its highly central position in the Belgian railway network.

These scenarios discern in very general terms plausible strategies for railway station (area) development in the Dender valley. Obviously, this region is part of the larger transport region of Aalst, and possible investment and development decisions would need to be made in congruence with all stakeholders and within fixed budgetary constraints[85]. Aside from the question whether any of the propositions listed would be politically feasible or not, we believe these visionary reflections add value in that they allow to 'think out of the box' and to think across scales – a phase rarely reached during the regional board meetings as voiced by a number of participants.

[85] Insights into how such complex multi actor and multi criteria planning phases can be organized are provided by the literature on stakeholder involvement in participatory settings and decision-support systems (for example Macharis et al. 2012, Macharis and Baudry 2018, te Boveldt 2019).

# CHAPTER 4. DRIVERS OF RIDERSHIP: DISENTANGLING NODES, PLACES, AND PEOPLE

## 4.1 Integration of node-place and trip end models for railway stations in Flanders

> Central to the utility of these concepts [sustainable communities, pedestrian pockets and transit oriented developments] is their implications on travel behavior.
>
> Calthorpe (1993: 46)

### 4.1.1 Introduction and background

Railway stations and their surroundings are a major focus of attention in scholarly work focusing on the integration of transport and land use development. This integrative approach has gradually emerged as a result of both the growing awareness of the importance of mobility management and the foregrounding of the concept of 'accessibility' in the context of sustainable development (Handy 2002, Bertolini et al. 2005, Ferreira et al. 2012). As elaborated in Chapter 1, one of the ways in which this integration can be pursued is by means of 'transit oriented development' (TOD). This planning paradigm refers to several mechanisms that can be implemented to intensify the density and mixing of housing and other activities near urban rail transport in inner cities as well as in metropolitan areas, with the overall objective of promoting transit ridership and other alternatives (walking and cycling) over the use of private cars (Cervero 2009).

The 'C' group of node-place writings discussed in Section 1.3.1 specifically deals with identifying the potential for TOD interventions as an outcome of the interplay between transport and land use (and sometimes) additional dimensions. Although these NPM contributions vary in terms of model conceptualization and indicator operationalization, they share a common purpose in that they aim to support a transition to increased ridership and therefore, presumably, a transition to more sustainable travel behavior. Surprisingly however, within the node-place modeling literature, analyses of the importance of node and place indicators in explaining ridership remain thin on the ground[86]. Following a thorough literature review of all contributions that directly build on and apply the NPM (see Figure 6), we found that only few studies elaborate on the correlations between ridership and the node-place indicators (Zemp et al. 2011, Falconer et al. 2016 and Caset et al. forthcoming). Some studies also incorporate ridership as one of the node indicators to arrive at classifications of stations (Reusser et al. 2008, Monajem and Nosratian 2015, Singh et al. 2017 and Kim et al. 2018) or as a means to validate the empirical node-place classifications found (Higgins and Kanaroglou 2016). However, to the best of our knowledge there is only one study that has used node-place indicators as a means of explaining ridership determinants (Olaru et al. 2019). The latter study used regression analysis to ascertain the associations between train patronage (AM peak, full day weekday and weekend) and the node and place indicators. For the case of the low-density city of Perth, Australia, these scholars found that the provision of Park and Ride, feeder buses and job accessibility by public transport are the strongest explanatory variables.

This relative lack of analytical cross-fertilization between the NPM literature and the one explaining passenger numbers and characteristics is somewhat surprising given the substantial body of literature addressing the challenge of explaining ridership and forecasting at railway stations. The next subsection will elaborate on this literature in more detail.

[86] Within the broader literature on TOD and related planning strategies such as the compact city, traditional town planning or new urbanism, appraisals of the impact of TOD measures on travel demand nonetheless exist. Some key references in this respect are: Handy (2005), who reviewed the available evidence in terms of 'new urbanism design strategies' on travel behavior and demand, and Ewing and Cervero (2010) who conducted a meta-analysis of the built environment-travel literature. More recently, Stevens (2017) conducted the first ever meta-regression analysis of a large collection of built-environment/travel studies. The NPM literature has nonetheless not taken up this pursuit, nor has it inferred findings from this body of research to feed into node-place modeling applications.

*A. Understanding rail ridership: Trip end models*

Quantifying the benefits of TOD in terms of ridership has traditionally been assessed using regional four-stage travel demand models (for example McNally 2000). However, this approach entails several potential problems (Marshall and Grady 2006, Cervero 2006, Gutiérrez et al. 2011). In most cases rail travel only accounts for a small percentage of trips made and regional models tend to be primarily designed to analyse road-based modes. Moreover, as argued by Gutiérrez et al. (2011) regional models are generally insensitive to land use and four-step travel models are cumbersome and expensive. Their performance thus tends to be relatively poor when assessing rail travel disaggregated to the station level.

This is particularly the case when attempting to forecast the demand for new stations or services where there is no existing level of rail demand to use as a basis for simulation. The majority of these rail-specific models can be placed into one of three categories, known as 'trip rate', 'trip end', and 'direct demand models'. The latter category is less relevant here as it forecasts the number of trips made on a given flow rather than total ridership at a station. Trip rate models forecast the number of trips made from a station as a function of the resident population in the station's expected catchment area. Trip end models differ in that they include additional explanatory variables alongside population to provide a more comprehensive representation of the processes which may determine rail usage levels. For example, some studies have aimed to quantify the link with land-use patterns (Sung and Oh 2011, Frei and Mahmassani 2013, Sun et al. 2016, Li et al., 2016).

The use of trip rate and trip end models to predict railway station demand has a long history (see for example Preston 1991, Lane et al. 2006). Ongoing research is still improving our knowledge on the matter, often by means of the adoption of enhanced techniques to improve model results. Examples include the use of geographically weighted regression to account for spatial variations in the demand impact of explanatory variables (Páez 2006, Chow et al. 2006, Kobayashi 2007, Blainey, 2010, Cardozo et al. 2012, Jun et al. 2015), the combination of machine learning techniques with regression models (Chiang et al. 2011), and integration with station choice models to provide a more realistic representation of station catchment areas (Young and Blainey 2019). While such models are most commonly developed for use in a specific urban or regional context (for example Zhao et al. 2013), there are also examples of more general and transferable models which are capable of predicting rail usage to a high degree of accuracy (for example Blainey 2010).

*B. Integrating node-place and rail ridership models*

The relative lack of integration between the NPM and rail demand forecasting literatures is particularly unfortunate given the limitations of most rail ridership models when used to predict demand. While, as noted above, it is possible to generate transferable models that predict existing levels of rail usage to a high degree of accuracy, these predictions tend to be based on a relatively small number of explanatory variables. When forecasting demand at a new station (or the demand change resulting from an alteration in exogenous conditions at an existing station), stakeholders will often be interested in the likely impact on ridership of a particular local factor. This may however not be easy to capture using the limited range of explanatory variables in the ridership model. We therefore argue that the incorporation of node-place variables in demand forecasting models has the potential to (at least partially) overcome this problem by allowing the effect of a much wider range of exogenous impacts on rail trips to be captured and predicted. Likewise, transferring techniques from rail ridership models to NPM applications may improve the analytical strength of the latter framework, as it introduces knowledge about the likely success of particular node or place interventions in terms of impacting rail ridership.

*C. Research objectives and structure*

Against this backdrop, this paper has a double objective. First, there is a methodological objective in that we aim to add to the body of literature in which the explanatory power of node-place modeling indicators in terms of ridership is examined. To this end, we draw on the trip end modeling literature and apply regression analyses to determine the most important explanatory factors. The data used for the modeling consist of the extensive node-place analysis for all railway stations in Flanders (see Section 2.2). Building on ridership data obtained from NMBS, we are able to explain ridership at a finer temporal level (distinguishing between total, morning, evening and off-peak ridership) than is usually the case in similar analyses (see Lane et al. 2006, Blainey 2010). Second, there is an empirical and related policy-support objective in that we apply the model to the case of Flanders. The models developed should allow policy makers to conduct a robust assessment of likely usage at potential new stations in the region, and to investigate the possible demand impacts of changes to existing stations and the area surrounding them.

The remainder of this section is organized as follows. The next subsection elaborates on the case, the data, the methodology and methodological shortcomings. Afterwards, the results are discussed in section 4.1.3 and we reflect on the potential to include these findings into the StationRadar tool (4.1.4). In the discussion and conclusions section (4.1.5) we couple back to the node-place model and reflect on how our findings might feed into the framework.

### 4.1.2 Case, data and methodology

*A. Empirical case*

The geographical scope of our research comprises the region of Flanders, operationalized as the Dutch speaking part of Belgium (see Figure 37a). For reasons of data coherence[87], we opted to focus on the region of Flanders only. The 253 railway stations that are part of our analysis are indicated on the map[88]. For each of these stations, we build on the range of node and place indicators that were developed and measured as part of section 2.2 and we collect additional data. We briefly summarize the indicators below to make this chapter self-standing. The full list of indicators, along with their acronym, a short description and their data source are provided in Table 8.

[87] Data for the regions of Flanders and Brussels is often operationalized and collected in different ways and stored in different datasets. In the context of this research, it is important to note that the employment density data developed by Verachtert et al. (2016) is composed on the basis of two separate sources for both regions. Geographically detailed employment data is available for Flanders whereas the level of detail for the Brussels employment data is considerably lower. Other cartographic material (the employment and amenity density maps) that is used in this dissertation is also composed of different sources for the two regions. This is not necessarily problematic as these density maps were created carefully and submitted to strict technical procedures. Given that this chapter deals with explanatory analyses, we nonetheless opted to reduce the geographical scope to the region of Flanders in order to maximalize data coherence.

[88] The region of Flanders contains 256 railway stations. Three stations are discarded from our analysis: Mortsel-Deurnsesteenweg, Zeebrugge-Strand and Visé-Frontière. The first two are only serviced during the weekend, and the latter is located in the non-adjoining municipality of Voeren, for which some consistent data sources were lacking. Furthermore, the stations in the Brussels Capital Region were not included in this analysis since data sources are not always consistent for both regions.

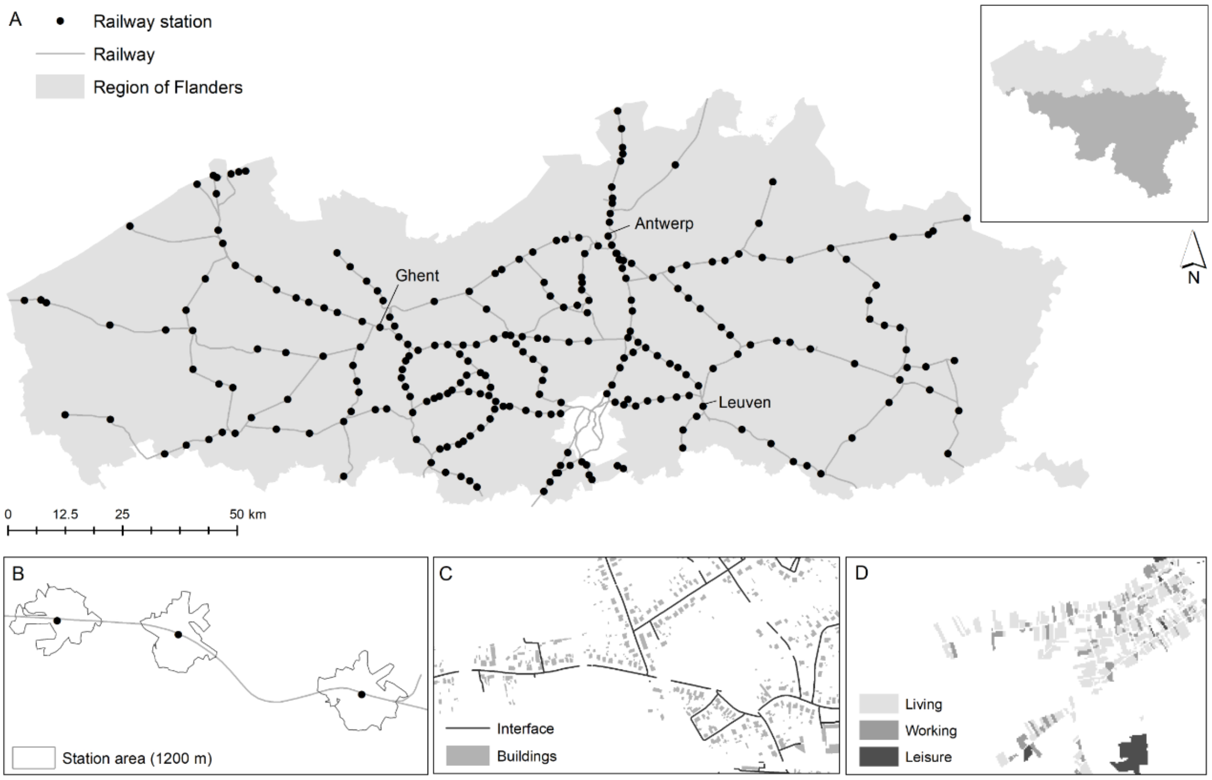



Figure 37: a) Flanders and its current railway network, b) walkable station area examples, c) spatial visualization of the 'interface', d) land use raster data illustration

*B. Data*

Independent variables

Table 8 provides an overview of all the independent variables which are further clarified in the below. Given that Section 2.2.2 has provided an extensive overview of much of the variables included here and their operationalization, we keep this part concise.

In terms of node indicators, two groups can be distinguished: those measuring feeder mode accessibility of the station (by car, bike and public transport), and those measuring railway accessibility. As for the first group, the car and bike indicators both reflect parking information, distinguishing between free, toll and total parking capacities. The feeder public transport indicators include number of bus, tram and metro (BTM) routes available at the station and total frequency of BTM departures (both for a Tuesday). As for the second group, the indicators include frequencies on a Tuesday, distinguishing between the daily number of departing trains and the number of off-peak departures (i.e. between 9AM and 4PM), amplitude (the proportion of the day in which train services are offered), and the two centrality measures (transfer and travel time centrality) explained earlier in Chapter 2. These centrality measures are inspired by the 'degree' and 'closeness' centrality indicators as developed by Curtis and Scheurer (2010, 2016).

In terms of place indicators, three groups of indicators are distinguished: those measuring aspects of 'density', 'diversity' and 'design' of the station area. As indicated earlier, 'station area' is defined here as the area reachable within a walkable street network distance of 1200 meter, which corresponds to approximately 15 minutes of walking (see Figure 37b for some station area examples). Street network distances were used instead of Euclidean distances, because these provide more realistic assessments (Horner and Murray 2004, Gutiérrez and García-Palomares 2008). As demonstrated in Table 8, the density dimension is composed of five indicators, measuring the density of basic, regional and metropolitan amenities and of residents and jobs in the station area. These are all raster data with grid cells of 100 x 100 m. For each of these raster layers, the density values of the grid cells that intersect geographically with the station area are summarized, which results in a total density value for the station.

Diversity of land use is measured both functionally and spatially. The functional mix is measured using a Shannon diversity index which examines the balance of land use types in terms of co-presence and surface occupied. The land use data consists of grid cells of 10 x 10 m and contains the following land use categories: living, working and leisure. The Shannon diversity index is maximal for those station areas in which all three land use types are present *and* in which these three land use types occupy identical surfaces. The spatial mix, in turn, is captured here by the Interspersion and Juxtaposition Index (IJI) (see McGarigal and Marks 1995) which measures the interspersion of different land use types (well-interspersed station areas have land use 'patches' or types that are equally adjacent to each other[89]). Importantly, this spatial measure is different from the one used previously (the Contagion Index) in Section 2.2. As stated in Section 2.2.3, the Shannon index and the IC were very strongly correlated, arguably indicating that the differences in functional and spatial land use diversity were not sufficiently captured. After manually checking and comparing results, the IJI seems more suitable to capture spatial land use mix for the data used.

Next, the design dimension is composed of three indicators (listed in Table 8). In line with Pafka and Dovey (2018), the first indicator focuses on the extent of the public/private interface within the station area as a proxy measure for 'how much' is 'caught' within the area. More specifically, this interface catchment (IC) is calculated by summarizing the length of all walkable street segments (as a proxy for the public sphere) that are also flanked by buildings (as a proxy for the private sphere) (see Figure 37c for an illustration). The second indicator, permeability, measures the extent to which the urban morphology is permeated by publicly accessible space (see also Marshall 2005) by means of mapping the total number of street crossings per station area (see also Ryan and Frank 2009). This measure relates to the ease of movement through an urban area due to the multiplicity of route choices between any pair of points. Both indicators are complemented by a third one that measures the total length of walkable and bikeable street networks within the station area.

Competition between stations was not considered in defining station catchments, and station areas are therefore not mutually exclusive and may overlap. In practice, demand at local stations may nonetheless be affected by the proximity of other or larger stations. To take this into account, station spacing indicators were calculated to represent travel times (by car and by train) from the local station to (1) the nearest station and (2) the nearest station of a higher order. The order was determined by classifying the stations according to a Jenks classification method into five categories based on their service frequency on a Tuesday.

In addition to the above characteristics, ridership may also be affected by socioeconomic characteristics of the station area residents, such as income, age, race or ethnicity and car ownership (Stead 2001, Ewing and Cervero 2001). The latter is likely of particular importance in the Flemish context, given the large influence of car ownership, or in a broader sense car availability, on the use of the car in Flanders (see Van Acker 2010). However, recent car availability data for Flanders (in terms of the number of registered vehicles) is limited to the municipal scale, which is too coarse for the purpose of this research. Furthermore, company cars, representing a large share of the car fleet in Flanders[90], are registered at the company's main address, further reducing the usefulness of this dataset in the context of this research. As a

[89] The measure ranges between 0 and 100 and is expressed as a percentage. IJI approaches 0 when the distribution of adjacencies among unique land use types becomes increasingly uneven. IJI = 100 when all land use types are equally adjacent to all other land use types (that is, maximum intersperson and juxtaposition). For more detail see McGarigal and Marks (1995: 121).

[90] According to May et al. (2019), around 13,5% of all employees in Belgium have a company car at their disposal. These company cars represent 11,5% of the total car park and represent 23% of distances traveled by Belgian cars.

consequence, car availability data could not be included. We nonetheless collected other socioeconomic data[91] at the scale of the statistical sector, pertaining to (1) the labor market situation of the station area residents, and (2) the economic sector in which the station area residents are employed (both based on the latest census data from 2011). These data were summarized over statistical sectors for all sectors intersecting with the station area.

Dependent variables

The ridership data reflects the number of boardings on a regular weekday in 2018, based on NMBS ticket sales data. Both individual and season tickets are taken into account. This implies that for some of the stations belonging to a 'tariff zone' (32 stations in total), tickets could not be attributed to one specific station (for example, 'zone Ghent' comprises five stations). For these stations, the publicly available 'October counts'[92] (which reflect manual counts by on-board personnel for a regular workday in October 2018) were imputed. As indicated by Sørensen et al. (2019), manual counts are characterized by varying accuracy. However, no other alternative was available in this case.

Besides the ticket sales data, NMBS also provided the proportions of people boarding on a regular workday during the morning peak (6 to 9 AM), evening peak (4 to 7 PM) and off-peak (between 9 AM and 4 PM). This allowed us to approximate boardings for these different periods of the day. Figure 38 illustrates the strongly skewed distributions of these four groups of ridership data. These curves demonstrate that the railway network in Flanders has very few stations with very high ridership numbers, and this during the different periods of the day. The largest stations in terms of ridership are Ghent, Antwerp and Leuven (indicated in Figure 37a) with respectively 56.314, 34.998 and 34.267 total boardings on a regular workday, while the stations of Aalst-Kerrebroek, Aalter and Hambos each accommodate around 26, 28 and 32 travelers respectively.

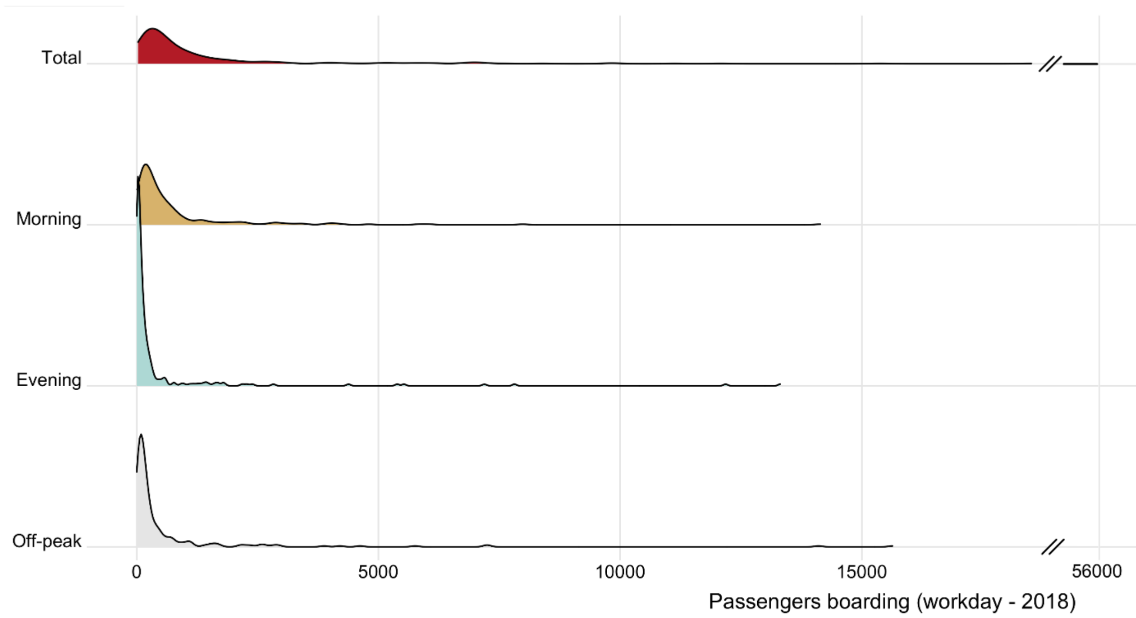



Figure 38: Distributions of ridership data for different periods of the day

[91] Car availability may nonetheless be correlated to these socioeconomic data, given that it has frequently been demonstrated (see Van Acker and Witlox 2010 for an overview) that variables such as age, employment status, educational level and other socioeconomic and demographic characteristics impact car ownership and car use.

[92] The data for 2018 can be found on this link: https://www.belgiantrain.be/nl/about-sncb/enterprise/publications/travellers-counts

| Indicator | Description | Source |
|---|---|---|
| Feeder mode accessibility (node value) | | |
| CA_park_free | Number of free car parking spots | NMBS (2018) |
| CA_park_toll | Number of toll car parking spots | |
| CA_park_total | Total number of car parking spots | |
| AT_park_free | Number of free bike parking spots | |
| AT_park_toll | Number of toll bike parking spots | |
| AT_park_total | Total number of bike parking spots | |
| BTM_routes | Number of unique bus, tram and metro routes to and from the railway station on a Tuesday | Calculated based on the GTFS data |
| BTM_freq | Frequency of bus, tram and metro departures on a Tuesday | provided by De Lijn, TEC and MIVB/STIB (June 2018) |
| Railway accessibility (node value) | | |
| TR_freq_tue | Frequency of departures on a Tuesday | Calculated based on the GTFS data provided by NMBS (June 2018) |
| TR_freq_off | Frequency of departures off-peak (between 10 and 11 AM on a Tuesday) | |
| TR_amp | Amplitude (the proportion of the day between the first and the latest train service at the station) | |
| TR_ttcentr | Travel time centrality (the minimum cumulative impediment in terms of travel time and service frequency, between station i and all other stations in the Belgian railway network) | |
| TR_trcentr | Transfer time centrality (the minimum cumulative impediment in terms of transfers needed, between station I and all other stations in the Belgian railway network) | |
| Built environment characteristics (place value) | | |
| P_DE_bas | The density of basic amenities in the station area | Calculated based on the data created by VITO (see Verachtert et al. 2016) |
| P_DE_reg | The density of regional amenities in the station area | |
| P_DE_met | The density of metropolitan amenities in the station area | |
| P_DE_job | The job density in the station area | |
| P_DE_res | The residential density in the station area | Calculated based on the data provided by FOD Binnenlandse Zaken (2013) |
| P_DI_shan | The functional mix of land uses in the station area (a Shannon diversity index calculated based on three types of land uses: living, working and leisure - see Figure 40d for an illustration of the raster data) | Calculated based on the data created by VITO (land use model, version 2013) |
| P_DI_IJI | The spatial mix of land uses in the station area (an interspersion and juxtaposition index calculated based on three types of land uses: living, working and leisure - see Figure 40d for an illustration of the raster data) | |
| P_DG_IC | The interface catchment of the station area (the total street network length of the interface between buildings and streets, as a proxy for the interface between public and private space - see Figure 40c for an illustration) | Calculated based on OpenStreetMap (2018) |
| P_DG_perm | The permeability of the street network in the station area (the sum of street crossings) | |
| P_DG_netw | The network length in terms of walking and biking infrastructure in the station area | Calculated based on OpenStreetMap (2018) |
| Station spacing | | |
| TT_tr_near | Travel time by train from the station to the nearest station | Calculated using the Network Analyst Extension in ArcGIS |
| TT_tr_higher | Travel time by train from the station to the nearest station of a higher order | |
| TT_car_near | Travel time by car from the station to the nearest station | |
| TT_car_higher | Travel time by car from the station to the nearest station of a higher order | |
| Socioeconomic characteristics (labor market situation and economic sector) | | |
| LMS_for | The number of foreigners living in the station area | Calculated based on the census 2011 data provided by StatBel |
| LMS_work | The number of workers living in the station area | |
| LMS_young | The number of residents younger than 15 years living in the station area | |
| LMS_old | The number of retired residents living in the station area | |
| LMS_stud | The number of students living in the station area | |
| ES_industry | The number of station area residents employed in agriculture, forestry and fishery, the (construction) industry, extraction of minerals, production of electricity, gas, steam and cooled air, distribution of water, waste and sanitation | |
| ES_retail_hotel_cat | The number of station area residents employed in retail, hotel, catering and transport and logistics | |
| ES_services_admin | The number of station area residents employed in information and communication, financial activities and insurances, exploitation of and trade in intangible heritage, free professions and scientific and technical activities, administrative and supporting services, | |
| ES_educ_health_cult | The number of station area residents employed in education, health care and societal services, public governance and defense | |

Table 8: Overview of the independent variables (indicators)

In summary, the calibration dataset is cross-sectional and consists of a 36 x 4 matrix, with 36 potential ridership determinants and four groups of ridership data (total, morning, evening and off-peak).

*C. Methodology*

<u>OLS regression analysis</u>

In order to estimate the importance of the independent variables in explaining ridership, we applied two different types of regression analysis.

First, a series of ordinary least square (OLS) regression equations were estimated to test the relative significance of the independent variables in predicting ridership. These analyses were conducted for two groups of data: (1) the full set of 253 railway stations and the different time windows, and (2) a geographical segmentation of the data according to the NTP typology of stations[93] developed in Section 2.2.3 (see Figure 19). We draw on these earlier exploratory efforts in order to examine if and to what extent the drivers of ridership differ for these empirically informed categories of stations. The four station types are distinguished by different node and place characteristics[94] and are illustrated in Figure 39.

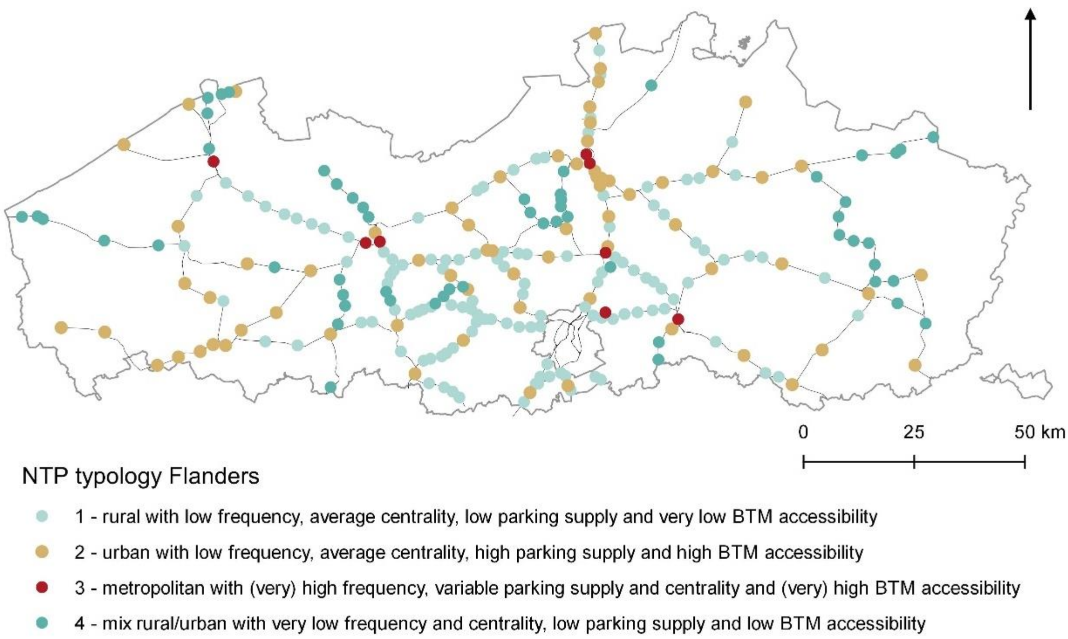



Figure 39: Station typology based on node, train and place characteristics

These clusters can be validated by running one-way analyses of variance (ANOVA) for the different key characteristics that shaped the station groupings (as detailed in Section 2.2.2). Judging from the cluster

[93] Some modifications were made with respect to the cluster result presented in Figure 19, which was calculated for both the regions of Flanders *and* Brussels. First, we merged the two 'metropolitan' station types into one type. Second, we reclassified two stations (Buda and Linkebeek) which were classified as 'metropolitan' and are located just across the border of the BCR. Compared to the new set of metropolitan stations, both stations no longer qualify as such. Based on their factor loadings and those of the initial clusters (see Section 2.2), these stations could classify as either type 1 or 4 stations. We ultimately decided to categorize them as type 1 stations based on the surrounding stations.

[94] The station types are also distinguished by statistically different ridership numbers. A one-way analysis of variance (ANOVA) indicated that there is a significant effect at the 95% confidence level ($F(4,248)=146{,}0$ and $p = .000$).

centers and factor loadings (see Appendix II in Section 2.2), we compared the means for the following variables between the different station types: *train frequency* (TR_freq_tue), *car parking capacity* (CA_park_total), *feeder public transport accessibility in terms of unique routes available* (BTM_routes), *density of basic amenities* (P_DE_bas) and *transfer centrality* (TR_trcentr). All analyses led to statistically significant F statistics, indicating an overall difference in these key characteristics between the types. The cluster sizes are as follows: type 1 (122 stations), type 2 (68 stations), type 3 (8 stations) and type 4 (55 stations). A rule of thumb for linear regression analyses implies that there are at least 20 cases per independent variable. Therefore, we will only discuss the results for the station types 1, 2 and 4.

The independent variables were added in a stepwise manner using forward selection. More specifically, during each step in the process of adding variables, the variable that led to the highest model fit (in terms of the R2adj statistic) was included in the model. This procedure continued until no remaining candidate variables were left.

In order to limit multicollinearity problems, we analyze the correlations between all pairs of independent variables. The correlation matrix informs that there are strong and significant correlations (>0.8), mainly within the group of place indicators, and between the feeder public transport routes and frequency indicators. This has important implications for the co-presence of these indicators in the same model. We monitor this more closely by assuring that the variance inflation factors[95] (VIF) of the variables do not exceed the commonly used threshold of 3. More specifically, when a variable is added to the model (in line with the stepwise procedure described above) which leads to VIFs higher than 3, the variable that was added last is removed again.

Because of the skewed data distributions we log-transformed all indicators. This resulted in four log-log models given by:

$$\ln (Y) = \boldsymbol{\alpha} + \boldsymbol{\beta}_1 \ln (x_1) + \boldsymbol{\beta}_2 \ln (x_2) + \ldots + \boldsymbol{\beta}_i \ln (x_i) + \boldsymbol{\varepsilon} \quad (1)$$

with intercept $\boldsymbol{\alpha}$, coefficients $\boldsymbol{\beta}$ and error term $\boldsymbol{\varepsilon}$. As all coefficients are fixed or 'global', this type of regression is called a 'global regression model'.

Geographically weighted regression analysis

Direct station-level ridership forecasting models drawing on the regression technique described above have the important drawback that they do not account for the possibility that parameters may not be constant across different points in space (see Blainey 2010 for a fuller discussion of this issue). As a corollary, Fotheringham and colleagues have outlined an approach that accounts for spatially varying parameters called 'geographically weighted regression' (GWR) (Brunsdon et al. 1996, 1999, Fotheringham et al. 1998). As argued by Cardozo et al. (2012), this technique explicitly considers the spatial component of the data by incorporating the value of the geographical coordinates of observations in its equation. The assumption is that nearby observations will have a greater influence on one another's parameter estimates than observations that are located further apart.

The $\boldsymbol{\beta}_j$ coefficients ($j = 0, 1, \ldots, p$) of the j variables $x_j$ ($j = 1, \ldots, p$) may thus vary for each location. In other words, instead of calibrating a single regression equation, GWR generates a separate regression equation for each observation with coordinates ($u_i$, $v_i$). The value of the dependent variable $y_i$ is estimated as follows:

[95] The VIF assess how much the variance of an estimated regression coefficient increases if the predictors are correlated.

$$\ln (Y_i) = \boldsymbol{\beta}_0 (u_i, v_i) + \boldsymbol{\beta}_1 (u_i, v_i) \ln (x_1) + \ldots + \boldsymbol{\beta}_p (u_i, v_i) \ln (x_p) + \boldsymbol{\varepsilon}_i \quad (2)$$

In order to examine the possibility of spatially varying parameters for the full set of railway stations, we subject the four best fit OLS models to a geographically weighted regression analysis in the software package GWR, version 4[96]. For each of these best fit models, a geographical variability test is conducted to determine if and which variables are fixed ('global') or varying ('local'). We afterwards estimate these global and local parameters using a Gaussian[97] model with an adaptive bi-square kernel function[98], and a 'golden-section search' method to automatically search for the optimal bandwidth size.

*D. Methodological limitations*

We conclude this methodological section by appraising a number of important methodological limitations, some of which emanate from interpreting results from cross-sectional models as causal mechanisms.

Due to the snapshot of data points at a single moment in time, cross-sectional models (contrary to panel data models) are not suited to pinpoint exactly to what extent the associations found are causal or not. Therefore, they serve the purpose of providing rough estimates of ridership determinants (Liu et al. 2014). The associations that will be described in the below thus warrant careful interpretation, as some of the variables included may be confounding in terms of the causal relationships at play. For example, the inclusion of train service variables may produce endogeneity problems, since service supply not only affects transit demand, but it may equally be a function of demand (Taylor and Fink 2003, Gutiérrez et al. 2011). Additionally, due to the generally high levels of correlation among (mainly) spatial and socio-economic variables, it is hard to untangle the inter-relations between these various factors on the one hand and on transit ridership on the other hand (Crane 2000, Taylor and Fink 2003).

Also, some potentially relevant variables were not included in our analyses. Some of these are either hard to operationalize – especially at the scale of 253 stations – or data is not available at the required level of detail. Examples of the former issue include variables measuring transit service *quality* in terms of comfort, reliability and convenience or car driver friendliness and traffic congestion levels of the station area. In terms of the latter, and as mentioned above, solid data capturing car availability of households at a sufficient geographical scale is not available in Flanders.

A final methodological weakness is pointed out by Taylor and Fink (2003) who argue that this type of causal analysis suffers from loss of information due to aggregation: "fully understanding the determinants of transit mode choice requires that analyses be disaggregated to the household or even trip level. But such analyses are extraordinarily data intensive and expensive to conduct". In other words, the analyses conducted in this section reason from ecological correlations, meaning that the findings can only be interpreted at the level of station areas and may not be extrapolated to the level of the individuals residing in the area. These ecological correlations are in turn influenced by the geographical scales at which the point-based data is aggregated into statistical sectors (the socio-economic data) and raster pixels (the 'place' data) *and* into station areas with a particular size (both pertain to the 'modifiable areal urban unit problem').

[96] National Center for Geocomputation (2009). See: gwr.maynoothuniversity.ie/gwr4-software.

[97] This option was preferred as the data is normally distributed.

[98] This option was preferred as it is suitable for data points that are distributed non-symmetrically in space.

### 4.1.3 Results

*A. The scale of Flanders and different time windows*

Table 9 summarizes the four best fit models in terms of $R^2_{adj}$ values, the unstandardized variable coefficient B, the t-statistic, the level of significance and the VIF. All variables included are statistically significant at the 95% confidence level. The high $R^2_{adj}$ values for all four models indicate high degrees of model fit to the data.

The total number of boardings (model 1) is best explained by six determinants. According to the $\beta$ coefficients, transfer centrality has by far the largest impact on total ridership in Flanders. The model indicates that a 1% increase in transfer centrality will result in a 2% increase in ridership. Likewise, train frequency and interface catchment exert an impact of 0.6% and 0.4%, respectively, while the remaining variables (especially BTM routes) all have lower $\beta$ values. Interestingly, when running the total ridership model with just train frequency and total car parking capacity included, an $R^2_{adj}$ value of .758 is obtained, which is remarkably high for just two explanatory factors.

Morning peak (model 2) has largely similar determinants as total ridership with some exceptions: BTM routes is not selected, whereas amplitude of train services does play a role. The negative coefficient for density of metropolitan amenities seems to indicate that a sizeable proportion of the stations with high levels of morning ridership are located outside of the largest metropolitan areas. The highest elasticities are noted for interface catchment and train frequency (both 0.6).

The determinants included for the evening peak (model 3) are largely similar to those of the total ridership model, except for job density. The largest elasticity values are nonetheless (again) recorded for transfer centrality (a 3% increase in evening ridership when this variable increases by 1%) and – to a lesser extent – train frequency (0.7%).

Lastly, the off-peak model (model 4) has the highest overall fit and the largest number of variables included. The variables are similar to those of the total model, but a number of additional variables were selected: amplitude of train services and the station spacing variable measuring the travel time by train to stations of a higher order. The positive (and rather low) coefficient value of the latter implies that off-peak ridership generally increases when a station is connected poorly to stations of a higher order. Besides the very high coefficient value for transfer centrality (3.6%), amplitude of train services also has a high value (1.4%).

Some more general observations can be made. First, the strongest determinants for ridership in Flanders seem to be situated within both domains of 'node' and 'place', but with the former being more important: the group of node variables generally exhibits most of the statistically significant variables with higher coefficient value. The train variables in particular seem to exert the strongest impacts on ridership. Further node-related findings are that including total parking capacities results in higher model fits than the disaggregate free and toll parking variables (for both the bike and car modes). Also, feeder public transport accessibility in terms of unique routes available (BTM routes) is more frequently significant and leads to higher model fits than the daily frequency of departures, suggesting that an increase in the number of available feeder transit routes will have a higher impact on ridership than an increase in daily frequency. Next, the only train variable that did not feature in any of the models is the travel time centrality variable. In fact, this indicator is not significant in any of the model runs, while transfer centrality does feature prominently. This leads us to suggest that rail travel demand in Flanders is more strongly impacted by the number of transfers required than the required travel times and service frequencies of rail trips.

| | | $R^2_{adj}$ = .848<br>**1. TOTAL**<br>*Total number of boardings on workday* | | | | $R^2_{adj}$ = .778<br>**2. MORNING**<br>*Number of boardings morning peak* | | | | $R^2_{adj}$ = .845<br>**3. EVENING**<br>*Number of boardings evening peak* | | | | $R^2_{adj}$ = .861<br>**4. OFF-PEAK**<br>*Number of boardings off-peak* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | B | t | Sig. | VIF | B | t | Sig. | VIF | B | t | Sig. | VIF | B | t | Sig. | VIF |
| NODE | CA_park_total<br>*Total car parking* | 0.281 | 6.871 | 0 | 2.538 | 0.331 | 7.63 | 0 | 2.371 | 0.18 | 3.337 | 0.001 | 2.578 | 0.246 | 5.333 | 0 | 2.638 |
| | AT_park_total<br>*Total bike parking* | 0.232 | 5.859 | 0 | 2.562 | 0.186 | 4.194 | 0 | 2.623 | 0.321 | 6.244 | 0 | 2.479 | 0.211 | 4.754 | 0 | 2.588 |
| | BTM_rout<br>*BTM routes at station* | 0.141 | 2.813 | 0.005 | 2.25 | | | | | 0.249 | 3.523 | 0.001 | 2.576 | 0.229 | 3.961 | 0 | 2.413 |
| | TR_freq_tue<br>*Total train frequency Tuesday* | 0.585 | 8.147 | 0 | 2.125 | 0.569 | 7.089 | 0 | 2.166 | 0.726 | 7.684 | 0 | 2.122 | | | | |
| | TR_freq_off<br>*Total train frequency off-peak* | | | | | | | | | | | | | 0.55 | 5.577 | 0 | 2.411 |
| | TR_amp<br>*Train service amplitude* | | | | | 0.532 | 1.978 | 0.049 | 1.672 | | | | | 1.396 | 4.938 | 0 | 1.828 |
| | TR_trcentr<br>*Transfer centrality* | 2.018 | 3.043 | 0.003 | 2.032 | | | | | 2.627 | 3.001 | 0.003 | 2.04 | 3.557 | 4.392 | 0 | 2.445 |
| PLACE | P_DE_met<br>*Density metropolitan amenities* | | | | | -0.232 | -5.009 | 0 | 1.757 | | | | | | | | |
| | P_DE_job<br>*Density jobs* | | | | | | | | | 0.336 | 8.325 | 0 | 1.843 | | | | |
| | P_DG_IC<br>*Interface catchment* | 0.353 | 5.342 | 0 | 1.613 | 0.563 | 6.797 | 0 | 2.072 | | | | | 0.45 | 6.072 | 0 | 1.636 |
| STATION SPACING | TT_tr_higher<br>*Travel time by train to closest station of higher order* | | | | | | | | | | | | | 0.129 | 2.223 | 0.027 | 1.147 |

Table 9: Summary statistics of the best fit models (indicators are logged)

Place variables are scarcer than node variables in the best fit models. Given the strong correlations within this group of variables, most models only include one place variable in order to avoid multicollinearity. An interesting observation here is that none of the two diversity variables (the Shannon diversity index and the IJI), feature in the best fit models. Although land use diversity is considered an important ingredient of successful TOD planning, it does not seem to impact ridership in Flanders to a great extent. However, some model runs do result in significant outcomes and have model fits that are similar to those with density or design variables included. This is especially the case for some of the evening and off-peak model runs, where both diversity variables are significant and lead to high model fits. The morning peak model runs on the other hand, do not include any significant diversity variables. Interestingly, the Shannon diversity index always leads to higher fits than the IJI, which suggests that the functional land use mix measure appears to be a stronger explanatory factor for ridership in Flanders than the spatial land use mix.

Another notable finding is the strong significance of the design variable interface catchment. Although most other place variables also render statistically significant outcomes, interface catchment always leads to the highest $R^2_{adj}$ values (except for model 3 where job density features more strongly). Of course, the interpretation of this land use variable in terms of its practical demand impact is less straightforward than that of an indicator measuring aspects of density (e.g. residential or job density). After all, increasing the public/private interface within a station area translates into a rather abstract planning task, compared to increasing the residential density of a station area by a certain percentage or number of housing units. It could therefore be questioned whether this variable may be instrumental in planning discussions. Furthermore, in line with the methodological limitations discussed above, and given the strong correlations between interface catchment and residential density (.917 at the .01 level) or basic amenity density (.905 at the .01 level), it is questionable whether this design variable is indeed a direct ridership determinant or rather a feature of high density station areas. As for the other two design variables, permeability also renders model fits that are close to those of interface catchment, while the indicator measuring the total length of bikeable and walkable infrastructure (network length) clearly performs weaker.

The station spacing variables do not feature in the majority of best fit models, but are nonetheless positively associated and statistically significant in most of the other model runs with a lower fit. Importantly, this implies that ridership is not only influenced by characteristics of the station itself (captured by the node and place variables), but also by inter-station characteristics such as their proximity in space and time.

To conclude, unlike the groups of variables discussed above, none of these socio-economic characteristics feature in the best fit models. Although most of these variables feature significantly and positively in model runs together with node variables, they are not significant when the place variables are added.

*B. Different types of railway stations, different determinants?*

Table 10 summarizes the results of the round of OLS regression analyses for the different station types. In line with Table 9, the statistically significant variables of the best fit models are provided with some key statistics. In order to facilitate the interpretation, we inserted the colour palet used in Figure 39 to point out the different station types. Since none of the socio-economic variables are selected in the best fit models, we removed those from Table 10. The discussion below is structured around the outcomes per station type (except for type 3 given its small cluster size), followed by a summary of the main trends.

<u>Type 1</u>. This group is composed of the most rural stations in Flanders, and is further characterized by low train frequency, average railway network centrality, low parking supply and very low accessibility by bus, tram or metro. The type 1 models demonstrate more or less consistent fits across the four time windows with $R^2_{adj}$ values fluctuating around .650. The best fits are however found for the morning and the off-peak.

In general, ridership for this group seems most influenced by car and train accessibility, by all three place dimensions (density, diversity and design) and by station spacing. The total and morning peak model are very similar and indicate that ridership is by far most influenced by the station's *transfer centrality*, followed by *travel time by car to the closest station of a higher order.* The positive coefficient for the latter implies that stations will generally perform better when there is no convenient alternative to drive by car to a nearby station with a higher train service frequency. *Residential density* also plays a significant role, followed by *total car parking capacity*. For the case of evening peak ridership, *train frequency* and *job density* play a role as well as does the design variable *permeability*. Ridership during the off-peak hours seems in turn most strongly influenced by *transfer centrality* and *interface catchment*.

Type 2. These stations are predominantly located in urban areas and are characterized by an average centrality in the railway network, high parking supply and high accessibility by feeder public transport. Judging from Table 10, the model fits are generally (much) higher than the group 1 stations, with the highest model fits for the evening and off-peak data (with $R^2_{adj} \sim .800$). The determinants between both groups also clearly differ. Instead of comprising the different node, place and station spacing groups, the determinants of type 2 are predominantly clustered within the node dimension, except for the evening peak model which includes high B values for the *Shannon diversity index* and *interface catchment*. Contrary to type 1, besides the car, feeder mode accessibility by bike and BTM are also important. Furthermore, train frequencies seem more important than the station's centrality in the network (possibly because network centrality is already moderate to high for these stations).

Type 4. The main feature that distinguishes this group of stations from the others is their very low performance on all train variables (service frequencies, network centrality and amplitude). A large share of these stations is located at the periphery of the network. Model fits are rather poor compared to the other types, except for the off-peak model with has a $R^2_{adj}$ value of .846. In general, *amplitude* seems to play a very large role, which may not surprise given the low network centrality positions of these stations hence the need to be able to reach the station early in the morning and/or late in the evening – arguably mainly for the case of commuters working in the more central areas of Flanders. *Car parking capacity* does not seem to play a large role while *bike parking capacity* seems rather important, especially for the evening peak model.

Drawing on the above findings, some general observations can be made. First, in line with the findings for the full set of railway stations (Table 9), it seems that the place variables play a less dominant role in explaining ridership in Flanders than is the case for the node variables. Judging from Table 10, place variables are only relevant in explaining ridership for the rural stations (type 1) and for the evening peak models. Moreover, the B coefficients of the place variables are relatively small compared to those of other variables (some exceptions aside for the evening peak model).

Second, some of the variables that did not show up in any of the generic models do appear in Table 10 (some of them with high B values): *residential density*, *Shannon diversity index* and *permeability*. Conversely, some of the findings for the generic models are corroborated by the geographically segmented analyses. For example, the explanatory power of the following variables is very limited in the Flemish context: *density of basic, regional and metropolitan amenities*, *toll and free parking supply*, *BTM frequency*, and *total street network length of walk- and bike infrastructure*.

Third, it seems that the model fits are generally lowest for the morning peak models compared to the models for the other time windows – with the sole exception of the station type 1 model. This seems to imply that – especially for the morning peak models – there are important determinants that were not factored in in our research design, or that were not measured in an appropriate way. This might pertain especially to the socio-economic variables collected, which only capture a fraction of what could possibly be relevant judging from earlier travel behavior research for the case of Flanders (for example van Acker 2010).

| | | 1. TOTAL Total number of boardings on workday | | | | 2. MORNING Number of boardings morning peak | | | | 3. EVENING Number of boardings evening peak | | | | 4. OFF-PEAK Number of boardings off-peak | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| | $R^2_{adj}$ | 0.623 | 0.749 | 0.972 | 0.587 | 0.683 | 0.566 | 0.888 | 0.532 | 0.608 | 0.836 | 0.957 | 0.593 | 0.69 | 0.8 | 0.905 | 0.846 |
| NODE | CA_park_total *Total car parking* | 0.334 | 0.22 | | | 0.373 | 0.334 | | 0.249 | 0.378 | 0.358 | | | 0.344 | 0.302 | | |
| NODE | AT_park_total *Total bike parking* | | 0.304 | 0.624 | 0.612 | | 0.314 | 0.791 | 0.532 | | | | 0.989 | | 0.39 | | 0.739 |
| NODE | BTM_rout *BTM routes at station* | | 0.386 | | 0.294 | | | | | | 0.575 | 1.108 | | | 0.374 | 1.757 | 0.444 |
| NODE | TR_freq_tue *Train frequency Tuesday* | | 0.447 | | | | 0.4 | | | 0.554 | 0.57 | 0.804 | | | | | |
| NODE | TR_freq_off *Train frequency off-peak* | | | | | | | | | | | | | 0.321 | 0.348 | | 0.602 |
| NODE | TR_amp *Train service amplitude* | | | | 1.487 | | | | 1.08 | | | | | | | | 3.055 |
| NODE | TR_ttcentr *Travel time centrality* | | | | | | | | | | | | 1.121 | | | | |
| NODE | TR_trcentr *Transfer centrality* | 2.883 | | 6.85 | | 2.777 | | | | | | | | 2.891 | | | |
| PLACE | P_DE_job *Density of jobs* | | | | | | | | | 0.357 | | | | | | | |
| PLACE | P_DE_res *Density of residents* | 0.446 | | | | 0.519 | | | | | | | | | | | |
| PLACE | P_DI_shan *Shannon diversity index* | | | | | | | | | | 1.352 | | | | | | |
| PLACE | P_DI_IJI *Interspersion and Juxtaposition Index* | | | | | -1.017 | | | | | | | | | | | |
| PLACE | P_DG_IC *Interface catchment* | | | | | | | | | | 0.648 | | | 0.721 | | | |
| PLACE | P_DG_perm *Permeability* | | | | | | | | | 0.46 | | | 1.396 | | | | |
| STATION SPACING | TT_tr_near *Travel time by train to closest station* | | | | | | | | | | | | | | | | 0.509 |
| STATION SPACING | TT_car_higher *Travel time by car to closest station of higher order* | 0.79 | | | | 0.791 | | | | 0.775 | | | | 0.554 | | | |

Table 10: Summary of the best fit models for the different NTP station types (indicators are logged)

Fourth, although the geographical segmentation of data provides more insight into the relative importance of determinants for different types of stations, the model fits of the generic models discussed in Section A are all higher than the ones discussed in Section B. This is most notable for the total and the morning peak models.

*C. Analyzing spatial nonstationarity*

The outcomes of the GWR analyses are summarized in Table 11. This table displays some key model statistics. Judging from this table, it seems that spatial nonstationarity certainly needs to be considered. After all, the GWR versions of the best fit log-log models all exhibit higher $R^2_{adj}$ values than the global calibrations of the model. Furthermore, the results of the ANOVA testing the null hypothesis that the GWR model represents no improvement over the global model are statistically significant, demonstrating that the GWR models provide a better fit than the OLS models. The drop in the Akaike Information Criterion[99] (AIC) with more than 3 units for the GWR models compared to the OLS models furthermore demonstrates that the GWR models significantly improve the model fits (Fotheringham et al. 2002).

| | 1. TOTAL<br>*Total number of boardings on workday* | | 2. MORNING<br>*Number of boardings morning peak* | | 3. EVENING<br>*Number of boardings evening peak* | | 4. OFF-PEAK<br>*Number of boardings off-peak* | |
|---|---|---|---|---|---|---|---|---|
| | Log-log model | GWR model | Log-log model | GWR model | Log-log model | GWR model | Log-log model | GWR model |
| $R^2_{adj}$ | .848 | .888 | .778 | .863 | .845 | .854 | .861 | .883 |
| F | | 2.954 | | 3.655 | | 2.547 | | 2.150 |
| AIC | 398 | 335 | 449 | 344 | 532 | 523 | 454 | 423 |
| Global coefficients | all | BTM_routes | all | / | all | /<br>(BTM_routes) | all | BTM_routes<br>TT_tr_higher |
| Local coefficients | / | all other variables | / | all | / | all | / | all other variables |

Table 11: Summary statistics of the best fit log-log models and the GWR models

The geographical variability tests indicate that all variables vary significantly over space, except for two variables. For the total ridership model, the *number of bus routes* variable (BTM_routes) does not seem to vary locally. The same is true for the off-peak model, which includes a second globally fixed variable, i.e. the *travel time by train to stations of a higher order* (TT_tr_higher). The *number of bus routes* variable is very close to being categorized as global in the evening peak model, and is therefore noted between brackets in Table 11.

Judging from the table, spatial nonstationarity is most important for the morning peak model, since the GWR model exhibits a very high fit ($R^2_{ad}$ = .863) compared to its log-log counterpart (.778). This difference in fit is much more pronounced compared to the other models. For this reason, we zoom in on the results of this GWR model in the remainder of this subsection.

The morning peak model

Figure 40 visualizes[100] the results of the GWR analyses: the parameter estimates and t-statistics for all local variables included (a to f), the local $R^2$ values (g) and the residuals (h).

Figures 40 a to f reflect the importance per station of the variables in explaining the variance in morning peak ridership. This importance can be expressed in terms of both the unstandardized B coefficients (the higher the stronger the impact on ridership) and in terms of the t-values which indicate the degree of

[99] AIC was first developed by Akaike (1973) as a way to compare different models on a given outcome. AIC scores are ordinal and rank different models. The best models is the model with the lowest AIC score.

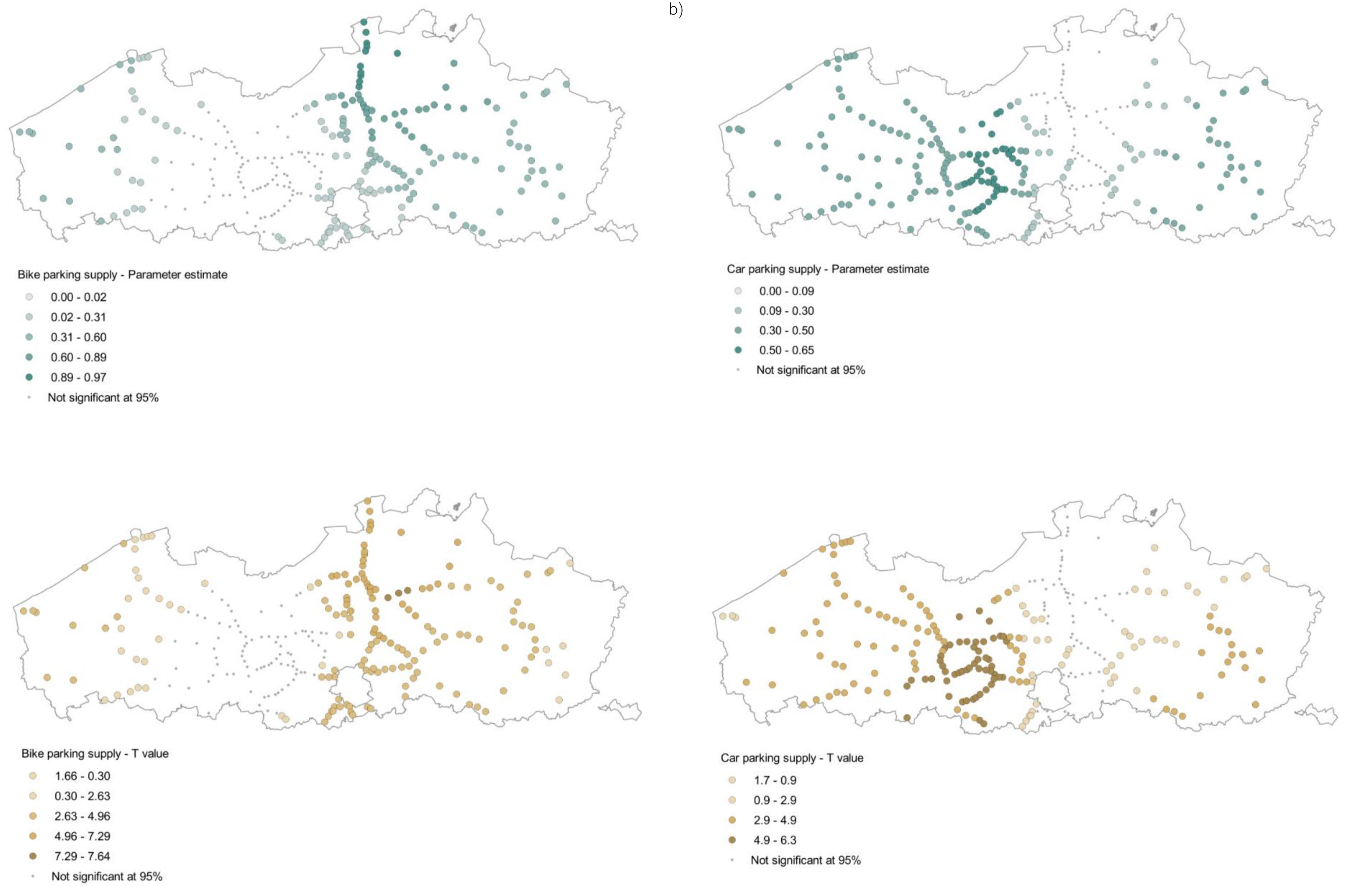
[100] The classification method for the legend items is based on standard deviations as the data is normally distributed (see Mennis 2006 for more cartographic support with respect to GWR analyses).

statistical significance. As demonstrated by Mennis (2006), maps of both key statistics are important if spatial nonstationarity is to be interpreted effectively. Some general observations can be made. First, there is only one variable for which the local coefficients are statistically significant for all stations: *interface catchment*. Judging from map f, this variable seems most important and significant for the central area of Flanders, around and in between Antwerp and the Brussels Capital Region (BCR). This seems to indicate that the walkability of the station area plays a larger role in explaining morning peak ridership for these stations. Second, the largest B values are nonetheless found for *amplitude*. For some stations, especially those located around and just west of the BCR, B coefficients of 2 and higher can be found. This implies that a one percent change in the amplitude of the train service would impact morning peak ridership by two percent. The geographical distribution of these high coefficient values west of the BCR and in the east of Flanders could be explained by the mostly low performance of these stations in terms of train services. Judging from Figure 39, a sizeable share of these stations belong to type 4, which are characterized by very low train frequencies and very low network centrality performances. The subsequent high coefficient values for these adjacent stations might indicate that there is a lot of trading going on for this variable. Similar assumptions[101] may be deduced for the other variables. For example, *train frequency* seems most important and most significant for the western part of Flanders. Especially the stations in between the regional cities of Bruges and Kortrijk exhibit the highest t values. This observation seems to indicate that in this area, trading of between stations mainly occurs based on service frequency. Amplitude seems to play a non-significant role in explaining morning peak ridership.

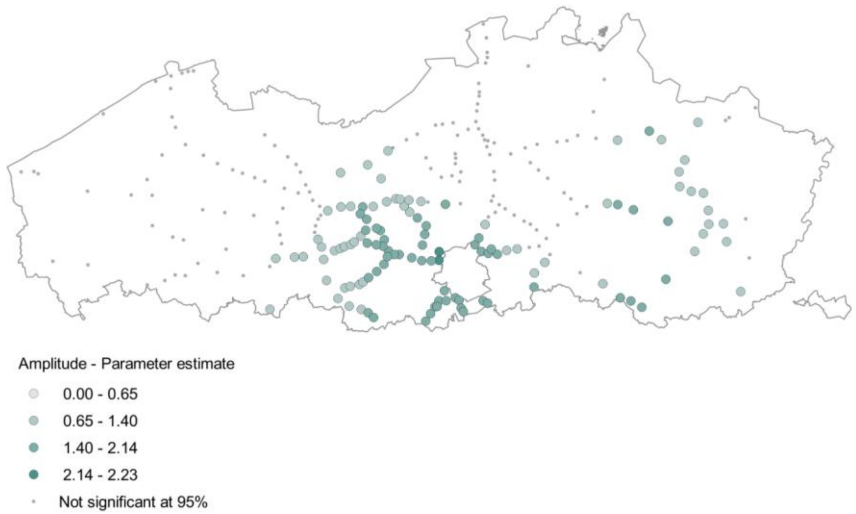
The spatial variation of the model's explanatory power can be determined by examining the spatial distribution of local fits produced with GWR. Judging from map g, the model has a higher predictive capacity in the east, in the central area of Flanders located just west of the Brussels Capital Region (BCR) and the small group of stations just north of the BCR. A high number of stations have local $R^2$ values that are higher than .83 with the highest values ranging up to .89. These model fit values are comparable with the best-performing models developed in other analyses using similar calibration techniques. This indicates that the model does a good job of capturing the variation in rail demand across the study region.

[101] Arguably, these assumptions could be verified more effectively when the station demand model would be integrated with a station choice model (see Young and Blainey 2019). Unfortunately, to the best of our knowledge there is no data available in Flanders at the scale required to calibrate such a model.

a) b)

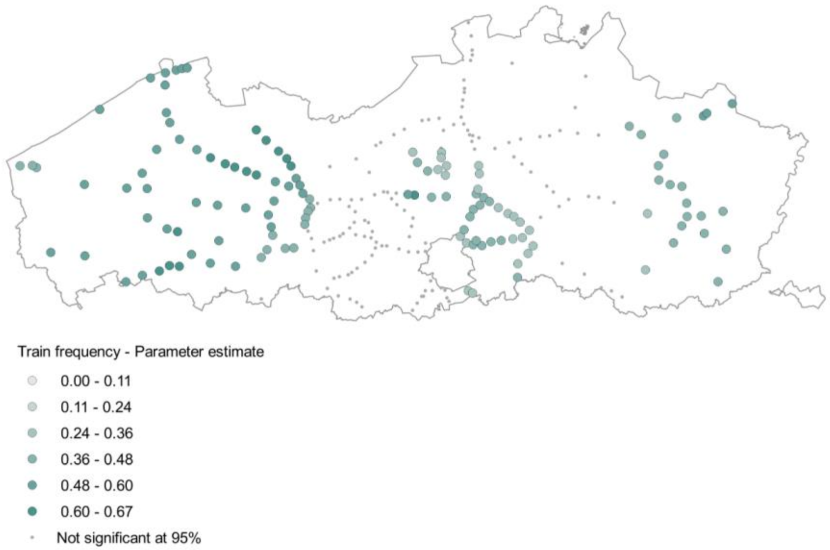

Bike parking supply - Parameter estimate
0.00 - 0.02
0.02 - 0.31
0.31 - 0.60
0.60 - 0.89
0.89 - 0.97
Not significant at 95%
Car parking supply - Parameter estimate
0.00 - 0.09
0.09 - 0.30
0.30 - 0.50
0.50 - 0.65
Not significant at 95%
Bike parking supply - T value
1.66 - 0.30
0.30 - 2.63
2.63 - 4.96
4.96 - 7.29
7.29 - 7.64
Not significant at 95%
Car parking supply - T value
1.7 - 0.9
0.9 - 2.9
2.9 - 4.9
4.9 - 6.3
Not significant at 95%

c)

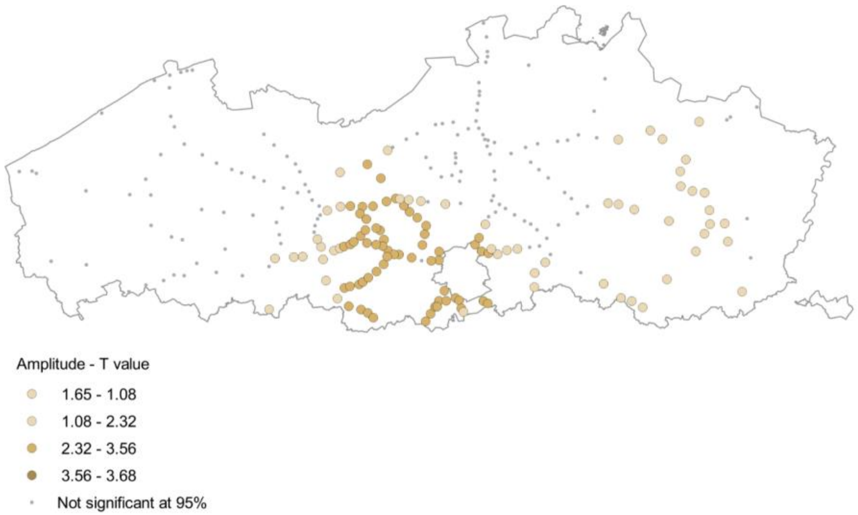


Amplitude - Parameter estimate
0.00 - 0.65
0.65 - 1.40
1.40 - 2.14
2.14 - 2.23
Not significant at 95%

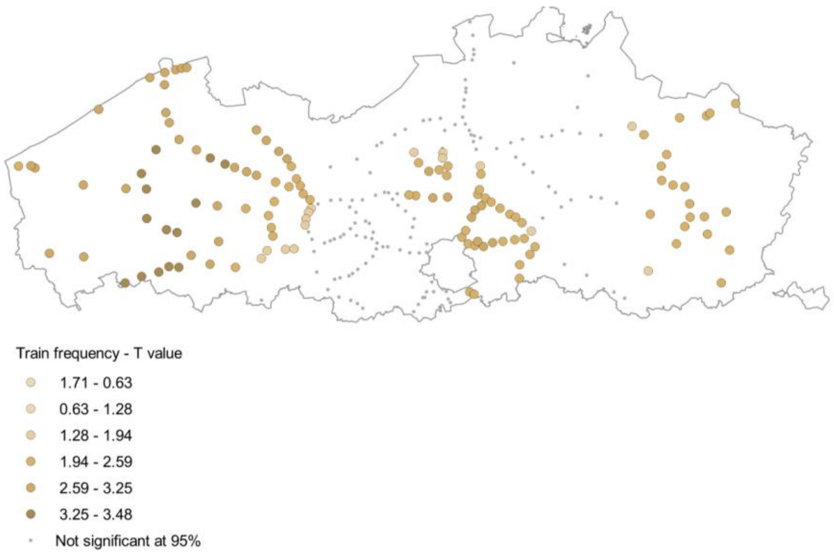

d)



Train frequency - Parameter estimate
0.00 - 0.11
0.11 - 0.24
0.24 - 0.36
0.36 - 0.48
0.48 - 0.60
0.60 - 0.67
Not significant at 95%

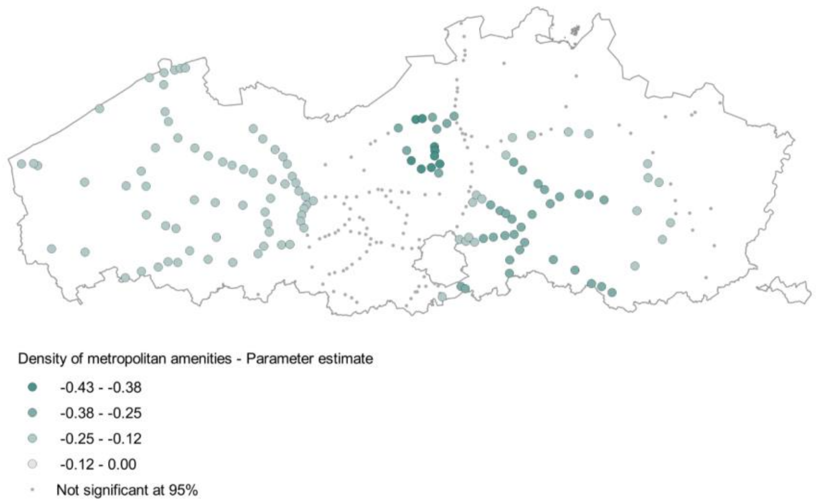



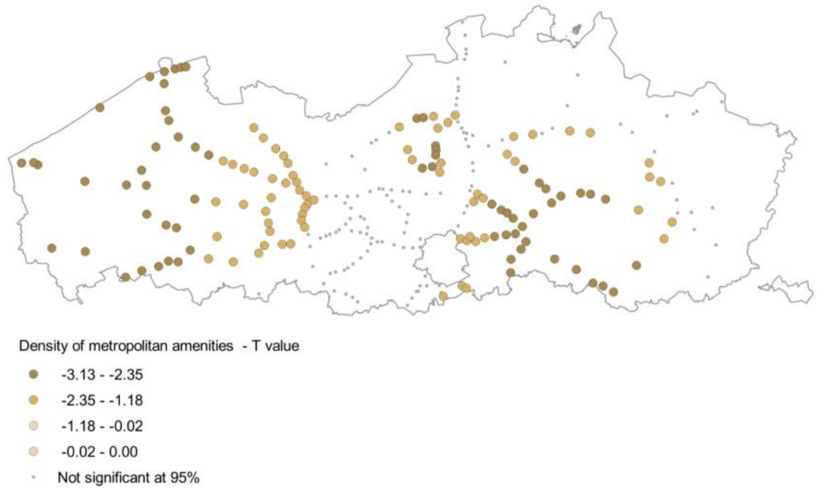
Amplitude - T value
1.65 - 1.08
1.08 - 2.32
2.32 - 3.56
3.56 - 3.68
Not significant at 95%

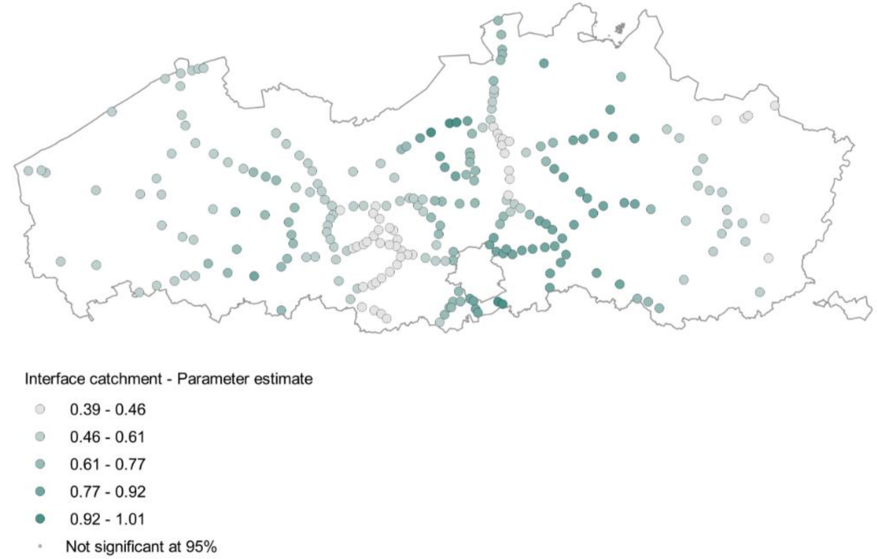
Train frequency - T value
1.71 - 0.63
0.63 - 1.28
1.28 - 1.94
1.94 - 2.59
2.59 - 3.25
3.25 - 3.48
Not significant at 95%

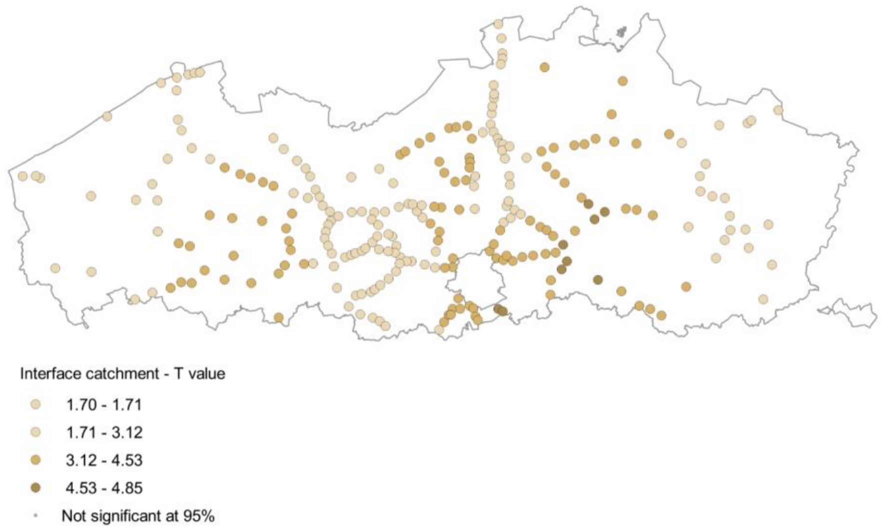
e)

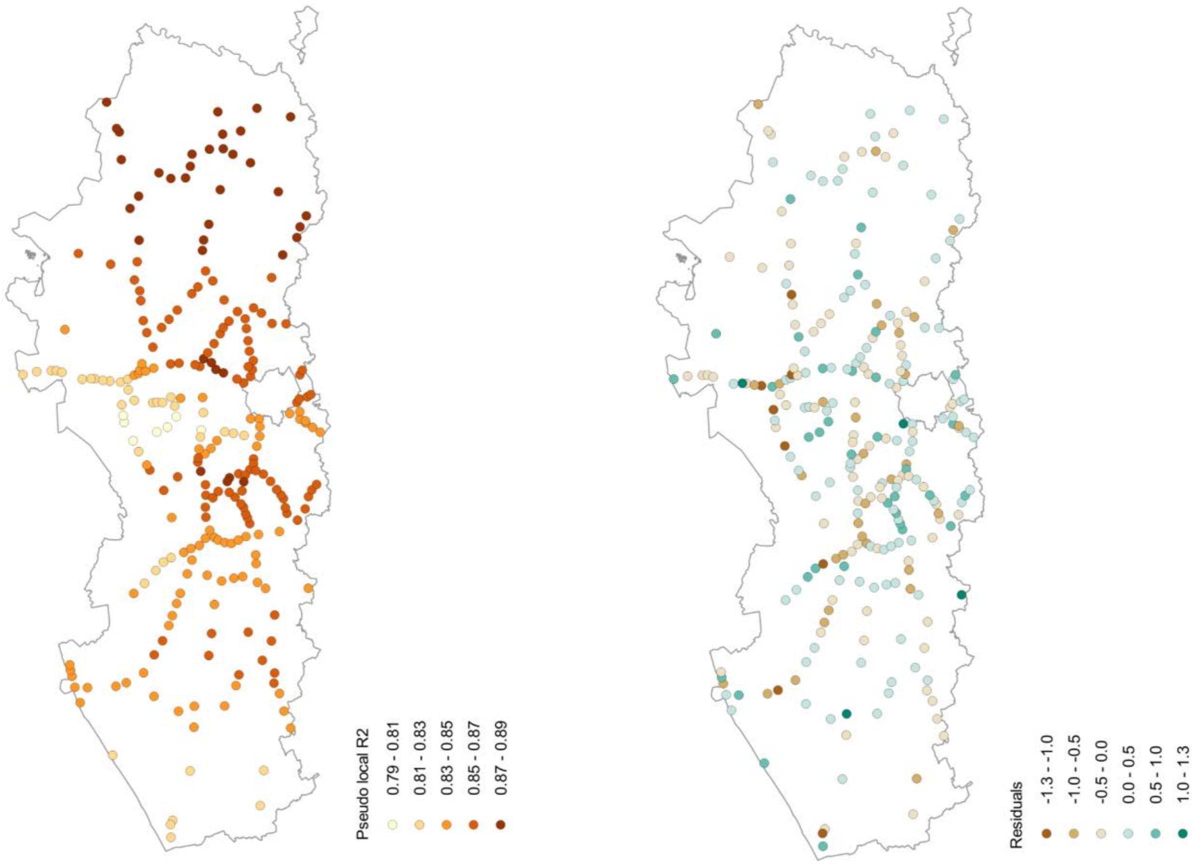

Density of metropolitan amenities - Parameter estimate
-0.43 - -0.38
-0.38 - -0.25
-0.25 - -0.12
-0.12 - 0.00
Not significant at 95%


Density of metropolitan amenities - T value
-3.13 - -2.35
-2.35 - -1.18
-1.18 - -0.02
-0.02 - 0.00
Not significant at 95%

f)


Interface catchment - Parameter estimate
0.39 - 0.46
0.46 - 0.61
0.61 - 0.77
0.77 - 0.92
0.92 - 1.01
Not significant at 95%


Interface catchment - T value
1.70 - 1.71
1.71 - 3.12
3.12 - 4.53
4.53 - 4.85
Not significant at 95%




g) h)

Figure 40: Geographical renderings of the parameter estimates of the local variables (a to f), the local $R^2$ values (g) and the residuals (h)

An analysis of the residuals between the GWR model and the OLS model indicates that the former has more desirable (smaller) residual values. Whereas the GWR residuals vary between -1.3 and 1.3, the OLS residuals vary between -2.2 and 1.7. Map h illustrates the geographical distribution of the GWR residuals. Their seemingly random distribution over space indicates that there does not seem to be an important dynamic that was not captured by the model (otherwise a spatially clustered pattern would appear). This geographical pattern is related to map g, since smaller local $R^2$ values point towards weaker model fits. The region around Antwerp and the very western part of Flanders therefore host relatively more stations with very high (positive or negative) residuals[102].

*D. An application to the case of Aalst, Denderleeuw and Ninove*

In this subsection, we apply the quantitative GWR findings discussed above to the station cases that were the subject of scrutiny in Section 3.3. In doing so we aim to deepen our understanding of the extent to

[102] The stations belonging to the two categories with the highest (positive or negative) residuals include: Zellik, Antwerp-Luchtbal, Sint-Mariaburg, Zwijndrecht, Nieuwkerken-Waas, Wolfstee, Mortsel-Liersesteenweg, Wondelgem, Lichtervelde, Ronse, Bruges and Koksijde. An example of a factor that might explain the high residuals for some of these stations (notably Ronse and Koksijde) concerns the isolated location of these stations. Both are (quasi) terminal stations and have potentially large catchment areas to serve. This information was not captured by the GWR model. Obviously, the same feature holds for some of the stations in the east of Flanders, where residual performance is notably better. Interpretation is thus far from straightforward and calls for further analyses in which additional potential determinants are included and tested.

which the regression analyses capture some of the local ridership dynamics that were raised by the various stakeholders during the workshop. The workshop dealt with the cases of Aalst, Denderleeuw and Ninove (see Figure 35). Judging from map g, these stations are located in an area with (very) high model fits (the area located west of the BCR). The local $R^2$ values of these stations for the morning peak GWR models are respectively .88, .87 and .87.

The GWR morning peak regression equations for these three stations are:

$\ln (Y_{Aalst}) = -1.75 + 0.63 \ln (\text{car parking supply}) + 1.45 \ln (\text{amplitude}) + 0.43 \ln (\text{interface catchment}) + 0.26$

$\ln (Y_{Denderleeuw}) = -1.67 + 0.60 \ln (\text{car parking supply}) + 1.51 \ln (\text{amplitude}) + 0.40 \ln (\text{interface catchment}) – 0.03$

$\ln (Y_{Ninove}) = -1.74 + 0.55 \ln (\text{car parking supply}) + 1.49 \ln (\text{amplitude}) + 0.43 \ln (\text{interface catchment}) – 0.09$

Judging from these equations – and contrary to what Table 9 prescribes for the morning peak model – *bike parking supply*, *train frequency* and *density of metropolitan amenities* are not statistically significant. Instead, *amplitude of train services* seems most important, followed by *car parking supply* and *interface catchment*.

In the below we elaborate on two specific ridership dynamics that came to the fore during the worktable discussion and we illustrate to what extent these dynamics correspond to the quantitative findings.

(1) Judging from the accounts given by the workshop participants, ridership in station Ninove mainly suffers from its poor railway connection to the main destination of its commuters, i.e. zone Brussels. The workshop participants argued that, from Ninove, Brussels can be reached much quicker by car than by public transport. Two causes seemed to be responsible: the transfer that is needed in station Denderleeuw and the poor train service frequencies to and from Ninove. Thus, according to the statements raised during the workshop, train service characteristics seem to particularly impact ridership in station Ninove.

Judging from Ninove's morning peak regression equation, one of its train service features – amplitude – seems to indeed play a large role. Train frequency on the other hand does not play a statistically significant role. Judging from the ridership dynamics sketched by the workshop participants, we expect the two network centrality measures to play large roles at station Ninove. However, due to the method followed (we used only *the best fit* log-log OLS model as an input for the GWR analyses), these variables were not specifically tested for nonstationarity in the morning peak GWR analysis. The models for the other three time windows nonetheless include transfer centrality. When examining these GWR regression equations for station Ninove, transfer centrality does not appear to be statistically significant (compared to station Aalst where it plays a large role in the evening peak (B = 1.72) and to station Denderleeuw where it plays an even larger role off-peak (B = 5.04)).

This particular observation for the case of station Ninove indicates that the perceived ridership determinants by the different stakeholders does not necessarily align with the findings from our quantatitive analysis.

(2) Judging from map a, the three stations are located in an area where car parking supply seems most important compared to the other stations (the geographical distribution of the t-statistics for this variable confirms this). The B values registered in the three morning peak equations all belong to the highest scores in Flanders. An explanation for this observation (which is remarkably similar for the total, evening and off-peak models) might be sought in the dense clustering of mostly rural and small stations at very small distances from each other (see Figure 39). The majority of these smaller stations have parking space for around 25 cars or less (with station Aalst-Kerrebroek having the smallest parking with space for seven cars). It seems reasonable that overcrowding occurs, presumably leading train travellers to drive their car to a station nearby with larger parking supply, which may lead to a trade-off between these stations in turn explaining the high values for this variable.

However, judging from the worktable discussions, there seems to be an additional factor at play when it comes to car parking supply. According to the stakeholders, the distinction between toll and free parking is instrumental in determining at which station people will board the train. Since the distinction between both parking types did not prove meaningful in the best fit OLS models, this distinction was also not verified in the GWR analyses. The apparent non-significance of the distinction between both parking types might imply two things: (1) the workshop participants overestimate the importance of this dynamic in influencing ridership, or (2) we did not operationalize this dynamic in an adequate way. Alternative operationalizations of this particular dynamic could have resulted in significant outcomes. For example, a dummy variable could have been created where a score of '1' would represent a situation in which a station has free car parking while its surrounding stations have only toll parking. A score of '0' would then signify the opposite situation.

These two points of reflection demonstrate that the outcomes of this type of modeling exercise may not necessarily align with how ridership dynamics are perceived by local stakeholders or station users. In other words, it highlights some aspects of the disconnect between perspectives built on primary data versus those using secondary data. This observation therefore calls for further engagement with both of these factors in order to elicit potentially important drivers for ridership which afterwards should be submitted for testing in the model (if feasible).

### 4.1.4 Translation of findings into StationRadar

Some StationRadar users might be interested in exploring the relative importance of the variables in explaining ridership at particular (groups of) stations. It therefore seems sensible to add this extra layer of information to the tool, in order to expand its exploratory support capability (see Section 3.2). A central question is which of the outcomes discussed in the above would be most suitable to fulfill this task.

Given that the GWR outcomes demonstrated that (1) spatial nonstationarity should certainly be considered, and (2) the GWR model fits are significantly better than the OLS models, we reason that these findings would be most suitable for inclusion in StationRadar. This implies that, for each individual station and for each of the four time windows considered, an additional station profile could be created indicating which of the node, train and place indicators likely have the highest impact on weekday ridership.

For the case of log-log models, this impact can be captured in a well-interpretable way by means of the unstandardized B coefficients which represent the arc elasticities: the ratio of a percentage change in some variable in response to a percentage change in another variable, all else being equal. Thus, the estimation of a linear relationship between the log of boardings at a station and the log of an independent variable directly yields these arc elasticities. In terms of visualizing these findings, the elasticities could be plotted in a similar fashion as the indicator scores in the radar diagrams. Additionally, there might be the option for the arc elasticities to be used as weighing factors for the calculation of the indicator scores.

A decision on whether or not to include this feature would nonetheless require expert consultations in order to assess the scientific and practical justifiability of this option. In a similar vein, in-practice validations of the general usefulness of these empirical findings to policy and planning professionals are key. As reported in Section 3.1, since some of the stakeholders were struggling to fully comprehend the calculation of some of the node-place indicators, it seems logic that this issue will certainly arise when these more complex explanatory analyses would be submitted for testing with practitioners. We nonetheless include this provisional idea here in order to keep all future planning support options open.

### 4.1.5 Discussion and conclusions

The research reported in this section aimed to single out the relative importance of a wide range of node-place variables in explaining rail ridership in Flanders. To this end, we conducted a series of regression analyses based on temporal and geographical segmentations of the data. We also verified the importance of spatial nonstationarity. In the below we will discuss the main conclusions and indicate room for improvement and further reflection.

First, a differentiation between the morning peak, evening peak and off-peak time windows seems crucial in grasping the determinants of ridership. As demonstrated by the 'full scale' (253 stations) and the 'segmented' OLS regression analyses (respectively Tables 9 and 10), the relative importance of variables alters significantly. Evening peak ridership arguably allows to explain better the dynamics at destination stations, while morning peak ridership likely explains ridership dynamics best for origin stations. Off-peak ridership data provides an additional perspective and likely allows to better explain leisure motivations and non-regular trips. Besides this temporal differentiation, the regression analyses based on the NTP station typology demonstrated that geographical segmentation according to similarity in station characteristics also reveals differences in determinants. For example, ridership at 'rural' stations compared to 'urban' stations in Flanders is impacted by quite different determinants.

Whereas these analyses at finer temporal and geographical levels provide useful clues for exploring and – to a certain extent[103] – explaining ridership in Flanders, an additional examination verifying spatial nonstationarity was conducted. Due to the time-intensive operation of the stepwise regression procedure described above, we opted to use the four best fit log-log models as an input for the GWR4 software. This resulted in the four models summarized in Table 11. Admittedly, examining the outcomes of additional GWR analyses that build on different global regression models would bolster the robustness of the conclusions made. After all, some of the variables that were not selected as part of the OLS models nonetheless resulted in high model fits, which arguably calls for further rounds of GWR analyses.

In terms of the relative importance of node-place variables, the OLS models indicate that (as for the unstandardized coefficients), the train variables exert the largest impact on ridership with *transfer centrality* clearly dominating. In some of the models *amplitude* plays a large role as well. The relative dominance of these train-related variables in the models is perhaps unsurprising, given that this has been a common feature of trip end models developed previously in other contexts (Blainey, 2010). Feeder mode accessibility in terms of the car and bike parking supply and public transport provision is also important, but generally less so than other included variables. The selected place variables are much less numerous in the different models, which may in part be due to the high levels of multicollinearity for these variables. There is nonetheless empirical confirmation that some less commonly used place variables, such as *interface catchment*, explain a significant and sizeable degree of variation. Finally, apart from the socio-economic variables, the explanatory power of the following variables is very limited in the Flemish context: *density of basic, regional and metropolitan amenities*, *toll and free parking supply*, *BTM frequency*, and *total street network length of walk- and bike infrastructure*. This generally reflects previous findings from similar models developed elsewhere, which are seldom capable of directly capturing the impact of these variables. These observations call for more future validation across different empirical cases in order to see to what extent these findings are reproduced.

These results also have a broader significance in light of the purported *dynamic* character of the node-place model (Bertolini 1998b, 1999, 2000b). As stated by Bertolini (1999: 203): "The starting point is the

[103] As discussed in Section 4.1.2, without panel data it is impossible to pin down more precisely 'to what extent' the relations found are causal or not.

assumption that in the long term – and provided that no 'disturbing' factors intervene (such as peculiarities in the topography of the area or in the morphology of the transportation networks, but also continuing external subsidies) – all locations will lie around the middle line. In other words: provided, and in the measure that demand and supply mechanisms are free to operate, the demand for transportation services from the activity place and the demand for activities from the transportation node will find a (temporary) balance". However, as demonstrated in our analyses, the interaction potential between factors of supply ('node' and 'place') and demand ('people') is not evenly distributed for all railway stations. For example, interventions in terms of a station's node value will likely have a higher effect on daily boardings for some stations compared to others. Therefore, besides the 'disturbing' and exogenous factors mentioned in the quote above, we would argue that existing demand dynamics should be recognized more explicitly as an additional limiting factor when aiming to realize the hoped-for development paths towards a more balanced position in the diagram[104].

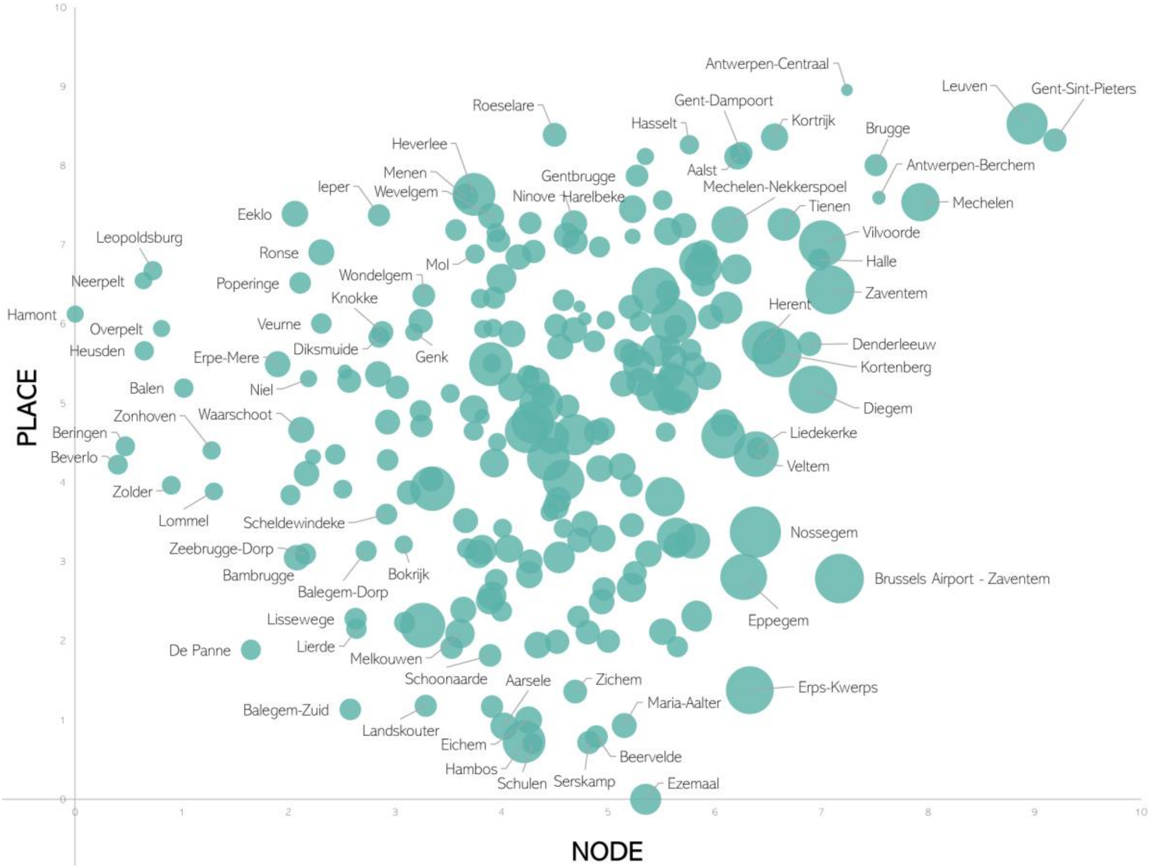
By means of an example, we plotted two standard node-place diagrams for the stations that were examined in this fourth chapter, and this for the GWR 'total model'. The bell sizes of the scatterplot in Figure 41a vary according to the parameter estimates of the variable *train frequency* (values of the bells range between .25 and 1.12), while the bell sizes of Figure 41b vary according to the parameter estimates of the variable *transfer centrality* (with a much larger range between .70 and 6.28). Note that the non-significant parameter estimates are not plotted and that the 'node' and 'place' values reflect aggregate scores based on all respective indicators.

Arguably, a promising (theoretical) development potential could be discerned for those stations that exhibit: (1) a weak performance in terms of transport accessibility (node value), (2) a moderate to high place value, and (3) a strong performance in terms of parameter estimates for both of these train service variables. Put differently: judging from Figure 41a, a station like 'Heverlee' which is characterized by a low node value, a high place value and a high elasticity in terms of train frequency likely has higher chances of capitalizing on train frequency interventions than a station with similar characteristics such as station 'Mol'. This is because the likelihood of attracting more riders to the station seems higher, which might in turn impact the demand for activities around the station in line with the transport-land use feedback cycle (see Wegener and Fürst 1999). This line of reasoning thus establishes a development potential that is the outcome of three elements: 'nodes', 'places' and 'people' (the latter defined (very) narrowly as ridership here). Similar thought experiments could be set up for the other variables in the models and for the different time frames examined.

However, admittedly and importantly, before pursuing this line of reasoning, we emphasize that this research would strongly benefit from the availability of panel data (even if for a smaller subset of stations), larger calibration datasets, and/or additional empirical evidence provided by station choice models.

[104] Similar remarks were raised earlier for the case of TOD in the Netherlands by Janssen-Jansen and Smit (2013).

a) Train frequency – parameter estimates




b) Transfer centrality – parameter estimates

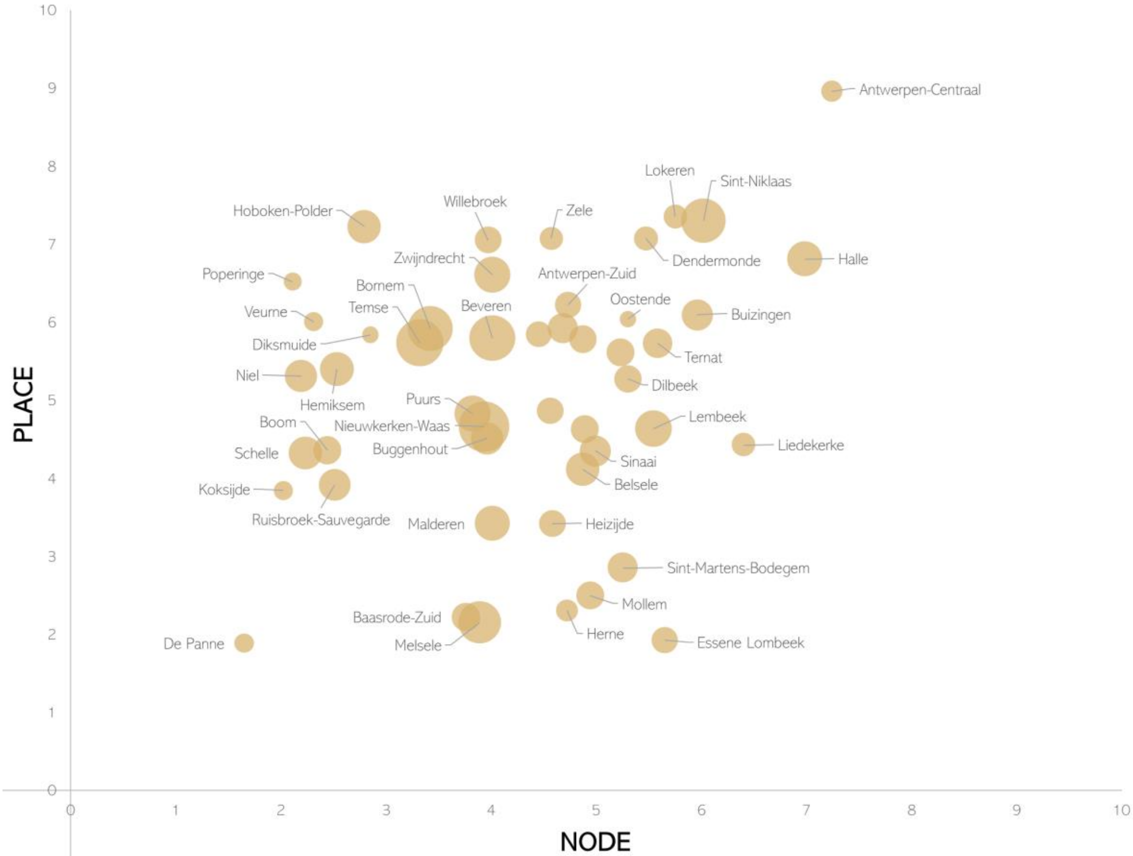



Figure 41: Node-place diagrams with bell sizes varying according to: a) the parameter estimates for the variable train frequency, and b) the parameter estimates for the variable transfer centrality. Both diagrams pertain to the GWR total model.

# CHAPTER 5. THE STATION RADAR TOOL

→ Visit StationRadar here: stationsradar.ugent.be

### 5.1 The components of StationRadar: Some illustrations

This section explains the structure and the different components of StationRadar by means of some illustrations. Below we provide a number of screenshots that illustrate the different tab pages that are currently included in the tool. We briefly explain their role and working.

Figure 42 illustrates the landing page of the tool, which contains a series of pictures taken by us at various Flemish and Brussels stations, along with some generic information.

The second tab page (Figure 43) allows to visualize the radar diagrams for a selection of stations that is made by the user. In this case, we included all 27 stations that are part of the Aalst transport region. The scores are calculated reactively, in that the performance values are scaled relative to this particular group of stations. When hovering over the diagram the relative performance values are shown along with a brief description of what the specific value implies (as indicated for some stations in the screenshots).

These relative scores can be interpreted further by consulting the absolute values included in the raw data table (Figure 44). These tables are reactive in that the user can for example group stations and sort the records from smallest to largest. Figure 45 illustrates the metadata page.

The tab page called *'indicatoren'* (Figure 46) illustrates the line charts which provide a more detailed, indicator-based performance visualization. For example, the screenshots in Figure 45 illustrate the scores for (1) the different 'density' indicators and (2) the two bus/tram/metro indicators for a subset of stations part of the Aalst transport region. These line charts were included as a response to the feedback received during the workshops as elaborated in section 3.1.5. The charts give a quick and comprehensive overview of indicator performance and of the data distribution across stations. When hovering over the plot, the absolute values are shown as illustrated for the case of station Aalst.

The *'kaarten'* ('maps') tab page allows to visualize spatial data, some of which are at the roots of particular indicator calculations. Two examples are provided in Figure 47. The first map illustrates the transfer centrality scores (weekend timetables, scores classified into quartiles) for all railway stations that are part of the NMBS GTFS dataset, whereas the second map indicates the density of regional amenities as developed by Verachtert et al. (2016). All maps are zoomable and additional attributes may be visualized (for example names of bus stops and railway stations).

Apart from the above there is an additional tab page that provides information (by means of two screen recording videos) about the tool functionalities in general and about the radar diagrams and how they should be interpreted in order to arrive at correct observations. The 'about' page elaborates on the general set-up of this research and allows users to contact us directly through a contact sheet.


Figure 42: Screenshot of the StationRadar landing page

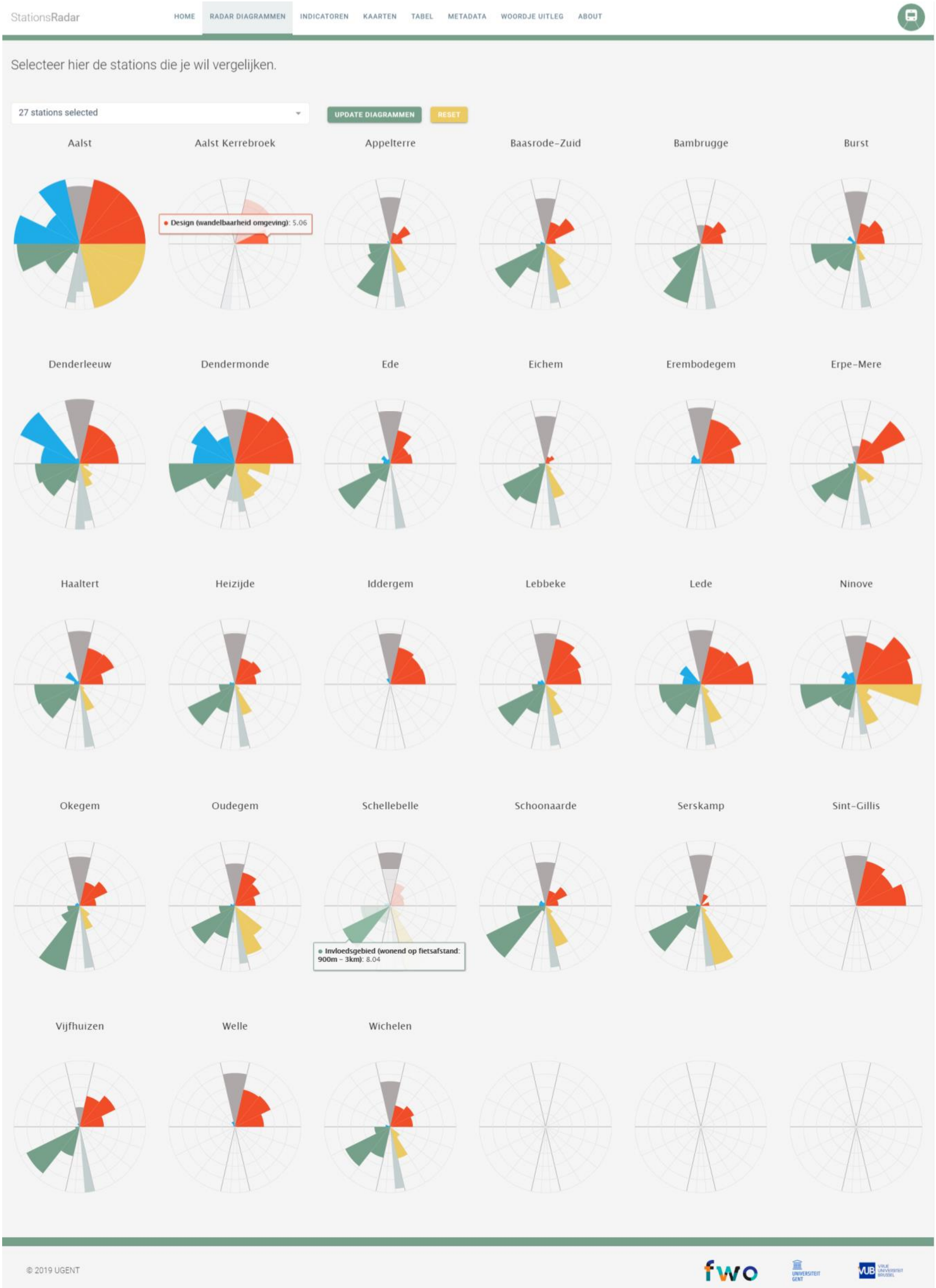
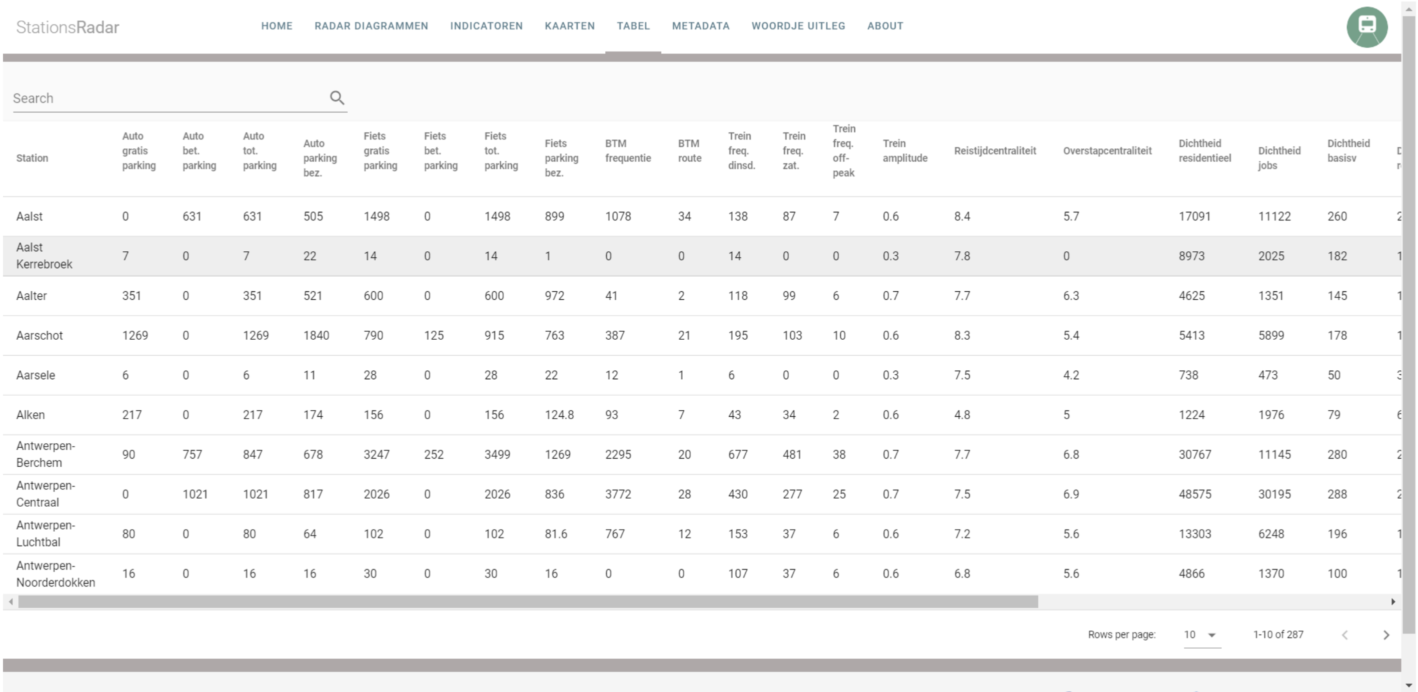



Figure 43: Screenshot of some radar diagrams



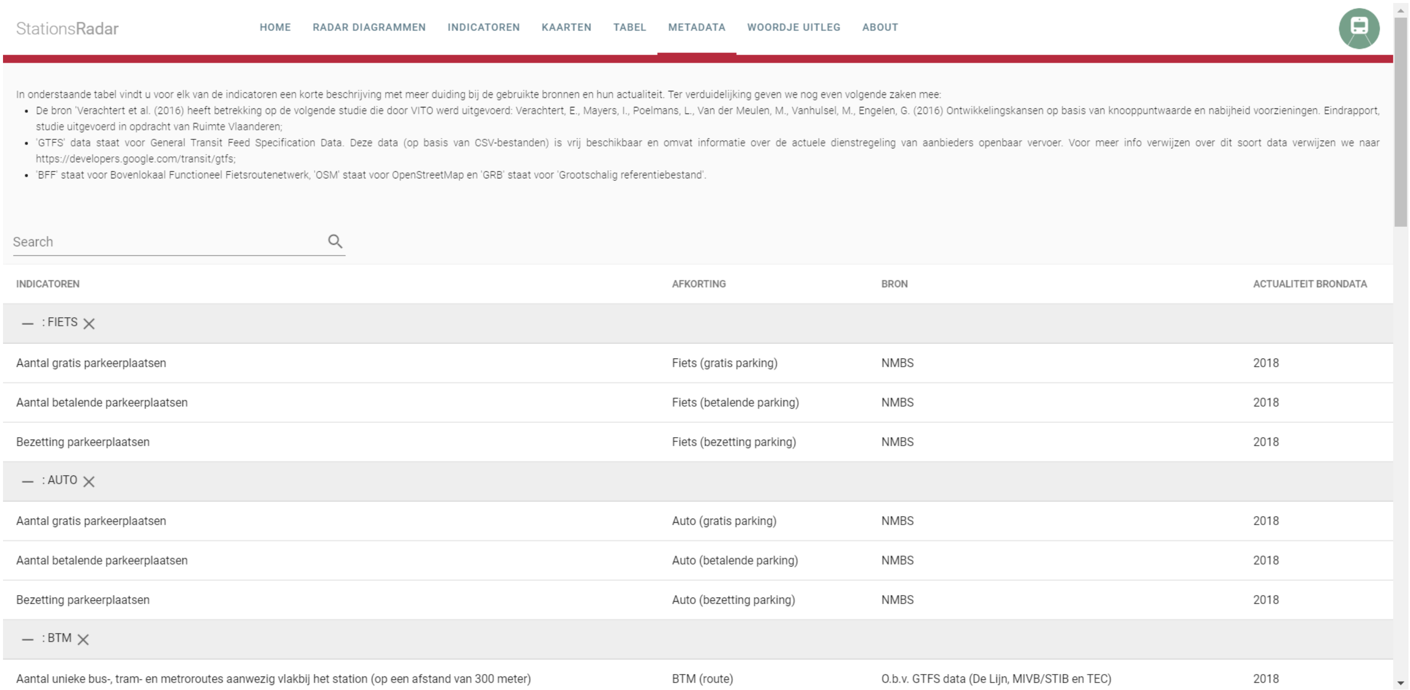
StationsRadar HOME RADAR DIAGRAMMEN INDICATOREN KAARTEN TABEL METADATA WOORDJE UITLEG ABOUT

Search

| Station | Auto gratis parking | Auto bet. parking | Auto tot. parking | Auto parking bez. | Fiets gratis parking | Fiets bet. parking | Fiets tot. parking | Fiets parking bez. | BTM frequentie | BTM route | Trein freq. dinsd. | Trein freq. zat. | Trein freq. off-peak | Trein amplitude | Reistijdcentraliteit | Overstapcentraliteit | Dichtheid residentieel | Dichtheid jobs | Dichtheid basisv |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aalst | 0 | 631 | 631 | 505 | 1498 | 0 | 1498 | 899 | 1078 | 34 | 138 | 87 | 7 | 0.6 | 8.4 | 5.7 | 17091 | 11122 | 260 |
| Aalst Kerrebroek | 7 | 0 | 7 | 22 | 14 | 0 | 14 | 1 | 0 | 0 | 14 | 0 | 0 | 0.3 | 7.8 | 0 | 8973 | 2025 | 182 |
| Aalter | 351 | 0 | 351 | 521 | 600 | 0 | 600 | 972 | 41 | 2 | 118 | 99 | 6 | 0.7 | 7.7 | 6.3 | 4625 | 1351 | 145 |
| Aarschot | 1269 | 0 | 1269 | 1840 | 790 | 125 | 915 | 763 | 387 | 21 | 195 | 103 | 10 | 0.6 | 8.3 | 5.4 | 5413 | 5899 | 178 |
| Aarsele | 6 | 0 | 6 | 11 | 28 | 0 | 28 | 22 | 12 | 1 | 6 | 0 | 0 | 0.3 | 7.5 | 4.2 | 738 | 473 | 50 |
| Alken | 217 | 0 | 217 | 174 | 156 | 0 | 156 | 124.8 | 93 | 7 | 43 | 34 | 2 | 0.6 | 4.8 | 5 | 1224 | 1976 | 79 |
| Antwerpen-Berchem | 90 | 757 | 847 | 678 | 3247 | 252 | 3499 | 1269 | 2295 | 20 | 677 | 481 | 38 | 0.7 | 7.7 | 6.8 | 30767 | 11145 | 280 |
| Antwerpen-Centraal | 0 | 1021 | 1021 | 817 | 2026 | 0 | 2026 | 836 | 3772 | 28 | 430 | 277 | 25 | 0.7 | 7.5 | 6.9 | 48575 | 30195 | 288 |
| Antwerpen-Luchtbal | 80 | 0 | 80 | 64 | 102 | 0 | 102 | 81.6 | 767 | 12 | 153 | 37 | 6 | 0.6 | 7.2 | 5.6 | 13303 | 6248 | 196 |
| Antwerpen-Noorderdokken | 16 | 0 | 16 | 16 | 30 | 0 | 30 | 16 | 0 | 0 | 107 | 37 | 6 | 0.6 | 6.8 | 5.6 | 4866 | 1370 | 100 |

Rows per page: 10 1-10 of 287

Figure 44: Screenshot of the raw data table



StationsRadar HOME RADAR DIAGRAMMEN INDICATOREN KAARTEN TABEL METADATA WOORDJE UITLEG ABOUT

In onderstaande tabel vindt u voor elk van de indicatoren een korte beschrijving met meer duiding bij de gebruikte bronnen en hun actualiteit. Ter verduidelijking geven we nog even volgende zaken mee:

- De bron 'Verachtert et al. (2016) heeft betrekking op de volgende studie die door VITO werd uitgevoerd: Verachtert, E., Mayers, I., Poelmans, L., Van der Meulen, M., Vanhulsel, M., Engelen, G. (2016) Ontwikkelingskansen op basis van knooppuntwaarde en nabijheid voorzieningen. Eindrapport, studie uitgevoerd in opdracht van Ruimte Vlaanderen;
- 'GTFS' data staat voor General Transit Feed Specification Data. Deze data (op basis van CSV-bestanden) is vrij beschikbaar en omvat informatie over de actuele dienstregeling van aanbieders openbaar vervoer. Voor meer info verwijzen over dit soort data verwijzen we naar https://developers.google.com/transit/gtfs;
- 'BFF' staat voor Bovenlokaal Functioneel Fietsroutenetwerk, 'OSM' staat voor OpenStreetMap en 'GRB' staat voor 'Grootschalig referentiebestand'.

Search

| INDICATOREN | AFKORTING | BRON | ACTUALITEIT BRONDATA |
|---|---|---|---|
| — : FIETS × | | | |
| Aantal gratis parkeerplaatsen | Fiets (gratis parking) | NMBS | 2018 |
| Aantal betalende parkeerplaatsen | Fiets (betalende parking) | NMBS | 2018 |
| Bezetting parkeerplaatsen | Fiets (bezetting parking) | NMBS | 2018 |
| — : AUTO × | | | |
| Aantal gratis parkeerplaatsen | Auto (gratis parking) | NMBS | 2018 |
| Aantal betalende parkeerplaatsen | Auto (betalende parking) | NMBS | 2018 |
| Bezetting parkeerplaatsen | Auto (bezetting parking) | NMBS | 2018 |
| — : BTM × | | | |
| Aantal unieke bus-, tram- en metroroutes aanwezig vlakbij het station (op een afstand van 300 meter) | BTM (route) | O.b.v. GTFS data (De Lijn, MIVB/STIB en TEC) | 2018 |

Figure 45: Screenshot of the metadata page

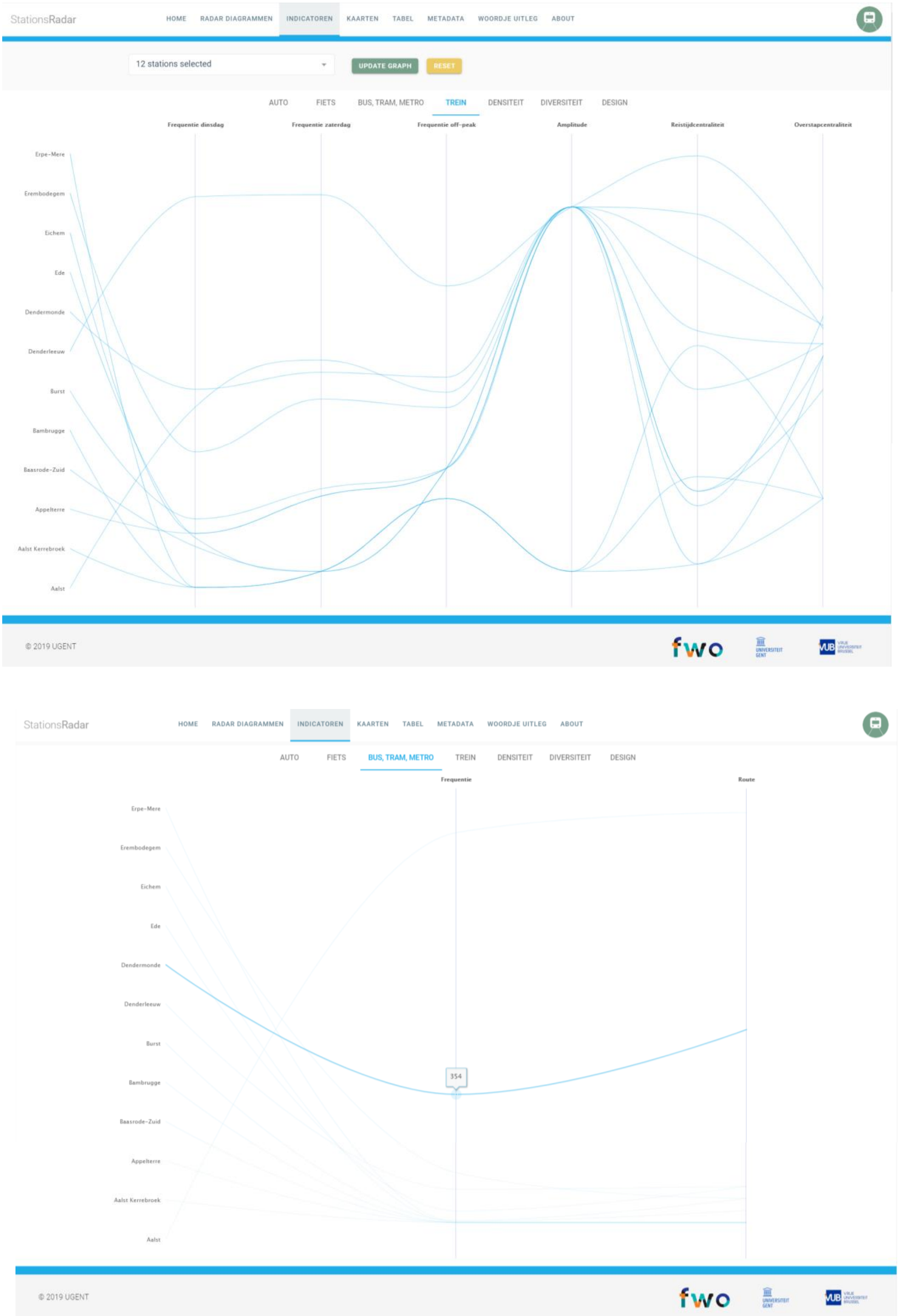



Figure 46: Screenshots of some line charts

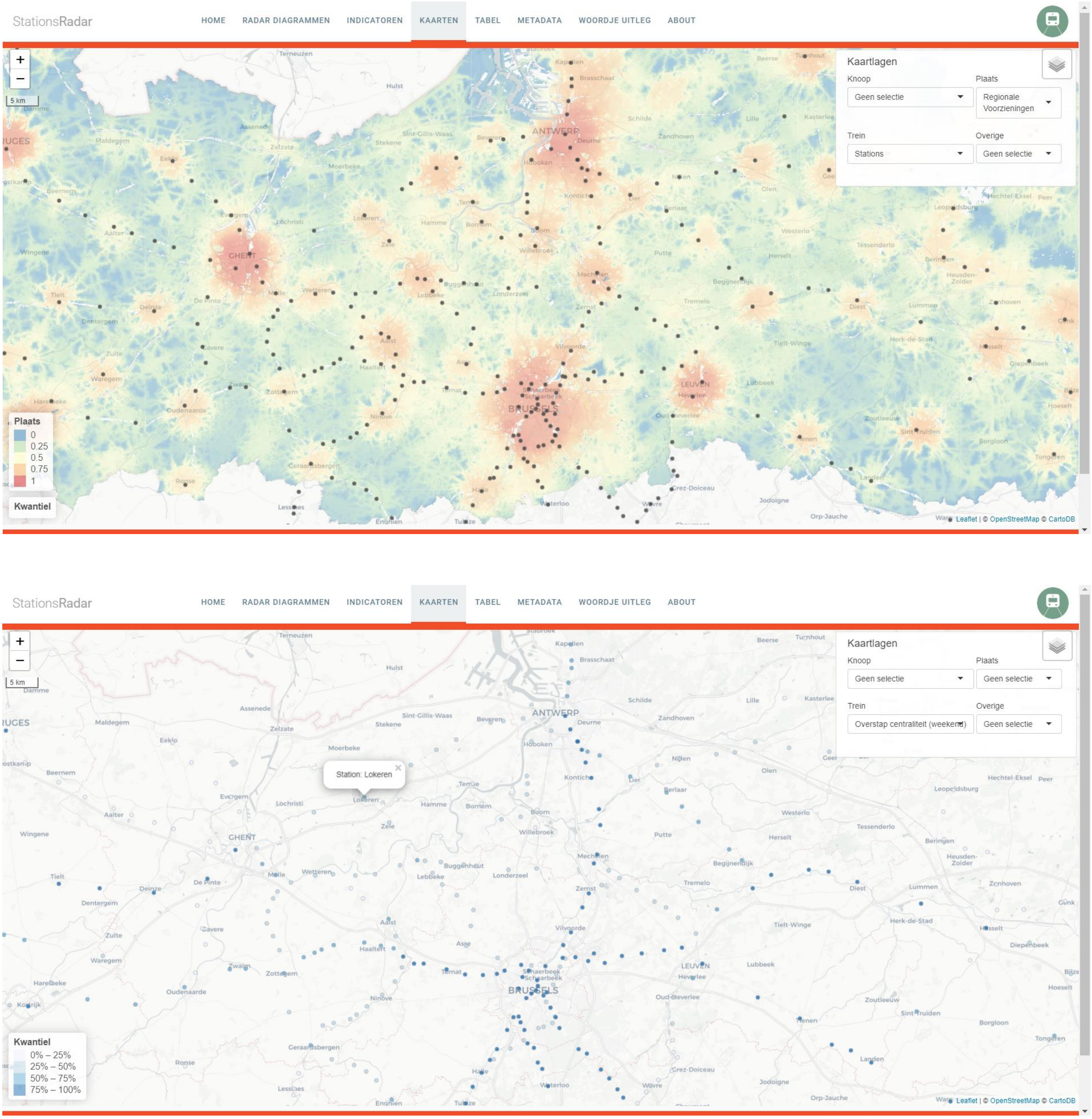



Figure 47: Screenshots of some maps

## 5.2 A closer look at the technological development process

The roots of StationRadar can be traced back to the preparatory work for the research presented in Caset et al. (2019a) (see Chapter 2). As part of this research, two network centrality measures (travel time centrality and transfer centrality) were calculated in R and were afterwards plotted on a web interface using the R packages called 'Shiny' and 'Leaflet'. Later, in the run-up to the research presented in Chapter 3 (Caset et al. 2019b), the radar diagrams were added to the web interface, along with the vector and raster layers[105], the data tables and the other informative tab pages that were present in the beta version of the tool (see Figure 23 for an illustration of the beta tool).

The radar diagrams were created using the R package 'ggplot2' which is easy to use and allows for flexibility in terms of code modifications. For example, in order to create the radar diagrams, we built on the 'polar graph' template and hardcoded the appropriate widths of the diagram 'slices'[106]. However, one of the limitations of this approach boils down to the fact that the Shiny Server Open Source version does not allow multiple processes to run in parallel. For example, imagine there are three users querying the website. Instead of simultaneously processing the queries, they are processed one after the other, which may in some cases result in sizeable loading time. Besides that, there are limited possibilities in terms of web design. Although it is still possible to modify some templates by tweaking the css and html code, it is a rather cumbersome process that does not allow for a full customization of the website.

Following the outcomes of the workshops, one of the main usability limitations centered around the lack of tool interactivity. The vast majority of participants expressed the need of plotting radar diagrams as a function of their own desired station selections. In order to live up to these expectations, we had to rethink the way in which the radar diagrams were created. Whereas ggplot2 offers many interesting features, it does not allow for that kind of flexibility required. We therefore opted to go for an open-source javascript framework by using 'Vue.js', 'Vuetify', and the javascript libraries 'D3.js' and 'Highcharts'. We designed the radar diagrams using D3.js and Highcharts by drawing on the ccs-styled 'mode-pie'[107]. The line charts that were introduced in the previous section were generated drawing on the 'spline with inverted axes' template (also using Highcharts and D3.js). As mentioned earlier, we included the reactive element into the calculations that allows dimension and indicator performance to be calculated on the fly.

The move to a javascript framework at the same time addresses some other reactivity and design limitations. A major advantage of using Vue.js is that all the calculations are performed on the side of the user, meaning that the server requirements are not too high. Additionally, it is possible to have a fully reactive website, which implies that the content design adapts automatically to the user's device (smartphones, tablets, laptop screens etc.). There is also the potential to increase the interactivity between the user and the website (for example, there is the option for users to rank particular columns in the data table from smallest to largest values).

By combining all of these features, we developed the beta tool that was tested in the workshops into a more mature and scalable 2.0 version.

---

105 In order to speed up the loading process, these layers were tiled using the QGIS plug-in QTiles.

106 The code for these tailored radar diagrams is provided open-access at https://github.com/FilipeamTeixeira/radardiagram.

107 In chosing this type of visualization, we were greatly inspired by the Urban Mobility Index website by 'Here': https://urbanmobilityindex.here.com/.

### 5.3 Future outlook

The development process of Stationradar from the beta version used during the workshops to the current 2.0 version ready for release, should be considered part of another loop in the experiential learning process schematized in Figure 24. The 'abstract concepts' have been modified and expanded and are ready to be submitted to a new round of 'testing in new situations'. These new situations are no longer mimicked in next-to-real-life workshop settings, but will (probably and hopefully) comprise actual circumstances in particular planning and policy contexts. Drawing on the network of partners and collaborators that has grown over the past years, we will be able to query the actual usage of the tool in the organizations that are active in the transport regions and/or in other regional partnerships (such as the intercommunal organizations). Additionally, national railway company NMBS expressed their interest in developing a spin-off of StationRadar for internal usage. The above illustrates that we consider StationRadar as a work in progress, and that a continuing cross-fertilization between both sides of the planning research and practice spectrum is strived for. This also implies that StationRadar should keep track of the availability of new (spatial) data layers that could increase the accuracy of the accessibility assessment[108].

In practical terms and in the short run, this pursuit will be set up as follows. After the tool release we will inform our network of partners, together with an extended network of relevant stakeholders who are active in the transport regions or in other relevant regional partnerships, both in Flanders as well as in the Brussels Capital Region. We will invite everyone to provide feedback and comments which will serve to further enhance the tool. In case we experience clear positive signals, further time and energy will be invested in examining and developing mid- to long-term quality assurance strategies concerning the periodic updating of the data and the development of an option that allows users to suggest and submit additional data. This will involve the appointment of a core team with dedicated roles and tasks in terms of content creation and technical maintenance. In case we experience that the tool's usage is very limited, we will evaluate the project and examine and report on the reasons for this lack of implementation.

A final point of reflection has a broader significance for the node-place modeling literature concerned with the development of planning support tools or analyses (the vast majority of the 'C' type of models, see Section 1.3). Since the practice of developing visual renderings of station-specific performance levels seems to become more prevalent (see Figure 8), we contend that future NPM research needs to engage more actively with the longstanding field of information visualization[109] (which in turn draws on the fields of human-computer interaction, visual design, computer science and cognitive science). Although the usability feedback we received during the workshops contains valuable clues, some central questions are left unanswered: Which kind of information/data visualization is most digestible for the user and requires the least amount of cognitive effort? Do the polar graph charts (see Figure 8) offer the best way of conveying what is needed, or can the line charts – or other perhaps more innovative charts – deliver a better job? In any case, as argued by the Interaction Design Foundation[110] (and others, for example MacEachren and Brewer 2004), graphical representations for exploratory purposes require interactivity to facilitate the ease of comprehension[111]:

---

[108] For example, the apparent rise of new mobility services in Flanders which might increasingly serve as first and last mile solutions to railway trips could be considered for inclusion in the tool (if the data are made available by the mobility providers).

[109] Some seminal works include Jacques Bertin's (1983) *'Semiology of graphics'*, Edward Tufte's (1990) *'Envisioning Information'*, Card et al.'s (1999) *'Readings in information visualization: Using vision to think'*, and Bederson and Scheiderman's (2003) *'The craft of information visualization: Readings and reflections'*.

[110] See: https://www.interaction-design.org/literature/topics/information-visualization.

[111] This point was also recently made by Silva et al. (2017) and Büttner et al. (2018) for the case of accessibility instruments.

> Information visualization is becoming increasingly interactive, especially when used in a website or application. Being interactive allows for manipulation of the visualization by users, making it highly effective in catering to their needs. With interactive information visualization, users are able to view topics from different perspectives, and manipulate their visualizations of these until they reach the desired insights. This is especially useful if users require an explorative experience.

Arguably, research endeavours concerned with developing NPM planning support tools would benefit from a larger engagement with these longstanding theories and empirical examinations about visual representations of abstract data and how these may reinforce human cognition.

# CHAPTER 6. DISCUSSION AND CONCLUSIONS

The introductory chapter of this dissertation provided a general overview of the different chapters, their structure, research objectives and the underpinning research questions that would be addressed. The introduction also discussed the type of scientific contributions that would be made, and indicated that these would comprise mainly methodological advancements, but would also span contributions of conceptual/theoretical and of empirical and policy-support nature. By means of conclusion, these contributions are revisited and expanded upon in this final chapter. We also take stock of the open ends of this research project and formulate suggestions for further research.

Figure 48 is guiding for this chapter and schematically illustrates the different scientific contributions that were made in this dissertation. We structured these around the three pillars of conceptual/theoretical, methodological and empirical/policy-support, and will discuss each of these separately in the below. The arrows indicate the links between these different contributions and will be further explained. Although we discuss the three pillars separately, overlap exists to some extent.

## 6.1 Methodology

As indicated in Figure 48, each chapter was built around one or more methodological advancements which were derived from a thorough review of the academic node-place modeling literature. More specifically, the 'C' group of writings served as the frame of reference for the work presented in this dissertation.

### 6.1.1 Chapter 2

Both of the empirical studies included in the second chapter shared a similar objective. They aimed to move forward the strand of NPM research which integrates the node-place modeling framework with indicators specifically designed in empirical TOD research and related fields of study (for example walkability and bikeability studies and street network connectivity studies). In light of this pursuit, a first methodological contribution proposed in Chapter 2 was aimed at *advancing the analytical strength* of this group of node-place analyses.

A first intervention along this line involved a rethinking of the way in which some commonly used NPM variables were operationalized. An obvious example is the 'land use diversity' variable. A large number of node-place modeling studies that are conceptually framed within the literature on TOD adopt the operationalization that was suggested in the Bertolini (1999) model[112]. As demonstrated in Chapter 1, this operationalization emanated from a need to capture the physical human interaction potential and realization in station areas, and is not grounded in empirical research that investigates the conduciveness of the built environment (in terms of its mix of land uses) for sustainable and active travel modes. This observation seemed to hint at a mismatch between the conceptual framing of some NPM studies and the methodological choices taken. In a similar vein, we contend that NPM studies aimed at operationalizing other frequently used TOD characteristics such as 'density' and 'design' require more intensive analytical cross-fertilization with present-day empirical research on the matter (for example Duric 2018)[113].

[112] Examples include Reusser et al. (2008), Vale (2015), Lyu et al. (2016), Zhou (2017) Caset et al. (2018), Vale et al. (2018) and Li et al. (2019).

[113] Alternative kinds of compact developments – other than the commonly used D's of the built environment – are equally worth the investigation as demonstrated by Elldér (2018).

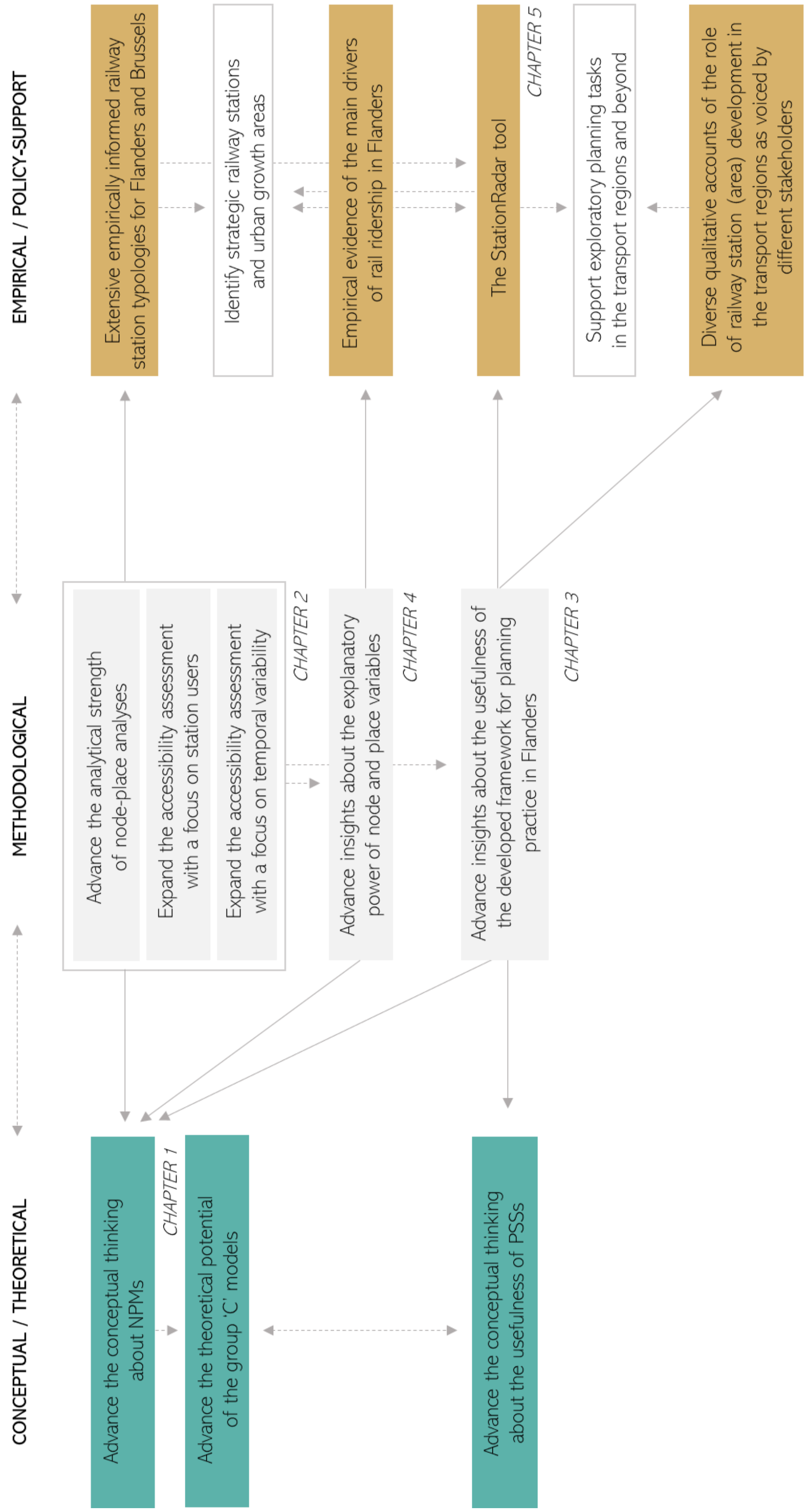



Figure 48: Overview of dissertation contributions

We therefore argue that a key goal for the 'C' group of models should revolve around the transferring of the existing knowledge about the morphological and infrastructural conditions under which people may choose public transport, walking and cycling over the car much more intensively to the methodology of node-place modeling. To this end, a greater analytical engagement with the fields of urban planning and urban design seems promising[114]. At the same time however, increased cross-fertilization between NPM- and TOD-focused research leads to questions of redundancy and identity. If, in essence, both analytical frameworks aim to elicit answers to similar questions (identifying the development potential for transit nodes and their surroundings, developing robust station typologies, ...) by using a similar methodological toolkit (built on variables designed to measure relevant characteristics of land use and transport interactions at and around transit hubs), then how exactly are both still different? Are both just semantically[115] different, or are there more fundamental methodological and/or theoretical tenets which grant the 'node-place model' a *raison d'être*? We will return to this question in Section 6.1.2.

Besides interventions and propositions in terms of the analytical strength of variables, additional rigor was also explored in terms of varying catchment area sizes and their impact on the derived typologies (see Section 2.1). The vast majority of node-place analyses operationalize place variables based on a predetermined and fixed size of the station area that is believed to correspond to a walkable distance[116]. Our study for the Brussels RER network demonstrated how different distance thresholds may strongly impact dimension and indicator performance (a finding also reflected in the work of Nigro et al. 2019). From a policy-support perspective, this has repercussions in terms of the inferences which may be made based on (1) the visual renderings of station profiles (the butterfly plots in this case) and (2) accounts of station type membership. This observation thus highlights the need for a greater awareness of the sensitivity of the empirical findings to varying parameters of scale[117].

The two other methodological interventions proposed in Chapter 2 revolve around an *expansion of the accessibility assessment* that is typically used in node-place analyses. Building on the accessibility framework of Geurs (2006, see also Geurs and van Wee 2004), we took some precursory steps to broaden our place-based accessibility assessment with a temporal component. Most notably, we complemented the framework with a demand-side perspective that reflects some key characteristics of the station users. Both methodological interventions crystallized into a conceptual framework that encompasses a rich variety of performance measures that give a hint of (1) the range of choices available (supply) and (2) the way and the extent in which these choices are currently being 'consumed' (demand). Both were structured across several fields, dimensions and indicators in a radar diagram, in line with their hypothesized reciprocal relations. In this way, station accessibility profiles were generated that summarize a variety of empirically collected information for all railway stations in the Flemish and Brussels railway network.

---

114 The work of Kickert et al. (2014) develops some interesting improvements along this line. These scholars measured and mapped the spatial morphology for 55 station areas drawing on a new set of quantitative density variables (see Berghauser Pont and Haupt 2010), in order to improve the accuracy of the density calculations and of the resulting station typology.

115 'Nodes' or 'transit stops'? 'Places' or 'walkable environments'?

116 Obviously, much can be said about the implicit choices this entails. For example, a particular distance threshold only equals a particular travel time budget for the case of the able-bodied. This dilemma pertains more broadly to the longstanding issue of the arbitrary selection of the isochrone that is inherent in cumulative opportunity measures (see also Vickerman 1974).

117 This critique resonates more strongly in the work of Qviström (2015) and Qviström et al. (2019), who urge scholars to move 'beyond circular thinking' in TOD studies and to rethink our understanding of the 'place qualities' of a station environment. Qviström et al. (2019: 787) scrutinize "the role of the 10-minute circle as trope, model and module, questioning a key premise of TOD: that a generic, circular catchment area can serve as universal frame for capturing the analysis of, and intervention in, socio-spatial processes. We argue that the passe-partout of the 10-minute circle engenders analysis of geometric, static space rather than heterogeneous, dynamic places and a focus on homogeneous two-dimensional density measurements rather than heterogeneous qualities". These scholars suggest to mobilize relational geography to "open up the tunnel vision that plagues TOD" (Ibid.).

Although these diagrams were (by and large) received positively by the stakeholders who were present at the workshops (see Chapter 3), some important reflections and limitations require mentioning.

A first limitation is of practical nature. Due to the existence of 'tariff zones' in the railway network, NMBS cannot provide data for the busiest stations in the Belgian railway network. As mentioned by an employee of the company: 'Ironically, for the busiest stations in the network, we know the least in terms of ridership'. As a corollary, a severe repercussion in light of the StationRadar tool and its planning support capacity is that for all 34 stations included in tariff zone Brussels (the heart of the RER network), none of the 'people' data incorporated in the radar diagrams can be provided.

On a conceptual level, a second reflection pertains to the understanding we attributed to the notion of 'people' as proposed in this dissertation. As mentioned in the introduction, we interpreted this notion in two ways: (1) the inclusion of *station user* data in the conceptual framework and (2) the validation of the conceptual framework by *stakeholders* closely involved in station area (re)development processes. In retrospect, we believe that a perspective pertaining to 'the station user' could and probably should be expanded in a more qualitative way in future elaborations of the StationRadar tool. More specifically, this group of node- and place-based actors is represented in a more or less reductionist way, as translated into a series of aggregated performance measures. However, although StationRadar is intended to serve as a planning support tool and is hence oriented towards a professional audience, the ultimate subjects that (should) feature centrally in the pursuit of station area development are the station area residents and the station users. In other words, the 'planning for nodes, places and people' adage that is featuring on the cover of this book may only fully live up to its presumptions when the developed conceptual framework is also benchmarked in dialogue with the station (area) consumers. This contention resonates more broadly with Handy and Niemeier's (1997: 1176) exploration of issues with respect to measuring accessibility:

> (a)lthough it is easy to say that a measure of accessibility must be developed, it is much harder to say exactly how to do this. The fundamental issue is that an accessibility measure is only appropriate as a performance measure if it is consistent with how residents perceive and evaluate their community. In other words, a practical definition of accessibility must come from the residents themselves, rather than from researchers, and reflect those elements that matter most to residents.

Therefore, an additional qualitative perspective on the accessibility needs, expectations and barriers as perceived by (potential) station users seems of high relevance here. Similar reflections were recently made by Silva and Larsson (2018) who made a plea to connect the different contexts and uses/perceptions of the accessibility concept: the academic context (theoretical), the policy and planning context (normative) and the every-day life context (practical). In a similar vein, Bertolini (2017: 208) hints at the importance of including non-expert stakeholders in his book 'Planning the mobile metropolis'. In the concluding remarks to a chapter that discusses the work of (among others) Straatemeier et al. (2010) in which the experiential learning cycle was applied to improve planning practice, it reads:

> The examples of applications of the experiential learning cycle presented in this chapter are by and large limited to the involvement of planning academics and planning professionals, or expert stakeholders. But what if other kinds of stakeholders, including non-expert ones, were to be included? Would the experiential cycle still hold? And perhaps more importantly, which forms should the joint activities of observing, reflecting and testing in new situations take? In all these applications, interactions between actors and knowledge were mainly in the form of workshops, but is this still an adequate form when more and more heterogeneous actors and types of knowledge are involved? Could perhaps the employment of web-based interaction be an answer?

These are questions open for discussion, but arguably the latter suggestion in Bertolini's quote could serve as a first test base for such an endeavour in the context of this research. For example, it would be interesting to increase the interactive support capabilities of StationRadar by allowing users to insert comments at particular places on the map. These comments would directly be available to the professional stakeholders as well, and could be colour coded into specific themes (for example barriers of access to and from the station, barriers of rail-based accessibility, opportunities for a better quality of place, etc.)[118].

These exploratory reflections in which StationRadar is envisioned to serve as a 'sounding board' that stores and displays data from citizens would arguably urge for further engagement with discourses on 'smart regions' and participatory approaches to both mapping and GIS such as community mapping (Thompson 2016) and 'GeoParticipation'[119] (see Pánek 2016) or 'public participation GIS' (see Craig et al. 2002, Corbett et al. 2016). Arguably, some of the more critical readings concerned with GIS and society as provided by what has been termed 'Critical GIS' (see Sheppard 2005 and O'Sullivan 2006) would offer valuable clues for future investigations down this road.

### 6.1.2 Chapter 3

The main methodological contribution of Chapter 3 consists of an in-practice validation of a purported planning support instrument that draws on node-place modeling principles. Similar endeavours are rare (or at least rarely reported on) in the academic NPM literature. Curiously, this is antithetical to the change-oriented research objectives which are often posited in these studies. Crucial questions such as 'To whom, in what way and to what extent are node-place analyses exactly useful?' are rarely (if not) asked. In order to address this type of research questions ('What can work?', 'Does it work?' and 'Why does it work?'), we buttressed the work of Balducci and Bertolini (2007), te Brömmelstroet (2010) and Straatemeier (2019). According to these scholars planning research needs to engage with practice and submit its findings to explicit testing in new situations in close cooperation with relevant stakeholders.

In order to get a grip on the 'usefulness' of the node-place modeling principles that shaped StationRadar, we built on the conceptual framework suggested by Pelzer (2017). Drawing on the work of (among others) Nielsen (1993), Pelzer argues that usefulness of a PSS can be codified into two main explanatory variables: 'usability' and 'utility'. Both were probed in Chapter 3, albeit split over different sections. Due to the design of the workshops and the data collection, the inferences that were made in Section 3.1 predominantly centered around the usability of the tool, with some hints of its utility in the context of the transport region. Section 3.2 afterwards aimed to elicit more robust clues as to StationRadar's utility.

In terms of usability, we concluded that StationRadar has the potential to become a functional and helpful tool for different stakeholders in the region, provided that some of the perceived limitations were tackled. As demonstrated in Chapter 5, we have tried to address these perceived barriers. In terms of *tool interactivity*, we worked towards a fully reactive calculation of the radar diagram and line chart scores based on the manual selection that is made by the user. In terms of *tool transparency*, we aimed for approval from NMBS for full disclosure of the 'people'-based data. Unfortunately, this request was not granted. This implies that the 'people'-based data may only be displayed in the radar diagrams. It remains to be seen how this may impact the tool's actual usage. In terms of *user friendliness*, we developed a reconfiguration of the calculation of the relative scores in a more intuitive way, i.e. proportional to the highest score in the distribution. A final usability remark deals with the *level of detail* provided by the tool. Compared to earlier NPM research, the radar diagrams can be considered very detailed as more dimensions were added and as all underlying indicators can be displayed. Judging from the survey results, the majority of participants

[118] Obviously, a critical assessment here would be crucial as this approach would likely exclude particular groups of society whose digital proficiencies are lacking (such as the elderly and children).

[119] Examples of existing geospatial tools that support citizen participation include CitySourced in the USA, FixMyStreet in the UK, Odkazprestarostu.sk in Slovakia and Emotional Maps in the Czech Republic.

(strongly) appreciated this level of detail. Unfortunately, the workshop set-up did not allow for a more thorough examination of each single indicator and its operationalization. A future validation of the indicators (by means of surveys or another multi actor workshop) would therefore be a sensible next step.

The above observations and reflections have a broader significance for the NPM literature, as the practice of developing visual renderings of station-specific performance levels seems to become more prevalent (Balz and Schrijnen 2009, Province of North Holland and Deltametropolis Association 2013, Singh et al. 2017, Vale et al. 2018, Caset et al. 2018, Groenendijk et al. 2018, Nigro et al. 2019) (see also Figure 8). Although each planning context is unique and each NPM analysis originates from a particular problem statement, it may well be the case that certain usability traits in terms of node-place modeling are transferable across cases. Future similar studies will hopefully shed more light on the matter.

Some food for further thought pertaining to the experiential design, revolves around the possible learning effects that took place over the course of the workshop series. Given that participants were subjected to only a small part of one single experiential learning loop (a one-off half-day workshop), interdisciplinary learning effects (if any) on the side of the practitioners were likely very modest. While the survey gauged for perceived (individual and group) learning effects and the Likert scale ratings returned all in all positive appreciations, the strongest learning effects likely occurred at the planning research side of the spectrum (i.e. with us, workshop moderators and tool developers). But even then, as argued by Tan (2013), social learning in planning processes takes time and may even span decades[120].

In terms of utility, drawing on expert interviews we expanded on the main planning tasks that the transport region partnership is currently facing, and detailed how and to what extent the support capabilities of StationRadar could be instrumental. We concluded that StationRadar's support capabilities are 'informing' and 'communicating', and that these may assist the exploratory – diverging – tasks that pertain to the development of the regional mobility plan. On the other hand, we learned that a number of crucial external elements need to be factored in in the conceptual framework, in order to arrive at a more comprehensive understanding of the tool's potential for usefulness in the specific context of the transport region. In order to make sense of these external elements, we structured these in line with some early writings about nodes and places by using the notions of 'process' and 'context'.

While being aware of (1) the limited generalizability of the small sample of experts and (2) the dominant focus of the interview protocol on the task-technology fit, our preliminary findings seem to endorse those of other studies in which the usefulness of PSS tools was examined in practice (for example Papa et al. 2017, Angiello and Carpentieri 2017, Silva 2017, Silva et al. 2017, Wulfhorst et al. 2017, Larsson and Olsson 2017). As a general observation it seems that besides perceived usability and utility, organizational and institutional barriers may strongly impact the extent to which applications of PSS root in practice.

A crucial question that stems from these findings is obviously the following. If these process- and context-factors indeed have such a decisive impact on the value that is attached to the knowledge generated by PSSs, how (if at all) can these barriers be addressed more purposefully? The recent commentary by te Brömmelstroet (2017) provides some clues in this respect by reviewing the state of the debate and by synthesizing a number of pathways in order to arrive at "a more realistic evaluation of how knowledge can regain its important role in urban planning" (p. 77). In the context of this dissertation, the second pathway that is proposed seems crucial; drawing on insights emerging from the related field of 'group model building' and 'group performance' studies, te Brömmelstroet argues that there is a need to acknowledge the 'distorting effect' of power, politics, personal agendas and the level of trust among the actors on the use

[120] The work of von Schönfeld et al. (2019a,b) is inspiring in this regard and provides an analytical approach with the aim of mapping social learning in planning processes, in order to disentangle in a more precise and robust way 'who learns what from whom'.

of knowledge in strategy-making processes. These elements all seem highly relevant for the Flemish context judging from the insights that were shared during the expert interviews. As stated by te Brömmelstroet (2017: 80), we need to increase our awareness of how such dynamics might drive the added value of PSS in order to arrive at more realistic expectations and a better understanding of how to cope with their effects. Therefore, besides a more thorough engagement with these related strands of research, this research would benefit from follow-up qualitative analyses in which the process and context factors are examined in greater depth with a larger group of respondents. From a pragmatic point of view, the process-related barriers discerned in Section 3.2 (such as budgetting and timing issues, the lack of a dedicated competence for transport and land use integration in the transport region and inter-municipal tensions) may provide the most tangible and effective starting point for tailored interventions (compared to context-related factors which seem much more difficult to change).

### 6.1.3 Chapter 4

The methodological contribution of the fourth chapter aimed to *advance insights about the explanatory power of node and place variables*. After all, a main purpose of planning for nodes, places and people consists of bringing about a modal shift from individual motorized transport to more public transport and active mode travels. Improving our understanding of the interaction between supply and demand of transit thus seems crucial in order to allocate node and place resources more appropriately.

In order to single out the relative importance of the wide range of node-place variables developed in Chapter 2, we devised a cross-sectional dataset and conducted a series of regression analyses based on temporal and geographical segmentations of the data. We also verified the importance of spatial nonstationarity. In very general terms, we found that the train variables exert the largest influence on ridership, with 'transfer centrality' featuring prominently, together with 'amplitude'. Feeder mode accessibility in terms of car and bike parking supply and public transport service levels is also important, but generally less so than other variables. The place variables feature less numerously in the different models.

We believe that these findings may add another relevant layer to the *dynamic* character of the node-place model as it was stressed from the start by Bertolini (1998b, 1999, 2000b). In order for stations to 'move' towards a more favorable position across the node-place diagram, it seems useful to have more information as to the likely impact which particular – and station-specific – node and place interventions might have in terms of ridership (and subsequent phases in the transport-land use feedback interactions). This line of reasoning thus establishes a development potential that is the outcome of three elements: 'nodes', 'places' and 'people' (the latter defined narrowly as ridership here). It is possible to include the findings of the geographically weighted regression into StationRadar, by means of visualizing the arc elasticities. This would nonetheless require further rounds of model improvement in line with the shortcomings discussed in chapter 4 *and* prior in-practice validations to ascertain the usefulness of such tool feature for its end-users.

Some further limitations and critical reflections require mentioning. First, from an empirical point of view, we emphasize that this research would strongly benefit from the availability of panel data (even if for a smaller subset of stations), larger calibration datasets (for instance by including the Brussels and Walloon stations based on coherent datasets), and additional empirical evidence provided by station choice models in the Belgian context.

Second, we nonetheless acknowledge that a methodological approach to explaining ridership that is based solely on this kind of analysis may be problematic. In her commentary on the work of Stevens (2017) – who presented the first ever meta-regression analysis of 37 built-environment/travel studies – Handy

(2017: 28) contends that the literature may have reached a saturation level of cross-sectional studies that offer 'no more than marginal improvements'. She argues that:

> We need qualitative explorations of the processes by which households decide where to live and of the formation of their preferences for different types of residential environments. These studies will help us understand the degree to which decisions and even preferences are alterable and what kinds of interventions might engender more demand for compact development.

Given that the confrontation between some of the qualitative ridership findings and the model outcomes pointed at some mismatches (see Section 4.1.3 part D), we support this plea and put forward some tentative clues for future investigation along this line in the context of this dissertation. A first sensible next step might be the selection of some case study stations and of households that recently moved to the station area. This group could provide an interesting sample as their travel budgets (likely) just drastically changed. In theory, these households are exhibiting exemplary spatial behavior, which arguably makes it interesting to shed more light on their relocation motivations. Which interventions might stimulate this behavior? Which ridership determinants are we currently missing? Which household profiles are most interested in moving to particular station environments in Flanders? Related to this, the questions of 'who benefits?' and 'who suffers?' when planning for TOD deserve more attention. As demonstrated at multiple occasions, the 'D' in TOD sometimes leans more towards 'displacement' than it does to sustainable 'development' (for example Loukaitou-Sideris and Banerjee 2000, Chapple and Loukaitou-Sideris 2019, Chatman et al. 2019). Related, TOD programs can have adverse impacts on the overall sustainability of travel patterns, as they may cause people to drive more by displacing poorer households from transit-rich neighborhoods (Chatman et al. 2019).

## 6.2 Concepts and theory

In terms of concepts and theory, a number of contributions are discerned and indicated as such in Figure 48. In Chapter 1 we aimed to provide more conceptual clarity regarding the literature on stations as nodes and places. To the best of our knowledge, the overview provided in Section 1.3 is the first comprehensive literature study of the NPM strand of research since the work of Peek et al. (2006). We demonstrated how the node-place model is not a mere methodological toolkit. It is a toolkit that has been specifically designed to provide answers to questions of conceptual and theoretical nature. Whereas the early writings about nodes and places clearly emerged from the theoretical writings about the 'network society' and the 'network city', the line of work commencing with the analytical node-place model (Bertolini 1999) seemed to increasingly tap into theories concerned with sustainable transport and land use developments. A specific group of NPM writings – coined the 'C' group – was distinguished based on its reconceptualization of the station area as a 'place'. New sets of indicators and dimensions were added to the NPM, following an intensifying analytical cross-fertilization with empirical literatures on compact cities (and related notions like TOD, smart growth and new urbanism). An illustration of this trend is the increasing attention in NPM work towards measures of the design of the built environment.

In previous chapters, we have nonetheless raised some food for further thought pertaining to the present-day interpretation and relevance of the well-rehearsed practice of node-place modeling.

First, we argue that the node-place model runs the risk of becoming too much of an off-the-shelf toolkit. A sizeable number of NPM studies seem to copy variables and indicators that have been used in earlier studies without any further in-practice validation examining their relevance and soundness. A bit of soul-searching leads to the insight that our model operationalization for the RER network (Section 2.1) ticks this box as well. We believe this may be problematic, as it gives rise to a practice in which node and place qualities seem to be determined *a priori* for a particular empirical case without much further scrutiny. Qviström et al. (2019) in this respect argue that TOD studies run the risk of falling prey to 'methodological cityism' (see Angelo and Wachsmuth 2015) in that they take ideas about 'the urban' for granted and express these as part of normative visions put forward in planning paradigms such as TOD[121].

In order to reduce this risk, we believe the 'C' group of models needs to reach back to the early writings on nodes and places. More specifically – and perhaps unfortunately – Bertolini's (1997, 2000a) and Bertolini and Spit's (1998) recurrent plea to reconnect the object, the process and the context of planning seems as relevant now as it was two decades ago. The NPM literature seems to have lost these self-reflexive considerations somewhere along the way. In order to reconnect, we argue that the 'C' NPM research needs to engage more with the literature on planning support systems – and more specifically, with those studies concerned with assessing the usefulness of PSSs in planning practice. This should however go hand in hand with further developments within this field of PSS research that seeks answers to dealing with persistent external factors besides perceived usability and utility. Although our account of StationRadar's usefulness in the transport regions has provided some empirical confirmation for the need to expand existing frameworks of PSS usefulness, more work of conceptual and empirical nature is needed to advance this field of inquiry.

Second, the introduction of the explanatory layer to the NPM literature (see Chapter 4) arguably raises additional questions about the nature of the NPM. In fact, it raises questions as to what makes the node-place model a *'model'*. In their research article on GIS and models of accessibility potential, Geertman and Ritsema van Eck (1995: 68) define this notion as follows:

> In this study, we use model in the sense of 'analytical model', denoting 'a selective representation of a coherent part of reality as a system consisting of elements (variables) and relations between these elements' (Swanborn 1981, p. 159). Such a model can be used as a tool to study the behavior of the system represented and its reaction to changes in any of its elements. Some of these analytical models have proved useful for estimating missing data, forecasting future situations, and studying the effects of planning proposals.

It seems that, even after the introduction of this prescriptive information to the standard – descriptive – node-place model, our proposed framework does not adhere to the principles of an analytical model as it is defined above. After all, whereas we estimated relations between aspects of 'node' and 'people' and between 'place' and 'people', an empirically informed link between 'node' and 'place' is still lacking. In other words, our current knowledge about the "relations between these elements" (see quote above) is not robust enough in order to predict or forecast the impact of planning interventions for all three of these elements. In a similar vein, much of the NPM studies in the 'B' and 'C' groups refer to the transport land use feedback cycle for their theoretical substantiation. Therefore, they (more or less implicitly) argue that the interactions between the node and place dimensions are or can be 'modeled' in the NPM, in line with the equilibrium assumption. We nonetheless contend that, as long as those interactions are not captured in a more robust way for the empirical case under scrutiny, we cannot genuinely speak of a 'model', except maybe when invoking the much broader definition as adopted in Gregory et al. (2009: 468) of it being "an idealized and structured representation of (part of) the world."

We would therefore argue that the node-place 'model' is first and foremost a descriptive *framework* that is able to conceptualize, measure and visualize salient characteristics of railway stations and their

[121] The work by Pojani and Stead (2015) is inspiring in this regard. These scholars organized a design workshop involving key TOD specialists, with the purpose of exploring to what extent the 'ideal' internationally formulated TOD principles and models are relevant to the Dutch context. They found that the Dutch 'ideal' TOD in many ways mirrors its 'universal' counterpart found in the literature, but that "context- and culture-specific priorities are also present in this vision" (p. 142).

surroundings in order to inform planning or policy debate. This semantic clarity is important, as it arguably allows for more conceptual clarity.

## 6.3 Empirical output and policy support

The concrete and relevant output that resulted from the research presented in Chapters 2 to 5 is visualized in Figure 48. The empirical findings of Chapters 2 and 4 are complementary. The extensive railway station typologies have informed the regression analyses examining the main drivers of ridership, whereas the latter in turn informed the station typologies. Since these empirical findings are reported in this dissertation and will be incorporated in the StationRadar tool, they will be fully available to the interested stakeholder. Both chunks of empirical evidence might support the policy pursuit (see Section 1.2.3) of identifying strategic railway stations and urban growth areas. Importantly, the empirical outcomes of these chapters should be considered jointly with those of earlier policy supporting research conducted for the regions of Flanders and Brussels. We refer to the work of van Meeteren et al. (2015) examining critical population thresholds in terms of the labour market, the housing market and the transport sector (see also van Meeteren 2016 and Boussauw et al. 2018) and the work of Storme et al. (2015) investigating the geography of 'top facilities' in Flanders.

The main output that has been created as part of Chapter 3 consists of the StationRadar tool, as indicated in Figure 48. Besides the tangible output of the tool, the workshops and the expert interviews resulted in rich qualitative accounts of the role that railway station (area) development can play in the transport region as voiced by many different stakeholders. Both of these qualitative accounts serve the purpose of supporting the exploratory planning tasks in the transport region (and perhaps in other regional partnerships such as the intercommunal organizations). StationRadar could also be invoked in other policy discussions that deal with the identification of strategic railway stations and urban growth areas.

Besides the empirical output listed in Figure 48, we endorse Pelzer's (2015: 162) plea to aim for the establishment of 'communities of research and practice'. At both Ghent University and Vrije Universiteit Brussel, future coalitions could be established that serve to connect planning and policy professionals with academics, dissimilate findings and exchange critical feedback.

# REFERENCES


### A

Akaike, H. (1973) 'Information theory as an extension of the maximum likelihood principle', In: Petrov, B. N., Csaki, F. (Eds.) *Second International Symposium on Information Theory*, Akademiai Kiado, Budapest (1973), 267 – 281.

Albrechts L. (1999) 'Planners as catalysts and initiators of change. The new structure plan for Flanders', *European Planning Studies* 7 (5), 587 – 603.

Amar, G. (1989) *Lieu-mouvement, les enjeux de la station*. Paris, RATP, Unité prospective.

Andrienko, G., Andrienko, N., Jankowski, P., Keim, D., Kraak, M., MacEachren, A., Wrobel, S. (2007) 'Geovisual analytics for spatial decision support: Setting the research agenda', *International Journal of Geographical Information Science* 21, 839 – 857.

Arciniegas, G., Janssen, R., Rietveld, P. (2013) 'Effectiveness of collaborative map-based decision support-tools: Results of an experiment', *Environmental modelling & software* 39, 159 – 175.

Argyris, C., Schön, D. (1974) *Theory in practice: Increasing professional effectiveness*. Oxford: Jossey-Bass.

Arnhem Nijmegen City Region (2011) *Knooppunten! Bereikbaarheid en ruimtelijke ontwikkeling op knooppunten van openbaar vervoer*. Nijmegen.

### B

Babb, C., Duckworth-Smith, A., Falconer, R., Isted, R., Olaru, D., Biermann, S. (2015) 'The performance and potential of rail stations in and outside freeway medians: The application of a node/place model to Perth', *Paper presented at the Australasian Transport Research Forum.* Australia: Australasian Transport Research Forum

Baeten, G., Swyngedouw, E., Albrechts, L. (1999) 'Politics, institutions and regional restructuring processes: From managed growth to planned fragmentation in the reconversion of Belgium's last coal mining region', *Regional Studies* 33 (3), 247 – 258.

Balducci, A., Bertolini, L. (2007) 'Reflecting on practice or reflecting with practice?', *Planning Theory & Practice* 8 (4), 532 – 555.

Balz, V., Gerretsen, P., Thoele, H., Draaisma, H., Ram, M., de Zeeuw, A. (2006) *Ruimte en lijn: Ruimtelijke verkenning Stedenbaan 2010 – 2020*. Province of South Holland, The Hague.

Balz, V., Schrijnen, J. (2009) 'From concepts to projects: Stedenbaan, the Netherlands'. In: Curtis, C., Renne J.L., Bertolini, L. (Eds.) *Transit Oriented Development – Making it Happen*. Ashgate Publishing Limited, 75 – 90.

Banister, D. (2008) 'The sustainable mobility paradigm', *Transport Policy* 15 (2), 73 – 80.

Batty, M. (1995) 'Planning support systems and the new logic of computation', *Regional Development Dialogue* 16 (1), 1 – 17.

Bekink, J. (2017) *A comparative analysis of station area evaluation models in the Dutch practice of transit-oriented development.* Master Thesis. University of Groningen, Faculty of Spatial Sciences.

Berghauser Pont, M., Haupt, P. (2010) *Spacematrix: Space, density and urban form*. NAi, Rotterdam.

Bernick, M. (1996) 'Transit villages: Tools for revitalizing the inner city', *Access* 9, 13 – 17.

Bertolini, L. (1995) *Le città del treno: La valorizzazione delle stazioni ferroviarie e delle aree circostanti*. PhD dissertation. Torino: Politecnico di Torino.

Bertolini, L. (1996a) 'Nodes and places: Complexities of railway station redevelopment', *European Planning Studies* 4, 331 – 346.

Bertolini, L. (1996b) 'Knots in the net: On the redevelopment of railway stations and their surroundings', *City: analysis of urban trends, culture, theory, policy action* 1 (1-2), 129 – 137.

Bertolini, L. (1997) 'What sort of a problem is a railway station? Towards a conceptualization of complexity in planning', *Unpublished paper.*

Bertolini, L. (1998a) 'Station area redevelopment in five European countries. An international perspective on a complex planning challenge', *International Planning Studies* 3, 163 – 184.

Bertolini, L. (1998b) 'Knooppunten en brandpunten in gelijke tred: (Her)ontwikkeling van stationslocaties', *Stedebouw & Ruimtelijke Ordening* 4, 4 – 9.

Bertolini, L. (1999) 'Spatial development patterns and public transport: The application of an analytical model in the Netherlands', *Planning Practice and Research* 14 (2), 199 – 210.

Bertolini, L. (2000a) 'Planning in the borderless city: A conceptualization and an application to the case of station area redevelopment', *Town Planning Review* 71 (4), 455 – 475.

Bertolini, L. (2000b) 'Van knooppunten en netwerksteden', *paper presented at the Plandag 2000 conference, Stichting Planologische Diskussiedagen*. Delft, The Netherlands, 51 – 59.

Bertolini, L., Dijst, M. (2003) 'Mobility environments and network cities', *Journal of Urban Design* 8 (1), 227 – 243.

Bertolini, L., Salet, W. (2003) 'Planning concepts for cities in transition: Regionalization of urbanity in the Amsterdam Structure Plan', *Planning Theory and Practice* 4 (2), 131 – 146.

Bertolini L. (2004) 'Fostering urbanity in a mobile society: An exploration of issues and concepts'. *Paper presented at the AESOP Conference*. Grenoble.

Bertolini, L. (2005) 'Cities and transport: Exploring the need for new planning approaches', In: Albrechts, L., J. Mandelbaum, S. (Eds.) *The network society: A new context for planning?* Routledge, 67 – 81.

Bertolini, L., Clercq, L., Kapoen, L. (2005) 'Sustainable accessibility: A conceptual framework to integrate transport and land use plan-making. Two test-applications in the Netherlands and a reflection on the way forward', *Transport Policy* 12 (3), 207 – 220.

Bertolini, L. (2006) 'Fostering urbanity in a mobile society: Linking concepts and practices', *Journal of Urban Design* 11 (3), 319 – 334.

Bertolini, L. (2008) 'Station areas as nodes and places in urban networks: An analytical tool and alternative development strategies', In: Bruinsma, F., Pels, E., Rietveld, P., Priemus, H., van Wee, B. (Eds.) *Railway development: Impacts on urban dynamics*. Physica Verlag, 35 – 57.

Bertolini, L., Rietveld, P. (2008) *Knooppuntontwikkeling in corridorverband: Economische betekenis en institutionele prikkels*. Amsterdam: Universiteit van Amsterdam.

Bertolini, L., Curtis, C., Renne, J. L. (2012) 'Station area projects in Europe and beyond: Towards transit oriented development?', *Built Environment* 38, 31 – 50.

Bertolini, L. (2012) 'Integrating mobility and urban development agendas: A manifesto', *DisP* 48 (1), 16 – 26.

Bertolini, L. (2017) *Planning the mobile metropolis: Transport for people, places and the planet*. Palgrave.

Blaikie, N. (2010) 'Research questions and objectives'. In: Blaikie, N. (Ed.) *Designing Social Research*. Polity Press, 56 – 79.

Blainey, S.P. (2010) 'Trip end models of local rail demand in England and Wales', *Journal of Transport Geography*, 18(1), 153 – 165.

Blondia, M. (2014) *Een geïntegreerd regionaal openbaar rvervoersproject voor de Nevelstad & strategieën voor de transformatie van het Vlaams openbaar vervoersnetwerk*. PhD dissertation. Leuven: KU Leuven.

Blondia, M., De Deyn, E. (2012) 'Regional LRT as a backbone for the peri-urban landscape: Research by design on an intermodal public transport network'. *Paper presented at the AESOP Conference*. Ankara.

Boelens, L., de Herder, W. (1994) 'Re-working HSL: Over netwerken, plekken en fundamentele reflectie', *Rooilijn* 8, 355 – 362.

Boelens, L., Sanders, W., Schwanen, T., Dijst, M., Verburg, T. (2005) *Environmental differentiation along the Stedenbaan*. Urban Unlimited: Utrecht University.

Boudry, L., Cabus, P., Corijn, E., De Rynck, F., Kesteloot, C., Loeckx, A. (2003) *De eeuw van de stad: Over stadsrepublieken en rastersteden*. Ministerie van de Vlaamse Gemeenschap – Administratie Binnenlandse Aangelegenheden, Brussel.

Boussauw, K., Derudder, B., Witlox, F. (2011) 'Measuring spatial separation processes through the minimum commute : the case of Flanders', *European Journal of Transport and Infrastructure Research* 11 (1), 42 – 60.

Boussauw, K., Witlox, F. (2011) 'Linking expected mobility production to sustainable residential location planning: some evidence from Flanders', *Journal of Transport Geography* 19 (4), 936 – 942.

Boussauw, K., Neutens, T., Witlox, F. (2012) 'The relationship between spatial proximity and travel-to-work distance: The effect of the compact city', *Regional Studies* 46 (6), 687 – 706.

Boussauw, K., Allaert, G., Witlox, F. (2013) 'Colouring inside what lines? Interference of the urban growth boundary and the political-administrative border of Brussels', *European Planning Studies* 21 (10), 1509 – 1527.

Boussauw, K., Boelens, L. (2015) 'Fuzzy tales for hard bleuprints: The selective coproduction of the Spatial Policy Plan for Flanders, Belgium', *Environment and Planning C* 33, 1376 – 1393.

Boussauw, K., van Meeteren, M., Sansen, J., Meijers, E., Storme, T., Louw, E., Derudder, B., Witlox, F. (2016) 'Planning for agglomeration economies in a polycentric region: Envisioning an efficient metropolitan core area in Belgium'. In: van Meeteren (2016) *From polycentricity to a renovated urban systems theory: Explaining Belgian settlement geographies*. PhD dissertation. Ghent: Ghent University, 231 – 256.

Boussauw, K., van Meeteren, M., Sansen, J., Meijers, E., Storme, T., Louw, E., Derudder, B., Witlox, F. (2018) 'Planning for agglomeration economies in a polycentric region: Envisioning an efficient metropolitan core area in Flanders', *European Journal of Spatial Development* 69, 1 – 26.

Boussauw, K., van Meeteren, M. (2018) 'Op zoek naar de Brusselse metropool: Een kwestie van schaal en georganiseerde verstedelijking', *Paper presented at the Plandag 2018 conference*. Dordrecht, 117 – 128.

Brand-van Tuijn, H. A., Fanoy, J. A., Schotanus, B. (2001) 'Zandlopermodel: uitbreiding van het model van Bertolini', *Paper presented at the Colloquium Vervoersplanologisch Speurwerk.* Amsterdam, 1377 – 1388.

Breheny, M. (1992) 'The compact city: An introduction', *Built Environment* 18, 241 – 246.

Breheny, M., Rookwood, R. (1993) 'Planning the sustainable city region'. In: Blowers, A. (Ed.) *Planning for a sustainable environment*. London: Earthscan, 150 – 189.

Bruggeman, D. (2019) *Urban questions in the countryside. Urbanization and the collective consumption of electricity in Belgium, 1900-1940*. PhD dissertation. Ghent: Ghent University.

Brunsdon, C., Fotheringham, A.S., Charlton, M. (1996) 'Geographically weighted regression: A method for exploring spatial nonstationarity', *Geographical Analysis* 28, 281 – 298.

Brunsdon, C., Fotheringham, A.S., Charlton, M. (1999) 'Some notes on parametric significance tests for geographically weighted regression', *Journal of Regional Science* 39, 497 – 524.

Burns, L. (1979) *Transportation, temporal, and spatial components of accessibility*. Lexington books: Lexington MA.

Büttner, B., Kinigadner, J., Ji, C., Wright, B., Wulfhorst, G. (2018) 'The TUM accessibility atlas: Visualizing spatial and socioeconomic disparities in accessibility to support regional land-use and transport planning', *Networks and Spatial Economics* 18 (2), 385 – 414.

## C

Calthorpe, P. (1989) ‘Pedestrian pockets: New strategies for suburban growth’. In: Kelbaugh, D. (Ed.) *The pedestrian pocket book: A new suburban design strategy*. Princeton Architectural Press, Princeton, 7 – 20.

Calthorpe, P. (1993) *The next american metropolis*. Princeton: Princeton Architectural Press.

Cardozo, O. D., García-Palomares, J. C., Gutiérrez, J. (2012) ‘Application of geographically weighted regression to the direct forecasting of transit ridership at station-level’, *Applied Geography* 34, 548 – 558.

Casabella, N., Frenay, P. (2009) ‘Regional planning choices: Comparing the RER in Brussels (BE) and the Stedenbaan in South-Holland (NL)’, *Paper presented at the 4th International Conference of the International Forum on Urbanism (IFoU)*. Delft.

Cascetta, E., Pagliara, F. (2008) ‘Integrated railways-based policies: The regional metro system (RMS) project of Naples and Campania’, *Transport Policy* 15, 81– 93.

Caset, F., Derudder, B., Boussauw, K., Witlox, F. (2017) ‘Planning for railway network connectivity and spatial proximity: Balancing node and place functions in Flanders and the Brussels Capital Region’. *Paper presented at the BIVEC-GIBET Transport Research Days 2017*. Liège, 140 – 157.

Caset, F., Vale, D. S., Viana, C. M. (2018) ‘Measuring the accessibility of railway stations in the Brussels Regional Express Network: A node-place modeling approach’, *Networks and Spatial Economics* 18 (3), 495 – 530.

Caset, F., Teixeira, F. M., Derudder, B., Boussauw, K., Witlox, F. (2019a) ‘Planning for nodes, places, and people in Flanders and Brussels: Developing an empirical railway station assessment model for strategic decision-making’. *Journal of Transport and Land Use*.

Caset, F., Teixeira, F. M., Boussauw, K., Derudder, B., Witlox, F. (2019b) ‘What strategies for which railway stations? An experiential approach to the development of a node-place based planning support tool in Flanders’, *Paper presented at the BIVEC-GIBET Transport Research Days 2019*. Ghent, 168 – 195.

Caset, F., Blainey, S., Derudder, B., Boussauw, K. Witlox, F. (submitted) ‘Integrating node-place and trip end models to explore drivers of rail ridership in Flanders, Belgium’.

Castells, M. (1989) *The informational city. Information technology, economic restructuring and the urban-regional process*. Oxford: Blackwell.

Castells, M. (1996) *The rise of the network society*. Oxford: Blackwell.

Ceccato, V. (2013). *Moving safely: Crime and perceived safety in Stockholm's subway stations*. Maryland: Lexington Books.

Cervero, R. (1998) *The transit metropolis: A global enquiry*. Island Press, Washington.

Cervero, R., Kockelman, K. (1997) ‘Travel demand and the 3D’s: Density, diversity and design’, *Transportation Research Part D* 2 (3), 199 – 219.

Cervero, R. (2002) ‘Built environments and mode choice: Toward a normative framework’, *Transportation Research Part D*, 7, 265 – 284.

Cervero, R. (2006) ‘Alternative approaches to modeling the travel-demand impacts of smart growth’, *Journal of the American Planning Association* 72 (3), 285 – 295.

Cervero, R. (2009) ‘Public transport and sustainable urbanism: Global lessons’. In Curtis, C., Renne, J. L., Bertolini, L. (2009) (Eds.) *Transit oriented development: Making it happen*. Routledge.

Champlin, C., te Brömmelstroet, M., Pelzer, P. (2018) ‘Tables, tablets and flexibility: Evaluating planning support systems performance under different conditions of use’, *Applied Spatial Analysis and Policy* 3, 467 – 491.

Chapple, K., Loukaitou-Sideris, A. (2019) *Transit-oriented displacement or community dividends? Understanding the effect of smarter growth on communities*. Cambridge: The MIT Press.

Chatman, D. G., Xu, R., Park, J., Spevack, A. (2019) 'Does transit-oriented gentrification increase driving?', *Journal of Planning Education and Research*. Retrieved from (September 23rd 2019): https://doi.org/10.1177/0739456X19872255.

Chen, X., Lin, L. (2015) 'The node-place analysis on the 'hubtropolis' urban form: The case of Shanghai Hongqiao air-rail hub', *Habitat International* 49, 445 – 453.

Cheng, J., Bertolini, L., le Clercq, F., Kapoen, L. (2013) 'Understanding urban networks: Comparing a node-, a density- and an accessibility-based view', *Cities* 31, 165 – 176.

Chiang, W-C., Russell, R. A., Urban, T.L. (2011) 'Forecasting ridership for a metropolitan transit authority', *Transportation Research Part A* 45, 696 – 705.

Chorus, P., Bertolini, L. (2011) 'An application of the node-place model to explore the spatial development dynamics of station areas in Tokyo', *Journal of Transport and Land Use* 4 (1), 45 – 58.

Chorus, P. (2012) *Station area developments in Tokyo and what the Randstad can learn from it*. PhD dissertation. Amsterdam: University of Amsterdam.

Chorus, P., Bertolini, L. (2016) 'Developing transit-oriented corridors: Insights from Tokyo', *International Journal of Sustainable Transport* 10 (2), 86 – 95.

Chow, L. F., Zhao, F., Liu, X., Li, M. T. (2006) 'Transit ridership model based on geographically weighted regression', *Transportation Research Record* 1972 (1), 105 – 114.

Corbett, J., Cochrane, L., Gill, M. (2016) 'Powering up: Revisiting participatory GIS and empowerment', *The Cartographic Journal* 53, 334 – 340.

Cornelissen, J., Groenendijk, J. M. (1999) 'Knooppunten: sturen en aangestuurd worden', *Paper presented at the Colloquium Vervoersplanologisch Speurwerk*. Delft, 59 – 77.

Crane, R. (2000) 'The impacts of urban form on travel: An interpretative review', *Journal of Planning Literature* 15, 3 – 23.

Curtis, C. (2017) 'Public transport-orientated development and network effects'. In: Hickman, R., Givoni, M., Bonilla, D., Banister, D. (Eds.) *Handbook on Transport and Development*. Edward Elgar Publishing, 136 – 148.

Curtis, C., Scheurer, J. (2010) 'Planning for sustainable accessibility: Developing tools to aid discussion and decision-making', *Progress in Planning* 74 (2), 53 – 106.

Curtis C, Scheurer J. (2016) *Planning for sustainable accessibility: An international sourcebook*. Routledge.

Curtis, C., Renne, J. L., Bertolini, L. (2009) (Eds.) *Transit oriented development: Making it happen*. Ashgate Publishing Limited.

**D**

Dalvi, M. Q., Martin, K. M. (1976) 'The measurement of accessibility: Some preliminary results', *Transportation* 5, 17 – 42.

Damay, L. (2014) 'A RER in Brussels? A sociological history of rivalries and political regulations (1989 – 2013)', *Brussels Studies* 74, ISSN 2031-0293.

da Schio, N., Boussauw, K., Sansen, J. (2018) 'Accessibility versus air pollution: A geography of externalities in the Brussels agglomeration', *Cities* 84, 178 – 189.

De Block, G., Polasky, J. (2011) 'Light railways and the rural-urban continuum: Technology, space and society in late nineteenth-century Belgium', *Journal of Historical Geography* 37 (3), 312 – 328.

De Vos, J., Witlox, F. (2013) 'Transportation policy as spatial planning tool: Reducing urban sprawl by increasing travel costs and clustering infrastructure and public transportation', *Journal of Transport Geography* 33, 117 – 125.

Demmatteis, G. (1988) 'The weak metropolis'. In: Mazza, L. (Ed.) *World cities and the future of the metropolis*. Milano, Electa-SVII Triennale, 121 – 133.

de Olde, C. (2018a) 'Changing planning culture in Flanders, third time a charm?', The Blog of the AESOP Young Academics Network. Retrieved from (June 23rd, 2019): https://aesopyoungacademics.wordpress.com/2018/04/05/changing-planning-culture-in-flanders-third-time-a-charm/.

de Olde, C. (2018b) 'Concrete-stop: From metaphor to reality', The Blog of the AESOP Young Academics Network. Retrieved from (June 23rd, 2019): https://aesopyoungacademics.wordpress.com/2018/07/23/3540/.

Dickinson, R. E. (1957) 'The geography of commuting: The Netherlands and Belgium', *Geographical Review*, 47(4), 521– 538.

Dieleman, F., Wegener M. (2004) 'Compact city and urban sprawl', *Built Environment* 30 (4), 308 – 323.

Dijst, M. (1995) *The elliptic life: Action space as integral measure for access and mobility model development with two-earner families with children in Houten and Utrecht*. PhD dissertation. TU-Delft, Utrecht/Delft.

Dobruszkes, F., Mwanza, H. (2003) 'Les enjeux posés par le futur RER bruxellois', *Paper presented at the colloquium Stratégie pour une remétropolisation globale et aménagement du territoire.* Brussels, 83 – 92.

Dorst, K. (2011) 'The core of 'design thinking' and its application', *Design Studies* 32 (6), 521 – 532.

Dovey, K., Pafka, E., Ristic, M. (Eds.) (2018) *Mapping urbanities: Morphologies, flows, possibilities*. New York: Routledge.

Dovey, K., Pafka, E. (2018a) 'Densities'. In: Dovey, K., Pafka, E., Ristic, M. (Eds.) *Mapping urbanities: Morphologies, flows, possibilities*. New York: Routledge, 62 – 81.

Dovey, K., Pafka, E. (2018b) 'Functional mix'. In: Dovey, K., Pafka, E., Ristic, M. (Eds.) *Mapping urbanities: Morphologies, flows, possibilities*. New York: Routledge, 19 – 40.

Ducruet, C., Beauguitte, L. (2014) 'Spatial science and network science: Review and outcomes of a complex relationship', *Networks and Spatial Economics* 14, 297 – 316.

Duffhues, J., Mayer, I. S., Nefs, M., van der Vliet, M. (2014) 'Breaking barriers to transit-oriented development: Insights from the serious game SPRINTCITY', *Environment and Planning B* 41, 770 – 791.

Dujardin, C., Thomas, I., Tulkens, H. (2007) 'Quelles frontières pour Bruxelles? Une mise à jour', *Reflets et perspectives de la vie économique* 2007(2–3), 155 – 176.

Duric, M. (2018) 'Transit assemblages'. In: Dovey, K., Pafka, E., Ristic, M. (Eds.) *Mapping urbanities: Morphologies, flows, possibilities*. New York: Routledge, 129 – 141.

**E**

EEA (2016) *Urban sprawl in Europe: Joint EEA-FOEN report*. Luxembourg: Publications Office of the European Union. ISSN1977-8449. Retrieved from (August 19th 2019): https://emis.vito.be/sites/emis.vito.be/files/articles/3331/2016/Urban%20sprawl%20in%20Europe.pdf.

Elldér, E. (2018) 'What kind of compact development makes people drive less? The "Ds of the built environment" versus neighborhood amenities', *Journal of Planning Education and Research*. Retrieved from (August 19th 2019): https://doi.org/10.1177/0739456X18774120.

Everaars, J. J. (2001) *Locatieontwikkeling: Relatiemodel tussen ruimte, economie en verkeer en de invloed van actoren hierop in beeld gebracht*. Master's dissertation. Enschede: Universiteit Twente.

Ewing, R., Cervero, R. (2001) 'Travel and the built environment: A synthesis', *Transportation Research Record*, 1780, 87 – 114.

Ewing, R., Cervero, R. (2010) 'Travel and the built environment: A meta-analysis', *Journal of the American Planning Association* 76 (3), 265 – 294.

Ewing, R., Clemente, O. (2013) *Measuring urban design: Metrics for livable places*. Island Press, Washington DC.

**F**

Falconer, R., Babb, C., Olaru, D. (2016) 'Cities as systems: Node and place conflict across a rail transit network'. In: Biermann, S., Olaru, D., Paul, V. (Eds.) *Planning boomtown and beyond*. UWA Press, 460 – 489.

Faludi, A., Waterhout, B. (2006) 'Introducing evidence-based planning', *disP – The Planning Review* 42 (165), 4 – 13.

Ferreira, A., Beukers, E., te Brömmelstroet, M. (2012) 'Accessibility is gold, mobility is not: A proposal for the improvement of transport-related Dutch CBA', *Environment and Planning B* 39 (4), 683 – 697.

Flemish Government (2017) 'Working together on the space of tomorrow. Brochure to the White Paper on the Spatial Policy Plan for Flanders'. Retrieved from (August 19th 2019): https://www.ruimtevlaanderen.be/Portals/108/WhitePaperSpatialPolicyPlanFlanders_brochure2017_1.pdf.

Flemish Government (2018a) 'Tekst aangenomen door de plenaire vergadering van het ontwerp van decreet betreffende de basisbereikbaarheid'. Retrieved from (August 19th 2019): http://docs.vlaamsparlement.be/pfile?id=1475622.

Flemish Government (2018b) 'Beleidsplan Ruimte Vlaanderen: Strategische Visie'. Retrieved from (August 19th 2019): https://www.ruimtevlaanderen.be/Portals/108/BRV_StrategischeVisie_VR20181307DOC.pdf.

Fotheringham, A.S., Charlton, M.E., Brunsdon, C. (1998) 'Geographically weighted regression: A natural evolution of the expansion method for spatial data analysis', *Environment and Planning A* 30, 1905 – 1927.

Fotheringham, A.S., Brunsdon, C., Charlton, ME. (2002) *Geographically weighted regression: The analysis of spatially varying relationship*. New York, NY: Wiley.

Forester, F. (1989) *Planning in the face of power*. Berkeley, University of California Press.

Fransen, K., Neutens, T., Farber, S., De Maeyer, P., Deruyter, G., Witlox, F. (2015) 'Identifying public transport gaps using time-dependent accessibility levels', *Journal of Transport Geography* 48, 176 – 187.

Frei, C., Mahmassani, H. S. (2013) 'Riding more frequently: Estimating disaggregate ridership elasticity for a large urban bus transit network', *Transportation Research Record: Journal of the Transportation Research Board*, No. 2350, 65 – 71.

Furneaux, B. (2012) 'Task-technology fit theory: A survey and synopsis of the literature'. In: Dwivedi, Y., Wade, M., Scneberger, S. (Eds.) *Information systems theory integrated series in information systems*. Springer, 87 – 106.

**G**

Geertman, S., Ritsema van Eck, J. (1995) 'GIS and models of accessibility potential: An application in planning', *International Journal of Geographical Information Systems* 9 (1), 67 – 80.

Geertman, S., Stillwell, J. (Eds.) (2003) *Planning support systems in practice: Advances in spatial science*. Berlin: Springer Verlag.

Geertman, S. (2006) 'Potentials for planning support systems: A planning-conceptual approach', *Environment and Planning B* 33, 863 – 880.

Geertman, S., Stillwell, J. (Eds.) (2009) *Planning support systems: Best practices and new methods*. Heidelberg: Springer.

Geurs, K. T. (2006) *Accessibility, land use and transport*. PhD dissertation. Delft: TU Delft. Eburon.

Geurs, K. T., van Wee, B. (2004) 'Accessibility evaluation of land-use and transport strategies: Review and research directions', *Journal of Transport Geography* 12 (2), 127 – 140.

Gilliard, L., Wenner, F., Belahuski, G.B., Nagl, E., Rodewald, A., Schmid, F., Stechele, M., Zettl, M., Bentlage, M., Thierstein, A. (2018) 'Using boundary objects to make students brokers across disciplines: A dialogue between students and their lecturers on Bertolini's node-place model', *Transactions of the Association of European Schools of Planning* 2 (1), 81 – 98.

Goodspeed, R. (2016) 'The death and life of collaborative planning theory', *Urban Planning* 1 (4), 1 – 5.

Goodspeed, R. and Pelzer, P. (forthcoming) 'Organizing, facilitating, and evaluating PSS workshops'. In: Geertman, S., Stillwell, J. (Eds.) *Handbook on Planning Support Science*.

Gregory, D., Johnston, R., Pratt, G., Watts, M., Whatmore, S. (2009) *The dictionary of human geography*. Fifth edition, Wiley-Blackwell.

Groenendijk, L., Rezaei, J., Correia, G. (2018) 'Incorporating the travellers' experience value in assessing the quality of transit nodes: A Rotterdam case study', *Case Studies on Transport Policy* 6 (4), 564 – 576.

Grosjean, B,, Leloutre, G. (2015) 'Un RER pour (re)définir Bruxelles-Capitale'. In: Grosjean, B., Leloutre, G., Pucci, P., Grillet-Aubert, A., Bowie, K., Bazaud, C. (Eds.) *La desserte ferroviaire des territoires périurbains*. Paris, 13 – 69.

Gutiérrez, J., García-Palomares, J.C. (2008) 'Distance-measure impacts on the calculation of transport service areas using GIS', *Environment and Planning B* 35 (3), 480 – 503.

Gutiérrez, J., Cardozo, O.D., García-Palomares, J.C. (2011) 'Transit ridership forecasting at station level: An approach based on distance-decay weighted regression', *Journal of Transport Geography* 19 ,1081 – 1092.

H

Hajer, M. A. (1996) 'Heterotopia Nederland of wat Bunnik mist', *Stedebouw & Ruimtelijke Ordening*, 77, 4 – 10.

Hall, P. (1988) *Cities of tomorrow*. Oxford and Cambridge, Blackwell.

Hall, P., Ward, C. (1998) *Sociable cities: The legacy of Ebenezer Howard*. Chichester, John Wiley & Sons.

Handy, S., Niemeier, D. A. (1997) 'Measuring accessibility: An exploration of issues and alternatives', *Environment and Planning A* 29, 1175 – 1194.

Handy, S. (2002) 'Accessibility- vs. mobility-enhancing strategies for addressing automobile dependence in the U.S', *Paper presented at the ECMT round table on Transport and Spatial Policies: The role of regulatory and fiscal incentives*. Paris, 101 – 114.

Handy, S., Paterson, R. G., Butler, K. (2003) *Planning for street connectivity: Getting from here to there. Planning Advisory Sercive*. Chicago: American Planning Association.

Handy, S. (2005) 'Smart growth and the transportation-land use connection: What does the research tell us?', *International Regional Science Review* 28 (2), 146 – 167.

Handy, S. (2017) 'Thoughts on the meaning of Mark Stevens's meta-analysis', *Journal of the American Planning Association* 83 (1), 26 – 28.

Hanson, S. (Ed.) (1995) *The geography of urban transportation*. The Guilford Press, New York & Sons, Chichester.

Healey, P. (1992) 'Planning through debate: The communicative turn in planning theory', *Town Planning Review*, 63, 143 – 162.

Healey, P. (1997) *Collaborative planning: Shaping spaces in fragmented societies*. London, MacMillan.

Hess, P. M., Moudon, A. V., Logsdon, M. G. (2001) 'Measuring land use patterns for transportation research', *Transport Research Records* 1780, 17 – 24.

Higgins, C.D., Kanaroglou, P.S. (2016) 'A latent class method for classifying and evaluating the performance of station area transit-oriented development in the Toronto region', *Journal of Transport Geography* 52, 61 – 72.

Horner, M. W., Murray, A. T. (2004) 'Spatial representation and scale impacts in transit service assessment', *Environment and Planning B* 31, 758 – 795.

Howard, M. C., Rose, J. C. (2018) 'Refining and extending task–technology fit theory: Creation of two task–technology fit scales and empirical clarification of the construct', *Information & Management*. Retrieved from (August 19th 2019): https://doi.org/10.1016/j.im.2018.12.002.

Huang, R. (2017) *Measuring transit-oriented development network synergy based on node typology*. Master's dissertation. Twente: University of Twente.

Hubert, M. (2008) 'Expo '58 and "the car as king". What future for Brussels's major urban road infrastructure?', *Brussels Studies*. Retrieved from (September 27th 2019): https://journals.openedition.org/brussels/624.

Hubert, M., Lebrun, K., Huynen, P., Dobruszkes, F. (2014) 'De dagelijkse mobiliteit in Brussel: Uitdagingen, instrumenten en prioritaire werkdomeinen'. In: Macharis, C., Dobruszkes, F., Hubert, M. (Eds.) *Mobiliteit en logistiek in Brussel*. VUBPress, 13 – 55.

Hughes, P. (1993) *Personal transport and the greenhouse effect. A strategy for sustainability*. Routledge.

**I**

Indovina, F. (1990) 'La città diffusa'. In: Indovina, F., Matassoni, M., Savino, M., Torres, M., Vettoretto, L. (Eds.) *La città diffusa*. Venezia: Iuav-Daest, 19 – 45.

Innes, J. E. (1995) 'Planning theory's emerging paradigm: Communicative action and interactive practice', *Journal of Planning Education and Research*, 14, 183 – 189.

Iris Consulting (2001) *Stedenbouwkundige voorstudie station Antwerpen-Luchtbal: Startnota*.

IRIS (2011) *Mobiliteitsplan*. Brussels Hoofdstedelijk Gewest.

Irvin-Erickson, Y., La Vigne, N. (2015) 'A spatio-temporal analysis of crime at Washington, DC metro rail: Stations' crime-generating and crime-attracting characteristics as transportation nodes and places', *Crime Science* 4 (14), 1 – 13.

Ivan, I., Boruta, T., Horák, J. (2012) 'Evaluation of railway surrounding areas: The case of Ostrava city'. In: Longhurst, J.W.S., Brebbia, C.A. (Eds.) *Urban Transport XVIII: Urban Transport and the Environment in the 21st Century*. Southampton: WITPress, 141 – 152.

**J**

Janssen-Jansen, L., Smit, N. (2013) 'Visie versus vraag: Over de TOD-maakbaarheidsutopie', In: Tan, W., Koster, H., Hoogerbrugge, M. (Eds.) *Knooppuntontwikkeling in Nederland: (Hoe) moeten we transit-oriented development implementeren?* Platform 31, 43 – 55.

Jeffrey, D., Boulangé, C., Giles-Corti, B., Washington, S., Gunn, L. (2019) 'Using walkability measures to identify train stations with the potential to become transit oriented developments located in walkable neighbourhoods', *Journal of Transport Geography* 76, 221 – 231.

Jenks, M., Burton, E., Williams, K. (Eds.) (1996) *The compact city: A sustainable urban form?* E&FN Spon, London.

Jun, M.-J., Choi, K., Jeong, J.-E., Kwon, K.-H., Kim, H.-J. (2015) 'Land use characteristics of subway catchment areas and their influence on subway ridership in Seoul', *Journal of Transport Geography* 48, 30 – 40.

**K**

Kamruzzaman, M., Baker, D., Washington, S., Turrell, G. (2014) 'Advance transit oriented development typology: Case study in Brisbane, Australia', *Journal of Transport Geography* 34, 54 – 70.

Kickert, C. C., Berghauser Pont, M., Nefs, M. (2014) 'Surveying density, urban characteristics, and development capacity of station areas in the delta metropolis', *Environment and Planning B* 41, 69 – 92.

Kim, H., Sultana, S., Weber, J. (2018) 'A geographic assessment of the economic development impact of Korean high-speed rail stations', *Transport Policy* 66, 127 – 137.

Kitamura, R., Kermanshah, M. (1984) 'Sequential models of interdependent activity and destination choice', *Transportation Research Record* 987, 29 – 39.

Klosterman, R. (1997) 'Planning support systems: A new perspective on computer aided planning', *Journal of Planning Education and Research* 17 (1), 45 – 54.

Klosterman, R., Pettit, C. (2005) 'Guest editorial: An update on planning support systems', *Environment and Planning B* 32, 477 – 484.

Kobayashi, T. and Lane, B. (2007) 'Spatial heterogeneity and transit use', *paper presented at the 11th World Conference on Transportation Research*. Berkeley.

Kolb, D.A., Fry, R. (1975) 'Toward an applied theory of experiential learning'. In: Cooper, C.L. (Ed.) *Theories of group process*. New York: John Wiley & Sons Ltd, 33 – 57.

Kujala, R., Weckström, C., Darst, R. K, Mladenović, M., Saramäki, J. (2018) 'Data descriptor: A collection of public transport network data sets for 25 cities', *Scientific Data* 5: 180089. DOI: 10.1038/sdata.2018.89.

L

Lallemand, C.(2018) 'Le RER finalisé… en 2031?', *Le Vif*. Retreived from (August 19th 2019): https://www.levif.be/actualite/belgique/le-rer-finalise-en-2031/article-normal-819229.html?cookie_check=1562763946.

Lane, C., DiCarlantonio, M. and Usvyat, L. (2006) 'Sketch models to forecast commuter and light rail ridership: Update to TCRP report 16', *Transportation Research Record*, 1986, 198 – 210.

Larsson, A., Olsson, J. (2017) 'Potentials and limitations for the use of accessibility measures for national transport policy goals in freight transport and logistics: Evidence from Västra Götaland County, Sweden', *Region* 4 (1), 71– 92.

Lebrun, L., Dobruszkes, F. (2012) 'New RER stations for Brussels? Challenges, methods and constraints', *Brussels Studies* 56, ISSN 2031-0293.

Lebrun, L., Hubert, M., Huynen, P., De Witte, A., Macharis, C. (2013) *Katernen van het kenniscentrum van de mobiliteit in het Brussels Hoofdstedelijk Gewest. Deel 2: De verplaatsingsgewoonten in Brussel*. Brussel.

Lee, J., Choi, K., Leem, Y. (2016) 'Bicycle-based TOD as an alternative to overcome the criticisms of the conventional TOD', *International Journal of Sustainable Transport* 10 (10), 975 – 984.

Li, Z., Han, Z., Luo, X., Su, S., Weng, M. (2019) 'Transit oriented development among metro station areas in Shanghai, China: Variations, typology, optimization and implications for land use planning', *Land Use Policy* 82, 269 – 282.

Liedtke, I. (2018) *Hoe bereikbaar is bereikbaar? Een onderzoek naar de besluitvorming omtrent mobiliteitsopgaven*. Master's dissertation. Utrecht: Utrecht University.

Liu, C., Erdogan, S., Ma, T., Ducca, F.W. (2014) 'How to increase ridership in Maryland? Direct ridership models (DRM) for policy guidance', *paper presented at the TRB 93rd annual meeting*. Washington D.C., 3414 – 3417.

Liu, J., Wu, D., Hidetosi, F., Gao, W. (2015) 'Investigation and analysis of urban spatial structure around the train stations in Kitakyushu by using space syntax and GIS', *Open Journal of Civil Engineering* 5, 97 – 108.

Loukaitou-Sideris, A., Banerjee, T. (2000) 'The blue line blues: Why the vision of transit village may not materialize despite impressive growth in transit ridership', *Journal of Urban Design* 5 (2), 101 – 125.

Lyu, G., Bertolini, L., Pfeffer, K. (2016) 'Developing a TOD typology for Beijing metro station areas', *Journal of Transport Geography* 55, 40 – 50.

M

MacEachren, A.M., Brewer, I. (2004) 'Developing a conceptual framework for visually-enabled geocollaboration', *International Journal of Geographical Information Science* 18 (1), 1 – 34.

Macharis, C., Turcksin, L., Lebeau, K. (2012) 'Multi actor multi criteria analysis (MAMCA) as a tool to support sustainable decisions: State of use', *Decision Support Systems* 54 (1), 610 – 620.

Macharis, C. Baudry, G. (2018) *Decision-making for sustainable transport and mobility: Multi actor multi criteria analysis*. Cheltenham: Edward Elgar.

Manheim, M. L. (1974) *Fundamentals of transportation systems analysis, volume 1: Basic concepts*. MIT Press, Cambridge.

Marôco, M. (2014) *Statistical analysis with SPSS statistics: 6th edition*. Pêro Pinheiro, Portugal.

Marshall, S. (2005) *Streets and patterns*. London: Spon Press.

Marshall, S., Banister, D. (2007) *Land Use and Transport: European Research Towards Integrated Policies*. Oxford: Elsevier.

Marsden, G., Reardon, L. (2017) 'Questions of governance: Rethinking the study of transportation policy', *Transportation Research Journal Part A* 101, 238 – 251.

Marshall, N., Grady, B. (2006) 'Sketch transit modeling based on 2000 census data', *Transportation Research Record: Journal of the Transportation Research Board* 1986 (1), 182 – 189.

Marshall, S., Banister, D. (Eds.) (2007) *Land use and transport. European research towards integrated policies*. Elsevier, Amsterdam.

Marti, C. M., Bertolini, L., Weidmann, U. (2018) 'Transit orientation: more than just coverage: A new method for the assessment of transit and development co-location', *Transportation Research Record: Journal of the Transportation Research Board* 2672 (8), https://doi.org/10.1177/0361198118786674.

Martinotti, G. (1993) *Metropoli. La nuova morfologia sociale della città*. Bologna, il Mulino.

May, X., Ermans, T., Hooftman, N. (2019) 'Company cars: Identifying the problems and challenges of a tax system', *Brussels Studies*. Retrieved from (August 19th 2019): https://journals.openedition.org/brussels/2499.

McGarigal, K., Marks, B. J. (1995) *FRAGSTATS: Spatial pattern analysis program for quantifying landscape structure. Technical report PNW-GTR-351.* Portland, OR: US. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

McNally, M. G. (2000) *The four step model*. Institute for Transportation Studies, University of California, Irvine.

Mees, P. (2010) *Transport for suburbia: Beyond the automobile age*. Earthscan, London.

Meijers, E. (2000) *Knooppunten binnen stedelijke netwerken*. Nijmeegse Planologische Cahiers 52. Katholieke Universiteit Nijmegen.

Meijers, E., Drenth, D. H. (2000) 'Naar ruimtelijke kwaliteit op de knooppunten van de netwerkstad', *paper presented at the Plandag 2000 conference, Stichting Planologische Diskussiedagen*. Delft, 123 – 132.

Meijers, E., Drenth, D. H., Jansen, A. (2002) 'Knooppunten en mobiliteit'. In: Bruinsma, J., van Dijk, F., Goter, C. (Eds.) *Mobiliteit en beleid*. Assen, Van Gorcum, 109 – 121.

Mennis, J. (2006) 'Mapping the results of geographically weighted regression', *The Cartographic Journal* 43 (2), 171 – 179.

Meyer, M. D. and Miller, E. J. (2001) *Urban transportation planning: A decision-oriented approach*. New York: Mc Graw Hill.

Monajem, S., Nosratian, F.E. (2015) 'The evaluation of the spatial integration of station areas via the node place model; An application to subway station areas in Tehran', *Transportation Research Part D* 40, 14 – 27.

Morandi, C., Moretti, A. (1996) 'Scenari di trasformazione in alcuni casi di nodi-stazioni del nord Milano attraverso un approccio "locale" e "relazzionale"', *Archivo di studi urbani e regionali*, 26 (53), 115 – 128.

N

Nawrocki, J., Nakagawa, D., Matsunaka, R., Oba, T. (2014) 'Measuring walkability and its effects on light rail usage: A comparative study of the USA and Japan'. In: Brebbia, C. A. (Ed.) *Urban Transport XX*. Wessex Institute of Technology, 305 – 316.

Newman, M. E. J. (2010) *Networks: An introduction*. Oxford: Oxford University Press.

Nielsen, J. (1993) *Usability engineering*. Academic Press, San Diego, CA.

Nigro, A., Bertolini, L., Moccia, F.D. (2019) 'Land use and public transport integration in small cities and towns: Assessment methodology and application', *Journal of Transport Geography* 74, 110 – 124.

NMBS (2013) *Modal split van de klanten in de Belgische stations: Resultaten en duiding*. Internal document.

O

OECD (2013) 'Definition of functional urban areas (FUA) for the OECD metropolitan database'. Retrieved from (February 14th 2018): http://www.oecd.org/gov/regional-policy/Definition-of-Functional-Urban-Areas-for-the-OECD-metropolitandatabase.pdf.

OECD (2016) 'Functional urban areas in OECD countries: Belgium'. Retrieved from (February 14th 2018): http://www.oecd.org/gov/regionalpolicy/functional-urban-areas-all-belgium.pdf.

Olaru, D., Moncrieff, S., McCarney, G., Sun, Y., Reed, T., Pattison, C., Smith, B., Biermann, S. (2019) 'Place vs. node transit: Planning policies revisited', *Sustainability* 11 (2), 1 – 14.

Ollivro, J. (1996) 'L'ambiguïté des gares, clé du développement contemporain', *Les Annales de la Recherche Urbaine* 71, 35 – 44.

Ortuño-Padilla, A., Espinosa-Flor, A., Cerdán-Aznar, L. (2017) 'Development strategies at station areas in southwestern China: The case of Mianyang City', *Land Use Policy* 68, 660 – 670.

Oswald, F., Baccini, P. (2003) *Netzstadt: Designing the urban*. Birkhäuser.

Owens, S. E. (1992) 'Energy, environmental sustainability and land-use planning'. In: Breheny, M. J. (Ed.) *Sustainable development and urban form*. London: Pion, 79 – 105.

O'Sullivan, D. (2006) 'Geographical information science: Critical GIS', *Progress in Human Geography* 30 (6), 783–791.

P

Páez, A. (2006) 'Exploring contextual variations in land use and transport analysis using a probit model with geographical weights', *Journal of Transport Geography* 14, 167 – 176.

Pafka, E., Dovey, K. (2018) 'Walkable access'. In: Dovey, K., Pafka, E., Ristic, M. (Eds.) *Mapping urbanities: Morphologies, flows, possibilities*. New York: Routledge, 41 – 61.

Pánek, J. (2016) 'From mental maps to GeoParticipation', *The Cartographic Journal* 53, 300 – 307.

Papa, E. (2005) 'Urban transformations and rail stations system – the study case of Naples', *paper presented at the 45th Congress of the European Regional Science Association.* Amsterdam, The Netherlands, 23 – 27.

Papa, E., Pagliara, F., Bertolini, L. (2008) 'Rail system development and urban transformations: Towards a spatial decision support system'. In: Bruinsma, F., Pels, E., Rietveld, P., van Wee, B. (Eds.) *Railway development: Impacts on urban dynamics*, 337 – 357.

Papa, E., Moccia, F.D., Angiello, G., Inglese, P. (2013) 'An accessibility planning tool for network transit oriented development: SNAP', *Planum* 2 (27), 1 – 9.

Papa, E., Bertolini, L. (2015) 'Accessibility and transit-oriented development in European metropolitan areas', *Journal of Transport Geography* 47, 70 – 83.

Papa, E., Silva, C., te Brömmelstroet, M., Hull, A. (2016) 'Accessibility instruments for planning practice: A review of European experiences', *Journal of Transport and Land Use* 9 (3), 57 – 75.

Papa, E., Coppola, P., Angiello, G. Carpentieri, G. (2017) 'The learning process of accessibility instrument developers: Testing the tools in planning practice', *Transportation Research part A* 104, 108 – 120.

Papa, E., Carpentieri, G., Angiello, G. (2018) 'A TOD classification of metro stations: An application in Naples'. In: Papa, R., Fistola, R., Gargiulo, C. (Eds.) *Smart planning: Sustainability and mobility in the age of change*. Springer, 285 – 300.

Park, S., Choi, K., Lee, J. S. (2015) 'To walk or not to walk: Testing the effect of path walkability on transit users' access mode choices to the station', *International Journal of Sustainable Transport* 9 (8), 529 – 541.

Peek, G. J., van Hagen, M. (2002) 'Creating synergy in and around stations: Three strategies for adding value', *Transportation Research Records* 1793, 02-2941.

Peek, G. J., Bertolini, L., De Jonge, H. (2006) Gaining insight in the development potential of station areas: A decade of node-place modelling in the Netherlands', *Planning Practice and Research* 21, 443 – 462.

Peek, G. J. (2006) *Locatiesynergie: Een participatieve start van de herontwikkeling van binnenstedelijke stationslocaties*, PhD dissertation. Delft: TU Delft. Eburon.

Peek, G. J., Louw, E. (2008a) 'A multidisciplinary approach of railway station development: A case study of 's-Hertogenbosch'. In: Bruinsma, F., Pels, E., Rietveld, P., Priemus, H., van Wee, B. (Eds.) *Railway development: Impacts on urban dynamics*. Physica Verlag, 125 – 143.

Peek, G. J., Louw, E. (2008b) 'Integrated rail and land use investment as a multi-disciplinary challenge', *Planning Practice & Research*, 23 (3), 341 – 361.

Pelzer, P., Geertman, S., van der Heijden, R., Rouwette, E. (2014) 'The added value of planning support systems: A practitioner's perspective', *Computers, Environment and Urban Systems* 48, 16 – 27.

Pelzer, P., Geertman, S. (2014) 'Planning support systems and interdisciplinary learning', *Planning Theory & Practice* 15 (4), 527 – 542.

Pelzer, P., Arciniegas, G., Geertman, S., Lenferink, S. (2015) 'Planning support systems and task technology fit: A comparative case study', *Applied Spatial Analysis and Policy* 8 (2), 155 – 175.

Pelzer, P. (2015) *Usefulness of planning support systems : Conceptual perspectives and practitioners' experiences.* PhD dissertation. Utrecht: Utrecht University.

Pelzer, P. (2017) 'Usefulness of planning support systems: A conceptual framework and an empirical illustration', *Transportation Research Part A* 104, 84 – 95.

Peny, A. (1990) 'Entre ville et réseau: La station du métro', *Revue d'historie des chemins de fer* 2, 177 – 186.

Poelmans, L., Engelen, G. (2014) *Verklarende factoren in de evolutie van het ruimtebeslag*. Study commissioned by the Flemish Administration, 2014/RMA /R /90.

Pojani, D., Stead, D. (2015) 'Transit-oriented design in The Netherlands', *Journal of Planning Education and Research* 35 (2), 131 – 144.

Preston, J. M. (1991) 'Demand forecasting for new local rail stations and services', *Journal of Transport Economics and Policy* 25 (2), 183 – 202.

Province of North Holland and Deltametropolis Association (2013) *Maak plaats! Werken aan knooppuntontwikkeling in Noord-Holland.* Booxs. ISBN 9789076630168.

Pucci, P. (1996) *I nodi infrastrutturali: Luoghi e non luoghi metropolitani*. Milano: FrancoAngeli.

Pucci, P., Vecchio, G. (2019) 'Stations: Nodes and places of everyday life'. In: Pucci, P., Vecchio, G. (Eds.) *Enabling mobilities: Planning tools for people and their mobilities*. Springer International, 59 – 79.

## Q

Qviström, M. (2015) 'Putting accessibility in place: A relational reading of accessibility in policies for transit-oriented development', *Geoforum* 58, 166 – 173.

Qviström, M., Luka, N., De Block, G. (2019) 'Beyond circular thinking: Geographies of transit-oriented development', *International Journal of Urban and Regional Research* 43 (4), 768 – 793.

## R

Reusser, D. E., Loukopoulos, P., Stauffacher, M. Scholz R. W. (2008) 'Classifying railway stations for sustainable transitions: Balancing node and place functions', *Journal of Transport Geography* 16 (3), 191 – 202.

Ryan, S., Frank, L. F. (2009) 'Pedestrian environments and transit ridership', *Journal of Public Transportation* 12 (1), 39 – 57.

Ryckewaert, M. (2002) 'The minimal rationality of dwelling patterns in Flanders' Nevelstad', *Oase: tijdschrift voor architectuur* 60, 49 – 60.

## S

Sander, A. (1996) 'Des lieux-mouvements bien singuliers', *Les Annales de la Recherce Urbaine* 71, 45 – 54.

Schlossberg, M., Brown, N. (2004) 'Comparing transit-oriented development sites by walkability indicators', *Transportation Research Record*, 1887, 34 – 42.

Schön, K. (1983) *The reflective practitioner: How professionals think in action*. Temple Smith, London.

Schwengler, D. (2019) *Exploring opportunities of transit-oriented development on Brussels' suburban train network. A case-study based approach*. Master's dissertation. Brussels: Vrije Universiteit Brussel and Université Libre de Bruxelles.

Sennett, R. (1990) *The conscience of the eye. The design and social life of cities*, New York: Norton.

Sevtsuk, A., Mekonnen, M., Kalvo, R. (2013) *Urban network analysis: Toolbox for ArcGIS*. Singapore: Singapore University of Technology & Design in collaboration with MIT.

Sheppard, E. (2005) 'Knowledge production through critical GIS: Genealogy and prospects', *Cartographica* 40 (4), 5 – 21.

Silva, C. (2017) 'Bridging the implementation gap of accessibility instruments and planning support systems', *Transportation Research Part A: Policy and Practice* 104, 67 – 69.

Silva, C., Bertolini, L., te Brömmelstroet, M., Milakis, D., Papa, E. (2017) 'Accessibility instruments in planning practice: Bridging the implementation gap', *Transport Policy* 53, 135 – 145.

Silva, C., Larsson, A. (2018) *Challenges for accessibility planning and research in the context of sustainable mobility: Discussion paper.* International Transport Forum, Paris.

Singh, Y. J., Fard, P., Zuidgeest, M., Brussel, M., van Maarseveen, M. (2014) 'Measuring transit oriented development: A spatial multi criteria assessment approach for the city region Arnhem and Nijmegen', *Journal of Transport Geography* 35, 130 – 143.

Singh, Y. J., Lukman, A., Flacke, J., Zuidgeest, M., van Maarseveen M. (2017) 'Measuring TOD around transit nodes: Towards TOD policy', *Transport Policy* 56, 96 – 111.

Smets, M. (1994) '1990 – 1993: Een keerpunt voor de stedebouw?' *Jaarboek Architectuur Vlaanderen*. Brussel: Ministerie van de Vlaamse Gemeenschap, 20 – 31.

Smets, M. (1995) 'La ville nébuleuse', *Europan 4: Construire la ville sur la ville, Règlement/Thème*, 40 – 43.

Soja, E. W. (1991) *The stimulus of a little confusion. A contemporary comparison of Amsterdam and Los Angeles*. Amsterdam: Centrum voor Grootstedelijk Onderzoek.

Sondermeier, J. (2000) 'De juiste knoop op de juiste plaats', *paper presented at the Plandag 2000 conference.* Amsterdam, 69 – 79.

Sørensen, A. Ø., Olsson N. O . E., Akthar, M. M., Bull-Berg, H. (2019) 'Approaches, technologies and importance of analysis of the number of train travellers', *Urban, Planning and Transport Research* 7 (1), 1 – 18.

Spaans, M., Stead, D. (2016) 'Integrating public transport and urban development in the southern Randstad'. In: Schmitt, P., van Well, L. (Eds.) *Territorial governance across Europe: Pathways, practices and prospects*. London: Routledge, 126 – 140.

Stadsregio Arnhem Nijmegen (2011) *Knooppunten! Bereikbaarheid en ruimtelijke ontwikkeling op knooppunten van openbaar vervoer*. Arnhem.

Staricco, L., Brovarone, E. V. (2018) 'Promoting TOD through regional planning. A comparative analysis of two European approaches', *Journal of Transport Geography* 66, 45 – 52.

Stead, D. (2001) 'Relationships between land use, socio-economic factors, and travel patterns in Britain', *Environment and Planning B*, 28 (4), 499 – 528.

Stevens, M. R. (2017) 'Does compact development make people drive less?', *Journal of the American Planning Association* 83 (1), 7 – 18.

Stewart, K. J., Gosain, S. (2006) 'The impact of ideology on effectiveness in open source software development teams', *MIS Quarterly* 30 (2), 291 – 314.

Stoilova, S., Nikolova, R. (2016) 'Classifying railway passenger stations for use transport planning: Application to Bulgarian railway network', *Transport Problems* 11 (2), 143 – 155.

Storme, T., Meijers, E., van Meeteren, M., Sansen, J., Louw, E., Koelemaij, J., Boussauw, K., et al. (2015) *Topvoorzieningen: verdiepingsrapport*. Brussel: Vlaamse overheid: Departement Ruimte Vlaanderen.

Straatemeier, T., Bertolini, L., te Brömmelstroet, M., Hoetjes, P. (2010) 'An experiential approach to research in planning', *Environment and Planning B* 37 (4), 578 – 591.

Straatemeier, T. (2019) *Joint accessibility design: A framework to improve integrated transport and land use strategy making*. PhD dissertation. Amsterdam: University of Amsterdam.

Strale, M. (2019) 'Travel between Brussels and its outskirts', *Brussels Studies*. Retrieved from (September 4th 2019): https://journals.openedition.org/brussels/2499.

Sun, G., Zacharias, J., Ma, B., Oreskovic, N. M. (2016) 'How do metro stations integrate with walking environments? Results from walking access within three types of built environment in Beijing', *Cities* 56, 91 – 98.

Sung, H., Oh, J. (2011) 'Transit-oriented development in a high-density city: Identifying its association with transit ridership in Seoul, Korea', *Cities* 28, 70 – 82.

**T**

Tan, W. (2013) *Pursuing transit-oriented development. Implementation through institutional change, learning and innovation.* PhD dissertation. Amsterdam: University of Amsterdam.

Taylor, B. D., Fink, C. N. Y. (2003) 'The factors influencing transit ridership: A review and analysis of the ridership literature'. UC Berkeley. Retrieved from (August 19th 2019): https://escholarship.org/uc/item/3xk9j8m2.

te Boveldt, G. (2019) *All aboard? A new evaluation approach for institutionally complex transport projects*. PhD dissertation. Brussels: Vrije Universiteit Brussel.

te Brömmelstroet, M. (2010) *Making planning support systems matter: improving the use of planning support systems for integrated land use and transport strategy-making*. PhD dissertation. Amsterdam: University of Amsterdam.

te Brömmelstroet, M., Silva, C., Bertolini, L. (2014) *COST action TU1002 – Assessing usability of accessibility instruments*. Brussels: COST.

te Brömmelstroet, M., Curtis, C., Larsson, A., Milakis, D. (2016) 'Strengths and weaknesses of accessibility instruments in planning practice: Technological rules based on experiential workshops', *European Planning Studies*, 24 (6), 1 – 22.

te Brömmelstroet, M. (2017) 'Towards a pragmatic research agenda for the PSS domain', *Transportation Research Part A* 104, 77 – 83.

Thomas, I., Cotteels, C., Jones, J., Peeters, D. (2012) 'Revisiting the extension of the Brussels urban agglomeration: New methods, new data, … new results?', *Belgeo* 1 (2), 1 – 12.

Thompson, M. (2016) 'Upside-down GIS: The future of citizen science and community participation', *The Cartographic Journal* 53, 326 – 334.

**V**

Van Acker, V. (2010) *Spatial and social variations in travel behaviour: Incorporating lifestyles and attitudes into travel behaviour-land use interaction research*. PhD dissertation. Ghent: Ghent University.

Van Acker, V., Witlox, F. (2010) 'Car ownership as a mediating variable in car travel behaviour research using a structural equation modelling approach to identify its dual relationship', *Journal of Transport Geography* 18, 65 – 74.

Van Acker, V., Mokhtarian, P. L., Witlox, F. (2014) 'Car availability explained by the structural relationships between lifestyles, residential location, and underlying residential and travel attitudes', *Transport Policy* 85, 88 – 99.

Van Aken, J. E. (2004) 'Management research based on the paradigm of the design sciences: The quest for field-tested and grounded technological rules', *Journal of Management Studies* 41, 219 – 246.

van de Weijer, M. (2016) 'Ruimtelijke idealen en een weerbarstige realiteit'. In: Devisch, O., Roosen, B. (Eds.) *Verkavelingsverhalen*. Public Space, Mechelen, 33 – 37.

van den Hoek, J. (2008) 'The MXI (mixed-use index) as a tool for urban planning and analysis', *Corporations and Cities*. Delft: Delft University of Technology, 1 – 15.

Vandermotten, C., Roelandts, M., Aujean, L., Castiau, E. (2006) 'Central Belgium: Polycentrism in a federal context'. In: Hall, P., Pain, K. (Eds.) *The polycentric metropolis: Learning from mega-city regions in Europe*. Earthscan, London, 146 – 153.

Vanderstraeten, G., Van Butsele, S., Toebak, K. (2018) 'De (on)wil om samen te werken. Sentimenten in het regiodebat', *paper presented at the Plandag 2018 conference.* Dordrecht, 129 – 135.

Van Eenoo, E., Fransen, K., Boussauw, K. (2019) 'Exploring and quantifying mental car dependency in urban areas in Flanders (Belgium) applying social practices theory', *paper presented at the BIVEC-GIBET Transport Research Days 2019*. Ghent, 348 – 357.

Vaessens, B. (2005) 'Synergie op stationslocaties', *Paper presented at the Colloquium Vervoersplanologisch Speurwerk 2005*. Rotterdam, 189 – 208.

Vale, D. (2015) 'Transit-oriented development, integration of land use and transport and pedestrian accessibility: Combining node-place model with pedestrian shed ratio to evaluate and classify station areas in Lisbon', *Journal of Transport Geography* 45, 70 – 80.

Vale, D., Saraiva, M., Pereira, M. (2016) 'Active accessibility: A review of operational measures of walking and cycling accessibility', *Journal of Transport and Land Use* 9 (1), 209 – 235.

Vale, D., Viana, C. M., Pereira M. (2018) 'The extended node-place model at the local scale: Evaluating the integration of land use and transport for Lisbon's subway network', *Journal of Transport Geography* 69, 282 – 293.

Van Hecke, E., Halleux, J-M, Decroly, J-M, Mérenne-Schoumaker, B. (2007) *Noyaux d'habitat et régions urbaines dans une Belgique urbanisée: Monographies enquête socio-economique 2001*. Brussels, SPF Economie et Politique Scientifique Fédérale.

van Meeteren, M., Boussauw, K., Sansen, J., Storme, T., Louw, E., Meijers, E., De Vos, J., Derudder, B., Witlox, F. (2015) *Kritische massa: Verdiepingsrapport*. (Research report). Comissioned by Ruimte Vlaanderen, Brussels.

van Meeteren, M. (2016) *From polycentricity to a renovated urban systems theory: Explaining Belgian settlement geographies.* PhD dissertation. Ghent: Ghent University.

van Nes, A., Stolk, E. (2012) 'Degrees of sustainable location of railway stations: Integrating space syntax and node place value model on railway stations in the Province of North Holland's strategic plan for 2010 – 2040', *paper presented at the 8th International Space Syntax Symposium*. Santiago de Chile, Chile.

van Nes, A., Berghauser, P. M., Mashhoodi, B. (2012) 'Combination of space syntax with spacematrix and the mixed use index', *paper presented at the 8th International Space Syntax Symposium*. Santiago de Chile, Chile.

Vanoutrive, T., Malderen, L. Van, Jourquin, B., Thomas, I., Verhetsel, A., Witlox, F. (2010) 'Mobility management measures by employers: Overview and exploratory analysis for Belgium', *European Journal of Transport and Infrastructure Research* 2 (10), 121 – 141.

Vega, A. (2012) 'Using place rank to measure sustainable accessibility', *Journal of Transport Geography* 24, 411 – 418.

Ven, K., Verelst, J. (2008) 'The impact of ideology on the organizational adoption of open source software', *Journal of Database Management* 19 (2), 58 – 72.

Verachtert, E., Mayeres, I., Poelmans, L., Van der Meulen, M., Vanhulsel, M., Engelen, G. (2016) *Ontwikkelingskansen op basis van knooppuntwaarde en nabijheid voorzieningen. Eindrapport.* (Technical report VITO 2016/RMA/0545). VITO, Vlaamse Instelling voor Technologisch Onderzoek.

Verhetsel, A., Thomas, I., van Hecke, E., Beelen, M. (2007) *Pendel in België. Deel 1: de woon- en werkverplaatsingen*. Brussel, Federale Overheidsdienst Economie, KMO, Middenstand en Energie.

Vermeiren, K., Poelmans, L., Engelen, G., Loris, I., Pisman, A. (2018) 'What is urban sprawl in Flanders?', *paper presented at the REAL CORP 2018 Conference*. Vienna, 537 – 545.

Vermeiren, K., Poelmans, L., Engelen, G., Broekx, S., Beckx, C., De Nocker, L., Van Dyck, K. (2019) *Monetariseren van de impact van urban sprawl in Vlaanderen*. Comissioned by the Department of Environment, Brussels.

Vickerman, R. W. (1974) 'Accessibility, attraction, and potential: A review of some concepts and their use in determining mobility', *Environment and Planning A* 6, 675 – 691.

Viganò, P. (2013) 'The horizontal metropolis and Gloeden's diagrams. Two parallel stories', *Oase* 89, 94 – 111.

Vigar, G. (2017) 'The four knowledges of transport planning: Enacting a more communicative, trans-disciplinary policy and decision-making', *Transport Policy* 58, 39 – 45.

Voets, J., De Rynck, F. (2008) 'Contextualising city-regional issues, strategies and their use: The Flemish story', *Local Government Studies* 34 (4), 453 – 470.

von Schönfeld, K. C., Tan, W., Wiekens, C., Janssen-Jansen, L. (2019a) 'Unpacking social learning in planning: Who learns what from whom?', *Urban Research & Practice*. Retrieved from (August 19th 2019): https://doi.org/10.1080/17535069.2019.1576216.

von Schönfeld, K. C., Tan, W., Wiekens, C., Salet, W., Janssen-Jansen, L. (2019b) 'Social learning as an analytical lens for co-creative planning', *European Planning Studies*. Retrieved from (August 19th 2019): https://doi.org/10.1080/09654313.2019.1579303.

Vonk, G., Geertman, S., Schot, P. (2005) 'Bottlenecks blocking widespread usage of planning support systems', *Environment and Planning A* 37, 909 – 924.

Vonk, G. (2006) *Improving planning support. The use of planning support systems for spatial planning*. PhD dissertation. Utrecht: Utrecht University.

VRP (2016) *Manifest mobiliteit 2.0: Pleidooi voor een betere (stads)regionale samenhang tussen mobiliteit en ruimtelijke ontwikkeling*. Brochure, retrieved from (November 6th 2019): http://vrp.be.

VRP (2019) *Inspiratieboek Attractieve Mobipunten*. Retrieved from (August 19th 2019): https://www.vrp.be/news/boek-attractieve-mobipunten/

**W**

Wegener, M., Fürst, F. (1999) *Land-use transport interaction: State of the art*. Institut für Raumplanung, Dortmund.

White, R., Engelen, G., Uljee, I. (2015) 'Modeling in support of spatial planning and policy making: The example of Flanders'. In: White, R., Engelen, G., Uljee, I. (Eds.) *Modeling cities and regions as complex systems: From theory to planning applications*. Cambridge, MA: The MIT Press, 251– 294.

Wulfhorst, G., Büttner, B., Ji, C.(2017) 'The TUM accessibility atlas as a tool for supporting policies of sustainable mobility in metropolitan regions', *Transportation Research Part A* 104, 121 – 136.

**Y**

Young, M. A., Blainey, S. P. (2019) 'An automated online tool to forecast demand for new railway stations and analyse potential abstraction effects', *Transport Practitioners' Meeting*, 10-11 July 2019, Oxford.

**Z**

Zemp, S., Stauffacher, M., Lang, D.J., Scholz, R.W. (2011) 'Classifying railway stations for strategic transport and land use planning: Context matters', *Journal of Transport Geography* 19 (4), 670 – 679.

Zhang, Y., Marshall, S., Manley, E. (2019) 'Network criticality and the node-place-design model: Classifying metro station areas in Greater London', *Journal of Transport Geography*. https://doi.org/10.1016/j.jtrangeo.2019.102485.

Zhao, J., Deng, W., Song, Y., Zhu, Y. (2013) 'What influences metro station ridership in China? Insights from Nanjing', *Cities* 35, 114 – 124.

Zhou, Q., Dai, D. (2017) 'The evaluation of transit oriented development of metro station areas using node place index in Shenzhen China', *paper presented at the inaugural World Transport Convention.* Beijing, China.

Zweedijk, A., Serlie, Z. (1998) 'Een "knoop-plaats"-model voor stationslocaties', *Geografie* 7 (5), 35 – 37.

# SAMENVATTING

*'We moeten allemaal dichter bij elkaar gaan wonen' (2016). 'Nu nog vrijstaand bouwen is crimineel' (2017), 'Straks rijdt er geen bus meer op het platteland' (2018), 'Alleen Britten staan langer in de file' (2019), 'Wie geeft zijn baksteen op?' (2019), 'Salariswagen is ook emotie' (2019), 'Openbaar vervoer meestal trager dan auto' (2019) 'In 5 jaar ruim helft minder treinloketten' (2019) …*

In Vlaanderen woedt een bij tijden hevig publiek debat over ruimtelijke idealen en de confrontatie met een weerbarstige realiteit. Een greep uit enkele recente krantenkoppen[122] (hierboven) illustreert een aantal facetten die nauw met elkaar verweven zijn in dit debat. De ruimtelijke realiteit in Vlaanderen is immers een resultante en tegelijk een aandrijver van heel wat maatschappelijke processen. Het versnipperde Vlaamse landschap is de neerslag van een historisch gegroeide cultivering van woonvoorkeuren en eigendomsstructuren en hangt bovendien nauw samen met de wijze waarop ons huidige mobiliteitssysteem is georganiseerd en wordt bestuurd.

Vanuit de Vlaamse Departementen Mobiliteit en Openbare Werken en Omgeving weerklinkt de laatste jaren een duidelijk signaal om eindelijk werk te maken van meer compacte verstedelijking. Dit ruimtelijk ontwikkelingsprincipe wordt rechtstreeks gekoppeld aan een mobiliteitsvisie die de bereikbaarheid van belangrijke maatschappelijke functies via het openbaar vervoer prioritiseert. Volgens beide departementen heeft het treinnetwerk een centrale rol te spelen in deze beoogde transitie naar meer duurzame dagelijkse verplaatsingspatronen in de regio. Verwijzend naar planningsparadigma's zoals knooppuntontwikkeling en de internationaal meer gangbare term *'transit oriented development'* (TOD), luidt de veronderstelling immers dat compacte en 'gemixte' ontwikkelingen rondom knooppunten van openbaar vervoer (mee) kansen bieden voor een minder autoafhankelijke mobiliteit. Plannen voor ruimtelijke nabijheid en bereikbaarheid per openbaar vervoer lijkt zodoende het credo te zijn geworden voor heel wat verstedelijkte regio's wereldwijd.

Dit proefschrift *'Planning for nodes, places, and people. A strategic railway station development tool for Flanders'*[123] vertrekt vanuit de veronderstelling dat knooppuntontwikkeling inderdaad het potentieel heeft om mobiliteit te verduurzamen in Vlaanderen. Een van de centrale vragen die uit deze aanname voortvloeien is de vraag hoe, waar en welke ontwikkelingskansen voor stations(omgevingen) geïdentificeerd kunnen worden. Hoewel de empirische resultaten van dit proefschrift toelaten om voorzichtige antwoorden te formuleren op het 'waar' en het 'welke', focust dit onderzoek zich hoofdzakelijk op het 'hoe' van deze queeste. De insteek van dit proefschrift is daarom methodologisch van aard. Concreet houdt dit in dat we een strategisch planningsondersteunend instrument voor stationsontwikkeling uitwerken, dat we dat vervolgens testen in een specifieke Vlaamse planningspraktijk om zodoende te eindigen met een vrij beschikbare en schaalbare webtool: StationsRadar.

Een aantal bouwstenen liggen aan de basis van dit instrument en vormen tevens de inhoudelijke ruggengraat van dit proefschrift. Het eerste – inleidende – hoofdstuk kadert de nodige achtergrond. Enerzijds schetsen we een beknopte verstedelijkingsgeschiedenis van Vlaanderen, bespreken we een stand van zaken op vlak van de integratie mobiliteit en ruimte, en zoomen we in op de huidige beleidsstrategieën van de beide hogervernoemde departementen. Anderzijds introduceren we de methodiek die aan de basis ligt van de analyses in dit proefschrift: het 'knoop-plaats model'. We distilleren de voornaamste trends en

[122] Deze headlines zijn afkomstig uit de krant De Standaard en Knack Magazine.

[123] Een Nederlandse vertaling luidt als volgt: 'Plannen voor knopen, plaatsen, en mensen. Een strategische ontwikkelingstool voor treinstations in Vlaanderen'.

evoluties binnen deze literatuur en maken duidelijk hoe onze analyses zich hiertoe verhouden. We sluiten dit hoofdstuk af met een overzicht van de structuur en van het narratief van het proefschrift.

In het tweede hoofdstuk wordt het conceptuele raamwerk ontwikkeld dat aan de basis ligt voor de vervolganalyses in het proefschrift. Als opstap naar de ontwikkeling van dit raamwerk voerden we een analyse uit voor het Gewestelijk ExpresNet in en rond het Brussels Hoofdstedelijk Gewest. We bouwden hiervoor verder op een eerdere toepassing van het knoop-plaatsmodel in Nederland: het vlindermodel. Deze oefening resulteerde in een stationstypologie voor alle stations in het netwerk, en dit voor verschillende geografische afbakeningen van de stationsbuurt. Het bood ons ook meer inzicht in hoe een van de hoofdingrediënten van TOD – de bewandelbaarheid van de bebouwde omgeving – in het model kan worden geïntegreerd. Met deze kennis in het achterhoofd schaalden we onze analyses op naar alle stations in Vlaanderen en het Brussels Hoofdstedelijk Gewest. We breidden ons eerdere raamwerk verder uit door het opnemen van gebruikersdata. Deze data werd aangeleverd door NMBS en geeft voor elk station een zicht op het invloedsgebied, het type stationsgebruiker en de intensiteit van gebruik. Dit laatste aspect informeert over het vertrek- of bestemmingsgehalte van het station. Op basis van deze rijke dataset werden opnieuw stationstypologieën uitgewerkt en werd een manier gezocht om de data op een overzichtelijke wijze in unieke stationsprofielen te gieten. De resultaten werden uiteindelijk opgenomen in een bèta webtool die de stationsprofielen en alle kaartmateriaal weergaf.

Om de bruikbaarheid van de ontwikkelde methodiek te verifiëren werd de tool vervolgens onderworpen aan meerdere tests in de vorm van drie halfdaagse workshops. Als planningscontext kozen we ervoor om aansluiting te zoeken bij de recent opgerichte vervoerregio's. De bedoeling van deze partnerschappen bestaat er immers uit om het openbaar vervoer binnen de regio uit te tekenen *en* om mobiliteits- en ruimtelijke plannen zo veel mogelijk te integreren. Het eerste onderdeel van Hoofdstuk 3 rapporteert over deze workshops en duidt onze bevindingen op vlak van de bruikbaarheid van de tool voor de interdisciplinaire groep stakeholders in de vervoerregio. We proberen meer zicht te krijgen op de meerwaarde van de ontwikkelde stationsprofielen, op het nut van de indicatoren die aan de basis liggen ervan en van andere praktische bruikbaarheidsaspecten. In een tweede onderdeel zoomen we aan de hand van een reeks expert-interviews verder in op de specifieke planningsopgaves binnen de vervoerregio en de manier waarop StationsRadar hier al dan niet kan aantakken. Een derde deel bespreekt tot slot de workshopcasus van de stations Ninove, Denderleeuw en Aalst. We illustreren hoe de tool op bepaalde momenten tijdens de interdisciplinaire discussie ondersteunend werkte, en welke ontwikkelingscenario's voor de stations(omgevingen) werden uitgedacht.

Een vierde hoofdstuk is opnieuw kwantitatief van insteek. Op basis van de rijke dataset proberen we aanwijzingen te vinden die een idee kunnen geven van de belangrijkste factoren die treingebruik in Vlaanderen beïnvloeden. We verzamelen hiertoe nog wat extra data en voeren vervolgens een reeks regressie-analyses uit om zodoende het relatieve belang van de verschillende variabelen voor het verklaren van het aantal opstappers in de stations te proberen verklaren. We bouwen hiervoor verder op de recente literatuur met betrekking tot *'trip end modeling'* en het modelleren van het aantal opstappers op het niveau van de stations. Dit houdt in dat we ook nagaan in hoeverre de regressiecoefficiënten geografisch en temporeel variëren al dan niet. We koppelen vervolgens terug naar de knoop-plaats methodiek en bespreken hoe deze nieuwe laag informatie geïntegreerd zou kunnen worden in het raamwerk, en zodoende kan bijdragen tot een betere inschatting van het ontwikkelingspotentieel van stations(omgevingen). We bespreken ook hoe deze empirische resultaten geïntegreerd kunnen worden in de StationsRadar tool.

Hoofdstuk 5 licht de StationsRadar tool toe. We bespreken de werking en de verschillende onderdelen van de tool aan de hand van een voorbeeld, waarna we meer duiding geven bij het technologische ontwikkelingsproces en een blik werpen op de *'way forward'*.

Een laatste – concluderend – hoofdstuk licht de beoogde wetenschappelijke bijdragen van dit proefschrift toe, fileert de tekortkomingen van het werk en rijkt aanknopingspunten aan voor vervolgonderzoek.

## SUMMARY


*'We all have to live closer together' (2016), 'It's criminal to develop freestanding lots' (2017), 'Soon there will be no more buses in the countryside' (2018), 'Only Brits have longer traffic cues' (2019), 'Who will give up his brick?' (2019), 'A company car is emotion too' (2019), 'Public transport is slower than the car' (2019), 'More than half of all train ticket offices shut down in 5 years' (2019) …*

In recent years, the public debate about a future vision for spatial development in Flanders has been alive and at times intense. The recent newspaper headlines[124] in the above are raising some of the different themes which are closely intertwined in the debate. Flanders' fragmented urban landscape is the blueprint of a historically grown cultivation of residential preferences and property structures. This in turn influences and is influenced by the way in which our current mobility system is organized and governed.

From the Flemish Departments of Mobility and Public Works and of Environment, clear signals are sent out to start working on more compact urban development. This strategic spatial development principle is directly related to a mobility vision which prioritizes the accessibility of important societal functions by means of public transport. According to both departments, the railway network has a central role to play in this transition to more sustainable daily travel patterns in the region. By referring to the 'transit oriented development' (TOD) planning paradigm, the assumption made is that compact and mixed-use developments that are purposefully located around transit hubs can help creating the opportunities for less car dependent mobility. Unsurprisingly perhaps, planning for spatial proximity and accessibility seems to have become the credo for many urbanized regions worldwide.

This dissertation 'Planning for nodes, places, and people. A strategic railway station development tool for Flanders' starts from the assumption that TOD indeed has the potential to support a transition to a more sustainable mobility system in Flanders. One of the central questions that stem from this assumption is the question of how, where and what development opportunities can be identified for which railway stations and their surroundings. Although the empirical output of this dissertation provides clues to formulate tentative answers to the 'where' and 'what' questions, this research mainly focuses on the 'how' of the pursuit. This dissertation therefore has a major methodological component. More specifically, this entails that we develop a strategic planning support instrument for railway station development, test it in Flemish planning practice in order to arrive at a useful and openly available webtool coined 'StationRadar'.

A number of building blocks are at the basis of this instrument and form the substantive backbone of this dissertation. A first – introductory – chapter provides the relevant background information. On the one hand, we introduce the empirical case of Flanders and start with a brief history of the main transport and land use developments that have shaped the contemporary spiral of car dependence and urban sprawl. This is followed by a state of affairs of current urbanization in Flanders, which is in turn used to identify some major societal challenges and to elaborate on the way forward as propagated by the Flemish Government. On the other hand, we introduce the methodological approach that is at the basis of all analyses in this dissertation: the 'node-place model'. We distill the main trends and evolutions within this


[124] These headlines are derived from newspaper De Standaard and Knack Magazine.

academic literature and clarify how our analyses relate to this group of writings. We conclude this chapter with an overview of the structure and the narrative of the dissertation.

Chapter 2 works towards an application of the node-place framework for the region of Flanders and the Brussels Capital Region (BCR). As a first step, we conducted analyses for the Brussels Regional Express Network by building on an earlier elaboration of the node-place model in The Netherlands: the 'butterfly model'. This exercise resulted in a station typology for all railway stations in the network and this for different geographical demarcations of the 'station area'. This provided us with more insights about the way in which a major ingredient of TOD – the walkability of the station environment – could be integrated in the model. Building on this work, we scaled up our analyses to all stations located in Flanders and the BCR. We expanded the conceptual framework with a temporal component and with a demand-side perspective reflecting key characteristics of the station users. The data was provided by NMBS and provides information about the station's catchment sizes, the type of station users and the intensity of use. The latter reflects the extent to which the station functions as an origin or as a destination station. On the basis of this rich dataset, new station typologies were developed and we investigated how the data could be visualized in a well-structured way into unique station profiles. The results were included in a beta webtool, which visualized the station profiles and cartographic material.

In order to test the usefulness of the developed method, we submitted the webtool to multiple tests that took the shape of three half-day workshops. The planning context that was selected as a case study, consisted of the recently established transport regions. The objective of these regional partnerships consists of drawing out the public transport network in the region and of integrating mobility and land use plans as much as possible. The first section of Chapter 3 reports on these workshops and elaborates on our findings in terms of the usefulness of the tool as perceived by the interdisciplinary groups of stakeholders in the transport regions. We try to get a grip on the perceived usefulness of the developed station profiles, of the indicators that are at the roots of these visualizations and of other tool features. In a second section, we draw on a series of post-workshop expert interviews in order to elaborate on the planning tasks that the transport regions face, and the way in which StationRadar might support these. A third section discusses the workshop case of Ninove, Denderleeuw and Aalst. We illustrate how – at particular moments – the tool was able to support an interdisciplinary dialogue about station development potential. We also derive some development scenarios for these stations based on the discussion.

Chapter 4 in turn aims to add an additional layer of information to the tool. On the basis of the acquired data we investigated which of the different node and place variables are most important to explain the intensity of station use in Flanders. To this end we collected additional data and conducted a series of regression analyses in order to appraise the relative importance of these variables in explaining the number of people boarding the station for different periods of the day. We build on the recent literature with respect to trip end modeling and ridership models at the stop level. This implies that we also verify spatial nonstationarity of the regression coefficients. Afterwards we couple back to the node-place methodology and discuss how this new layer of information may be integrated in the framework, and how this might add to an improved understanding of a station's development potential. We also elaborate on the integration of these findings in the StationRadar tool.

The fifth chapter introduces the reader to the StationRadar tool. We discuss its working and the different components by means of an example. Afterwards we elaborate on the technological development process of the tool and on the 'way forward' as we see it.

A final – concluding – chapter discusses the scientific contributions of this dissertation, critically evaluates its shortcomings and suggests clues for further research.

# ABOUT THE AUTHOR

Freke Caset (°1992, Belgium) is a geographer educated at Ghent University (BSc, MSc, PhD) and Vrije Universiteit Brussel (PhD). She entered academia in October 2015, working on various projects at the Social and Economic Geography (SEG) research group of Ghent University. In January 2016 she started her PhD project (funded by FWO) jointly at the SEG and the Cosmopolis research groups.

@c_freke
researchgate.net/profile/Freke_Caset

### Scholarly publications

*Published journal articles:*

Caset, F., Teixeira, F. M., Derudder, B., Boussauw, K., Witlox, F. (2019) 'Planning for nodes, places, and people in Flanders and Brussels: Developing an empirical railway station assessment model for strategic decision-making', *Journal of Transport and Land Use*.

Cheng, L., Caset, F., De Vos, J., Derudder, B., Witlox, F. (2019) 'Investigating walking accessibility to recreational amenities for elderly people in Nanjing, China', *Transportation Research Part D* 76, 85 – 99.

Wenner, F., Caset, F., De Wit, B. (2019) 'Conference locations and sustainability aspirations. Towards an integrative framework?', *disP The Planning Review* 55, 43 – 51.

Caset, F., Boussauw, K., Storme, T. (2019) 'Corrigendum to 'Meet & fly: Sustainable transport academics and the elephant in the room', [Journal of Transport Geography 70, 64 – 67], *Journal of Transport Geography* 74, 413.

Caset, F., Vale, D. S., Viana, C. M. (2018) 'Measuring the accessibility of railway stations in the Brussels Regional Express Network: A node-place modeling approach', *Networks and Spatial Economics* 18 (3), 495 – 530.

Caset, F., Boussauw, K., Storme, T. (2018) 'Meet & fly: Sustainable transport academics and the elephant in the room', *Journal of Transport Geography* 70, 64 – 67.

Derudder, B., Cao, Z., Liu, X., Shen, W., Dai, L., Zhang, W., Caset F. et al. (2018) 'Changing connectivities of Chinese cities in the world city network, 2010 – 2016', *Chinese Geographical Science* 28 (2), 183 – 201.

Caset, F., Derudder, B. (2017) 'Measurement and interpretation of 'global cultural cities' in a world of cities', *Area* 49 (2), 238 – 248.

*Forthcoming journal articles:*

Caset, F. (forthcoming) 'Transit neighborhoods and structural inequity: Careful detective work across scales and contexts', Book review for *Transfers*.

Caset, F., Blainey, S., Derudder, B., Boussauw, K., Witlox, F. (forthcoming) 'Integrating node-place and trip end models to explore drivers of rail ridership in Flanders, Belgium', *Journal of Transport Geography*.

*Conference proceedings:*

Caset, F., Derudder, B., Boussauw, K., Witlox, F. (2017) 'Planning for railway network connectivity and spatial proximity: Balancing node and place functions in Flanders and the Brussels Capital Region'. *Paper presented at the BIVEC-GIBET Transport Research Days 2017*. Liège, 140 – 157.

Caset, F., Teixeira, F. M., Boussauw, K., Derudder, B., Witlox, F. (2019) 'What strategies for which railway stations? An experiential approach to the development of a node-place based planning support tool in Flanders', *Paper presented at the BIVEC-GIBET Transport Research Days 2019*. Ghent, 168 – 195.

#### Research reports

Staelens, P., Caset, F., Witlox, F. (2016) *Rapport ruimtevraag bedrijventerreinen West-Vlaanderen*.

Staelens, P., Caset, F., Witlox, F. (2016) *Methodiekenanalyse economische ruimtevraag Gent 2030*.

Caset, F., Van Acker, V., Witlox, F. (2016) *I-Mobiliteitsbudget: Eindrapport analyses enquêtes*.

Caset, F., De Vos J., Van Acker, V., Witlox, F. (2015) *Literatuurstudie: Intelligent Mobiliteitsbudget gekaderd binnen literatuur en precedenten*. Universiteit Gent.

#### Popular-scientific publications, blogs and newspaper articles

Storme, T., Meire, S., Dewinter, M., Caset, F. (forthcoming) 'AGORA: een forum voor mobiliteit'. *AGORA Magazine*.

Wenner, F., Caset, F., De Wit, B. (2019) 'Conference locations and sustainability aspirations: Towards an integrative framework?', AESOP young academics blog. Published April 5 2019.

Caset, F., Baets, L. (2018) 'Duurzaamheid als fantasie : Een interview met Erik Swyngedouw', *AGORA Magazine* 34 (1), 10 – 13.

Caset, F., de Beer, M., van Karnenbeek, L., Bruggeman, D. (2018) 'Stemmen uit het Antropoceen', *AGORA Magazine* 34 (1), 4 – 6.

Boussauw, K., Storme, T., Caset, F. (2018) 'Airmiles zijn geen statussymbool', De Standaard. Published June 26 2018.

Caset, F., Bruggeman, D. (2017) 'Stadsuniversiteit / Stadsacademie': Een interview met Michiel Dehaene', *AGORA Magazine* 34 (4), 35 – 37.

Caset, F. (2016) 'Pleidooi voor pluralisme : Plandag 2016', *AGORA Magazine* 32 (3), 45.

Caset, F., Koelemaij, J. (2016) 'Metropolis Charleroi: Overcoming post-industrial struggles?', The Proto City. Published June 27 2016.

Caset, F. (2015) 'High-end art and the quest for global city status', The Proto City. Published August 24 2015.