POST–SPARTACUSPLAN

EXPLORING THE FUTURE POSSIBILITIES OF INNOVATIVE PUBLIC TRANSPORTATION FOR SPATIAL AND MOBILITY TRANSITION IN BELGIAN LIMBURG

MINSEONG KIM

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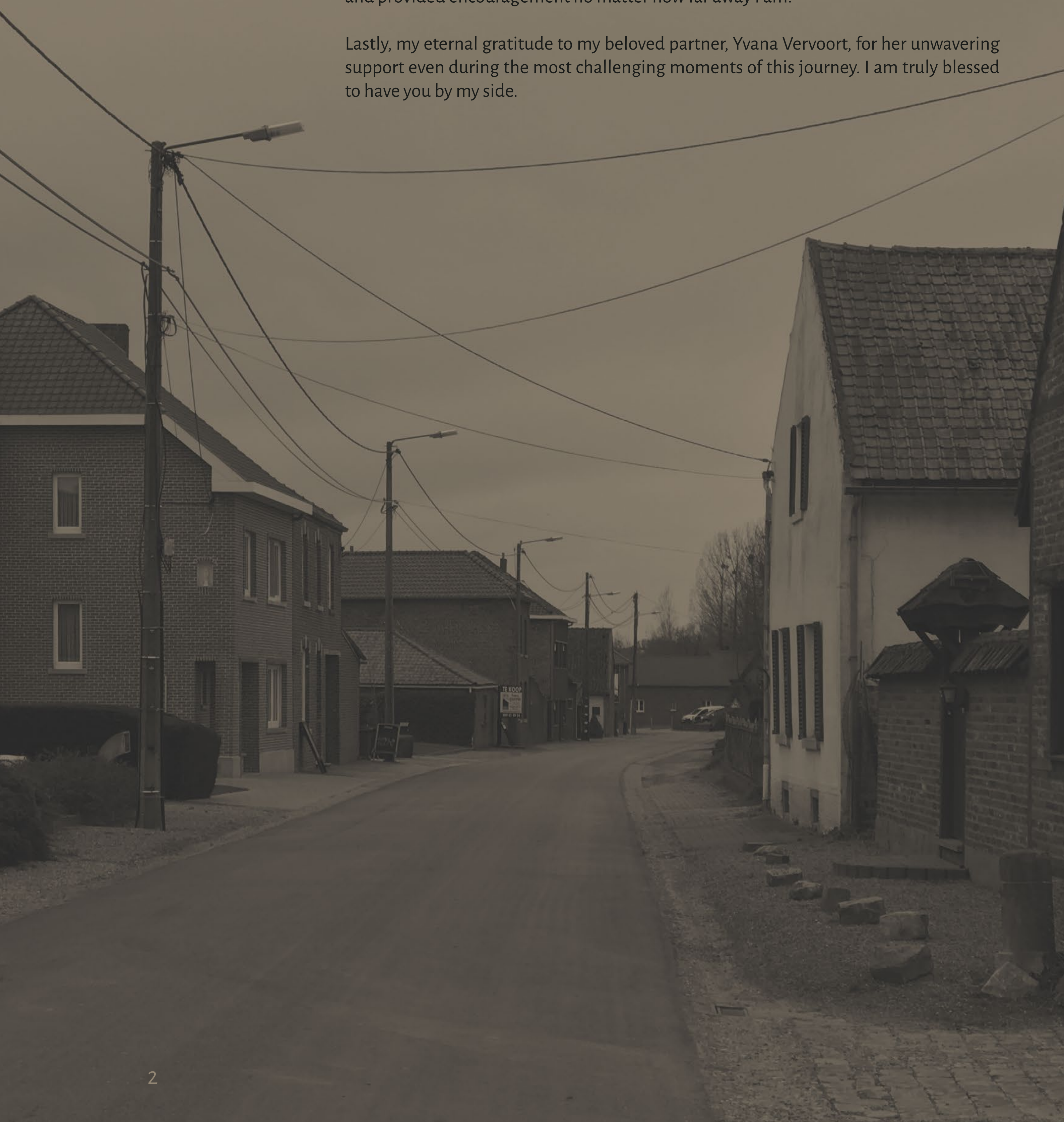

ABSTRACT

Spartacusplan, the transportation plan for the Belgian province of Limburg from 2004, is now turned into the most extensive and ambitious bus rapid transit (BRT) project in Europe. However, the proposed vehicles and network do not correspond well to the region's highly dispersed, poly-centric structure. Moreover, the dispersed urbanisation patterns and their adverse effects need further measures than Bouwshift to facilitate the spatial transition.

The thesis explores the possible strategy for accelerating spatial transition through the interplay between urban and transportation planning. The thesis takes the lens of mobility justice by Sheller (2018), and seeks alternative paths to facilitating spatial transition without depriving accessibility on "unsuited" areas.

To achieve these objectives, a multi-criteria analysis is conducted to determine the most suitable mix of elements and vehicle automation technology, and its corresponding infrastructural requirements. Trade-offs between accessibility gains through higher levels of automation and increased infrastructure are examined. Additionally, the study categorizes the potential of each location in Limburg based on criteria related to the built environment and accessibility. Through pattern language, the study resulted in urban design patterns and digital tools for transportation planning, providing practical guidance to urban designers and transportation planners for site-specific interventions across the province.

The findings of this study suggest that, considering Limburg's dispersed and poly-centric spatial structure, the higher infrastructural requirements for achieving level 4 driverless operations within Spartacuslijn are justified. Based on this model of dispersed BRT, the burden of densification can be shared with smaller cores, where the lifestyle is more aligned with rural areas. This can be achieved by providing accessibility and nodality in smaller cores through branch services connected to Spartacuslijn, offering single-seat rides to major destinations.

The proposed approach and strategy presented in this thesis offer a synergetic pathway for regional planning by integrating transportation planning and urban planning. Furthermore, the insights gained from this research can potentially be applied to other parts of Flanders and to dispersed urban areas worldwide.

Keywords:

Urban Planning, Transportation Planning, Bus Rapid Transit (BRT), Mobility Justice, Autonomous vehicle, Nebular City, Spatial transition, Pattern Language, Limburg, Flanders, Belgium.

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1.1 PROBLEM SETTING

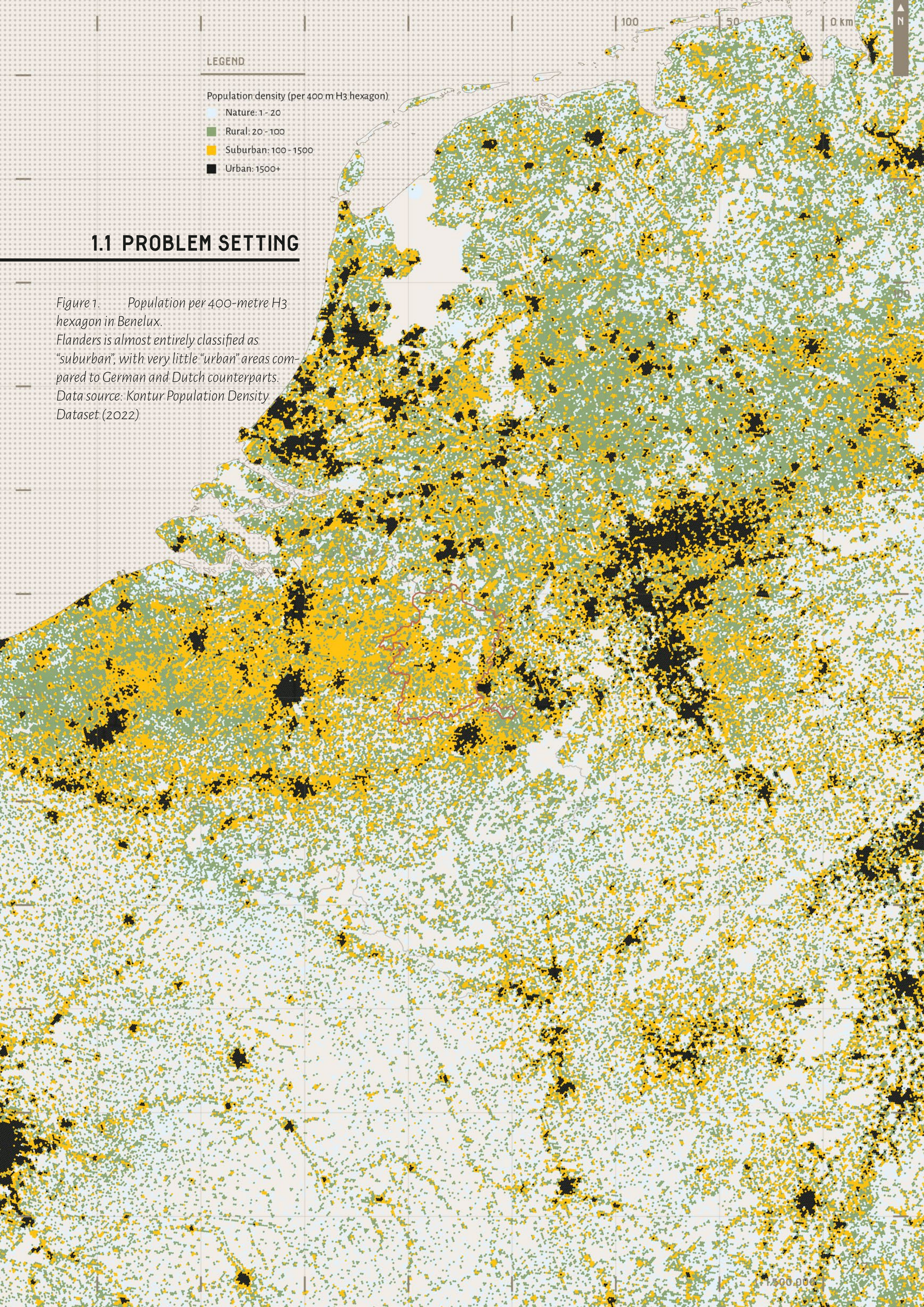


Figure 1. *Population per 400-metre H3 hexagon in Benelux.*
Flanders is almost entirely classified as "suburban", with very little "urban" areas compared to German and Dutch counterparts.
Data source: Kontur Population Density Dataset (2022)

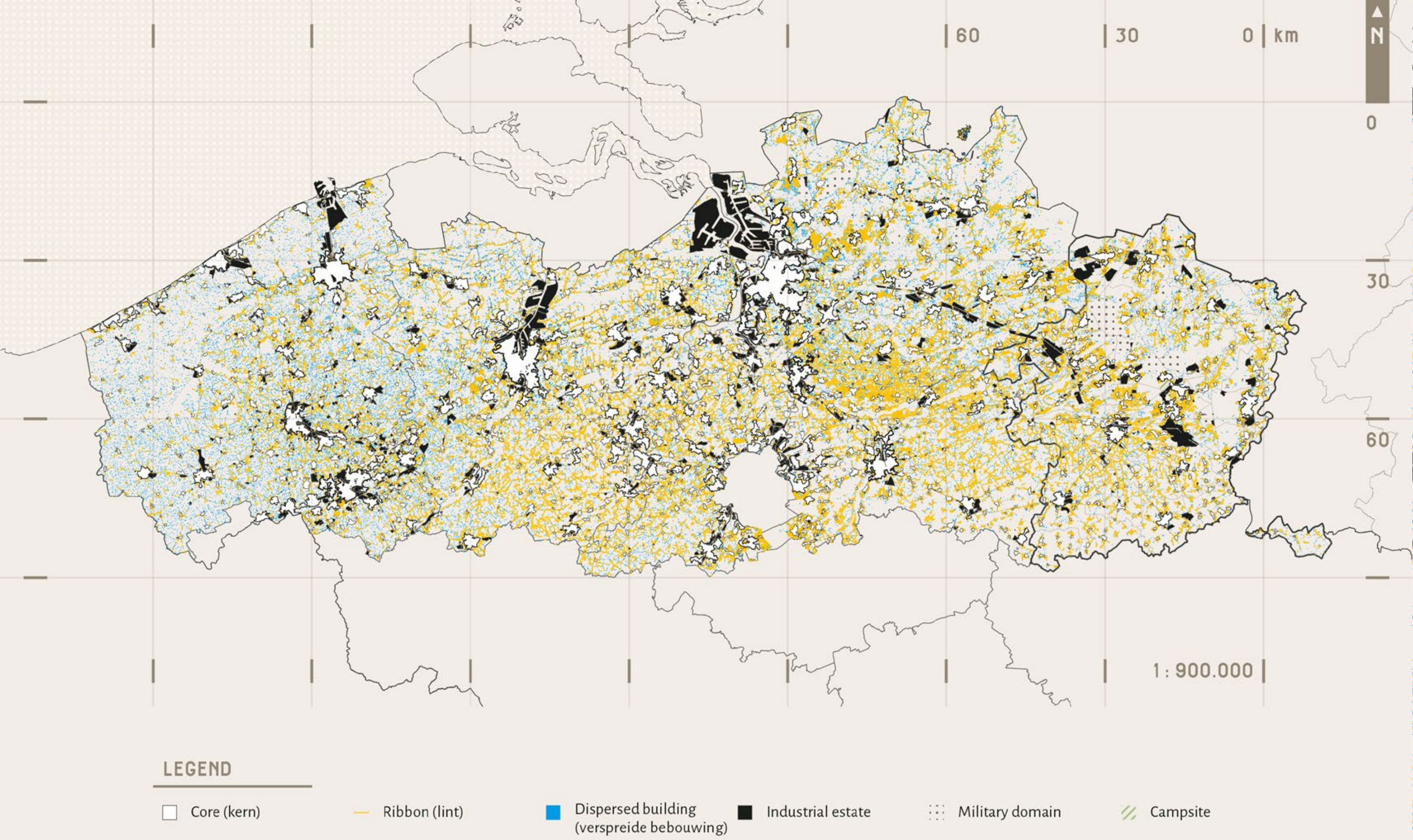


Figure 2. Flemish Departement Omgeving's typology of Flemish urbanisation. Data source: Pieters et al. (2021)

In the problem settings, the issues surrounding the Flemish Nebular city, and the context concerning Limburg will be briefly introduced. The detailed analysis of the problems will follow after the problem statement.

Flanders, Belgium, is known as one of the most dispersed regions in Europe, second only to the Netherlands (European Environment Agency, 2016). However, unlike the relatively organized and concentrated form of dispersion found in their northern neighbours, Flanders faces a unique type of sprawl that sets it apart from the rest of Europe. This dispersion can be traced back to the 19th and 20th-century policies aimed at keeping people under the influence of Catholic churches, which furthered the chaotic Belgian sprawl. Transport infrastructure, including railways, vicinal tramways (buurtspoorwegen), and waterways, significantly facilitated this dispersion. The government actively promoted it through subsidies for rail tickets for commuters starting in 1874 (Dehaene & Loopmans, 2003). Later, motorization accelerated this trend, resulting in an extraordinarily diffuse and disorganized ribbon development across Flanders (De Meulder et al., 1999). This situation is commonly referred to as the "Nebular City" (Nevelstad) in Flanders (Indovina, 1990, as cited in Dehaene & Loopmans, 2003).

The Nebular City is often considered the root of many challenges in Flemish urban planning. It poses significant difficulties in water management, biodiversity conservation, access to open spaces, and sustainable energy production. Moreover, it has increased costs for providing public services and infrastructure, such as law enforcement, sewage, water, electricity, and public transportation.

Basemap data sources, apply to all:

Basiskaart Vlaanderen (GRB), OpenStreetMap contributors (Canals & railways), EEA Copernicus CORINE Land Cover 2018 (Built-up land cover data)

The dispersed settlement pattern is also creating challenges in Flemish transportation planning. Public transportation is economically unfeasible in Nebluar City, since having houses along the road makes very little density inside the catchment area compared to (more or less) grid-based North American sprawl, forcing the transit operators to cover the longer distance for much less demand.

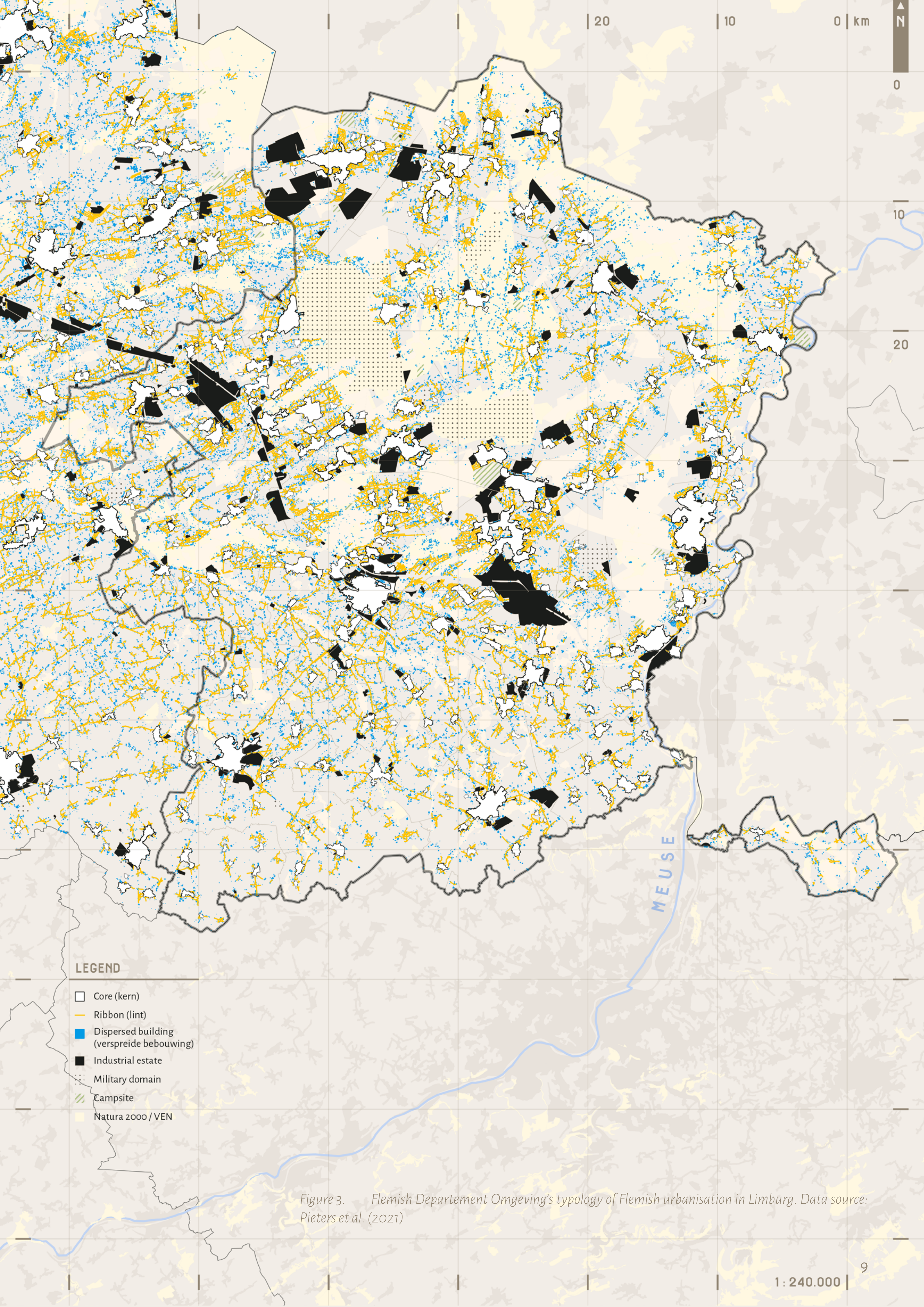


Figure 3. Flemish Departement Omgeving's typology of Flemish urbanisation in Limburg. Data source: Pieters et al. (2021)

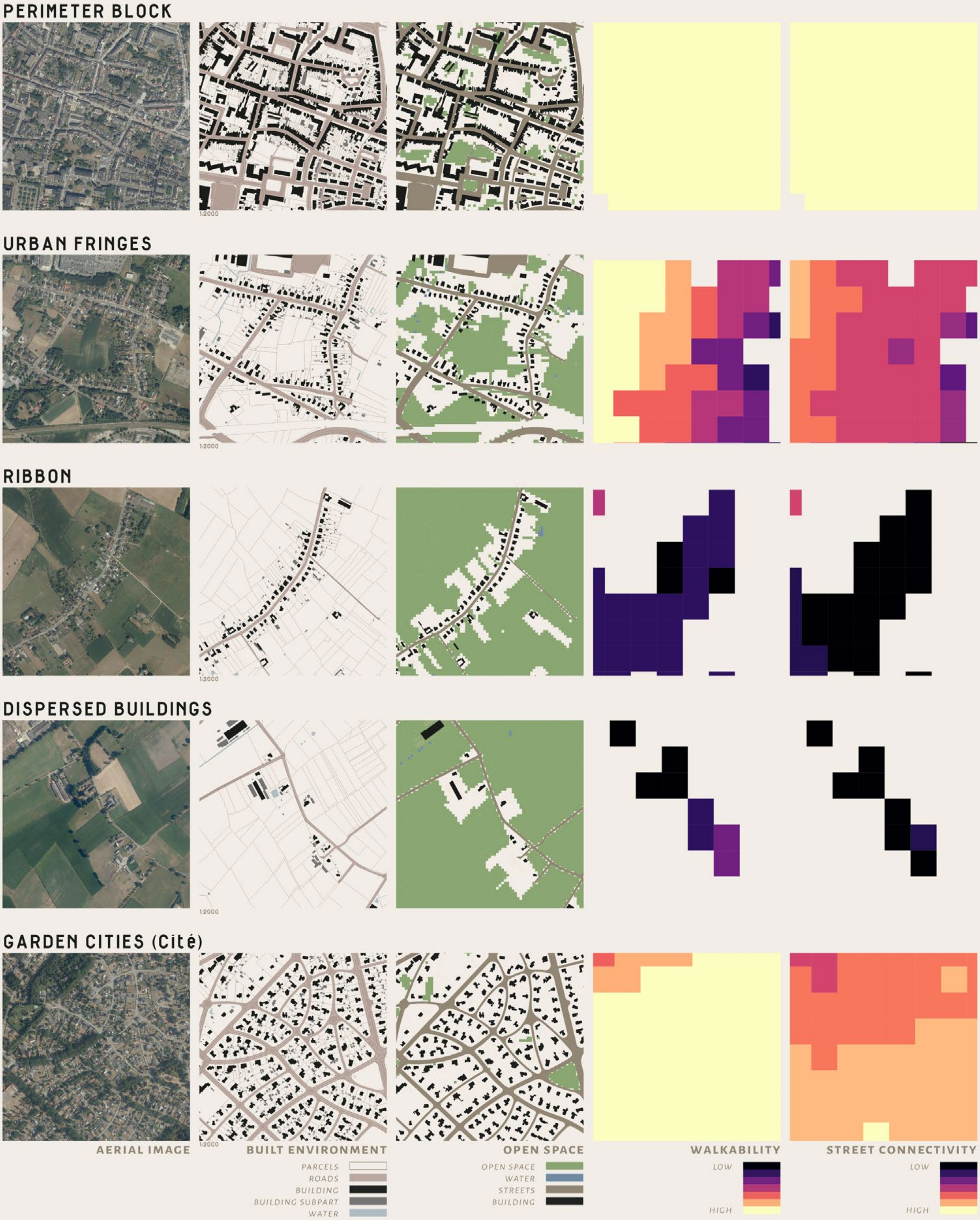
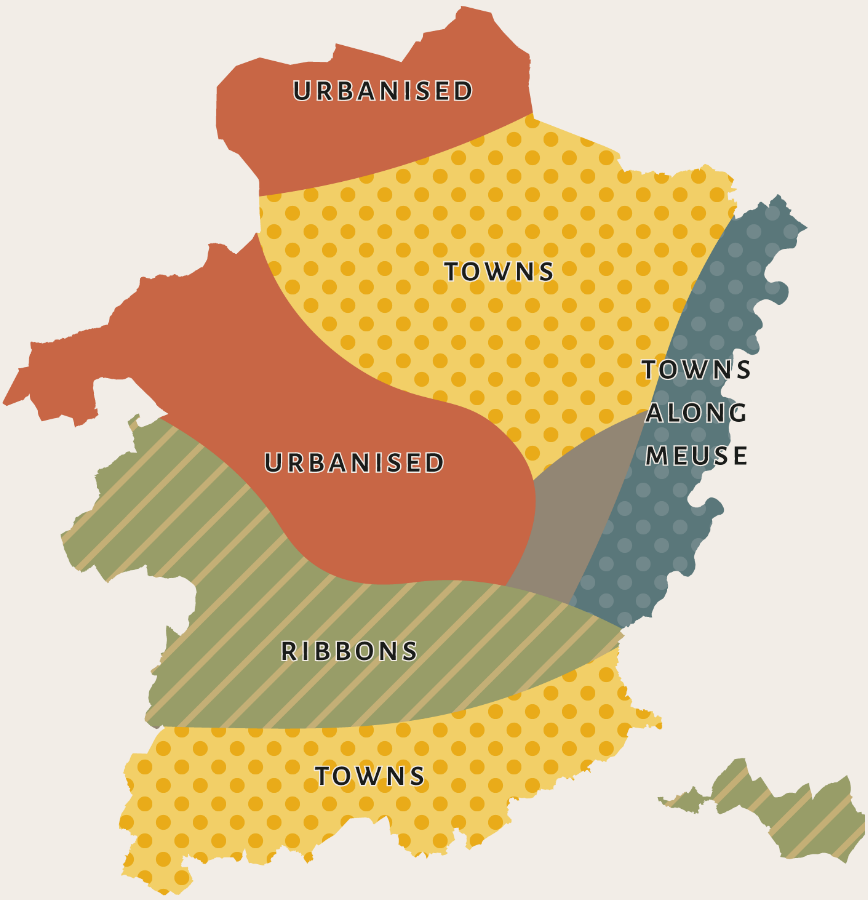


Figure 4. De Meulder et al. (1999) and Departement Omgeving's typology of Flemish urbanisation and its parameters in the 1:2000 scale. Locations (from top to bottom): Sint-Katharina, Hasselt; Wolske, Hasselt; Pietelbeekstraat, Hasselt; Winter-Loosenerheid, Hamont; Eisden-Tuinwijk, Maasmechelen. Data source: VITO & Vlaams Instituut Gezond Leven vzw (2021), Agentschap Informatie Vlaanderen (2018), Basiskaart Vlaanderen (GRB)

The site of this thesis, the Province of Limburg (Belgium), is not an exception to this problem. On a smaller scale, the type of dispersion is classified by De Meulder et al. (1999) into three types: perimeter block, urban fringes, and ribbons. This is similar to the Flemish Department Omgeving's classification of core, ribbon, and dispersed buildings; in which the perimeter block belongs to both core or ribbon, and all other types belong to ribbon type. Figure 3 shows the spatial prevalence of the ribbon developments and dispersed buildings in Limburg. It is observable that the (rather agaric) south Limburg has a high concentration of ribbon developments, while the relatively newly developed coal mining and industrial region of northern Limburg tend to have more concentrated settlements. On the smaller scale, as shown in Figure 4, the open space and green space are blocked from the line of buildings in perimeter blocks, urban fringes, and ribbons. Walkability and street connectivity also worsen as it gets more dispersed (VITO & Vlaams Instituut Gezond Leven vzw, 2021). This is particularly problematic for ensuring enough catchment area from the stop, and the last leg of people's journey between a public transportation hub and their final destination. However, there's another unique typology only found in Limburg: the planned "Garden City" type built to house coal miners in central Limburg. The Garden City types suffer far less in terms of street connectivity and walkability, and open spaces were planned in designated locations for use instead of being trapped behind houses.

On top of the spatial dispersion, Limburg also suffers from more layers of problems on top of existing issues: deindustrialisation and lack of a rail network. As the Garden Cities' original purpose may suggest, some garden cities now face socioeconomic challenges. The mines started to close down in the 1980s, and industries along the canals followed. From the transportation planning perspective, the poverty resulting from deindustrialisation would increase the risk of transportation poverty, raising the question of justice in transportation.



own work

Figure 5. Limburg's dominant settlement pattern per area, generalised. Own work; Data source: De Paep et al. (2020)

LEGEND

Railways

Proposed spartacuslijn

Figure 6. Belgium and surrounding region's rail network and proposed Spartacuslijn 1, 2, 3.

Another layer, the (lack of) rail network, is evident from the Figure 6. With three layers of critical issues (dispersion/deindustrialisation/transportation), the province and the Flemish government try to turn the tide by proposing three solutions: a transportation plan called Spartacusplan (De Lijn Limburg, 2004); introducing logistics, tourism, and innovative industries to mitigate impacts of deindustrialisation (Daems & Provincie Limburg, 2013; Provincie Limburg, 2019); and lastly Betonstop/Bouwshift for spatial dispersion. But are they effective or appropriate?

First, Spartacusplan is a transportation plan that came in 2004 that proposed three light rail lines shown in Figure 6. However, after nearly 20 years, the plan is somehow (unintentionally) turned into Europe's one of the most ambitious, and the most extensive bus rapid transit system (BRT), proposing 99 kilometres of dedicated busway. While that sounds good, from the urban planning point of view, with the lens of mobility justice, the plan only serves parts of urban fabric that are already dense and well-served by transit. In reality, the region is poly-centric and dispersed, scattered with ribbons and smaller cores. From the transportation perspective, its model is simply a copy-paste of the solution designed for the ring of Brussels, an area with fundamentally different characteristics and scales; the vehicle's speed nor the operating pattern is suited for the reality of Limburg at all.

Second, the plan is to introduce logistics, tourism, and innovative industries. While the results cannot be judged for now, in order to realise it, the creation of a (both physical and economic) network for the exchange of ideas and talent inside the region is crucial (Batten, 1995; Dall'Orso, 2019), along with the urban design of quality working areas (Florida, 2002). With the growing need for cross-pollination, quality public space, and network in fostering innovative economies, the urgency for coordinated urban and transportation planning efforts becomes greater.

Finally, the Betonstop (concrete stop), now Bouwshift (construction shift), did put a brake on the further consumption of open spaces by setting a timeline until 2040 to stop the additional consumption of open space. However, from the urban planning perspective, it is heavily criticised for being unjust, ineffective, and expensive (Van De Werf et al., 2022). Nevertheless, with further expansion blocked, the question of how to address the existing spatial dispersion remains.

In conclusion, the research aims to develop an alternative – and more just – urban and transport planning strategy by taking the layers of issues surrounding Limburg's Nebular city context into account. The project will proceed further by approaching from both transportation and urban planning perspectives, potentially finding a synergetic strategy by combining both fields.

Before diving into the context and its issues deeper, the problem statement and the research structure will be first presented to provide the structure of the complex issues surrounding Limburg.

The research structure diagram below illustrates the overall flow of the research. The research approaches from both transportation planning and urban planning, which later merge in application and operationalising. The research first analyses the immobility patterns of Belgian Limburg (4), which creates personas (4.5) that embody immobility. They can be used to visualise the effects of design. And then, the research decides upon the ideal mix of BRT elements and realisable vehicle automation technologies (5). Based on the capabilities of the new model of BRT, the spatial framework is created (6), which categorises each hectare of land into 7 types. A new spatial transition strategy is developed for each category. And based on the defined categories, the pattern language is used to create design tools (7, 8), which allows for designing neighbourhoods and BRT networks with diverse stakeholders. The created patterns are applied in the design exercise and tested for its efficacy (9). Then the strategy for planning and realising the project is defined (10), which visualises and derives strategy from the stakeholder analysis done in chapter 5.2.

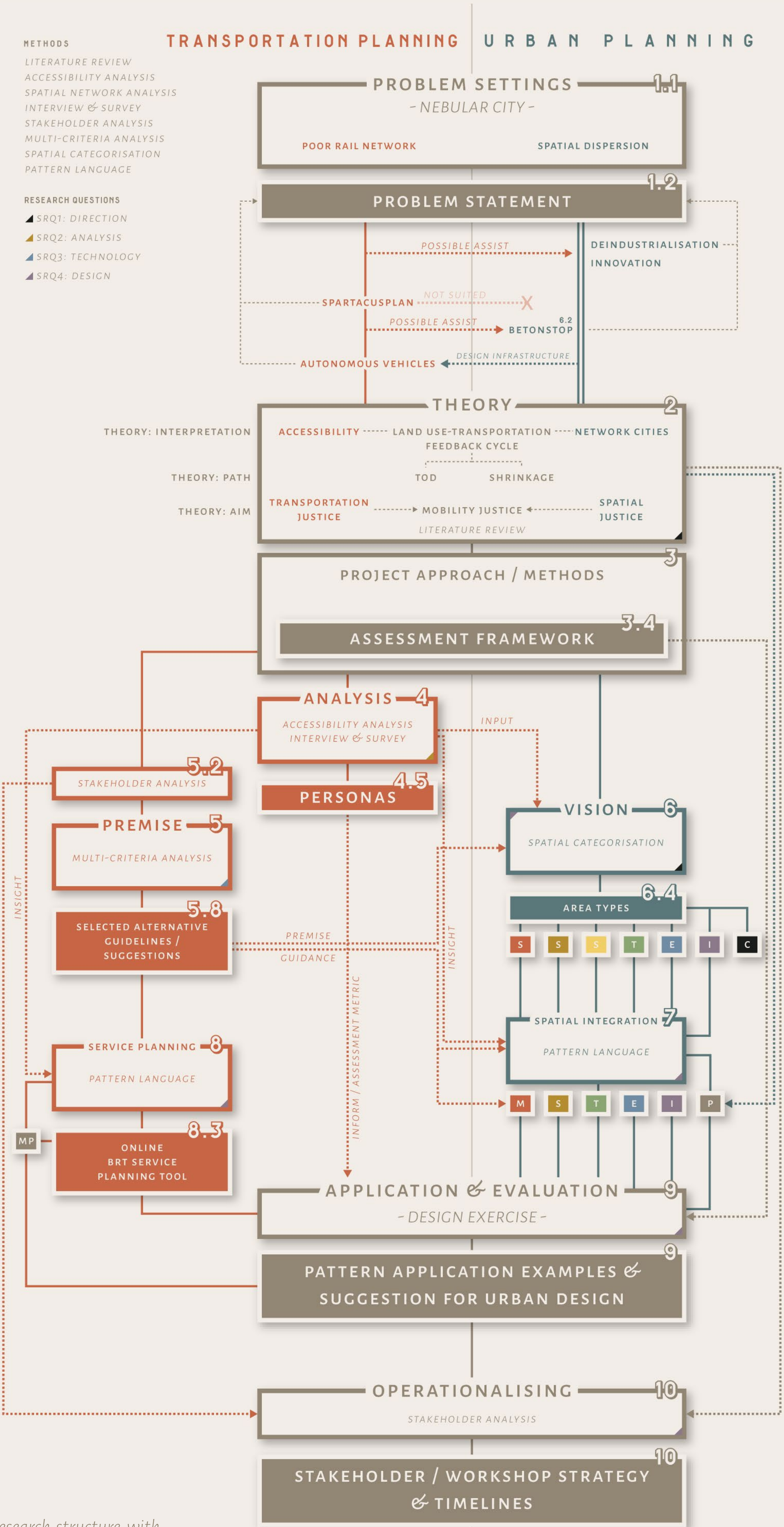


Figure 7. Research structure with key steps (colour outlines) and outcomes (colour filled).

1.2 PROBLEM STATEMENT

SPATIAL DISPERSION

The dispersion is costing the region an enormous budget each year to provide public services (including public transportation), which resulted in the complete stop in further expansion of built land until 2040; however, this only prevents the worsening of the situation and does not tackle the damages already made. Therefore additional measures on top of current efforts to tackle the sources of spatial dispersion are desperately needed, while ensuring liveability and accessibility of those living in the dispersed settlements through the spatial transition.

DEINDUSTRIALISATION

The region also suffers from de-industrialisation and its socioeconomic challenges, increasing the risk of transportation poverty. The province is now trying to find its solution through innovative industries, logistics, and tourism; however, the prerequisite of innovation, the strong network, is lacking in Limburg, and different approaches for urban design surrounding industrial areas are required.

SPARTACUSPLAN, BRT, AND AUTOMATION

Moreover, Limburg lacks proper public transportation infrastructures, both intra-province and inter-province. The Spartacusplan and three light rail lines were proposed as a solution, and subsequently scrapped. The following decision to switch light rail to BRT was not based on the consideration of the characteristics of BRT, nor is it suited for Limburg's dispersed, poly-centric spatial structure. While BRT can work flexibly operate on poly-centric regions, the operating costs would make it unfeasible. Autonomous vehicles may provide a solution for this, but as of 2022, it is becoming apparent that it will not be possible in the near future without solid supporting infrastructures.

1.3 PROBLEM CONTEXT

1.3.1 DEINDUSTRIALISATION

Figure 8. Nieuwsblad.be article about closure of Ford Genk factory. Title reads: Ford Genk close in 2014. Image Source: Nieuwsblad.be; EPA

Figure 9. Categorised map of industrial locations in Limburg (own work)

In Limburg, the spatial and transportation challenges of dispersion are toppled with the challenges of deindustrialisation. Until the latter half of the 20th century, Limburg thrived with (secondary sector) industries: coal mining, chemicals, and metal industries flourished in Limburg (Provincie Limburg, n.d.). The coal mines, the engine of Limburg's economy for decades – closed down in the 1980s (Daems & Provincie Limburg, 2013). Now the manufacturing sector, settled along the Albert Canal and Iron Rhein, is also facing a decline. The historic event was when the largest employer, the Ford Genk factory, closed down in 2014 (Jta, 2012), losing roughly 8000 jobs in Limburg (Daems & Provincie Limburg, 2013).

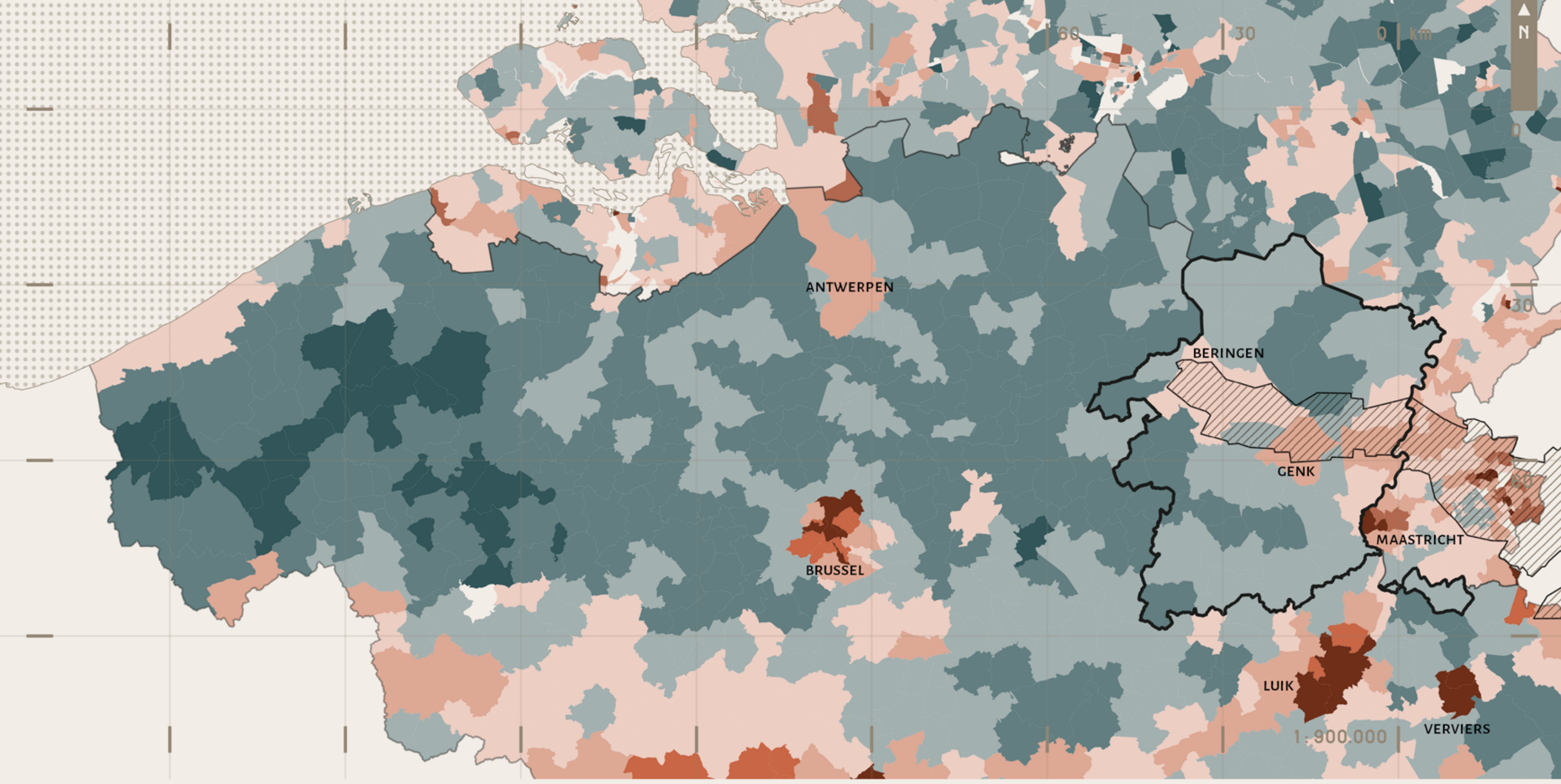


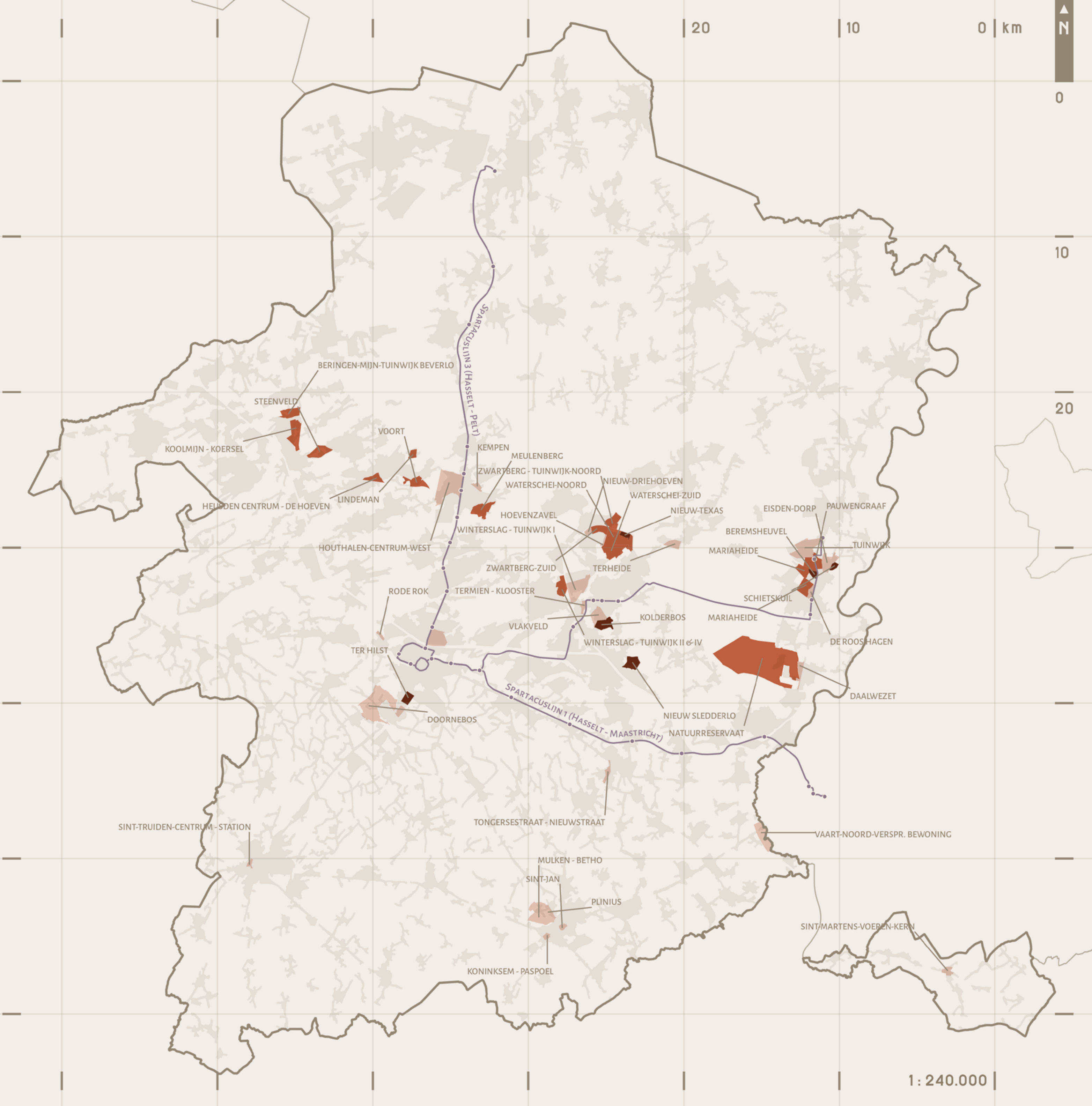
Figure 10. Labour market participation rate in Belgium and Netherlands with an overlay of coal mine concessions. Data sources: CBS (2021), Statbel (2021), Hans Erren (CC-BY-SA 3.0)

LEGEND

Labour market participation rate

- 0 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- 75 - 80
- 80+
- Coal mine concessions

The deindustrialisation and its socioeconomic woes are visible in Limburg. On Figure 10, while parts of nearby Dutch Limburg and Wallonia have a significantly lower level of labour market participation, the labour market participation in the coal mining areas of Belgian Limburg remains one of the highest in Flanders, on par with large cities like Antwerpen (where impoverished urban districts are located) and coastal municipalities populated by retirees.



LEGEND

- Neighbourhoods with mainly social housing in serious difficulties
- Neighbourhoods with moderate difficulties
- Neighbourhoods with light difficulties

Figure 11. Neighbourhoods with socioeconomic challenges. Data sources: Vanderstraeten et al. (2021), Hans Erren (CC-BY-SA 3.0)

According to Steunpunt Wonen (Vanderstraeten et al., 2021)'s research on neighbourhoods with socioeconomic challenges, Nearly all of the neighbourhoods facing moderate or serious challenges lie along the former coal mining areas and the canal, especially in cities such as Maasmechelen, Genk, Houthalen-Helchteren, Heusen-Zolder, and Beringen. The only exceptions are Hasselt's Ter Hilst and Lanaken's Natuurreservaat, which for the latter, is a refugee camp and a care facility. The planned garden cities built to house all the mine workers are now facing moderate to serious socioeconomic challenges, such as Meulenberg, Zwartberg, Winterslag, and Waterschie.

In response to the effects of deindustrialization, the Flemish government proposed SALK-plan (Strategisch Actieplan voor Limburg in het Kwadraat) to revitalize the economy of Limburg (Ibid.). The principles are simple: more jobs, more market-oriented schools, a stronger business environment, more innovation, more exports, and targeted deregulation. On the regional scale, Euregio Meuse-Rhein's message is also clear: more cross-border cooperation, more innovation applied in the region under the "Eindhoven – Leuven – Aachen knowledge triangle", becoming the Logistics hub of western Europe between Antwerpen and Ruhrgebiet, and finally strengthening the tourism in the region (Stuurgroep EMR2020, 2013).

Figure 12. Limburg's Incubators and its focus sectors

To stimulate innovation and transform the province's economic structure, the 7 "incubator" campuses were created across the province for diverse sectors of industry (Limburg Startup, n.d.; Provincie Limburg, 2019). Many share the campus with existing enterprises and educational institutions. This model of incubators provides a good development model for the region; the challenge is how to connect them with potential employees, institutions, and each other. Especially from the industrial standpoint, as mentioned earlier, the connection and network (both physical and social) are considered a prerequisite for fostering innovation and a knowledge economy (Batten, 1995; Dall'Orso, 2019). Only three campuses are well connected with the planned Spartacuslijnen, and connecting the other four remains challenging.

In terms of mobility, this transition in the industry means more uncertainty in the future transportation demands: where the new industries will want to connect, generating how much volume of traffic, and in which time – is unpredictable at this point and is likely to be ever-changing. This calls for flexibility in future transportation systems, not tied to a predetermined set of routes and destinations but can adapt to new challenges through time.

From the urban planning point of view, innovative industries will also require different demands for space. Namely, the old concept of separation between space of work and leisure would not work; the boundary between work and private life blurred for the "creative class" as Florida (2002) puts it, the office areas should no longer become desolate office parks; it would require quality space with a good range of cultural activities around, combined with nimble and flexible space that can adapt to changes and accommodate personal expressions.

In short, innovative industries will demand not only space and policies, but also a quality working environment through urban design surrounding the workplace, and a flexible and closer connection between enterprises, knowledge institutions, and residents.

1.3.2 SPARTACUSPLAN

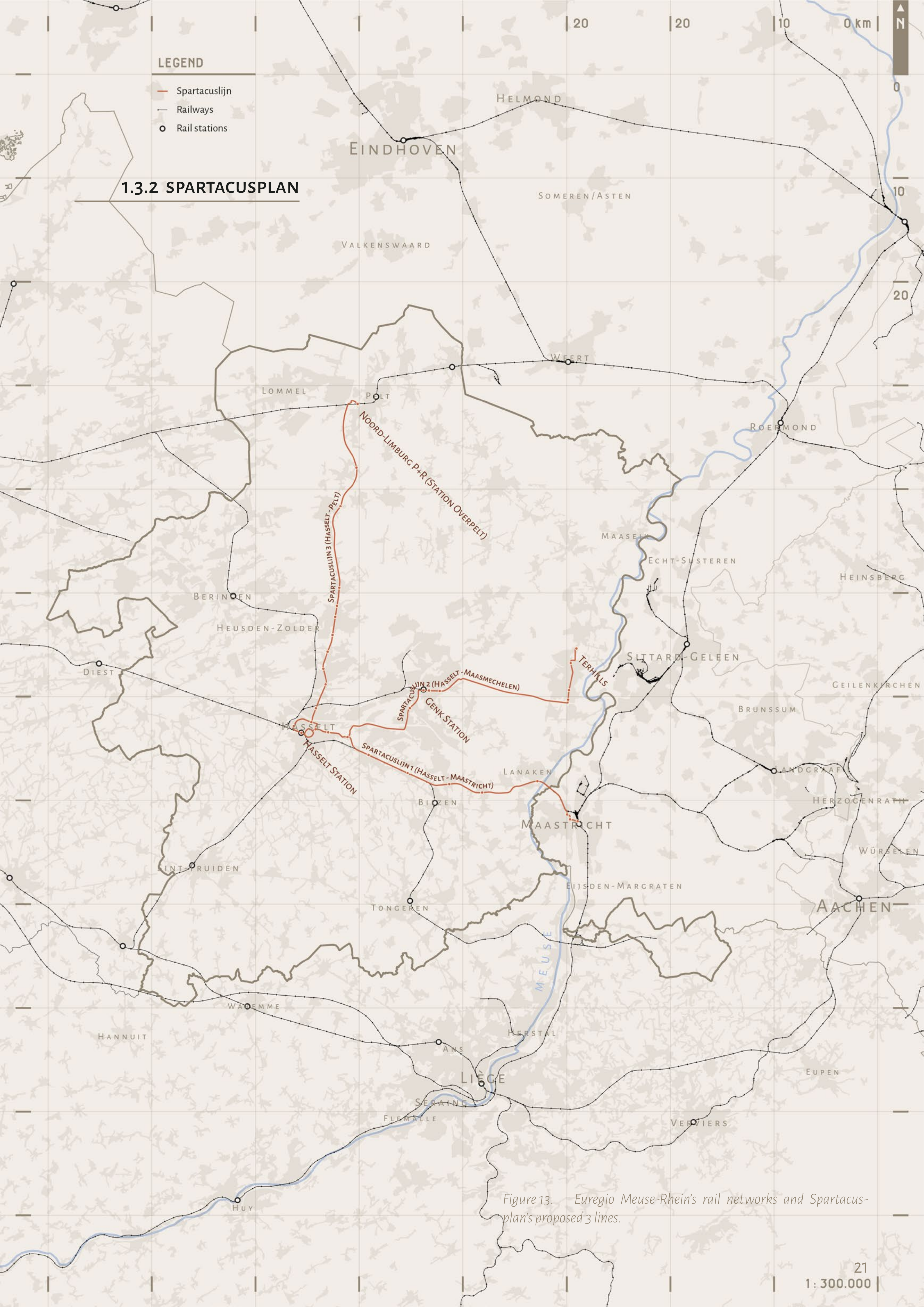


Figure 13. Euregio Meuse-Rhein's rail networks and Spartacus-plan's proposed 3 lines.

1 : 300.000

Belgian Limburg lacked a proper rail network due to its peripheral location at the border, and the relatively later period of population growth following the mining and industrialization resulted in severe car dependency and lacklustre public transportation in the region. Limburg remains an empty spot in the rail network in the area; like a dead-end road, trains to connect the west of Belgium branch into Limburg and terminate there, and no connections are made inside the province; the IJzeren Rijn in the north and the rail network in the south does not meet inside the province.

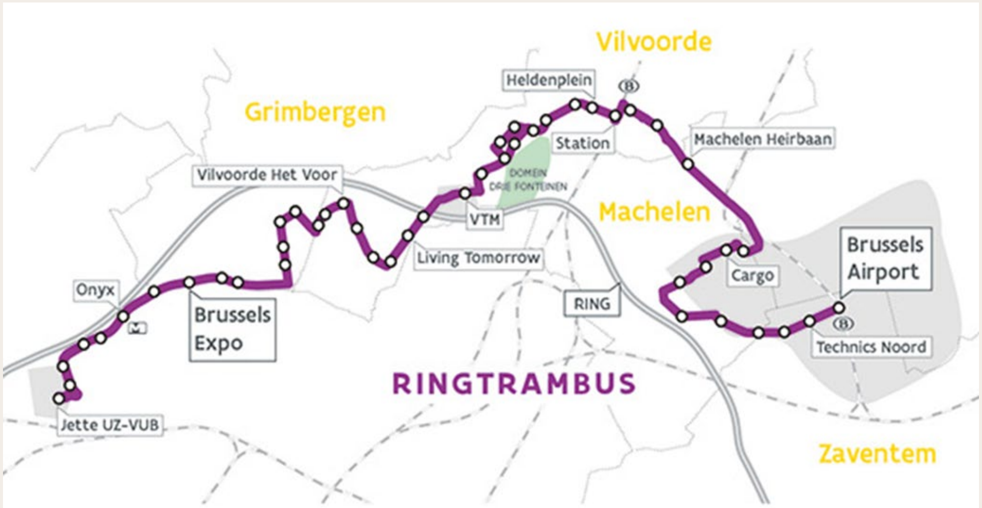
Looking across the borders, Wallonia, Dutch Limburg, and Aachen are all surprisingly well-connected by train; despite the obvious language border and different railway systems, the "Drielandentrein" (three countries train) connects the major cities in Euregio Meuse-Rhein except Belgian Limburg (Provincie Limburg, n.d.-b). The connection between Liege and Limburg is also well connected via railway line. Therefore, the only remaining corridor is the connection within Belgian Limburg, and the connection between Belgian Limburg and the Netherlands. Obviously, as there are already disused railway tracks and trackbeds present for the said traject, reactivating the disused railways should be the best option, also given the context of the whole network in Benelux and Germany. However, the Belgian federal entities Infrabel (rail infrastructure) and NMBS (rail operator) have been surprisingly unwilling to invest in Limburg's rail network, despite years of demands from local organisations. As of 2022, the line between Hasselt and Maastricht is permanently closed (Thuwis, 2020; Van Diepen, 2021).

Due to the unwillingness from the federal level, the task of the rail network problem is somehow pushed onto the regional level. The bus and tram operator De Lijn had to tackle it, which is limited in capacities (trams and busses), and isolated from the broader railway network. Therefore De Lijn came up with the transport plan of Belgian Limburg in 2004 called "Spartacusplan". The plan aims to supplement the lacklustre rail network, and provide better connectivity in the region. The plan has proposed 3 light rail lines (Spartacuslijn 1, 2, 3) connecting major cities inside Limburg, and also connecting cross-border destinations of Maastricht, Sittard-Geleen, and Eindhoven. The regional express bus (snelbus) service also supplements peripheral corridors, such as the former traject of railway line 23 (Tongeren – Sint-Truiden), A13 (Tessenderlo – Hasselt) (De Lijn Limburg, 2004).

However, as of 2023, none of the lines has been realised. Moreover, all planned light rail lines are now been switched to bus rapid transit (BRT) using 24-metre "trambus" from the Belgian bus manufacturer Van Hool, due to low expected ridership, high costs, and failure to integrate into existing infrastructures such as Wilhelminabrug in Maastricht that could not take the tram's weight (De Werkvennootschap, 2022; Meukens, 2021; nieuwsblad.be, 2022). Whether this decision to replace planned light rails with BRT was a good choice is still subject to discussion, but it is clear that the starting point of the decision is not based on the inherent key characteristics of BRT; the service pattern was never re-adjusted along with the change, instead the urban, 24-metre trambus merely replaced the 30 to 45-metre light rail / tram-train vehicle running more or less the with the same route. The arguments for the decision were mostly on the cost-cutting aspects, not because of BRT's inherent characteristics; thus, its strengths (flexibility) and weaknesses (long-term operating costs, passenger preferences…) of BRT have been less of a concern.

Figure 14. Comparison between Light rail and trambus, on top of the dispersed urban fabric of South Limburg. The stops and trace were never changed, while the lower appeal of trambus due to lower speed and lack of significant branding attracting relatively less passengers.

Figure 15. Ringtrambus in Vlaams-Brabant, De Lijn (n.d.-a)



Trambus

Trambus refers to low-floor articulated buses that resemble modern tram vehicles cosmetically. In this research, the term Trambus specifically refers to Belgian bus manufacturer Van Hool's ExquiCity 24 model shown in the picture. The vehicle is 24 metres long, and carries 173 passengers per vehicle (De Lijn, n.d.). The maximum speed is 72 km/h, slower than many of the city buses (Meukens, 2021). Image source: De Lijn, n.d.

The source of the decision can be defined as "formula-setting" in urban infrastructure projects: many urban infrastructure projects follow a success formula, often from the same languages or regions. A good example can be found in the French-speaking world with the re-introduction of its modern tramways under the formula of "low-floor urban tramways combined with the urban redevelopment", which has been rapidly applied across the French-speaking world since the 1990s with the successful starting cases of Nantes and Grenoble (Boquet, 2017), and later exported across the world in 2010s. Such "formula-setting" of urban infrastructure projects happens when a new standard model of infrastructure projects is proposed with successful "headliner" cases, standardised technical specifications and accompanying interventions for synergy. While the tramway revival in the French-speaking world has been fairly beneficial, this does not mean that such practices always bring positive results, as its specifications often ignore the project's specific context.

Case	Mettis, Metz, Grand-Est, France	Ringtrambus, Vlaams-Brabant, Belgium	Spartacuslijn 1 / 2/ 3, Limburg, Belgium	Cambridgeshire Guided Busway	"Intercity" Hasselt – Genk
Vehicle	Van Hool ExquiCity 18 / 24 (Trambus)			Alexander Dennis Enviro 400	NMBS M7
Max. Speed	72 km/h			89 km/h (guideway limit)	120 km/h (rail limit) / 200 km/h (vehicle limit)
Right-of-way	Partial dedicated busway	Partial dedicated busway	Full dedicated busway	Partial dedicated guideway / busway	Full dedicated railway
Purpose	Urban public transport	Connecting destinations along the Brussels ring; Replacement of tramway	Compensating for lack of rail network in Limburg; Replacement of tramway	Reviving disused rail trackbed between Cambridge and Huntingdon	Intercity train crossing whole Flanders between Genk and Blankenberge; stopping on all stops between Hasselt – Genk
Character of transport	Urban; inner-city transport	Urban; continuous, suburban communities + Airport and Exposition	Regional; polycentric cities and towns + intermediate destinations (campus)	Regional; three regional cities + intermediate destinations	Regional; two separate regional cities + intermediate destinations (Corda campus, Bokrijk)
Length	18 km	ca. 15 km	99 km	20 km**	15 km
Stations	37	20*	33	8	4
Distance between stations	0,48 km	0,75 km*	3,0 km	2,5 km	3,9 km
Areas covered	56 sq km	137 sq km	721 sq km	1.854 sq km	190 sq km
Residents covered	134.737	370.630	358.876	488.624	146.523
Population density in covered areas	2.406 / sq km	2.705 / sq km	497 / sq km	263/sq km	771 / sq km
Sources	*Populations légales (2020); Eurométropole de Metz (n.d.);* **Meukens, (2021)**	*Statbel (2023); De Lijn (n.d.-a); Deneyer & Vander Gracht (2016); Dams et al. (2017);* **Meukens, (2021)**	*Statbel (2023); De Lijn Limburg (2004); Peeters (2021);* **Meukens, (2021)**	*Office for National Statistics (2022);*	*Statbel (2023);*
Sites	*Commune Metz, Woippy*	*Gemeente Jette, Brussel-Stad, Grimbergen, Vilvoorde, Machelen, Zaventem*	*Gemeente Hasselt, Diepenbeek, Bilzen, Lanaken, Maastricht, Genk, Maasmechelen, Zonhoven, Houthalen-Helchteren, Hechtel-Eksel, Pelt*	*District of Cambridge, South Cambridgeshire, Huntingdon*	*Gemeente Hasselt, Genk*

** Except Heizel – UZ Brussel section*

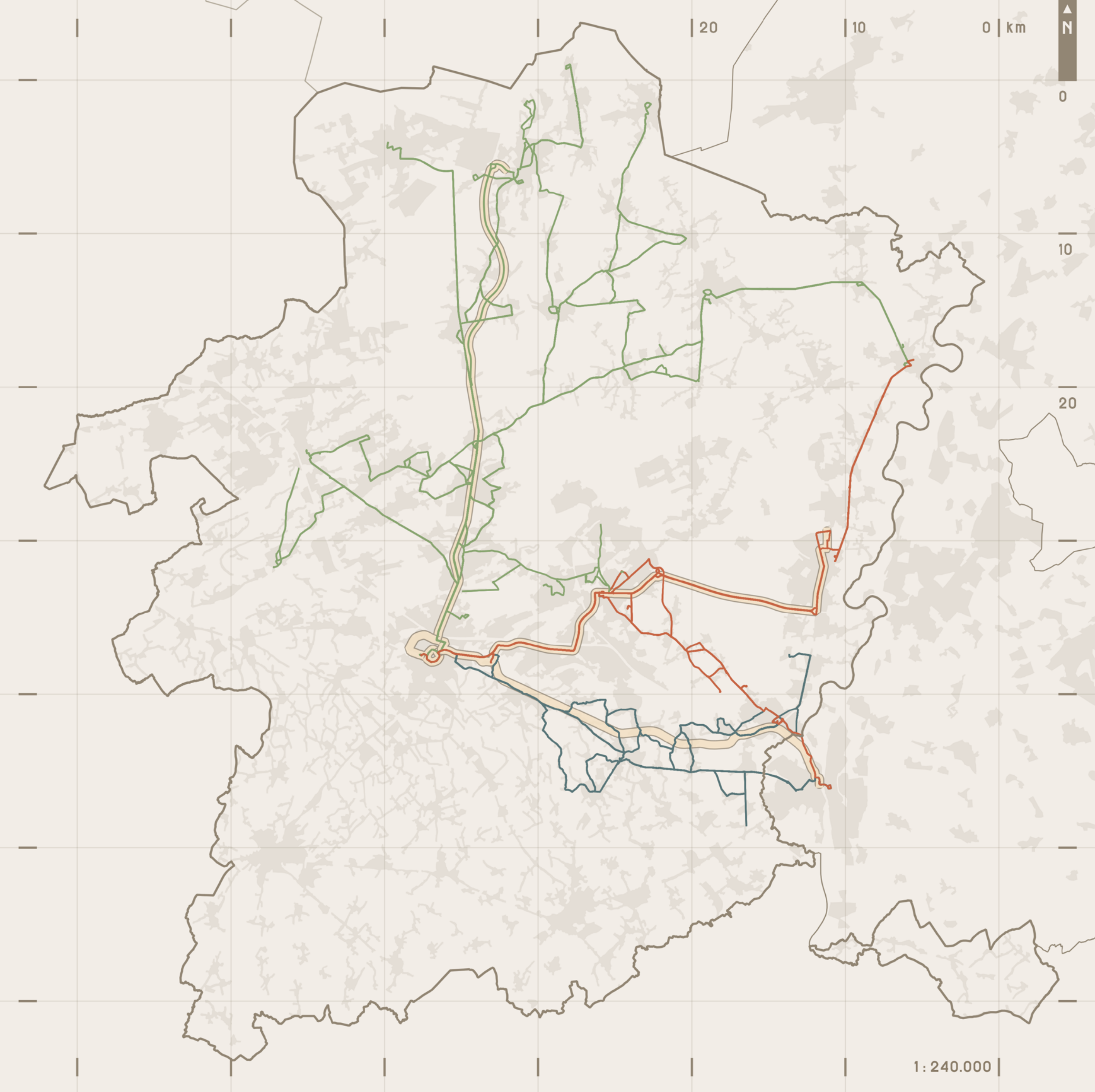
*** Dedicated section only, between St Ives Park & Ride – Cambridge North Station*

Table 1. Comparison between Trambus cases + intercity Hasselt-Genk

The trambus itself can also be considered a formula itself. However, the success formula (for which the success wasn't determined for Ringtrambus yet) was fundamentally for urban transportation. No other cities have been using trambus for regional, inter-city transportation, and it is particularly evident when compared with other cases' spatial contexts. The characteristics of Spartacuslijn are similar to that of the "Intercity" train between Hasselt and Genk (which stops at all stations between) than that of Ringtrambus or Mettis, especially given the distance between stations and its regional setting. This decision is not only problematic for being an afterthought, but also its implementation comes with issues too: According to Meukens (2021), the speed of the vehicle is significantly lower than initially planned light rail vehicles, and the required width for the busway is broader than that of light rail, forcing single-track operation in parts of the traject.

Given the dramatic history of the project – the intention (railway), the original plan (light rail), and the current plan (BRT) – the Spartacuslijnen can even be considered a pioneer case in the history of BRT: creating a fast (avg. speed > 40 km/h) inter-city BRT network serving the poly-centric region. There are no precedents, but only separate cases that fulfil part of the goals; there are fast inter-city BRT systems like Cambridge Guided Busway, but the area is relatively linear, not poly-centric; neither are suburban busways in North America or Australia.

And as noted in Figure 14(settlement patterns) and Table 1, it can also be argued that the whole idea of relying on only 3 corridors without branching services to strengthen the poly-centric region's public transport can also be contested. While there are indeed successful "isolated" BRT cases in many other densely populated areas across the globe, as shown in the Table 1, that is far from the case in Limburg; the suburban busways of North American and Australian cities are all based upon the branching services that diverge from the BRT corridor.



LEGEND

Reisweg

— 20a

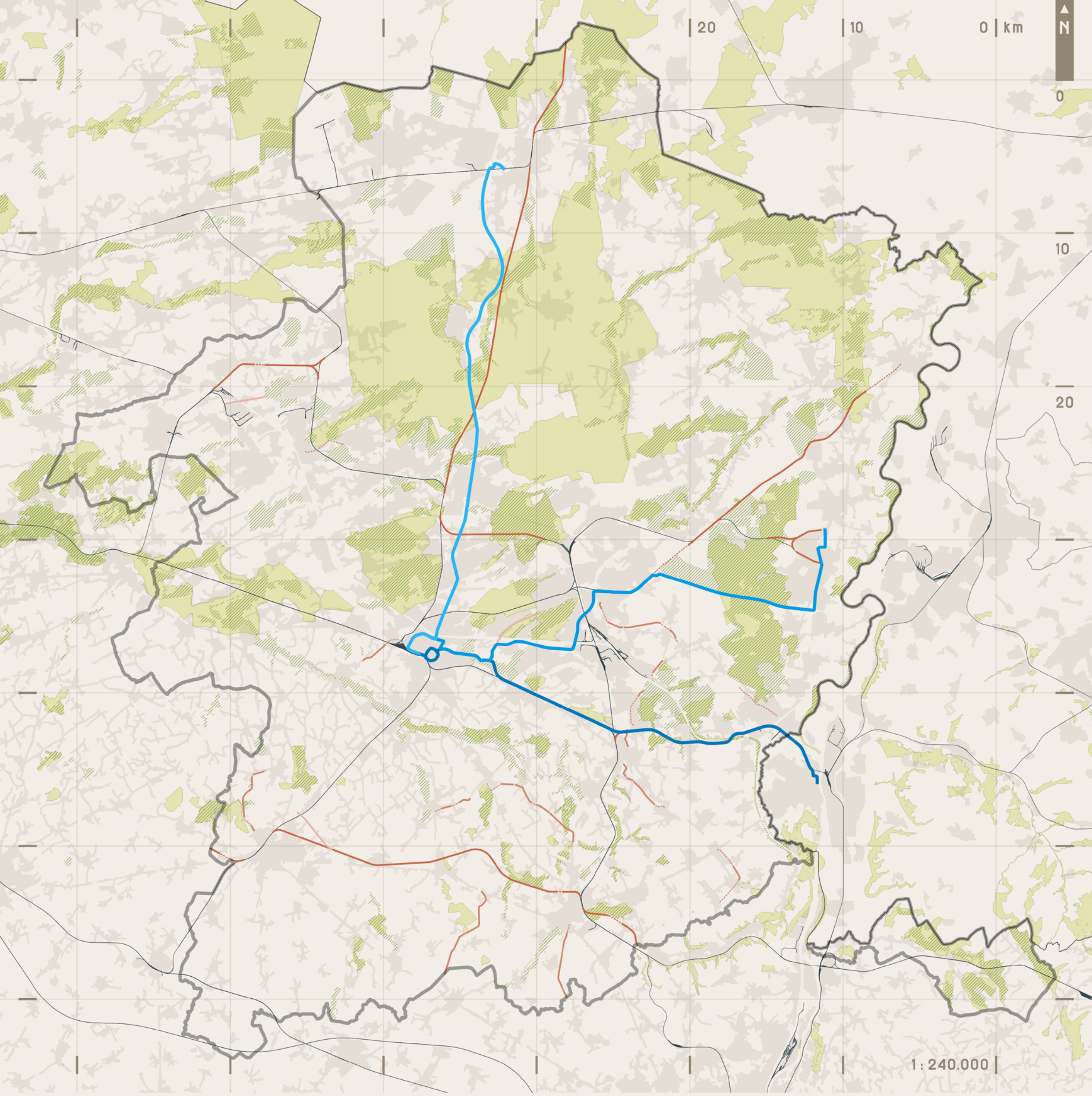
— 45

— Northern Limburg routes

Spartacuslijnen

Figure 16. current operating pattern of comparable services with Spartacuslijn. Data source: De Lijn (2021)

In fact, the existing service pattern along the Spartacuslijnen is already highly dispersed: De Lijn's route 20a and 45, which roughly follows the traject of Spartacuslijn 1 and 2, serves multiple sub-destinations on each run, through making small detours or having different destinations each run. The lines serving northern Limburg (13, 16, 18a, 22, 23, 35, 48, 52, 180, 182, 283) also concentrate into Spartacuslijn 3's traject and then disperse further out to Northern Limburg.



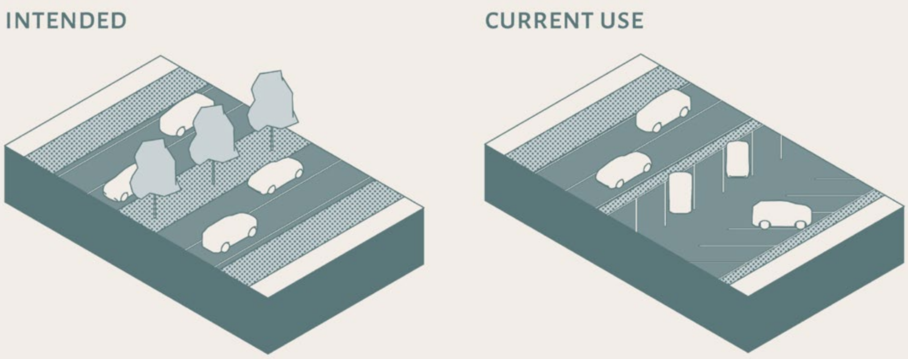
LEGEND

- VEN
- Natura 2000
- Spartacuslijn 1 (Hasselt - Bilzen - Maastricht)
- Spartacuslijn 2 (Hasselt - Maasmechelen - Sittard)
- Spartacuslijn 3 (Hasselt - Pelt - Eindhoven)
- Abandoned trackbeds
- Abandoned trackbeds (Unavailable)
- Vicinal tramway trackbeds
- Vicinal tramway trackbeds (Unavailable)
- Plots for unrealised projects (GTI/GNP)

Figure 17. Former trackbeds and GTI/GNW locations in Limburg. Trajects through Nature protection areas can be avoided by utilising those abandoned infrastructures. Data source: Agentschap voor Natuur en Bos (2021)

Moreover, there is abundant potential for expanding the Spartacuslijn corridors: the province has plenty of abandoned railway trackbeds, vicinal tramway trackbeds, and unrealised road spaces that are still kept in separate plots, used as bicycle paths, or turned into parking spaces in the middle of a forest. Such unrealised road expansions were planned during the industrial "golden age" of Limburg, which then expected much traffic will use the road. After deindustrialisation, the expected traffic didn't come, and many now belong to the "Large useless works" (grote nutteloze werken / grands travaux inutiles). Some are already integrated as a track for Spartacuslijnen (Genk N75), and the other spaces also open up new possibilities to the existing Spartacusplan.

Figure 18. The intended use of 4-lane boulevards in Limburg, and what the current use is in many parts of the province. Nearly half of the road is actually being used as parking space.



GTI/GNW

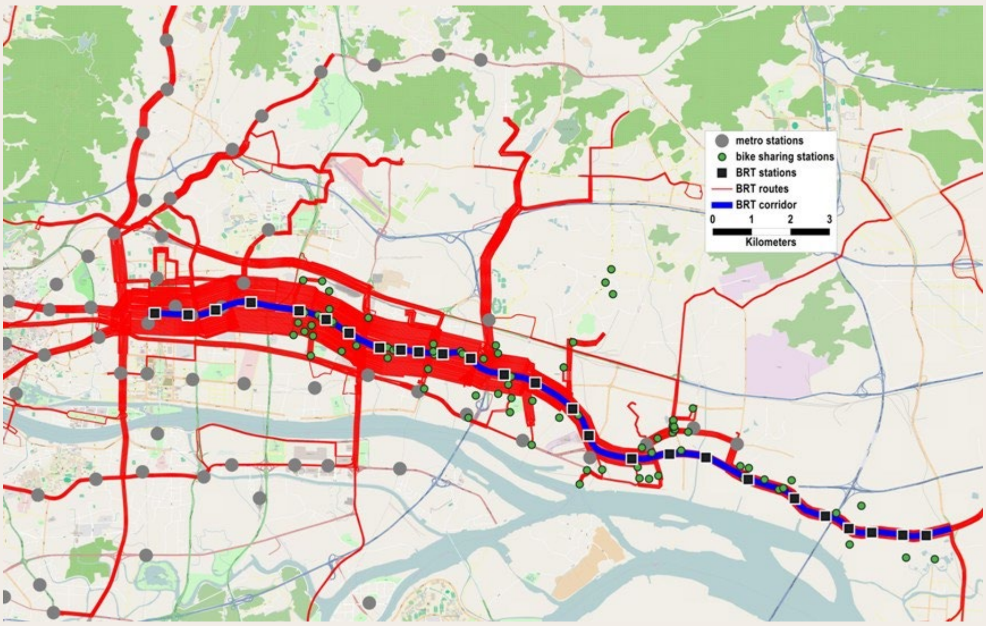
Grands travaux inutiles (GTI) / Grote nutteloze werken (GTW) is a Belgian-Dutch term for large infrastructure projects that are abandoned or underutilised. For example, the Tuibrug Godsheide is a 6-lane bridge between Genk and Hasselt; currently, only 2 lanes are used, and the remaining 4 lanes are simply abandoned. Similarly, many 4-lane roads in Limburg are used as 2-lane roads, with remaining space simply used for parking.

Therefore, it can be concluded that the trambus formula in Spartacuslijnen is undoubtedly not suitable. Instead, based on the critical analysis of Spartacusplan and the Nebular city of Limburg, the requirements for the alternative BRT model can be set. From the urban planning perspective, the system should be flexible: it should be able to serve the poly-centric structure of Limburg, across vastly different types of urban fabrics and socioeconomic contexts. Moreover, as has been the case for railways and vicinal tramways, the BRT should be able to steer the spatial development of the region, and it should also catalyse innovation, again with the flexible network. From the transportation planning perspective, the system should have enough speed to form a regional network. The capacity should be the same or higher currently proposed Spartacusplan, and generally, higher frequency should be beneficial. Therefore, a new formula of public transportation that can fulfil these requirements is crucial for Limburg.

1.3.3 ALTERNATIVE MODELS OF BUS RAPID TRANSIT

Before looking into alternative BRT models, the two BRT pathways need to be clarified: one is the "branching" BRT, where BRT routes generally integrate the existing enter and exit the corridor freely. An example of this is Guangzhou BRT (Figure 19), where 31 bus lines radiate from the BRT corridor. On the opposite end is the "isolated" BRT, where BRT routes separate from the existing bus network is created to operate almost exclusively on the BRT corridor. Istanbul's Metrobus (Figure 22) provides a good example. Given the requirements of the BRT set in chapter 1.3.2, the branching BRT would undoubtedly make a better pathway to take.

Figure 19. Guangzhou BRT's service pattern, ITDP (2018) https://brtguide.itdp.org/branch/master/guide/service-planning/basic-service-planning-concepts



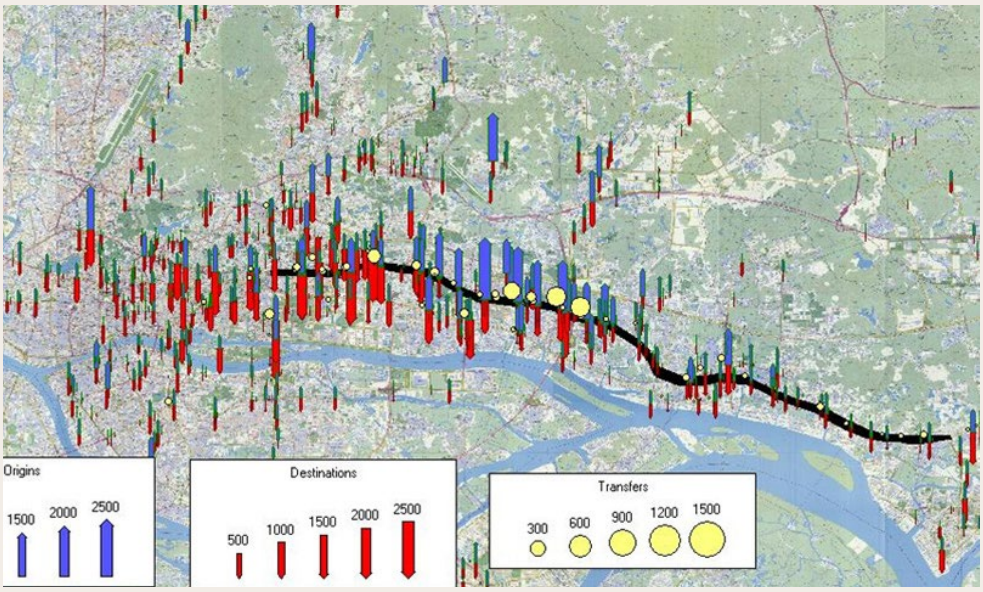
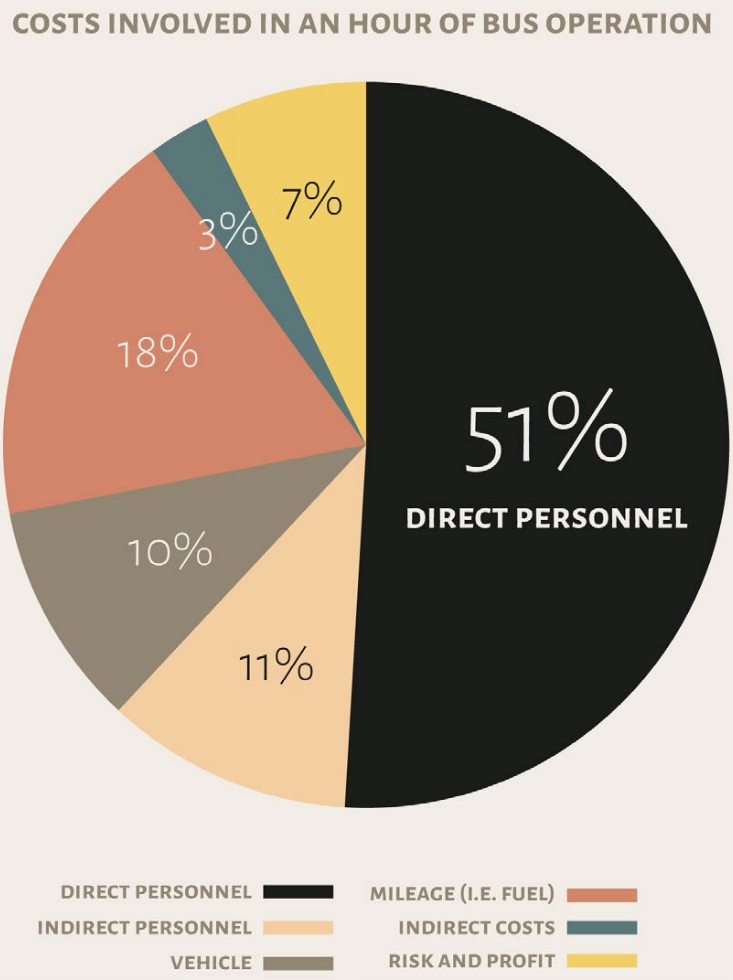


Figure 20. *Guangzhou BRT's demand pattern - only around 10% of trips are from one BRT station to another (Black line), Far East BRT Planning Co. (n.d.) https://www.fareast.mobi/cn/brt/guangzhou*

Figure 21. *Guangzhou BRT carries 800.000 passengers per day with normal 12-metre buses by operating 31 lines offering direct service leaving and joining the BRT corridor without passengers needing to transfer (Far East BRT Planning Co., n.d.). The stations have dedicated platforms for different lines, and buses can pass each other in the station. Photo taken by the author in 2015.*

Figure 22. *Being the only public transport on land between the European and Asian parts of Istanbul until 2013, Istanbul's Metrobus BRT carries 600.000 passengers per day with 100% articulated buses inside a closed infrastructure (Yazici et al., 2013). There are no passing lanes, and multiple buses stop behind each other every minute. This is the common form of high-capacity BRT in the developing world, which makes it an opposite model of Guangzhou BRT. Photo taken by the author in 2022.*

Figure 23. The costs involved in an average service hour of regional buses in the Netherlands (CROW-KpVV, 2015).

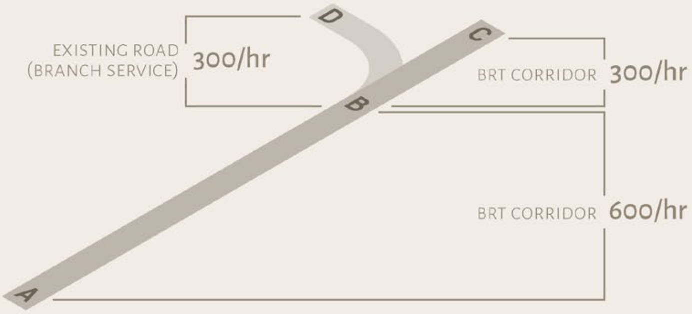


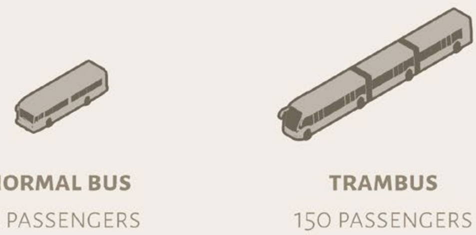
However, there is a catch: while the dispersed BRT network sounds great in theory, in reality, the question of operating costs arises in high-income countries like Belgium. While switching to BRT can reduce fixed costs, such as construction costs, it also increases variable costs, such as operating costs, as more drivers are required (The Transport Committee, 2005). Therefore despite being more flexible than rail-based systems both in routing and capacity-wise, the cost performance of BRT has always been limiting its flexibility in practice, especially dealing with higher peak capacity (Currie, 2005). This is because direct personnel costs, like conductors and drivers, take at least 50% of the operating costs involved per hour of service (CROW-KpVV, 2015), as illustrated on Figure 23.

This has been the key reason why high-frequency, high-capacity BRT systems with extensive branching services have been mainly implemented in low-income countries. If one wants to add a branching service, then the vehicle size must be reduced, and additional drivers should be paid – or the frequency of the service should be reduced. The status quo of transfer points will add extra waiting time and buffer time for transfer, which significantly decreases the attractiveness of the service.

But, as the age of cited studies suggests (2005), such assumptions on personnel costs seem to be out of date as of 2023, thanks to the development of driverless vehicles. Therefore the operating costs could no longer be an issue – or is it still?

DEMAND AND VEHICLE SETTINGS



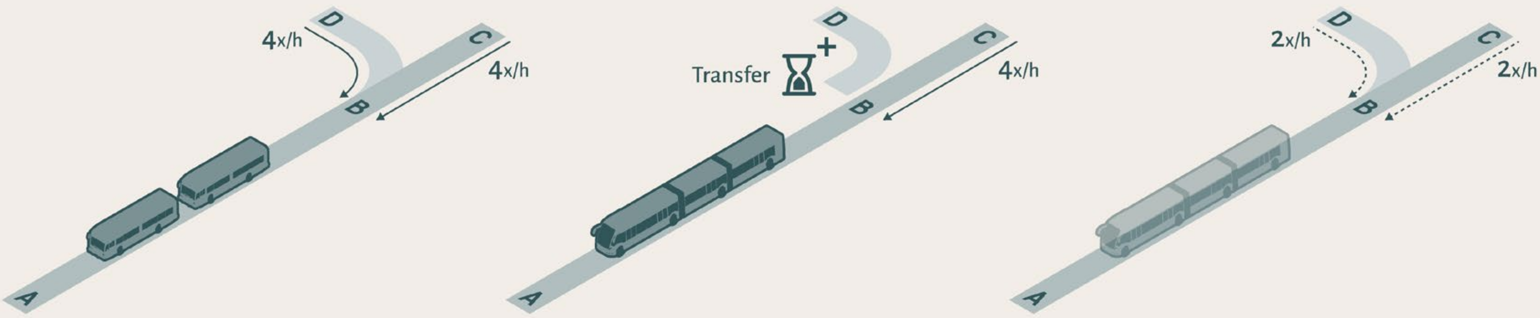


THE BRT DILLEMA

BRANCHING APPROACH
CASE GUANGZHOU

ISOLATED APPROACH
CASE TRAMBUS LIMBURG

LOW-FREQUENCY APPROACH
HYPOTHETICAL



Branching approach
PERSONNEL COSTS ●●●
TRAVEL TIME (A - D) ●○○

Isolated approach
PERSONNEL COSTS ●●○
TRAVEL TIME (A - D) ●●●
*INCL. TRANSFER BUFFER + WAITING TIME

Low-frequency approach
PERSONNEL COSTS ●○○
TRAVEL TIME (A - D) ●●○
*INCL. EXTRA WAITING TIME

Figure 24. Three possible approaches in branching services in BRT

1.3.4 THE DISILLUSIONMENT OF AUTONOMOUS VEHICLES

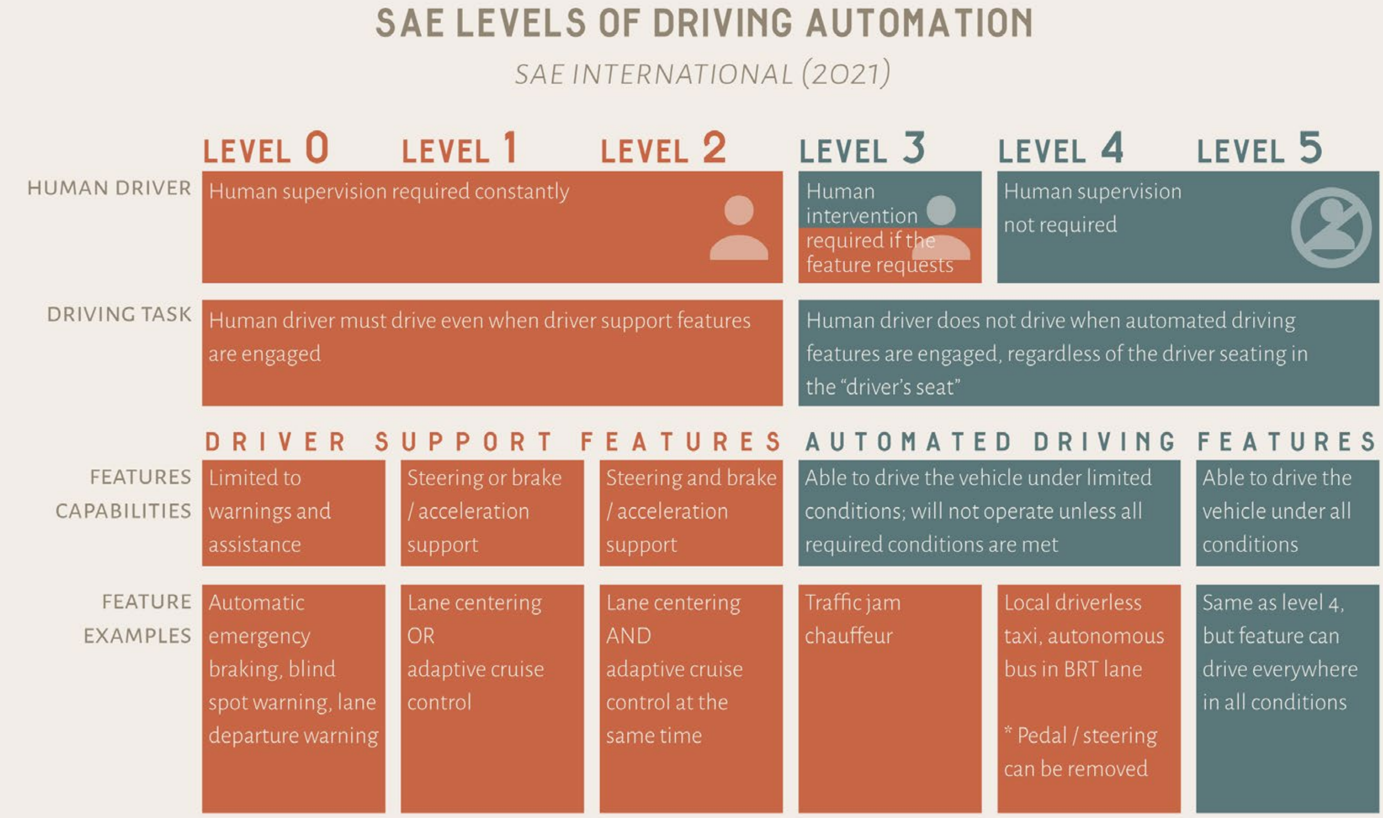


Figure 25. SAE levels of driving automation, SAE International (2021)

While for the last decade, there have been noticeable optimism and speculation over the use of driverless autonomous vehicle in both private vehicles and shared transport, making the development of automated vehicles a $100 Billion project from 2010 onwards (Snelder et al., 2022; Chafkin, 2022). However, in 2023, the promises are breaking down rapidly, with waves of disinvestment from autonomous vehicles (Chafkin, 2022; Etherington, 2022; T. Higgins, 2022). But why did it end up this way?

Operational design domains (ODD)

ODD is the set of situations where autonomous vehicles are designed to safely handle; this includes type of road (motorways, urban streets, etc.), geographic boundaries (designated corridor, area, city, etc.), speed range, terrain, weather, time of day, or other conditions (NHTSA, 2017). For example, a system can be designed to operate only on certain designated paths inside Bokrijk, under the speed of 30 km/h, and cannot operate autonomously when it is raining, cloudy, or too busy with foot traffic. The more versatile it gets (= larger ODD), the harder it gets to ensure safety.

SAE International (2021) classifies the level of automation in scales of level 0 (no automation) to level 5 (fully autonomous driving without a human driver). The operational design domains (ODD) are limited in level 3 (autonomous driving in certain ODDs with human override) and 4 (fully autonomous driving within ODDs, optional human override), while for level 5, the ODD is infinite. Thus there is no determinable stopping point. Although many self-driving projects initially promised to realise full autonomous driving (level 5) on public roads in mixed traffic, as of 2022, it is becoming more and more apparent that it is unlikely to happen due to the safety requirements of working in infinite-scale of ODD (Chafkin, 2022; Etherington, 2022; T. Higgins, 2022; Shladover, 2016). In private vehicles, even Level 4 is estimated to be also not possible in the near future (Visnic, 2022). In other words: the driverless future with level 5 self-driving vehicles is not coming for the foreseeable future, and even for limited level 4 driverless operation can only be expected to be applied in non-private vehicles.

On the other hand, connectivity between vehicles and other vehicles (Vehicle-to-vehicle, V2V) or infrastructure (Vehicle-to-infrastructure, V2I / I2V) plays another important role. In terms of V2I/I2V infrastructure Support for Automated Driving (ISAD) is specified (Carreras et al., 2018, as cited in Snelder et al., 2022), which classified the I2V level from A (high infrastructure support, traffic flow optimisation) to E (no infrastructure support) (Snelder et al., 2022). Further application cases include receiving signal and traffic information, or collecting data from roadside sensors. An example of a V2V application is platooning, meaning that only one driver controls a platoon of vehicles following the one with a human driver. It is currently researched mainly on freight transport (Snelder et al., 2022). Currently, the EU-project ENSEMBLE has been finished in 2022, which successfully demonstrated the aim of demonstrating a lower-level of V2V communication (named Platooning Support Function, PSF), and identified the challenges of realising semi-driverless V2V operation (named Platooning Autonomous Function, PAF) for trucks in motorways (Mascalchi & Willemsen, 2022):

1. The aim of preventing the split of the platoon can deteriorate the traffic flow due to its mitigation manoeuvers, which needs infrastructural measures such as intelligent traffic lights and dedicated platooning lanes to prevent it.

2. The braking performance has to be assessed and predicted per vehicle, location, tires, brakes, load, road condition, and weather. This is a relatively technological issue, also partly coming from the fact that ENSEMBLE puts different models of privately-owned trucks into single platoons, and also aims to reduce distance between vehicles, closing the gap between vehicles to under 1,2 seconds.

3. The positioning system of the vehicles should be improved, as vehicles should be able to assess their position with a precision of at least 1 metre, ten times per second.
Mascalchi & Willemsen (2022) concluded that semi-driverless platooning might be deployed on the road quicker than fully automated vehicles from a technological point of view. They highlighted the need for infrastructural investments and modification of regulatory frameworks to realise it.

This also means that there is a possibility in another realm: the BRT infrastructure for autonomous buses. Instead of trying to make the vehicles go everywhere by making the vehicles smarter, the infrastructure can be designed along with the tailor-made vehicles to reduce the ODD for driverless vehicles significantly. And for V2V applications like platooning, the presence of a dedicated bus lane eliminates the challenges of truck platooning (i.e. splitting platoon). The problematic aims of motorway truck platooning, such as traffic flow, reducing the distance between vehicles, preventing cut-ins by private vehicles, and fuel savings through aerodynamics, are irrelevant in the BRT context. Also, the fixed route allows infrastructural investments that allows better positioning of vehicles, such as Radio frequency identification (RFID), or magnetic guidance.

On the other hand, it should be obvious that any driverless operation outside of dedicated BRT infrastructure will not be possible, therefore BRT infrastructure specifically designed for autonomous driving is crucial. Consequently the operating cost issues remain, but the limited automation has the potential for creating operational capacity for the dispersed branch services by reducing duplicate labour costs inside the BRT corridor. Therefore the future of vehicle automation in Spartacuslijnen should also be completely reimagined. While the Flemish minister of mobility Lydia Peeters did mention potential Autonomous Rail rapid Transit (ART) operation in the long term (Peeters, 2021), such operation again replaces the trambus vehicle with same one with autonomous features, adding not much value for those living outside of the BRT corridor.

Autonomous Rail rapid Transit (ART)

ART, otherwise known as trackless tram, is a type of guided bus (not actual tram) that is optically guided through the dotted markings on the road. While having the word autonomous in its name, currently operating systems have onboard drivers (Chamberlain, 2022). It is currently operating only in China. The max speed is 70 km/h, similar to Van Hool's trambus ExquiCity 24 (72 km/h). Image source: CRRC https://bus-news.com/autonomous-rail-rapid-transit-buses-complete-trials-in-chengdu/

1.4 RESEARCH AIM

The ultimate aim of this research is to propose an alternative urban and transport planning strategy for Limburg by developing a new formula for implementing autonomous BRT that is suited for the situation in Limburg through the lens of mobility justice (and therefore including spatial justice), in the existing governance framework of Spartacusplan and three Spartacuslijnen. This shall be potentially achieved by applying the achievable level of vehicle automation and proposing modifications in the currently planned “Trambus”. The framework for spatial interventions that can combine the effects of BRT with the long-term spatial transition trajectory is created, along with the design tool/patterns for accommodating the system in the built environment and a digital tool for service planning. The Spartacuslijn is expected to go into implementation in the near future (2030), and its impacts lasting over 30 years from that (2060).

As suggested in Chapter 1.3.2, the rail connection between Limburg and Liege, Antwerpen, and Brussel is well established; only the connection between Limburg and the Netherlands remains an issue on the inter-regional scale. Moreover, at the time of the writing, the decision not to re-open the railways has been made (Thuwis, 2020; Van Diepen, 2021), and significant progress on the BRT project has already been made: Spartacuslijn 3 has confirmed its traject after multiple workshops and participatory sessions as part of the North-South link project (Noord-Zuid Limburg, n.d.), and Spartacuslijn 2 is also already given an environmental permit for parts of the traject as a “quick wins”. Both are currently ongoing under the framework of a complex mobility project, a coordinating body called De Werkvennootschap (De Werkvennootschap, 2020).

Therefore, the scope of the project is limited to the Spartacusplan and its traject; the study aims to provide an alternative “success formula” of public transportation to apply in Spartacuslijn BRT, create a recommendation for the level of infrastructural investment required for the corridors, provide visions on how the dispersed BRT can transform the region spatially, how it can be designed and applied, and finally visualise what kind of spatial and transportation interventions can be made.

1.5 RESEARCH QUESTIONS

The research question is determined based on the four elements of the project: the direction of the project, which concerns the literature reviews and the theoretical aim; the technological choice, which concerns the transportation technology aspect of the project; the question for analysis; and finally the goal for urban design exercise based on the aims set in chapter 1.4.

MAIN RESEARCH QUESTION:

*How can **innovative transportation technologies** help implement an **equitable and sustainable** transport network suited for Belgian Limburg that can catalyse the **spatial transition**?*

SUB-RESEARCH QUESTION:

DIRECTION_SRQ1

How the "just" mobility transition should be, and how can it be approached in the context of transforming the Flemish Nebular city?

ANALYSIS_SRQ2

What kind of immobility is present in Belgian Limburg?

TECHNOLOGY_SRQ3

What will be the ideal formula of transport technologies and BRT elements that can be applied in Limburg?

DESIGN_SRQ4

How can new public transport infrastructure be integrated into different spatial scale levels and timeframes?

N°2

THEORETICAL EMBEDDING

This section will be aimed at reviewing the spatial, justice, and transportation planning concepts surrounding the Nebular City and the implementation of BRT, which will then identify the potential ways the project can be directed towards. In this chapter, through the literature reviews, the different views regarding mobilities, Nevelstad, and spatial networks will provide the frame for reading the current spatial status (chapter 2.2), the relationship between transportation and land use, and the possible directions in shrinkage and development will be discussed (chapter 2.3). From the transportation planning perspective, the accessibility (chapter 2.4) and justice surrounding transit (chapter 2.5) will provide possible direction for the project to follow.

2.1 MOBILITY TRANSITION

TOWARDS JUST AND SUSTAINABLE FORMS OF TRANSPORTATION

Globally, the urgency of transitioning into a sustainable and socially just transportation system is growing. From the perspectives of climate change, urban liveability, transport economics, and distributive justice, multiple pieces of research suggest an urgent need for policy and design measures to facilitate behavioural changes that discourage the use of (private) automobiles and promote sustainable transport, including public transportation (Anciaes & Jones, 2020; Chapman, 2007; Santos et al., 2010; Pereira et al., 2016).

Automobile use has left its marks on the landscape by facilitating urban sprawl, creating social, economic, and ecological woes, by accelerating wildlife habitat loss, fragmenting patches, and forcing higher transport & household energy use (European Environment Agency, 2016; Dramstad & Olson, 2013). In the Flemish context, "Nevelstad" (the Nebular city) is a unique form of sprawl problem that Flanders is facing, where the division between cities and countryside is blurred, which brings specific problems such as flood risk (Poelmans, 2010), low liveability, and most notably, difficulties in providing regional public transportation (Smets et al., 2014). This dispersed and fragmented settlement pattern has been facilitated by centuries of dispersion policies and transportation infrastructures (De Meulder et al., 1999).

In recent years, there have been experiments on developing a suitable mode of public transportation system suitable form of transportation based on the Flemish settlement pattern has been devised. Notably, the ORDERin'F project has proposed a regional public transportation model based on existing modes, namely light rail transit (LRT) and bus rapid transit (BRT) (Smets et al., 2014). Recently, the progress surrounding automated driving has opened some possibilities regarding its applications in public transportation, (Ceder, 2020). On the other hand, the realisation of full (level 5) driverless vehicles on the public road are turning out to be unlikely due to their high safety requirements in all situations (Shladover, 2016).

Outside of the discussion over mobility regimes, sustainability, technologies, and practices that were introduced, recent mobilities research also concerns justice issues regarding rights for mobility, and mobility capabilities for guaranteeing equal access, such as transportation justice (Sheller, 2014). From the justice point of view, the technical solution (autonomous vehicles) alone cannot facilitate the transition towards sustainable mobility. Sheller (2019) argues that as far as inequality is present, the privileged "mobile elite" will still find ways to overuse energy.

2.2 FROM NEBULAR CITY TO NETWORK CITY

TOWARDS JUST AND SUSTAINABLE FORMS OF URBAN DEVELOPMENT

It is essential to understand the inseparable relationship cities have with mobility and movement from the geographic and social perspectives. American sociologist Nels Anderson attributed mobility as a key characteristic of urban life that differentiates it from the rural (Anderson, n.d., as cited in Creswell, 2021). In this paper, the definition of mobility will be using Creswell (2021)'s: Mobility is an equivalent of "place", and is differentiated from "movement", which is equivalent to "location". In other words, starting from the basic concept of movement between locations A and B, mobility contains attributions like context, meaning, ideology, and type.

Mobility (and migration) has been consistently associated with modernity and modern citizens. The movement consists of time and space, and from the Marxist readings of geography, the (modern) development of transport and communication has effectively "compacted" the space by drastically reducing the time component. Through this, the aura of the places was lost and commodified (Harvey, 1991, as cited in Creswell, 2021).
There are two predominant views of mobility. The sedentarist metaphysics, which reads the world from the framework of place, order, and belonging to the place, has been prevalent until the last century. In this view, mobility was seen with suspicion, commonly identified as a threat, instability, disorder, or mere by-product. Division by national or regional borders was normalised, and identity based on the belonging to the place was deemed moral. The morality attached to the place subsequently labelled mobility as immoral On the other hand, the nomadic metaphysics rejects belonging to the place, and appreciates the flows and dynamics. Mobility was attributed to positive concepts such as freedom, progress, change, resistance (against the powers), and cosmopolitan culture. The concept of place is deemed closed off, or even reactionary, and the concept of borders is considered something to be demolished (Creswell, 2021).

Coming back to the Belgian Nevelstad, it is noticeable that it is quite unique from most cases of sprawl in Europe. Generally, sprawl is driven by motorisation and its effects, with supporting factors such as demographics (population size, degradation of the city centre, migration, age), socio-economic situations (GDP, lifestyle), political decisions (subsidies on buildings and/or automobiles), technologies (transportation, communication), geophysical components (topography) (European Environment Agency, 2016). However, in Belgium, existing interpretations of sprawl are limited in applicability, as the population dispersion was started way before motorisation. The built-up areas were already spread along the roads across the landscape even on the 1771 – 1778 de Ferraris map, owing to the fertile soil being available everywhere (De Meulder & Dehaene, 2001, as cited in Gheysen & Leemans, 2022). De Meulder et al. (1999) explained the role of public transportation in accelerating the dispersion, which it was used to "ship" labour forces from the countryside to major industrial cities through cheap tickets for a dense network of railways and interurban tramways (buurtspoorwegen). This was also to keep labour forces flexible and resilient, who can simply switch between the "urban" economy and the "rural" economy depending on the economic situation. The political and social reasons, such as keeping the populace within the influence of small-town catholic churches, safe from the influence of the urban liberals and later socialists were also considered, which translated into the housing policies that favoured home ownership. This also resulted in the "export" of the working class (and later middle to upper class) to the countryside, thus avoiding the common urban problems of the industrialization era.

It can be therefore concluded that the Belgian dispersion policies may appear nomadic in practice, but in its context, it is sedentary by all intention. In this paper, it is almost logical to assume that the position regarding mobility will be firmly based on nomadic metaphysics. However, the sedentary desires of people should not be disregarded; the

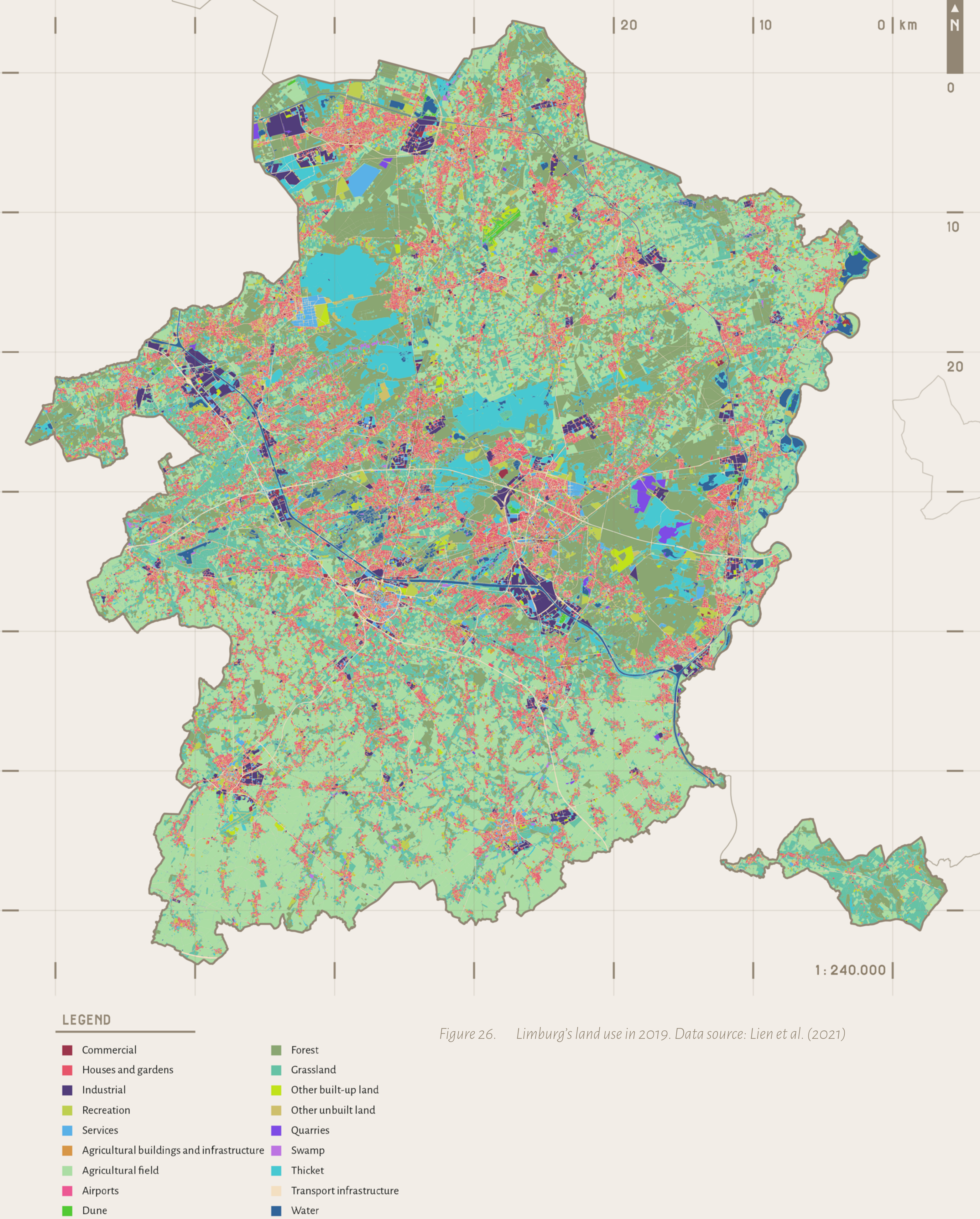


Figure 26. Limburg's land use in 2019. Data source: Lien et al. (2021)

more recent research of Sheller (2014) also points out that although asserting mobility as contemporary, or treating it as desired value has been indeed done in the beginning period of the nomadic theories ("romantic reading of mobility"), nowadays the research trend moved away from it towards practices and infrastructure regarding both movement and stasis. Creswell (2021) also points out that the dimension of place should not be ignored, and the inequalities that are often overlooked in the rosy vision towards mobility should also be properly addressed. In other words, the sedentarist desires of the populace – to remain in the familiar community and have a house that forms the generational wealth – needs to be acknowledged.

Solutions for Nevelstad were proposed as early as 1997 through the regional masterplan of 1997, Ruimtelijke Structuurplan Vlaanderen (RSV), which projected the dominant "compact city" approach in the Belgian urban fabric. This has been heavily criticised, as the asystematic urban fabric cannot tolerate such systematic densification (Leemans, 2021; De Meulder et al., 1999). Instead, there are growing cases of more moderate views on spatial dispersion in Flanders, aiming to embrace and acknowledge the inherent qualities of the Nevelstad, such as intermingling nature and urbanity. For example, Leemans (2021a) proposed nodal interventions designed on its characteristics, and Marin (2019) proposed circularity through the mixing of land uses.

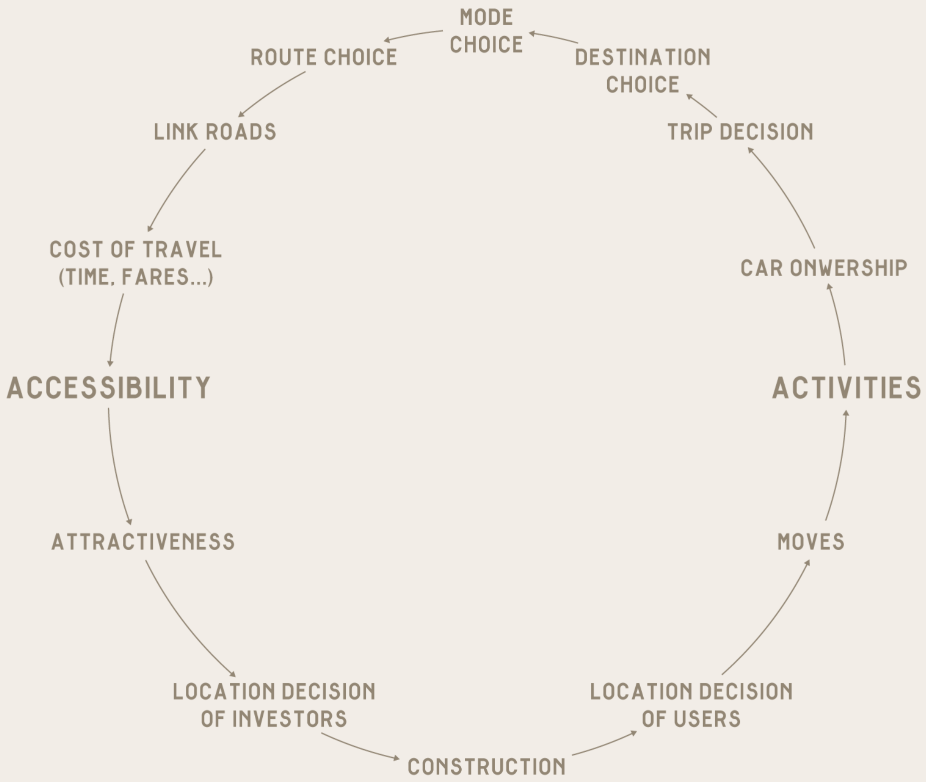
In line with the moderate views on spatial dispersion, in the last several decades, interpretations of the spatial structure of dispersed cities and towns, with a focus on its inherent characteristics and values, have emerged. Notable concepts include "Network Cities" by Batten (1995), "Netzstadt" by Oswald and Baccini (2003), and "Horizontal Metropolis" by Viganò et al. (2018). These concepts put focus on interaction and cooperation between cities, in contrast to the traditional central place theory by Christaller (1933), which focuses on exclusive areas of influence in the pre-industrial economies (Christaller, 1933, as cited in 손, 2011). Network Cities provides a reading into the inner workings of the spatial structure. It sheds light on how to transport and communications infrastructure combined with spatial planning can facilitate a creative knowledge-based economy based on supplementary cooperation between cities and towns through external economies of scale in the region. In central place theory, centrality was the determining factor in the location of cities; in Network cities, nodality determines the location of the cities. (Batten, 1995, as cited in 손, 1995). Netzstadt provides a systemic analysis framework and principles for designing the urban system, taking factors derived from both geology and human activities (송 et al., 2013). The defined elements in the framework consist of Nodes, Connections, and Scales, which combine forms a network. The four principles of Netzstadt give many lessons in further development, which shapability incorporates history and life into the built environment, sustainability takes own and global resources into account, reconstruction incorporates the fixing of errors, and responsibility puts responsibilities on the decision (Oswald et al., 2003, as cited in Aravot, 2004; Ibrahim, n.d.). Finally, Horizontal Metropolis proposes a viable, future-proof alternative to the traditional concentrated cities that have been the dominant ideal (Viganò et al., 2018). This can be almost seen as a radical counter-model of mainstream discourse over sustainable cities: it sees the state of diffuse urbanity as an asset for sustainability. This diffuse, decentralised model of development that blurs the border of city and countryside may shed light on the future of Flemish Nevelstad.

It can be concluded that more moderate views on spatial dispersion is growing, from the origin-of-woes to a mixed bag of positive and negative qualities. This means that balancing the inherent positive qualities while mitigating the damages introduced earlier in Chapter 1.1 would be ideal, although the status quo of the Flemish settlement pattern can be a challenge, especially in terms of transportation service provision; but concepts such as Network cities have shown that transit can play a crucial role in creating the knowledge-based economy in the region.


VERTREK
UUR
SPOOR
0958 HASSELT DIRECT 1
1127 ECAUSSINNES CARRIERES OMNIBUS 3
1436 LIEGE-GUILLEMINS OMNIBUS 5
1555 POPERINGE VIA KORTRIJK HALF-DIRECT 2
1643 VERVIERS-CENTRAL DIRECT 1
1708 ANTWERPEN C OMNIBUS 6
1749 CLABECQ VIA VIRGINAL SEMI-DIRECT 5
1814 RONSE OMNIBUS 3
2038 KNOKKE-BLANKENBERGE OMNIBUS 1
2117 ROUX VIA HAINE ST PIERRE-PIETON SEMI-DIRECT 2

2.3 TRANSPORTATION AND URBAN DEVELOPMENT

Figure 27. Wegener's circle, depicting the relation between accessibility and land use. Wegener (2004)



Now that the question of what Nebular City is has been answered in the previous chapter, then the question of what to do with Nebular City should be explored.

It is crucial to understand how transportation intervention in the form of Spartacuslijn and its branch services can affect the spatial transition of the region. As a general model, Wegener (2004) created the "land-use transport feedback cycle", that illustrates the land-use transport feedback cycle, which notes how trip and location decisions co-determine each other, then how the provision of accessibility can reflect on the land use of the region. In short: accessibility attracts development and construction, which results in more activities, thus influencing the decision process of the trip, and further translating to improvements in transportation. In practice, with the Betonstop, the cycle would be broken in the "construction" step in the countryside.

There can be two ways to approach this relationship between transportation and spatial development. On the one hand, is the additive growth scenario with Transit-Oriented Development (TOD) (Cervero et al., 2004), and the other is the subtractive, de-growth scenario of shrinkage (Blanco et al., 2009; Schwarz & Hoornbeek, 2009).

While there's no clear-cut definition of TOD regarding what aspects should be focused or to be added, most institutions that use the definition of TOD include the concept of creating dense urban development near the transit stop. The function mix, walkability, sustainability, prioritising pedestrians and cycling, generation of transit ridership, and quality urban environment can also be added to the definition depending on the person or institutions (Cervero et al., 2004). It is a very straightforward idea that generally follows the model suggested by Wegener (2004).

On the other hand, is the recently emerged discourse over planning shrinking cities. It is a fairly broad concept encompassing the design or planning measures that address the issues related to cities (from urban region to neighbourhood scale) that is experiencing a decline in population. From the planning perspective, also in the context of Limburg (although the province as a whole is not shrinking), this is particularly relevant as this allows for unorthodox, new approaches to mitigate the impacts of localised impacts of the spatial transition in the countryside, addressing issues such as inflated infrastructure for water and roadways, the emergence of vacant lots, and ecological restoration (Hollander, 2009).

Hollander (2009) defines two models of reconfiguring settlement patterns: the urban islands model, and the de-densification model. To briefly describe the two models, the urban islands model has roots in the Archipelago City by Oswald Mathias Ungers, which strengthens and confines the development to key nodes, and demolishes or re-locate areas outside of the key areas, introducing nature back into the formerly built areas. He concluded that the urban islands model is harder to realise, as it is politically hard to distinguish where is worthy of densification and where is not, and also the implementation also implies also harsh measures such as cutting down on public services from areas deemed unworthy, which in the case of Detroit, the low-income, minority residents that were still in the large number living in the “unworthy” areas strongly opposed the plan (Ibid.).

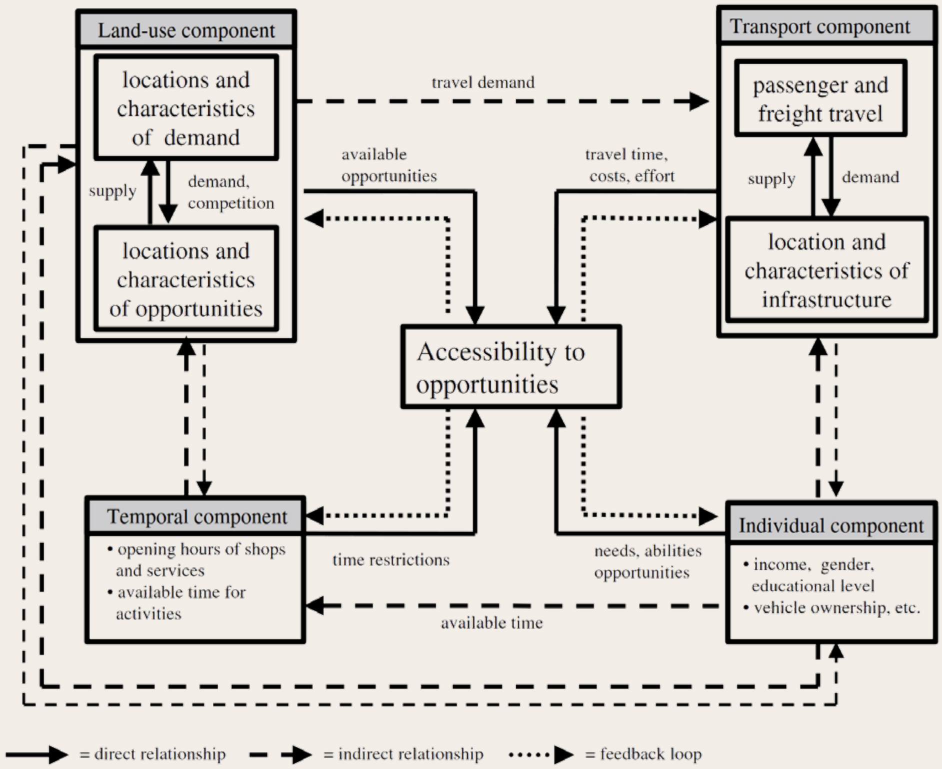
The other model, de-densification, takes the opposite approach: instead of increasing density in certain areas and vacating others, it aims to reduce density on across the city. For example, in many North American cities, due to a decrease in property values, residents are encouraged to purchase the nearby vacant lands and utilise them freely (Ibid.). Such measures are highly worthwhile to address the negative impacts of the spatial transition process.

In conclusion, transportation can influence spatial development by influencing the key parameters in development – the accessibility and attractiveness of the location. While TOD is fairly straightforward, the discourse over shrinkage comes with polarised models and uncertainties. The urban islands model can be put in the same category as the “compact city” ideals criticised earlier, however the ultimate value of spatial transition – core strengthening and fighting spatial dispersion – is very aligned with this approach. Then (at least from the spatial transition perspectives) the de-densification then can be compared with the status quo, albeit the approach in mitigating the impacts of spatial transition cannot be disregarded. Understanding their worth and pitfalls should be the prerequisite for setting the strategy for spatial transition.

2.4 ACCESSIBILITY

The key concept of Accessibility cannot be left undefined. It will be utilised as a common tool between transportation planning and spatial planning (Geurs and van Wee, 2004), as a key metric of the public transportation system's performance, and also as a tool to address the issues of justice in transportation (Martens, 2016). Based on definitions by Handy and Niemeier (1997), Geurs and van Wee (2004), and those introduced by them (Hansen, 1959; Dalvi & Martin, 1976; Burns, 1979; Ben-Akiva & Lerman, 1979, as cited in Geurs and van Wee, 2004), I will define accessibility as "ease and amount of access to potential opportunities and activities using the available transport modes" in this paper. Geurs and van Wee (2004) also identify 4 components of accessibility (Land-use, Transport, Individual, and Temporal), which relations can be read in Figure 28.

Figure 28. Diagram depicting the relationship between accessibility components by Geurs and van Wee (2004)



There are many ways to measure and quantify accessibility, taking one or more components mentioned above. Geurs and van Wee (2004) identified 4 perspectives of measures in their literature review: Infrastructure-based, Location-based, Person-based, and Utility-based. They suggested that good accessibility measures should be sensitive to key parameters of all components, but realistically it cannot be covered all at once. Martens (2016) also notes that rather simple measures will be sufficient in identifying people that lack accessibility, and it is better in terms of public communicability.

One can argue that simply maximising all accessibilities (as something that provides utility) for minimum investment would be ideal; in fact, this utilitarian view is already predominant in practice, often in the form of cost-benefit analysis. However, it is also heavily criticised for overlooking the inherent inequalities and violating the rights of disenfranchised people. (Martens, 2011, Pereira et al., 2016) This is why the aspect of justice needs to be integrated, which will be explained in the next section.

2.5 TOWARDS MOBILITY JUSTICE

Justice is not a state or abstract list of things to fulfil; rather, it is a process where diverse mobility and immobility interact. (Sheller, 2019; Rocco et al., 2021) The two major areas of Justice regarding spatial network and transportation, transportation justice and spatial justice, will be discussed further.

Pereira et al. (2016) argue that accessibility "works as a necessary, though not sufficient, condition for promoting equality of opportunity". They suggest taking other effects into consideration from the lens of distributive justice in relation to transportation and suggest two principles for the fair distribution of accessibility: 1) Individual's basic rights and liberties should never be violated or sacrificed, and 2) Investments and services should be directed in ways that reduce inequality of opportunities. 3) Guarantee minimum standards of accessibility to key destinations. In line with Pereira et al. (2016), in the book "Transport Justice: Designing fair transportation systems" (2016), Karel Martens presents new rules and principles of transportation planning that integrate the justice aspect. He introduced his frameworks for identifying population groups with substandard levels of accessibility for prioritising transport investments. He argues that based on the sufficiency threshold of accessibility and potential mobility, the transport planning and improvement in the transport system shall be focused on the people below the threshold and having low potential mobility, who are directly affected by the poor transport system. Sheller (2016) considered Martens' idea to be highly valuable in the social-democratic landscape of Europe. However, it is limited in scope as it only concerns transport being influenced by land use, not vice versa.

Transportation justice is certainly a useful direction. However, Sheller (2019) argues that transportation justice is not sufficient to cover the context of the complex crisis of mobility that we now face; it does not take the interaction between participants of mobility and the (creation of) space, and unlike many other aspects of justice, the procedural justice is often omitted in the discourse of transportation justice.

Spatial (in)justice is defined by Edward W, Soja (2010) as "intentional and focused emphasis on the spatial or geographical aspects of justice and injustice", involving "the fair and equitable distribution in space of socially valued resources and the opportunities to use them." Spatial justice shares the same definition of justice and a similar perspective on distributive justice. Furthermore, it also takes procedural justice into account. Lefebvre (1968)'s right to the city (Le droit à la Ville) already introduces the aspect of procedural justice by elevating the status of the public as a creating entity (Rocco et al., 2021), and David Harvey (2008)'s definition of the right to the city also claims "shaping power over the process of urbanisation".

Sheller (2019) suggests utilising spatial justice in expanding dimensions of transportation justice and theorises mobility justice, which overcomes the transportation justice by incorporating the spatial justice. Therefore it consolidates a broad spectrum of justice (migration, racial, gender, climate ...) and other means of movement (digital communication, migration...) upon the existing transportation justice, in facing the three crisis – urbanisation, migration, and climate. If transportation justice concerns the just distribution of accessibility, mobility justice aims to not only distribute, but also identify, acknowledge, empower, and engage the injustice in multiple dimensions. It can be translated that mobility justice encompasses transportation justice and spatial justice, and seeks to find solidarity with other dimensions of justice. Simply put: spatial justice aims to empower the underprivileged areas and groups with little regards to their movement, and transportation justice concerns the just distribution of accessibility with little regards to the identities and politics attributed to it, mobility justice brings the discourse of movements and politics to the table. For example, an neighbourhood that is deemed "already well-connected" based upon the current accessibility of the area, from the lens of transportation justice (thus lower importance of transit provision); but can be deemed important from the lens of mobility justice, in relation to empowering the mobility of migrants, women, youth, or environment. Sheller (2018)'s principles of mobility justice are as shown in the Figure 29.

PRINCIPLES OF MOBILITY JUSTICE

Sheller, M. (2018). Mobility Justice: The Politics of Movement in an Age of Extremes. Verso.

Each person's freedom of mobility shall be constrained by the rule of mutuality: i.e., not trampling, endangering, or depriving others of their capability for mobility.

Public transport systems must not arbitrarily deny access nor impose undue burdens, externalities, or limitations.

Gender, sexual identity, and other markers of identity shall not be used as the basis for restricting mobility or exclusion from public space.

Racial, ethnic, religious, or national profiling (including Indigenous identities) shall not be used to police entire groups or stop individuals from exercising freedom of movement.

Universal design should be required in all public facilities to ensure accessibility to all people and especially access to all modes of public transportation and media.

Children's rights to mobility and the rights of the elderly, pregnant women, and those needing assisted mobility should be protected and included in design and planning.

Individual mobility shall not be involuntarily restricted by threats of violence, either physical or symbolic, including enforced forms of clothing, segregated means of movement, or unevenly applying temporal or spatial limits on mobility.

Cities should ensure equitable provision of public transportation through a social benefit analysis based on population-level measures of social exclusion and minimum thresholds of accessibility (as described by Martens); and should seek to reverse the historical subsidies and other preferential treatment given to private automobility.

Transit-Oriented Development standards should be used to evaluate and measure social impacts of urban transport plans on accessibility, affordable housing, and social inclusion, and all communities should be included in decision-making processes.

Cities should preserve public space, support multi-modal shared space, and should not develop splintered infrastructures that systematically advantage some groups with superior levels of service and disadvantage others with inferior levels of service.

Complete Streets policies should ensure that all modes of moving are afforded space and that streets are not dominated by one mode, such as cars.

Public infrastructure for transport, communication, and information sharing shall be publicly funded and made accessible to all people.

Protections of habeas corpus shall extend to all people, both citizens and non-citizens, and there shall be no forms of state detention without legal representation, due process, and judicial appeal.

Information and communication technologies used in disaster recovery, and in general in any situations of digital divide, should be made as accessible as possible to those trying to recover, aiming to strengthen their capabilities.

Net neutrality and open data repositories should be maintained to ensure public access, and all publicly funded research should require open source publication.

There should be legal protection for data privacy, and states and corporations shall not have the right to search, seize, take, or use unauthorized private data.

There should be regulation of so-called "offshore" banking, and enforcement of requirements for financial reporting and taxation in places of residency.

All people have a right to exit and re-enter the territory from which they originate.

There is a right to refuge for those fleeing violence and loss of domicile by war, but we must also develop new international agreements on asylum for climate refugees.

There should be fairness and equity in determining the freedom of movement across borders without arbitrary exclusion of entire categories of persons on the basis of race, religion, ethnicity, nationality, sexuality, health status, or socioeconomic status.

No one should be detained or deported without due process, legal protections and the right to appeal, and no detention centers should be created in "offshore" jurisdictions.

Tourism shall be fairly exercised to ensure that it does not appropriate public or common lands, does not unduly disrupt the mobility rights or block the accessibility of places to those who dwell there, and does not leave behind undue burdens of waste or pollution.

Those displaced by climate change shall have a right to resettlement in other countries, and especially in those countries that contributed most to climate change

Principles of climate justice and environmental justice suggest that mobility consumed in one place should not externalize waste or pollution on other regions without legitimately agreed upon deliberation, transparency, and reparations.

Protection of the planetary commons (aquifers, rivers, oceans, seafloor, mountains, atmosphere, Antarctica, the Arctic, and extra-planetary bodies) shall outweigh any rights to global free trade or private rights to resource extraction.

Government subsidies for extractive energy industries should be redirected toward the development of clean, renewable energy, while also banning harmful practices and tracking royalty payments, tariffs, and profits through mechanisms such as the Extractive Industries Transparency Initiative.

Those industries and countries that have contributed the most to greenhouse gases and other forms of pollution have a responsibility of reparative justice to limit the impacts of their actions and to restore the atmosphere and environments as far as possible: a global trust fund shall be established into which polluters pay in order to meet the costs of urgent global climate change disasters.

All states shall be party to world forums at which carbon budgets (as well as other greenhouse gases) are agreed upon and reductions in greenhouse gas emissions regularly measured and met—and multinational corporations must be held responsible for this.

Figure 29. Sheller (2018)'s principles of mobility justice. Principles directly related to urban planning and transportation are highlighted.

Reflecting back on the proposed development models in chapter 2.3, mobility justice raises questions on both TOD and the Urban islands model. For TOD, from the mobility justice point of view, it shall not become an island for the affluent residents; and the Urban islands model, although originally to be inclusive and pluralistic in culture (Schrijver, 2006), the implementation has shown the risk of further pressuring disadvantaged groups by pulling public services and reducing infrastructures, and actually focus public funds into already privileged areas instead of focusing on disadvantaged people. Therefore the suggested risks in unpopular implementation is also highly justified: as Sheller (2019) puts it, for those who feel that their rights to the city is being limited, the decision-making on infrastructural investments and transportation planning could become a place for political strife.

In that regards, from the standpoint of mobility justice, procedural justice, often omitted in transportation justice, is also important. It involves access to information, understanding, and participatory knowledge creation (Sheller, 2019). Vigar (2017) also argues that transportation planning has been too rationalised and alienated from a transparent, democratic process. From the institutional actors, the EU-funded Mobility4EU's action plan also cites stakeholder participation and the creation of participatory forms of governance as the major objective in the mobility planning area of the action plan, which in the short-term, (until 2025) the R&D community should "Provide tools and measures to establish and further develop co-creation concepts for the development of novel transport solutions" (Mobility4EU, 2019). This is also in line with the Flemish government's Vision 2050, which specified co-creation and partnership multi-actor governance as part of its transitional framework (Vlaamse Regering, 2016).

Although there are ample cases of co-creation in urban planning (Gemeente Utrecht, 2020; Calvaresi & Cossa, 2013), in transportation planning, it remains a question whether co-creation is possible in the context of public transportation system design. Although cases using digital tools such as CoAXs have been used (Stewart, 2014; CoAXs, n.d.), in general, most of the transportation co-design attempts, at least in the U.S. has been unsatisfactory, due to the difficulty in bridging the gaps in stakeholder knowledge (Stewart, 2017). Although, in this case, the possibility will lie in the better means and tools for capacity building and the role of facilitator (which is the main role of planner), levelling the capacities of stakeholders . Given the lack of a clear definition of co-creation across disciplines (Pappers et al., 2020) and the underutilisation of co-creation in transport planning (Stewart, 2017), it may suggest that the possibility of co-creation in the field may still be alive.

2.6 THEORETICAL FRAMEWORK

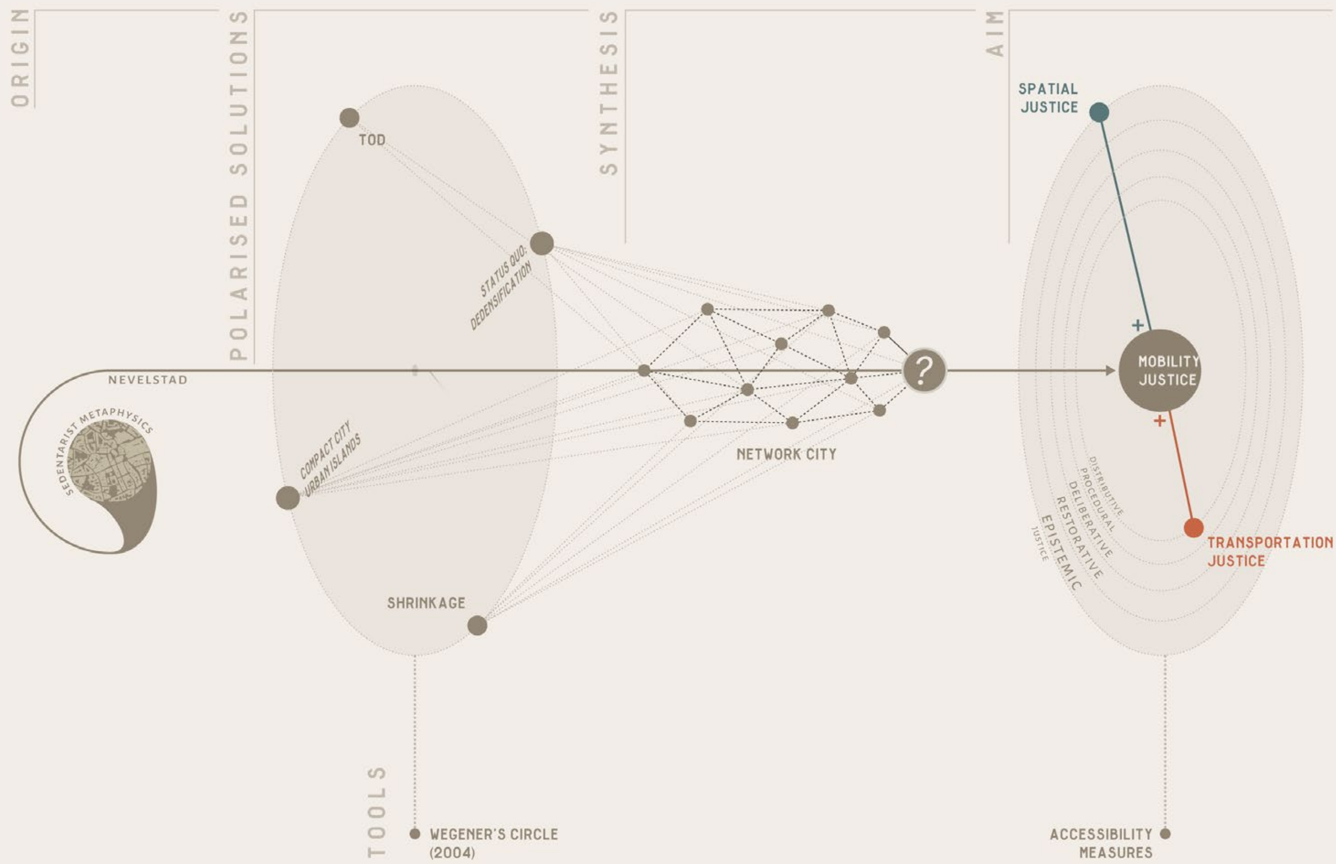


Figure 30. Theoretical framework

In conclusion, the sedentarist ideals were inherent in the formation of Nebular City. With the polarised models of compact city – status quo, urban islands – dedensification, TOD – shrinkage on the table, with one hand proposing radical changes, and on the other hand, disregarding the structural problems with dispersion, the challenge remains how to balance the measures in spatial transition, which should ultimately be heading towards mobility justice, encompassing spatial justice and transportation justice.

How the careful mix of approaches surrounding Nebular City should be able to find a middle ground for the polarised solutions, would be discussed further through the thesis.

N°3

METHODOLOGY

3.1 PROJECT APPROACH

In this chapter, the key approaches and the details of the methodologies are discussed. In the project approach, the key approach of the project is explained through the dichotomy of possible approaches in Flanders; in the methods section, the methods used in the thesis is briefly introduced.

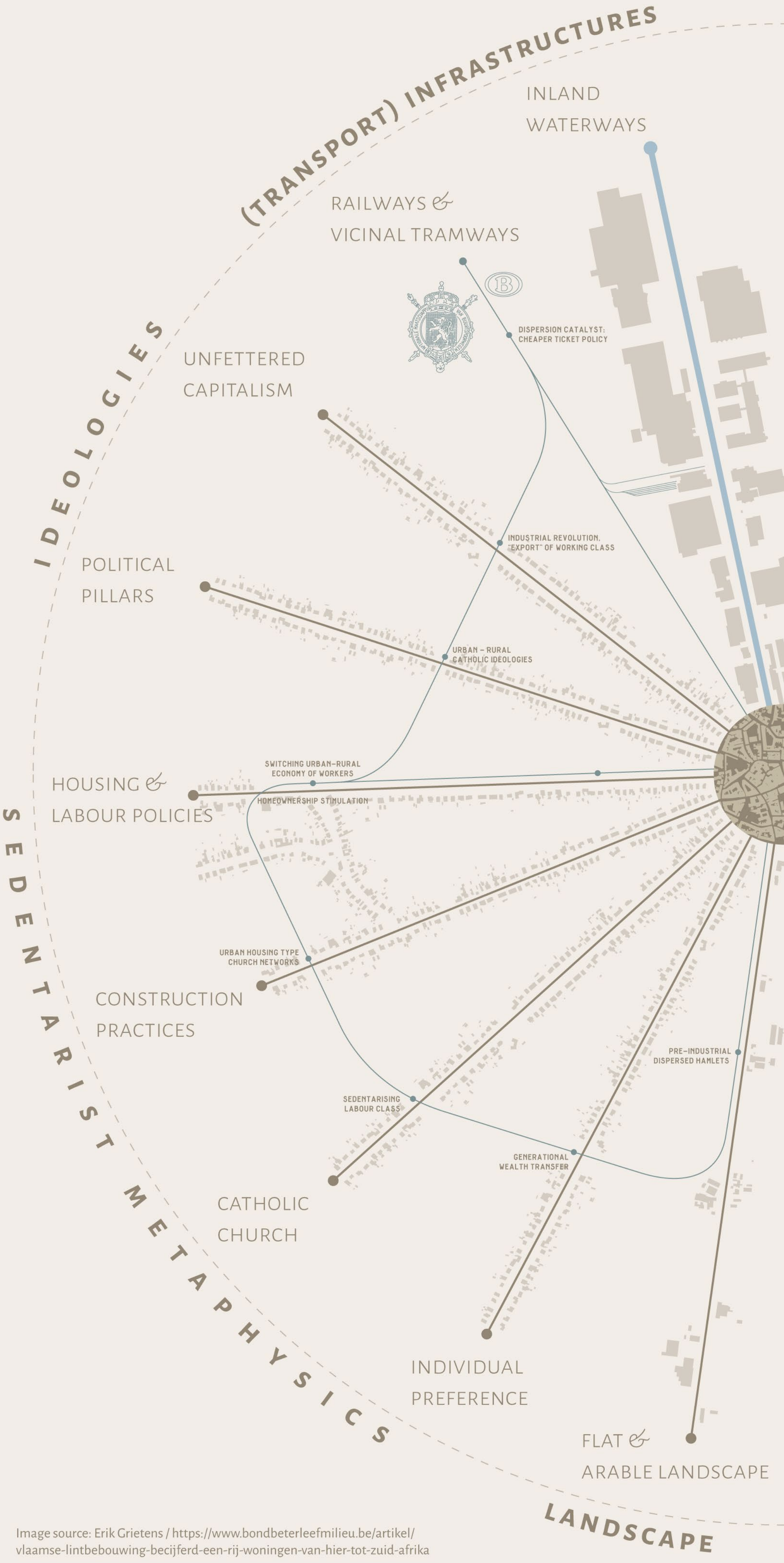


Figure 31. Ideas behind the Belgian Nebular City, and its future trajectories

Image source: Erik Grietens / https://www.bondbeterleefmilieu.be/artikel/vlaamse-lintbebouwing-becijferd-een-rij-woningen-van-hier-tot-zuid-afrika

AMBITIOUS SCENARIO:
COMPACT CITY IDEAL
RADICAL TRANSFORMATION
EVERYTHING IN-PLACE
AUTONOMOUS VEHICLES

IDEALISTIC
URBAN FORM FOCUS
TURBULENT IMPLEMENTATION
NEGLECTED COUNTRYSIDE

BUSINESS-AS-USUAL:
DISPERSION
NO TRANSITION: LEGACY DEVELOPMENT
NO AMENITIES, NO PLACENESS
CONVENTIONAL VEHICLES

EASY OPTION
REACTIVE
MINIMAL CHANGES

Based on the ideas presented in the theoretical framework, the path until the creation of the Nebular city, and the details of the middle ground approach are further clarified. To further describe the origin of the Belgian Nebular city cannot be attributed to a single cause of sedentarist metaphysic. The flat and arable landscape created settlements across the land (Gheysen & Leemans, 2022), and then a multitude of political, religious, and social powers intensified it. Then after industrialisation, as stated before, the transport infrastructure facilitated it further (De Meulder et al., 1999). This, in turn, can suggest the role of transportation in influencing the trajectory of development.

And the polarised solutions can be disassembled into parts. On the one hand, there is an idealistic side of solutions, often focused on realising "Compact City" ideal on the countryside, criticised for proposing radical, unrealistic transformations that are too much focused on the urban forms (De Meulder et al., 1999; Gheysen & Leemans, 2022). This can also be linked to transportation solutions, since the position implies holding optimistic views on sometimes unrealistic options. Therefore the level 5, fully automated, driverless vehicles with no need for supporting infrastructures are on the table, which partly has been the case for Spartacusplan with "ART" (Peeters, 2021).

On the other hand, are the realistic, feasible yet business-as-usual, incremental or status quo solutions that would not address the inherent problems entailed with the spatial dispersion. They simply accept the reality of dispersion as is – they cannot be changed nor reversed. Same attitude would also be present in transportation solutions, where only proven, existing vehicles and solutions would be used.

Figure 32. Project approach diagram

The middle ground between the two ends should be the direction this project shall follow. Instead of the ambitious compact city ideal that focuses on urban form changes, alternative ideals by Batten (1995), Oswald and Baccini (2003), and Viganò et al. (2018) should be followed, focusing on the creation of networks.

The radical transformation that focuses on creating dense neighbourhoods and neglecting the countryside behind for decades to come should not be the only solution, nor is it simply persisting on the current dispersed model without taking the inherent damage of dispersion into account. Therefore a gradual, flexible strategy for transformation should be set, which acknowledges the harms and benefits of the dispersion. A careful understanding of each area's harms and (potential) benefits is a prerequisite for it.

The short-term strategy should focus on the network changes, and long-term changes in the built form should be visioned to address the damages while maximising the positive qualities of closer nature and urbanity. However, this shall not follow a forced, unjust way as suggested in the Urban islands model; the urban islands model should be achieved by increasing the cores' attractiveness towards countryside residents who are inherently sedentarist., and through the process, the de-densification strategies should be applied to mitigate the impacts of shrinkage.

The amenities should also be created in the context of the network, instead of aimed to be created all-in-one in the place, nor simply disregarded in the process as is. In terms of transport solution, hopelessly waiting for the driverless technology to ripe someday nor relying on solutions done somewhere else shouldn't be the solution: the vehicle, infrastructure, and automation technology must be created hand-in-hand, even with lower level of automation.

In short, the project shall operate based on the middle grounds of the two extremes, aiming for the idealistic position in the long term, while gradually approaching the transition and utilising the benefits of dispersion in the short term. Through a thorough understanding of the harms and benefits of each locations, the spatial transition can utilise the beneficial qualities of dispersion.

3.2 METHODS

This section provides overview for the methods of the thesis. The data, parameters, and process are explained in detail in each respective chapter that comes later.

3.2.1 QUANTITATIVE: ACCESSIBILITY ANALYSIS

In relation to sub-question 2, the chapter 4 explores the immobility present in Limburg.

GTFS

General Transit Feed Specification (GTFS) is a standardised transit system data format. It contains information such as route, timetable, and mode. GTFS helps developers and researchers to easily analyse the transit system and develop services related to transit. For example, the public transit information on Google Maps is based on the GTFS format.

As part of auantitative analysis, accessibility analysis is conducted in Chapter 4. Geurs and van Wee (2004) suggest recognising each accessibility measure's limitation and choosing one based on the study purpose is crucial. In recent years, with the availability of standardised public transportation data formats for software applications, such as General Transit Feed Specification (GTFS) (MobilityData, n.d.), several open-source tools to analyse accessibility using public transportation data emerged, such as Open Transit Indicators (Azavea Inc., 2018), and open source accessibility toolkit (Noblis, n.d., as cited in Blanchard & Waddell, 2017), and UrbanAccess (Blanchard & Waddell, 2017).

Given the purpose of the study, it is logical to conduct an accessibility analysis based on public transport and active transportation access in a given location. In this project, an open-source Python package UrbanAccess (Ibid.) is used to measure accessibility. The package looks into amount of metrics available to reach within a certain timeframe using public transportation timetable from the given static GTFS data and on foot. The OpenStreetMap data is used as the network.

Descriptions on detailed processing and data is discussed in Chapter 4.2.1.

The resulting accessibility analysis will be used to identify which areas should be focused/prioritised to provide transportation service, following the transportation justice principles of Karel Martens (2016) from his book "Transport Justice: Designing fair transportation systems". It will be therefore used for Spatial Network analysis (3.2.3) and spatial categorisation (3.2.5).

3.2.2 SPATIAL ANALYSIS: SPATIAL NETWORK

In Chapter 4, the relationship between cities and towns is scored and visualised in order to understand the pattern of movement and life in Limburg. The methodology and definition of cores is based on a Regional Housing Market study by Atelier Romain & BUUR (Vandekerckhove et al., 2018). However, the purpose of the Regional Housing Market study is different from transportation planning, and concerns only nodality, amenities, commuting patterns, and jobs. Therefore the study will, in principle, replicate the methods of the Regional Housing Market study on the core definition process and scoring on commuting patterns and jobs. The study will further integrate the results of accessibility analysis and population data, and focus more on incoming and outgoing patterns of commuters.

The results of the spatial network is used for spatial categorisation (3.2.5) and network design. It will also be visualised to be used as a supporting material in the digital tool for public transportation planning.

3.2.3 QUALITATIVE: FIELDWORK, SURVEY, INTERVIEW, AND PERSONA CREATION

The travel pattern of Limburg will also be supplemented with the resident's perspective and experiences on movement. This will be incorporated into the understanding of the movement pattern from the quantitative analysis, which will lead to persona creation. The movement pattern of each personas will display the types of immobility and mobility needs present in the area, and ultimately be used as an example and metric on how people's experience with mobility can be improved through the project.

An online survey regarding people's experience with immobility and their wished movements has been conducted to understand the variables related to immobility and to make types of unrecognised movement patterns of the residents. The results are then used in the persona creation, representing the immobility patterns as a synthesised character.

The survey has been created on Qualtrics, and is available in Dutch. It has been shared on Local online forums in Limburg on Reddit and Facebook. The survey collects the following information about the participant's movement behaviour:

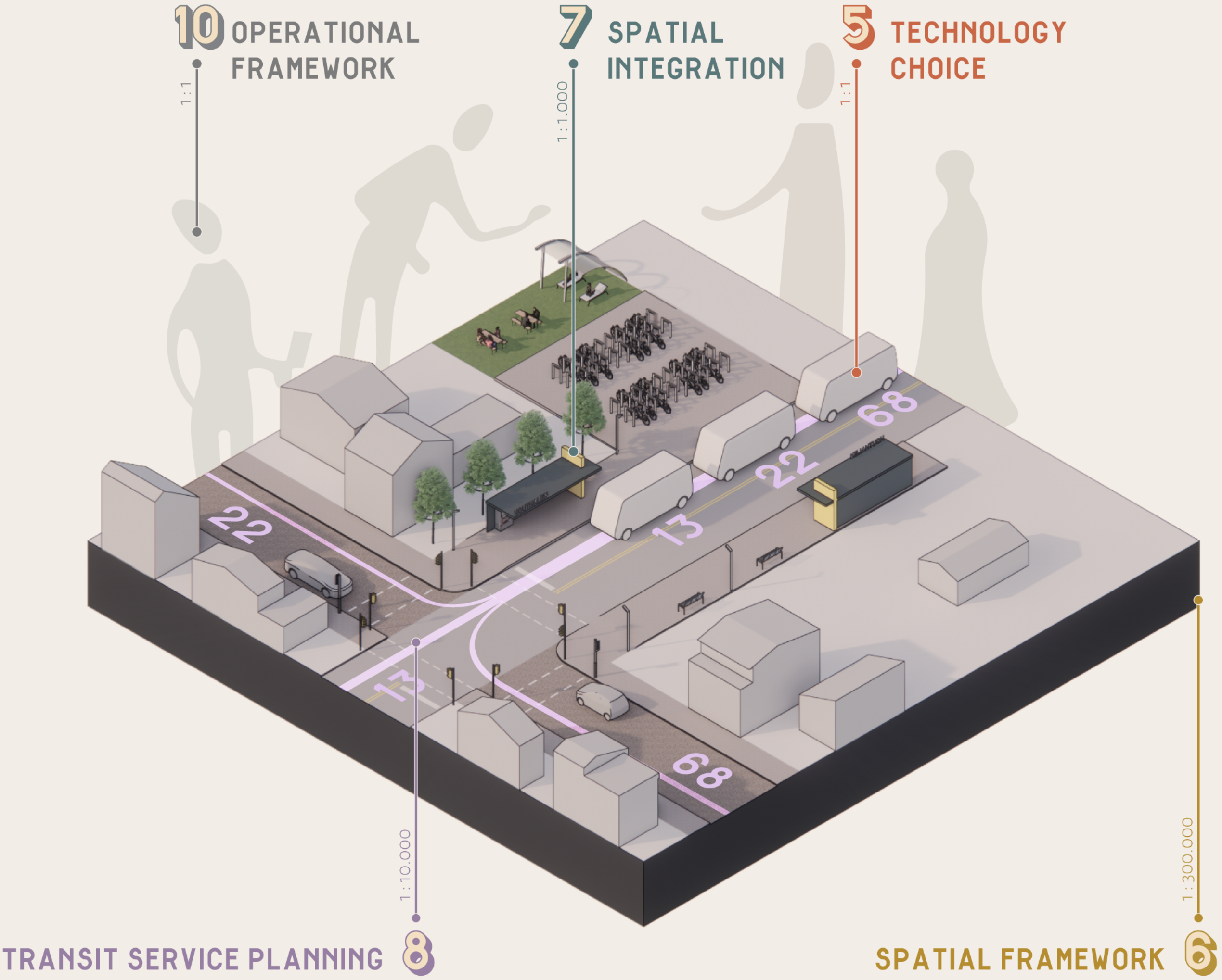
- Age
- Family composition
- Type of location they live in (city centre / town centre / countryside)
- Whether they always have access to certain mode of transportation (car as driver / car as passenger / public transportation / bicycle / on foot)
- How often does a person use certain mode of transport
- Whether they experience immobility or not
- If yes, what are their desired trips that they would want to make; desired trips mean trips that are unfortunately not possible to be made due to lack of transport options
- The desired trip's destination and preferred time of the day

The type of location was determined by the Flemish Planning Bureau's classification data of city cores and ribbons / dispersed buildings, in which large cores and mid-large cores (grote kernen / middelgrote kernen) were classified as "city centre", small cores and residential cores (kleine kernen / kleine woonconcentraties) as "town centre", and all other areas as a countryside. The data was put into ArcGIS storymaps and embedded into the survey. It was provided to the survey takers on ArcGIS storymap.

The questions of the surveys can be accessed through the link: https://tudelft.fra1.qualtrics.com/jfe/form/SV_033sVCftk6gtRv8

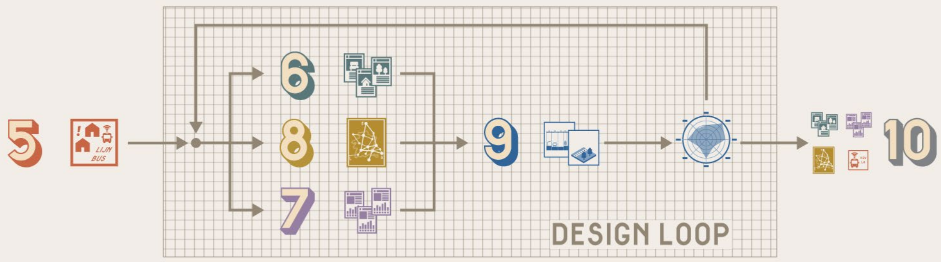
The unstructured in-depth interviews are conducted on top of the survey to further specify the types of immobility. The in-depth interviews took place with a family in Kortessem, pub visitors in Hoeselt, and Buurthuis Sledderlo in Genk.

The identified immobility types in the survey and interviews are translated into 4 Personas, which are visualised on a space-time diagram, depicting the regular activities of a week. The space-time diagram of each persona is used as an assessment of each testing site and its design exercise.



	5 TECHNOLOGY CHOICE	6 SPATIAL INTEGRATION	7 TRANSIT SERVICE PLANNING	8 SPATIAL FRAMEWORK	9 APPLICATION EXERCISE/TESTING	10 OPERATIONAL FRAMEWORK
SCALE	1 : 1 Vechicle, Right-of-way	1 : 1.000 Corridor, Node, Public space, Neighbourhood	1 : 10.000 Neighbourhood ~ City	1 : 300.000 Region	1 : 1.000 ~ 10.000 Selected sites	Neighbourhood ~ Region
						
OUTCOME	Mix of technical elements and spatial elements	Catalogue of spatial interventions	Routing options and destination profiles	Vision and manifesto: Spatial transition and urban network	Site-specific application of toolbox, with detailed plans and assessment	Stakeholder & participation strategy, Timelines
METHOD	Stakeholder analysis, Multi-criteria analysis, Accessibility analysis	Pattern Language	Pattern Language	Hectare-level data analysis	Pattern Language, Research by design	Stakeholder mapping

Figure 33. Design process diagram



3.2.4 STAKEHOLDER ANALYSIS & MULTI-CRITERIA ANALYSIS

Based on the findings of the literature reviews, an ideal mix of elements and technologies of the BRT system will be looked into through a multi-criteria analysis. The trade-off between infrastructural requirements, operating costs, versus benefits in accessibility and emissions are looked into. The resulting technology mix, and its spatial requirements and impacts, will lay the premise of the design exercise. The hypothesis for the future dispersed operation to be compared with existing operations is created based on the issues laid out in Chapter 1.1.

The stakeholder analysis is first conducted to identify the requirements and wishes of the stakeholders. The requirements and wishes will determine the criteria for multi-criteria analysis. A case study on current autonomous BRT projects with full-size vehicles is conducted, which is used for the morphological analysis that creates a set of alternatives.

In conducting the accessibility analysis for multi-criteria analysis, the aforementioned accessibility analysis techniques will also be applied. A hypothetical network is created based on the hypothesis defined in the chapter.

The specific methods and criteria settings will be further laid out in detail in Chapter 5.

The results of the Multi-criteria analysis will be used for setting the spatial transition trajectory, and will therefore influence the spatial categorisation and ultimately design of the interventions in the pattern language.

3.2.5 SPATIAL FRAMEWORK: SPATIAL CATEGORISATION

Based on the available hectare-level raster data, a synthesis map is created that categorises each hectare block's potential. The specific methods, data used, and criteria settings will be further laid out in detail in Chapter 6.

This will classify what strategy and (spatial) transition pathway should be suited for each part of the province, with how temporal/permanent the transportation service provision should be aiming to, and which types shall be prioritised in which timeframe. The categorised types will be defining the trajectories of pattern language.

3.2.6 PATTERN LANGUAGE

The design exercise will aim to create catalogue of possible design interventions using Alexander et al. (1977)'s pattern language. There will be two outputs from this: the first output would be for designing transport nodes, corridors, and their spatial integration, and the other for planning the public transport service in the future.

The first output is the set of pattern language to be used for spatial integration of BRT, and to support the spatial transition types defined in Chapter 6. It will utilise the pattern language as a communication tool for participation.

The second output uses pattern language to define principles of public transportation service planning, and it will provide a digital tool that visualises the characteristics of the destinations (meaning neighbourhoods available to be served by public transport in this context). The destinations will be classified into multiple types, based on parameters including their demographics, jobs, amenities, and urban form.

Since the pattern language will be used to facilitate stakeholder participation, the final outcome of the design would be open-ended; the patterns will be applied and tested for its applicability, but the outcomes from it will remain as a hypothetical product; it will be best understood as a “recommended scenario” rather than a definitive answer for the implementation.

3.3 CONCEPTUAL FRAMEWORK

The interplay of mobility and spatial transition is laid out in a road map. The railway (mobility) and road (spatial transition) both start from different perspectives with their own set of problems from the north, which interact with specific aspects of the main research question through the border. From the border towards the south, the urban and transportation planning elements interact with each other, leading towards the realisation of Post-Spartacusplan.

Each elements on the conceptual framework corresponds to the research structure as illustrated on Figure 35.

Figure 34. Conceptual framework

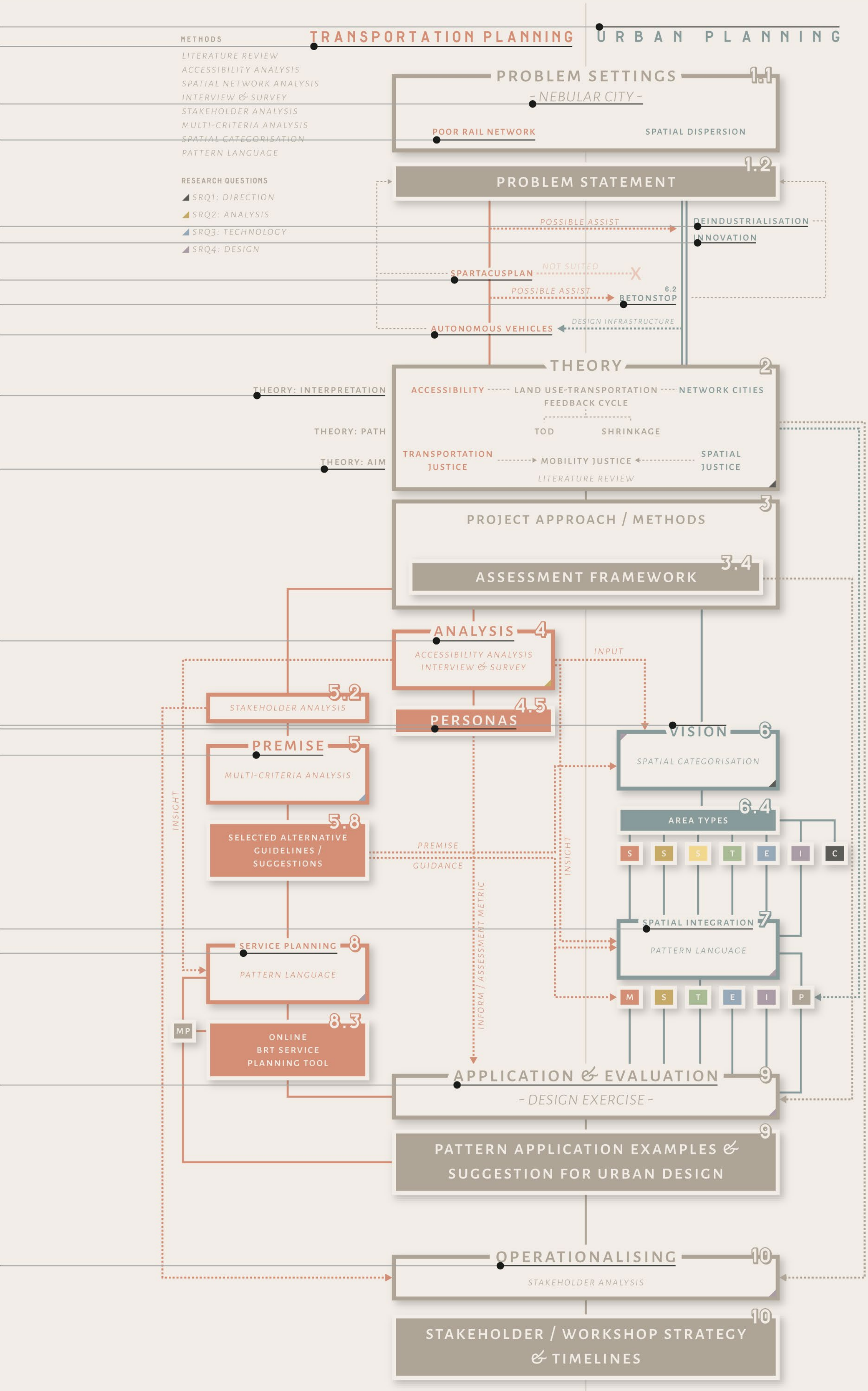
Q1 **Direction:** How the **"just" mobility transition should be**, and how can it be approached in the **context of transforming the Flemish Nebular city?**

Q2 **Analysis:** What **kind of immobility** is present in Belgian Limburg?

Q3 **Technology:** What will be the **ideal formula of transport technologies and BRT elements** that can be applied in Limburg?

Q4 **Design:** How can new public transport infrastructure be **integrated into different spatial scale levels and timeframes?**

Figure 35. Conceptual framework and research structure diagram connected with corresponding parts



METHODS
TRANSPORTATION PLANNING
URBAN PLANNING
LITERATURE REVIEW
ACCESSIBILITY ANALYSIS
SPATIAL NETWORK ANALYSIS
INTERVIEW & SURVEY
STAKEHOLDER ANALYSIS
MULTI-CRITERIA ANALYSIS
SPATIAL CATEGORISATION
PATTERN LANGUAGE
RESEARCH QUESTIONS
SRQ1: DIRECTION
SRQ2: ANALYSIS
SRQ3: TECHNOLOGY
SRQ4: DESIGN
PROBLEM SETTINGS
1.1
- NEBULAR CITY -
POOR RAIL NETWORK
SPATIAL DISPERSION
PROBLEM STATEMENT
1.2
POSSIBLE ASSIST
DEINDUSTRIALISATION
INNOVATION
SPARTACUSPLAN
NOT SUITED
X
POSSIBLE ASSIST
6.2
BETONSTOP
DESIGN INFRASTRUCTURE
AUTONOMOUS VEHICLES
THEORY
2
THEORY: INTERPRETATION
THEORY: PATH
THEORY: AIM
ACCESSIBILITY
LAND USE-TRANSPORTATION FEEDBACK CYCLE
NETWORK CITIES
TOD
SHRINKAGE
TRANSPORTATION JUSTICE
MOBILITY JUSTICE
SPATIAL JUSTICE
LITERATURE REVIEW
PROJECT APPROACH / METHODS
3
ASSESSMENT FRAMEWORK
3.4
ANALYSIS
4
ACCESSIBILITY ANALYSIS
INTERVIEW & SURVEY
INPUT
STAKEHOLDER ANALYSIS
5.2
PERSONAS
4.5
VISION
6
SPATIAL CATEGORISATION
PREMISE
5
MULTI-CRITERIA ANALYSIS
INSIGHT
AREA TYPES
6.4
S
S
S
T
E
I
C
5.8
SELECTED ALTERNATIVE GUIDELINES / SUGGESTIONS
PREMISE
GUIDANCE
INSIGHT
INFORM / ASSESSMENT METRIC
SPATIAL INTEGRATION
7
PATTERN LANGUAGE
SERVICE PLANNING
8
PATTERN LANGUAGE
M
S
T
E
I
P
MP
8.3
ONLINE BRT SERVICE PLANNING TOOL
APPLICATION & EVALUATION
9
- DESIGN EXERCISE -
9
PATTERN APPLICATION EXAMPLES & SUGGESTION FOR URBAN DESIGN
OPERATIONALISING
10
STAKEHOLDER ANALYSIS
10
STAKEHOLDER / WORKSHOP STRATEGY & TIMELINES

3.4 ASSESSMENT FRAMEWORK

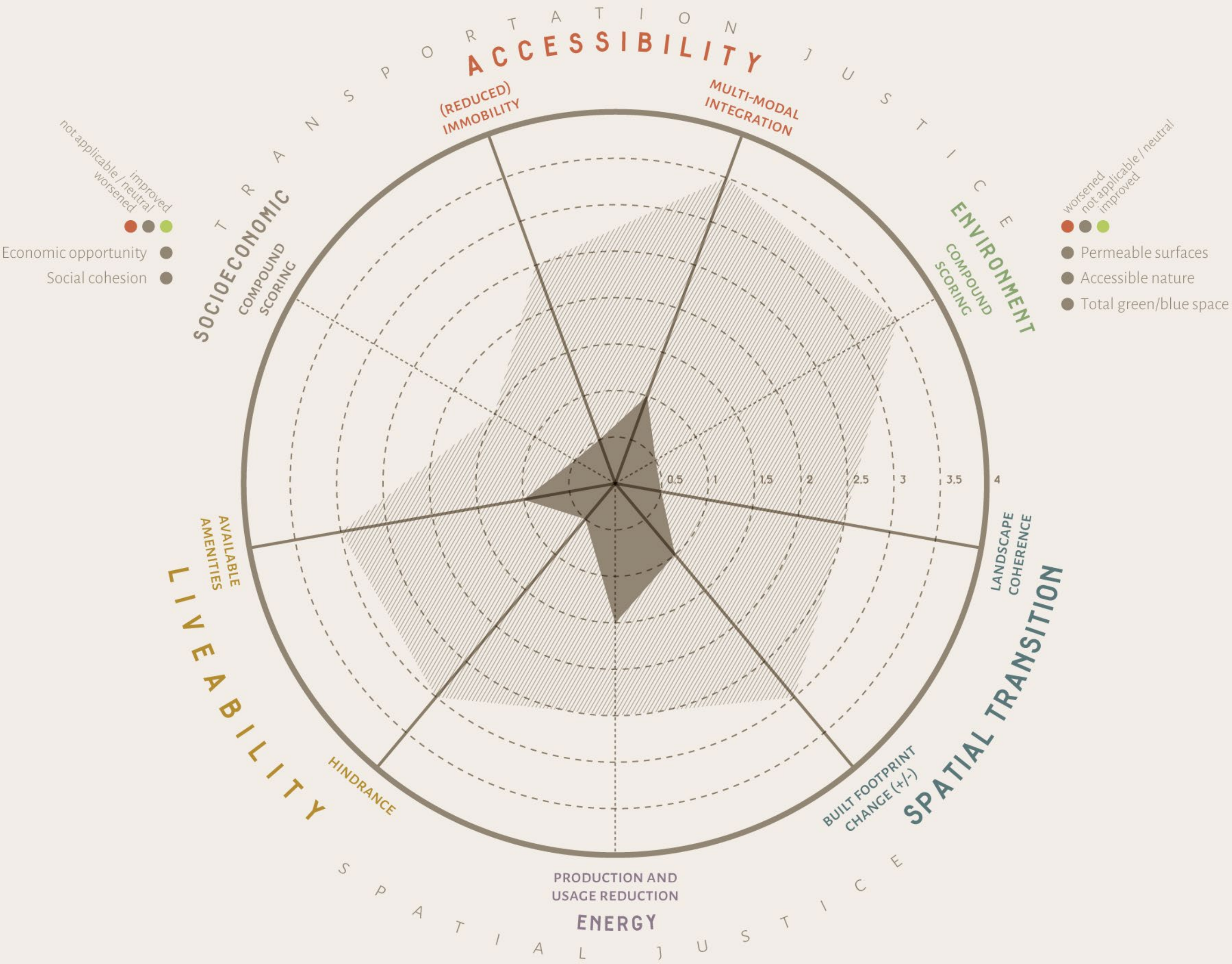


Figure 36. Assessment framework. The dark part depicts the assessment before the design intervention, and the bright part depicts the assessment after the intervention.

Based on the theoretical underpinnings, the built environment interventions on selected sites using pattern language will be assessed using the framework with 3 primary metrics (Accessibility, Liveability, Spatial transition) and 3 secondary metrics (Energy, environment, socioeconomic). The project's purpose remains to achieve the three primary metrics; however, as some patterns may mainly provide benefits on secondary metrics (i.e. infrastructural buffer space – greenery/energy production vs shared mobility/bike storage) while also creating tensions. Therefore secondary metrics are included in order to not penalise the use of such patterns.

Accessibility is the key metric for transportation justice (Martens, 2016). Accessibility metrics concern two sub-metrics: reducing immobility and multi-modal integration. Reduction of immobility is qualitative; addressing the immobile conditions potentially present in the areas, and improving access to public transport in the area is mainly taken into consideration. The multi-modal integration is measured by how many other types of modes are integrated into the station.

The liveability metrics concern two sub-metrics: the number of available amenities and hindrances. The number of types of accessible amenities will be counted, therefore, the simple number of amenities is not of concern. The accessible amenities are defined as amenities that are a) within 500 metres from the station or b) located along the same transit line, within 10 minutes or located at potential transfer points. The hindrances mainly concern visual hindrance (i.e. viaducts), noise (i.e. traffic, crowds, industry), and pollution (i.e. exhaust fumes, industry). Different measures can cause or reduce such hindrances.

The spatial transition metrics concern two sub-metrics: changes in built footprints and landscape coherence. Whether the built footprint shall increase or decrease depends on the type of areas that will be explained in the next chapter. If the footprint of the area shall be reduced, then the potential to reduce the built footprint in the long term will be measured. If the footprint of the area shall be increased, then the potentially added floor space will be measured instead of built footprints. The landscape coherence is qualitative, where connectivity between green patches will be mainly measured.

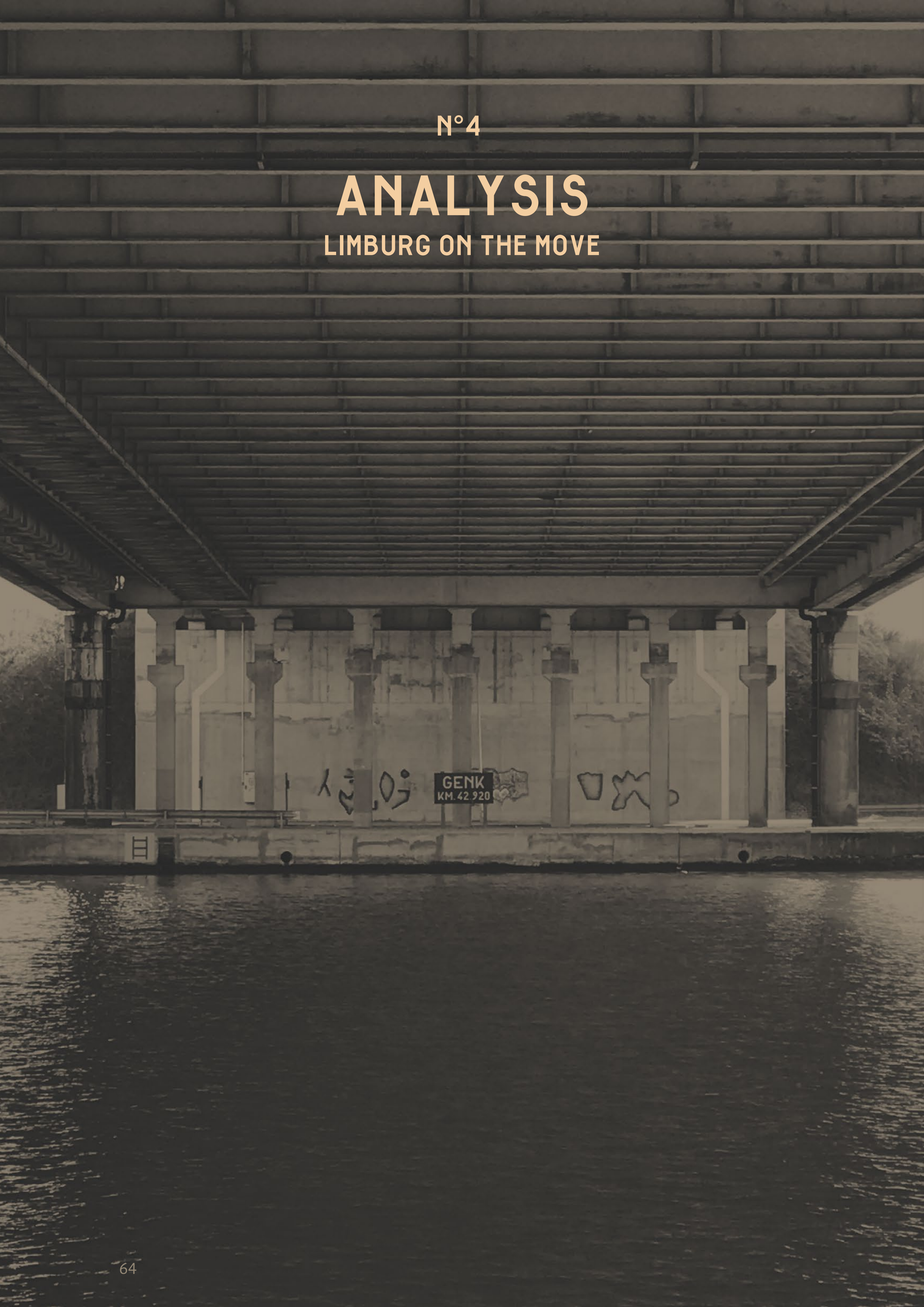
The secondary metrics concern the desirable "side effects" of the interventions. While the main goal of the project is aimed at the three primary metrics, the secondary metrics can also be improved as a result of improving the primary metrics. They are therefore measured as one compound.

Through the project, each pattern will have its set of effects on each metric in the assessment framework. The types defined in Spatial Framework will further clarify which aspects of the spatial framework should be focused on per type.

N°4

ANALYSIS

LIMBURG ON THE MOVE



4.1 INTRODUCTION

In this chapter, the immobility and the movement patterns of Limburg will be analysed, both quantitatively and qualitatively. The findings from the analysis will make a solid basis for creating the principles in the transport service planning patterns, and can provide insight for the creation of spatial framework and the design of spatial integration patterns.

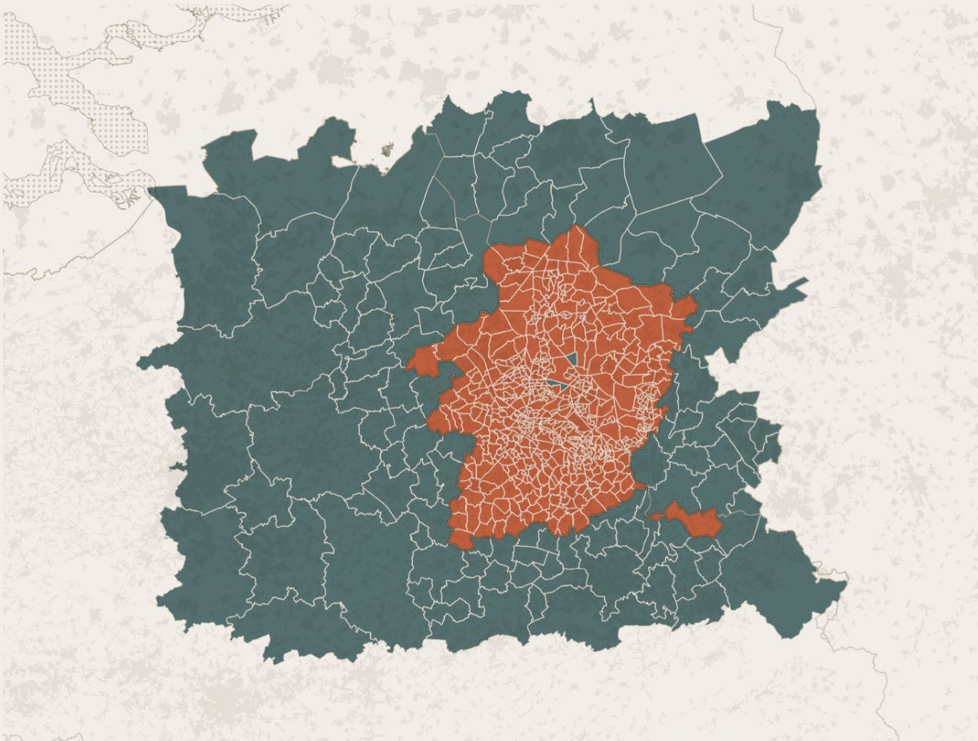
4.2 MOBILE-IMMOBILE: ACCESSIBILITY ANALYSIS

According to Martens (2016), accessibility is the guiding metric in transportation justice: areas that are below the accessibility threshold, in other words, areas that are not currently well served by the transportation network, should be prioritised, and the areas that are above the threshold should be the least concern.

Therefore the understanding of the accessibility of Limburg will become the guiding metric in deciding areas to prioritise in the project; in the spatial framework, accessibility would be used as the threshold criteria in classifying the types.

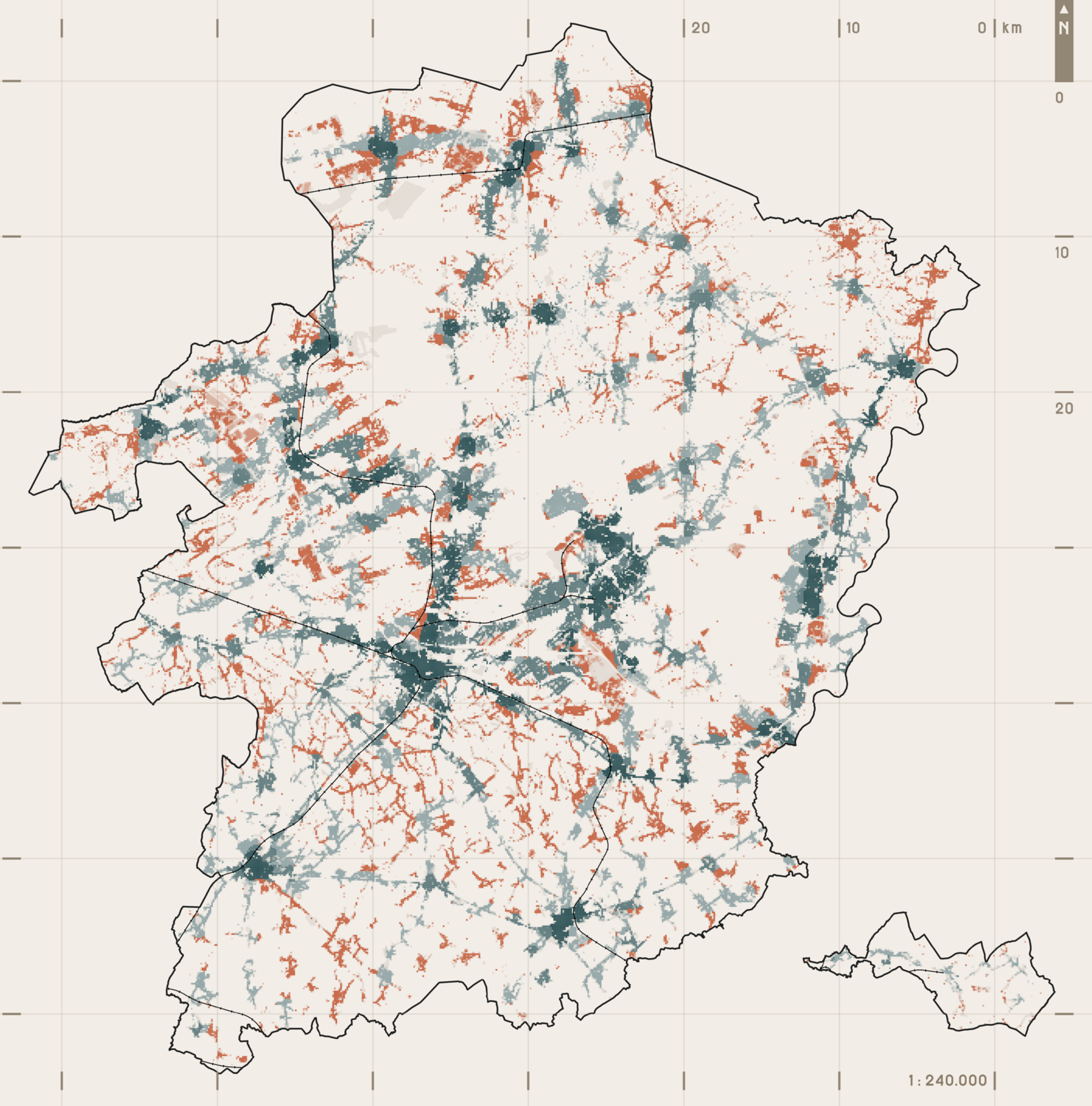
4.2.1 ACCESSIBILITY ANALYSIS

Figure 37. The zones set for accessibility analysis. Red depicts areas that actual data for number of jobs has been used, and blue depicts zones that number of jobs are calculated based on population. Data source: Statbel (2021), CBS (2019)



As briefly introduced in Chapter 3, the accessibility analysis is conducted to understand immobility and areas to prioritise. The zones used in the calculation are shown in Figure 37. Inside Limburg, the statistical sectors of Statbel are used, which is kept as-is around Spartacuslijn corridors. Sectors that are around the edges of the province are merged with several nearby sectors into one zone. Outside of Limburg, Zones are defined in the municipality level, which is also made more coarse by merging with other municipalities the farther it gets from Limburg.

Each zone contains data of the number of jobs and residents. Inside Limburg, the hectare-level raster data on jobs and residents were summarised per zone. In other areas, the population data from respective countries (CBS / Statbel) was used per municipality, and the job numbers were calculated based on the population data by weighting the number of residents by 0.549, which is the mean jobs to population ratio in Limburg municipalities. Roadway data is imported from OpenStreetMap.



LEGEND

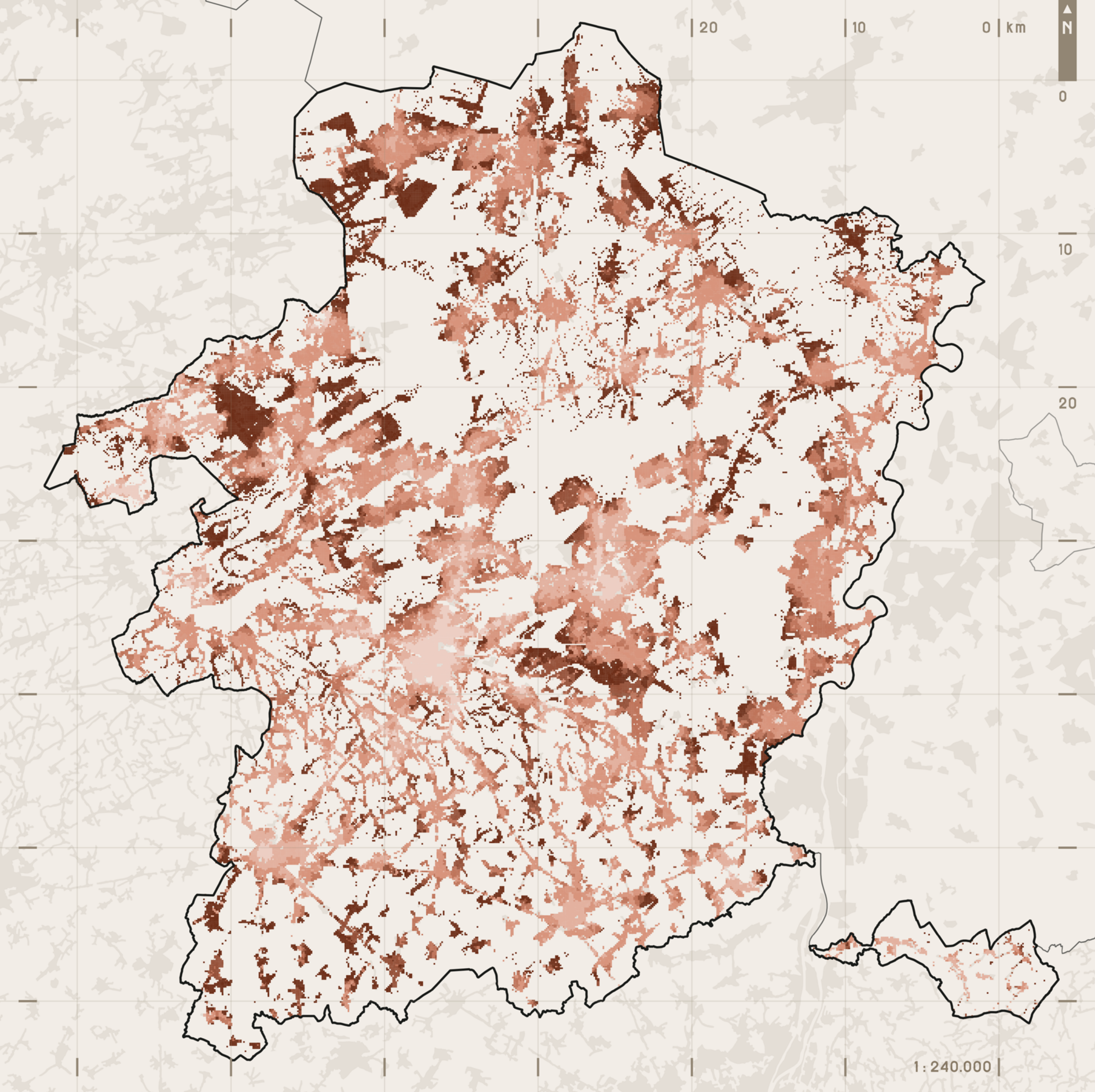
BUS SERVICE FREQUENCY IN 500 METRE:
HECTARE WITH RESIDENTS AND/OR WORKPLACE

- 15-min service
- 30-min service
- 60-min service
- No frequent service
- Railways

Figure 38. The frequency of bus service as of 07 October 2021, from 07h to 20h. Data Source: De Lijn, SNCB/NMBS, OVapi, AVV, TEC

Before conducting the actual accessibility analysis, the public transportation service level has been also calculated using static GTFS (General Transit Feed Specification) data on 07 October 2021, from regional transportation providers (De Lijn, Flanders, Belgium; NMBS/SNCB, Belgium; TEC, Wallonia, Belgium; OVapi, the Netherlands; AVV, Regio Aachen, Germany). The frequency has been calculated only between 07:00:00 to 20:00:00, since De Lijn service in Limburg stops only at 20 – 21h.

It is visible that outside of major cities and few major roads between cities, frequent service is often not ensured, and same applies to small cores in southern Limburg. In the case of industries south of Genk and along IJzeren Rijn, there have been barely any public transportation options were provided.



LEGEND

NR. OF JOBS WITHIN 30 MINUTE PUBLIC TRANSPORT RIDE

0
500
1000
2000
5000
10000 +

Figure 39. Number of jobs accessible from certain point using public transportation within 30 minutes analysed using UrbanAccess (Blanchard & Waddell, 2017)

Static GTFS

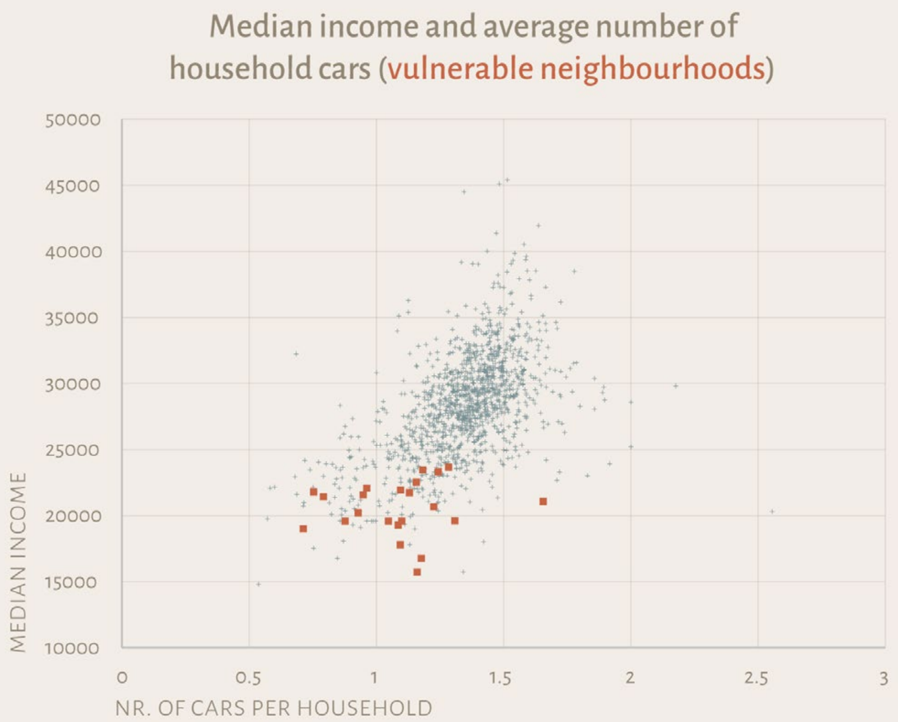
There are static GTFS and real-time GTFS: static GTFS is like a timetable book, which contains the pre-determined routes and timetables of certain date and time. Real-time GTFS on the other hand is like the station screens: it also receives actual locations and route data of the transit service, such as delays, current location of vehicles, and detours.

A Location-based accessibility analysis on the current public transportation network is conducted using the static GTFS data, within the timeframe: 07:30:00 to 11:30:00. It used the python package UrbanAccess (Blanchard & Waddell, 2017). It measures number of jobs within 30-minute reach, which the 30-minute cap is set according to Marchetti's constant (Marchetti, 1994). On-demand buses (Belbus) lines has been removed from the GTFS data, which was registered on De Lijn's GTFS data as a bus route with 30-minute interval.

The resulting accessibility map shows clearly that the Industrial sites along the Albert canal is poorly served, despite undergoing significant transition. This suggests that current transportation network does not serve the employment opportunities, even though the accessibility analysis' time scale is limited to morning peak hours. Moreover, the lacklustre public transportation is not limited to ribbon developments, but also on smaller towns that does not necessarily have issues with urban forms.

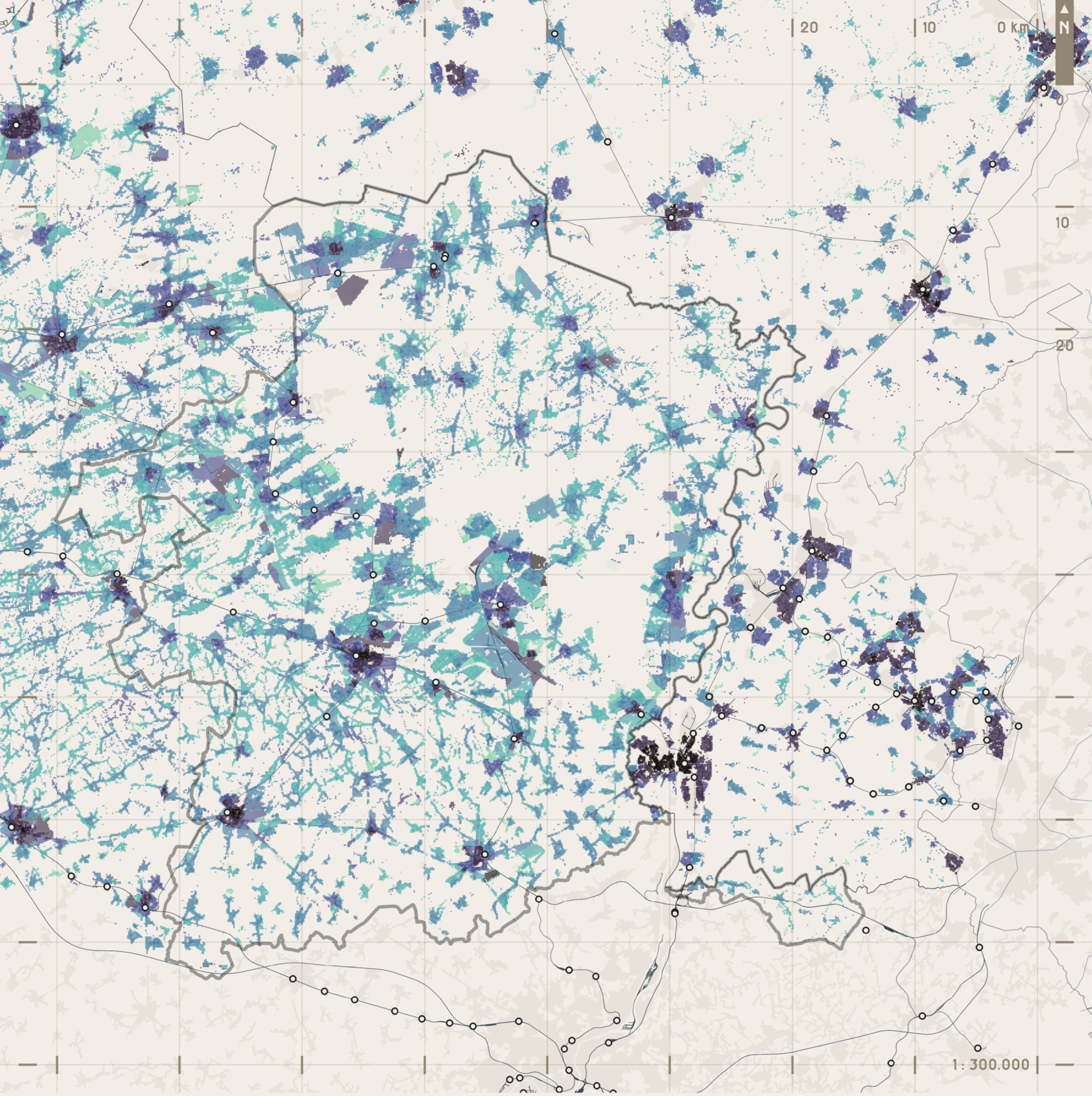
4.2.2 TRANSPORT POVERTY

Figure 40. Median income and average number of household cars per statistic sector in Limburg. Data sources: Statbel (2021)



Another aspect on mobility and immobility, also related to mobility justice, is transportation poverty (vervoersarmoede). Transportation poverty is marginalisation from (social) life and employment opportunities caused by limited mobility options, and the following poverty (Canters et al., 2015). The concept therefore elaborates the link between immobility and poverty, which roughly speaking works both ways: on the one hand, the lack of accessible transportation options pushes people towards poverty, while also on the other hand, people already suffering from poverty or in risk of going into poverty (i.e. disabled, elderly) also can suffer mobility challenges on top of existing hardships (Ibid.).

As seen on Figure 11, the neighbourhoods that were created for the workers in coal mining and industries are now facing severe socioeconomic challenges with a mainly migrant population. Naturally, such areas with moderate to serious socioeconomic challenges also translate to relatively lower access to cars than average Limburgers (Figure 40), suggesting a type of immobility mixed with social exclusion, poverty, and discrimination.



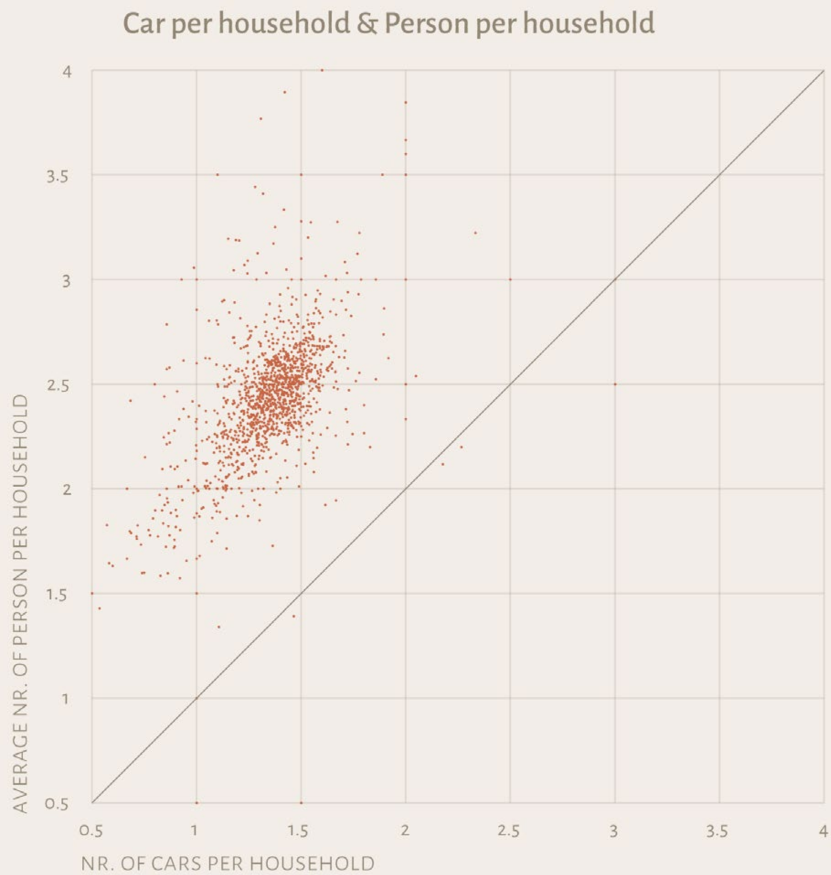
LEGEND

Nr. of cars per household, in habiatated 1 ha areas

- 0 - 0,7
- 0,7 - 1
- 1 - 1,2
- 1,2 - 1,4
- 1,4 - 1,6
- 1,6 - 1,8
- 1,8+
- Railway station
- Railway track

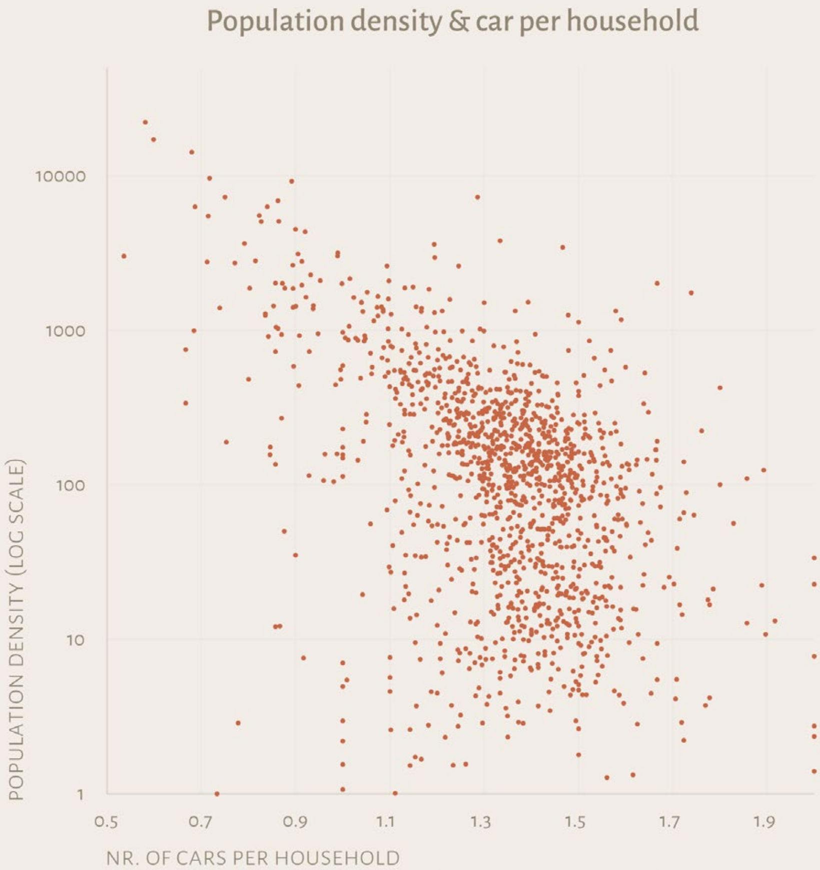
Figure 41. Average number of cars per household, on built-up areas. Data sources: Statbel (2021), CBS (2021)

Figure 42. Average number of cars per household (x) and household size (y) (upper), and Average number of cars per household (x) compared to population density (y) (below). Data sources: Statbel (2021)

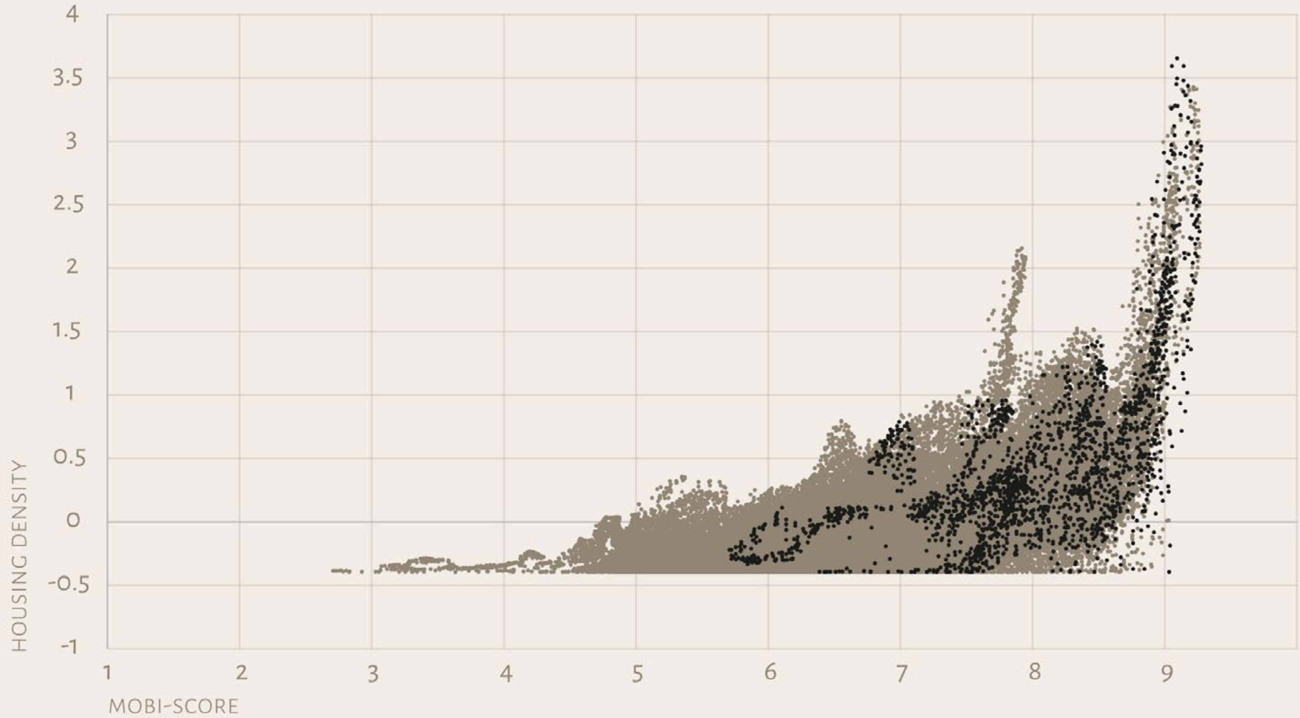


On areas where socioeconomic issues are not as apparent, immobility can still be present everywhere. While car ownership is certainly higher in the countryside, yet it is also not high enough to ensure complete access to every residents in the countryside. The average number of cars per household do not exceed 2 in vast majority of the neighbourhoods, while the majority of households have higher than 2 to 3 members in the household.

Naturally that includes young people who cannot get driver's licence, but that does not mean that they do not suffer from immobility; this limits their access to opportunities and activities, and can possibly influence their personal development towards an adult. Therefore, the fourth type of immobility can be identified: people in countryside that does not always have access to cars.



Housing density & Mobi-score:
Within 500 m of spartacuslijn vs outsode of Spartaucslijn



Car per household & Median net taxable income (2019)
Spartacuslijn vs non-Spartacus statistic sectors

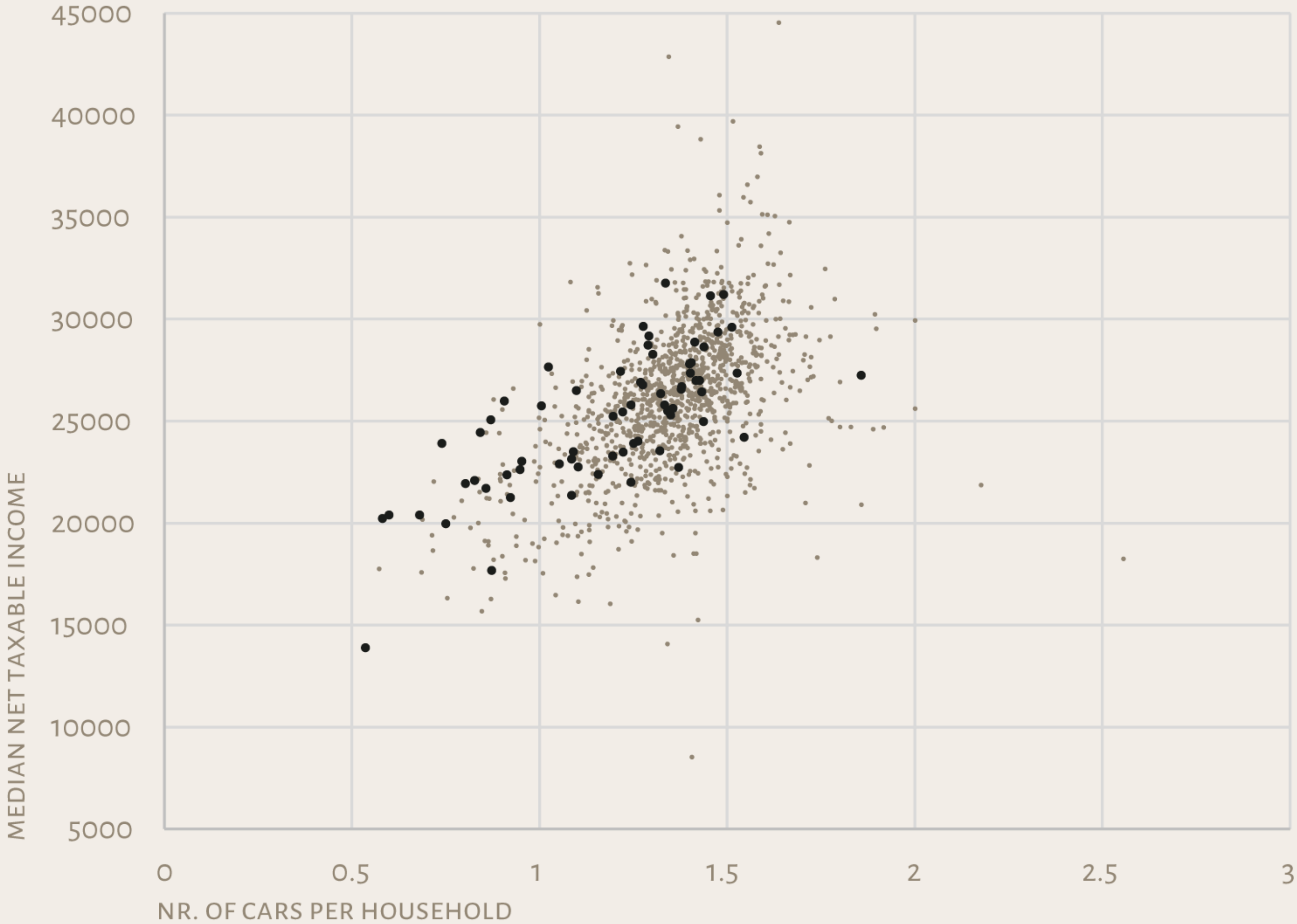


Figure 43. Graph: Housing density (y) and Mobi-score (x), hectare-level data; within 500 m of Spartacuslijn stops vs outside of Spartacuslijn stops (above) and Statistic sector-level car per household (x) Median net taxable income (y) (below). Data sources: Statbel, Departement Omgeving

And how does Spartacusplan relate to it? If looked into where Spartacuslijnen serve, it serves more or less the average neighbourhoods in Limburg, with slight tendency to serve areas with less car ownership. This is likely due to the stops being located in more urbanised areas. If looked per hectare level, it is evident that the vast majority of the Spartacuslijn's stop catchment areas are already well-served with public transportation; majority lies in areas with mobi-score higher than 7, indicating good level of amenities and transit connectivity. This also means that Spartacuslijn will provide less value in tackling immobility, as its focus lies mainly in existing well-connected transit cores.

Through the analysis on the accessibility and transportation poverty, it could be concluded that four types of immobility can be idenfied, which Spratacuslijn cannot sufficiently tackle.

1. Discrepancy in transit offers between employment opportunities and people.
2. Lacklustre public transportation across the countryside, regardless of the present issues with urban forms (both ribbons, dispersed buildings, and cores).
3. Immobility from social exclusion, poverty, and discrimination.
4. Immobility from lacking access to cars, temporarily or permanently.

4.3 MOVEMENT PATTERNS: QUANTITATIVE

The quantitative analysis over movement patterns can provide insights on the movement patterns and demands of the region in the larger scale. They will provide insights on the poly-centricity of Limburg: what is Limburg like compared to other regions, where people would wish to travel to, and who are commuting to, and finally where attracts the travel demands.

Looking at the broader commuting pattern in the national scale on Figure 44, it is visible that despite its proximity and ease of access (S43 train / A13 motorway) and economic importance, commuter flow to Liege and other parts of Wallonia remains relatively low, even compared to the Netherlands, where cross-border transportation infrastructure is poorly provided (no train connection, no motorway connection to Maastrict, Eindhoven, Weert; motorway A2-A76 only connects Sittard-Geleen and Parkstad). The Netherlands is one of the largest commuting destination for the region, while Liege and Wallonia's number lies lower than that of Halle-Vilvoorde, a region further away that shares the same language. It can be concluded that in terms of commuter flows, the language border remains unfortunately strong in the region, coupled with the relatively unfavorable economic situation in Wallonia. Tackling language borders and economic situation with Wallonia is unfortunately out of the scope of the study.

It is also noticeable that Limburg keeps relatively balanced inflow-outflow ratio towards other regions, except large urban regions of Antwerpen and Brussels. The high imbalance towards Netherlands is also noticeable, where far higher number of people commuting to the Netherlands than other way around.

Given the lacklustre rail network between Dutch and Belgian Limburg and high dependency between the two, it can suggest that immobility may present for those wishing / needing to travel across borders.

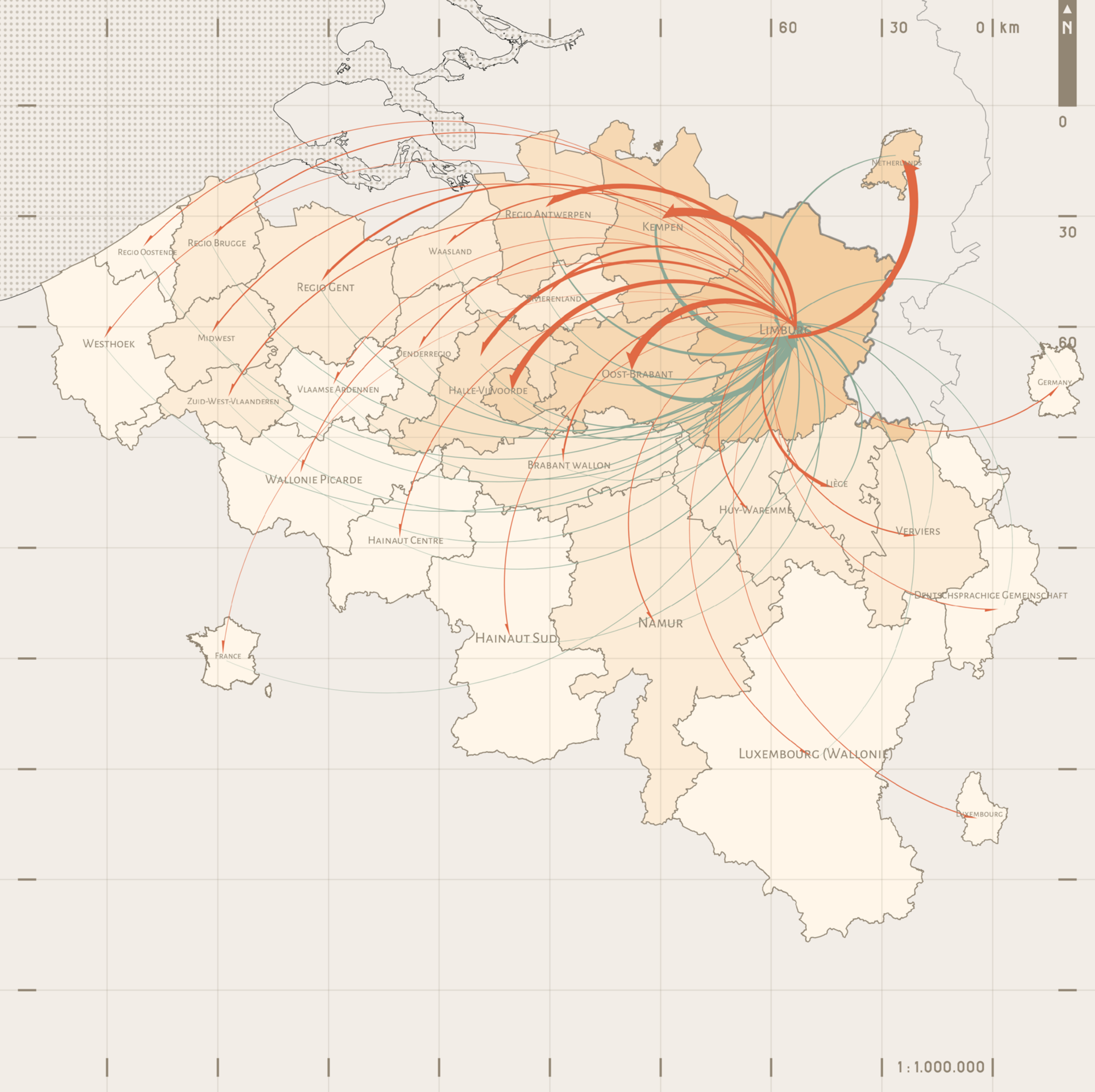
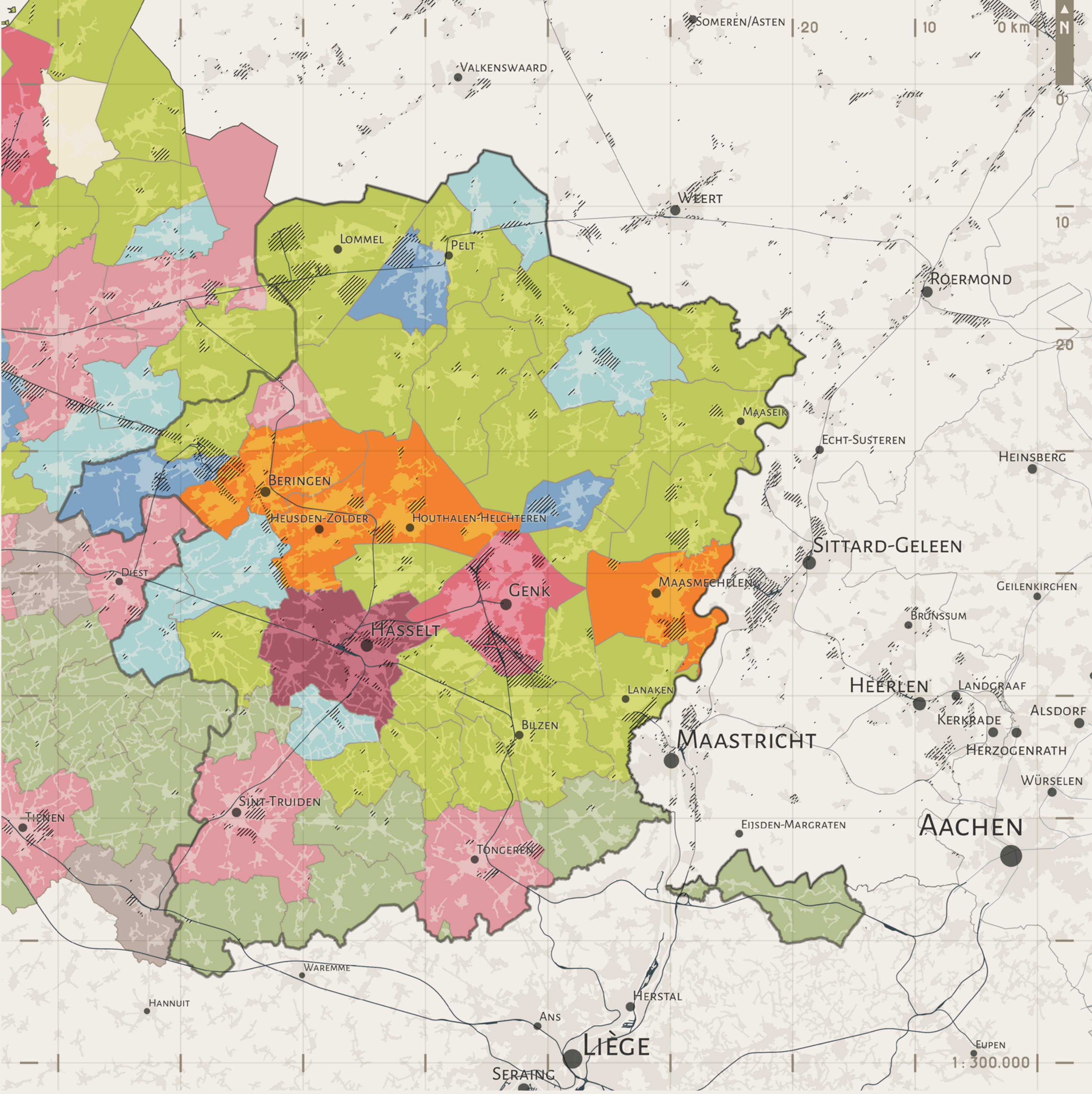


Figure 44. Commuting pattern across regions to and from Limburg. Data source: Steunpunt Werk (2022)

LEGEND

Nr. of commuters to and from Limburg

- 0 - 500
- 500 - 5000
- 5000 - 10000
- 10000 - 50000
- 50000 +



LEGEND

- Major cities
- Railway
- Major regional cities
- Regional cities
- Medium-sized cities
- Urbanised rural communities with industrial activity and demographic growth
- Rural and agricultural municipalities with industrial activity
- Highly urbanised municipalities with low incomes
- Shrinking, less urbanized municipalities
- Rural or urbanised rural municipalities with strong demographic growth
- Small agricultural municipality
- Rural

Figure 45. Classification of municipalities according to BELFIUS based on economic structure. Data source: Belfius (2018)

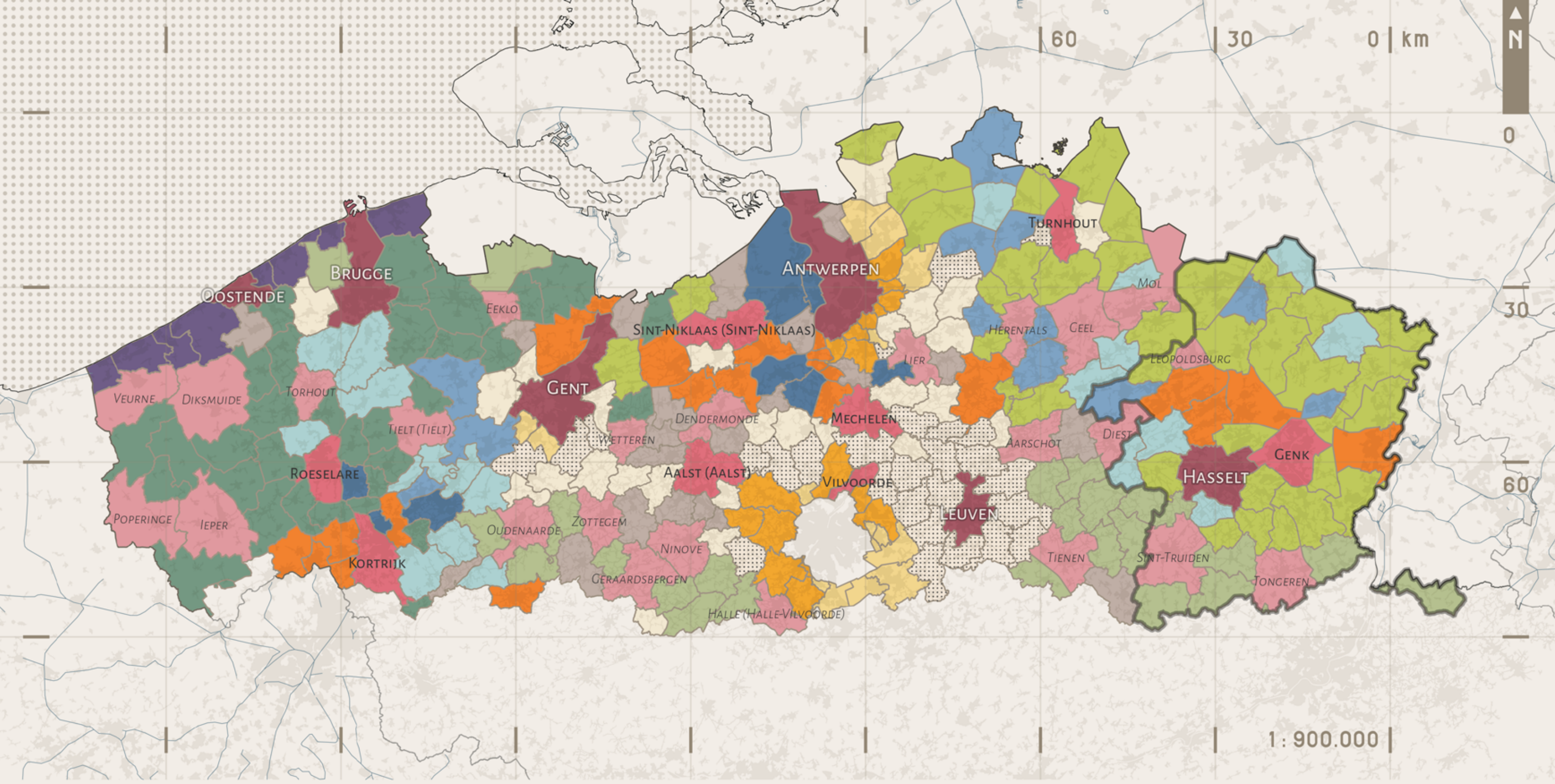


Figure 46. Classification of municipalities according to BELFIUS based on economic structure. Data source: Belfius (2018)

LEGEND

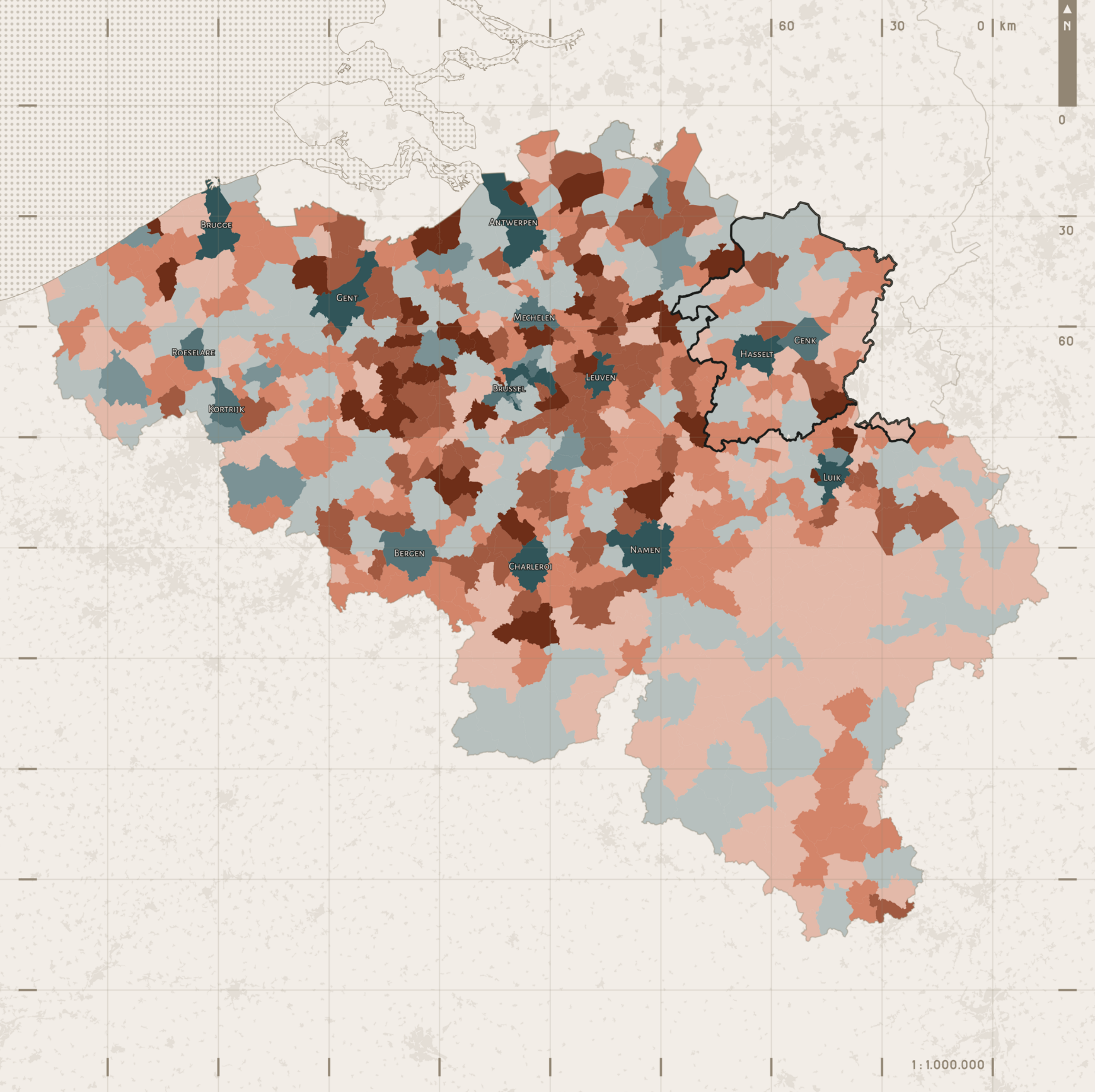
- Major regional cities
- Regional cities
- Medium-sized cities
- Cities and conurbations with an industrial character
- Urbanised rural communities with industrial activity and demographic growth
- Rural and agricultural municipalities with industrial activity
- Highly urbanised municipalities with low incomes
- Agglomeration municipalities with tertiary activity
- Residential suburb with high income
- Shrinking, less urbanized municipalities
- Urban fringes
- Rural municipality with heavy aging
- Rural or urbanised rural municipalities with strong demographic growth
- Small agricultural municipality
- Rural
- Coastal municipalities

Vlaamse Ruit

Vlaamse Ruit is the urbanised region between Gent, Brussel, Antwerpen, and Leuven, where large portions of Flemish population and economic activities take place.

Now it is clear that Limburg holds close relationship with the neighbouring Netherlands as a border region. Then the next question would be: what is Limburg actually like? For that, Belgian bank BELFIUS classifies the economic structure of Belgian municipalities into 16 types. According to Belfius classification, Limburg is relatively clearly rural compared to the Flemish diamond ("Vlaamse Ruit"); but also, it has several urbanised areas scattered across the province focusing on industrial activities. There is one major city (Hasselt), one regional city (Genk), and three medium-sized cities across the province, mainly along the railway lines. The central Limburg's former coal mining cities are classified as highly urbanised, low-income cities, and several industrial cities scatter around waterways and IJzeren Rijn. This diffuses the centrality of the region, which is a stark contrast with centralised areas Leuven (Smets et al., 2014).

From the study of Belgian municipalities, BELFIUS also noted that younger families Limburg and West Flanders tend to move closer to Brussels in Vlaamse Ruit; which they called it the "Brussel-effect". It can suggest further that the attraction inside Limburg remains lower mainly for younger population who wishes to work in the knowledge economy, which the lack of connectivity towards new industrial locations, such as incubators, can be contributing to.



LEGEND

Net commuter flow

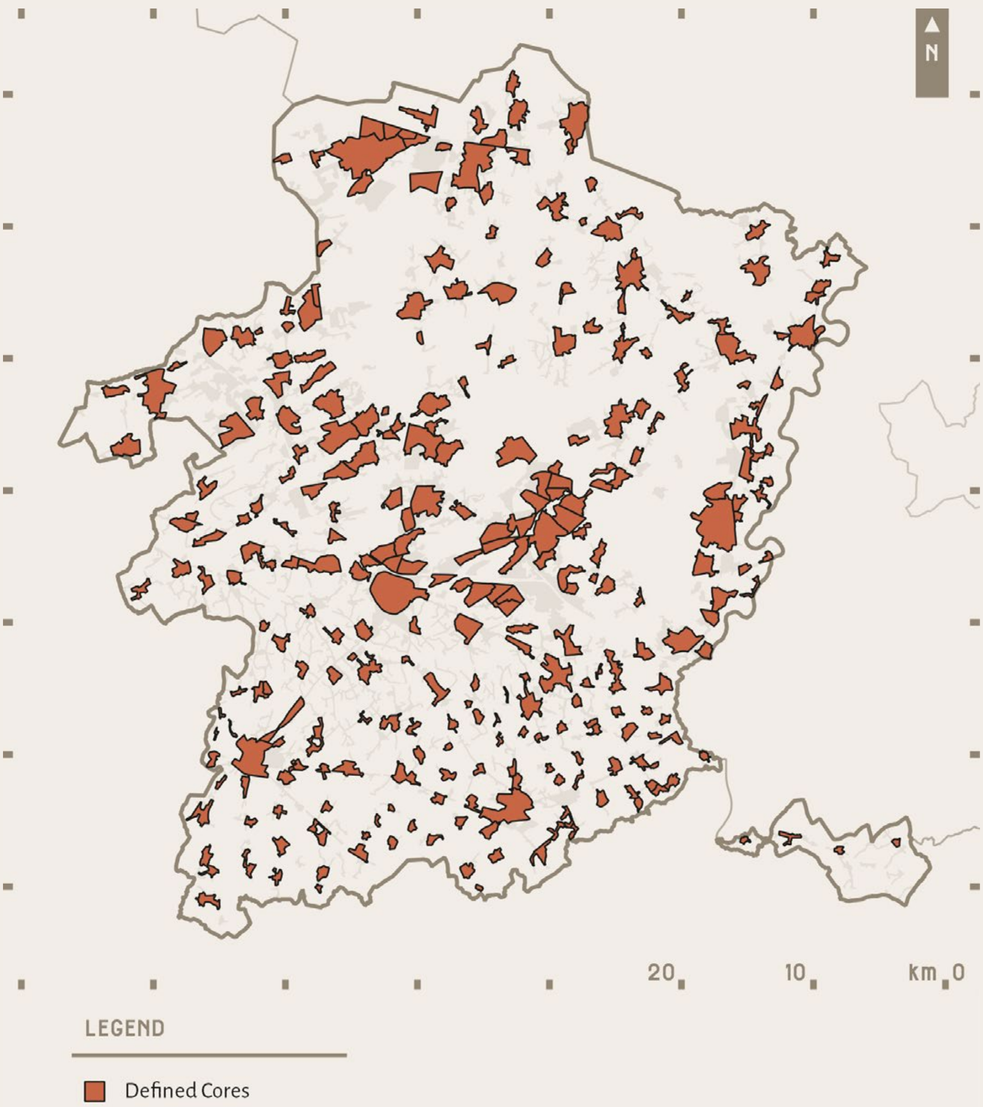
- -5642 - -3000
- -3000 - -2000
- -2000 - -1000
- -1000 - 0
- 0
- 0 - 10000
- 10000 - 20000
- 20000 - 30000
- 30000 - 184165

Figure 47. Net commuter flow of Belgian municipalities. Data source: Steunpunt werk (2022)

Looking into the actual commuting pattern, thanks to the dispersed industrial activities, the “magnet” cities of Hasselt and Genk do not completely dominate the commuter flow; this is again visible when compared to nearby urban areas of Leuven, where its surrounding municipalities are almost exclusively funnelling commuters into Leuven. In Limburg, especially in Central and North Limburg, cities take a net inflow of commuters. The relatively suburbanised South Limburg, on the other hand, tends to have higher outflow than inflow.

Figure 48. Calculation method of dividing commuter flow per cores, originally from Vandekerckhove et al. (2018)

Figure 49. Defined cores in Limburg and the Netherlands. Limburg's cores defined by Vandekerckhove et al. (2018)



While municipality-level analysis useful to get rough insights, such scale is too generalised for planning purposes. Therefore, by using the methods by Vandekerckhove et al. (2018) used in the Regional housing market study of Limburg, the "cores" are defined. And then the commuting patterns are assigned to each core through the process shown in Figure 49. For Belgian Limburg, the pre-determined cores by Vandekerckhove et al. (2018) are used, and Steunpunt Werk's commuting data along with Vlaams Planbureau voor Omgeving's hectare-level raster data for jobs and population is combined.

The same process has also been applied to the nearby Netherlands, where Spartacuslijn originally aimed to connect. For the Netherlands, CBS neighbourhood (buurt) data has been used. Neighbourhoods with urbanisation level (stedelijkheid; determined by density of addresses) 1, 2, and 3 have been selected and filtered to be defined as cores. Following Vandekerckhove et al. (2018)'s method, the continuous urban fabric has been congregated into one core by comparing it with satellite imagery. For the Netherlands, only population data is used; therefore, no jobs or commuting pattern is analysed.

It should also be noted that the "cores" in this chapter are not the same concept as the cores introduced in Chapter 1, as the cores in this chapter mean "congregated settlements that can be a potential destination for transportation service", while the cores in Chapter 1 is a classification based on the analysis on the built form of the area. Therefore

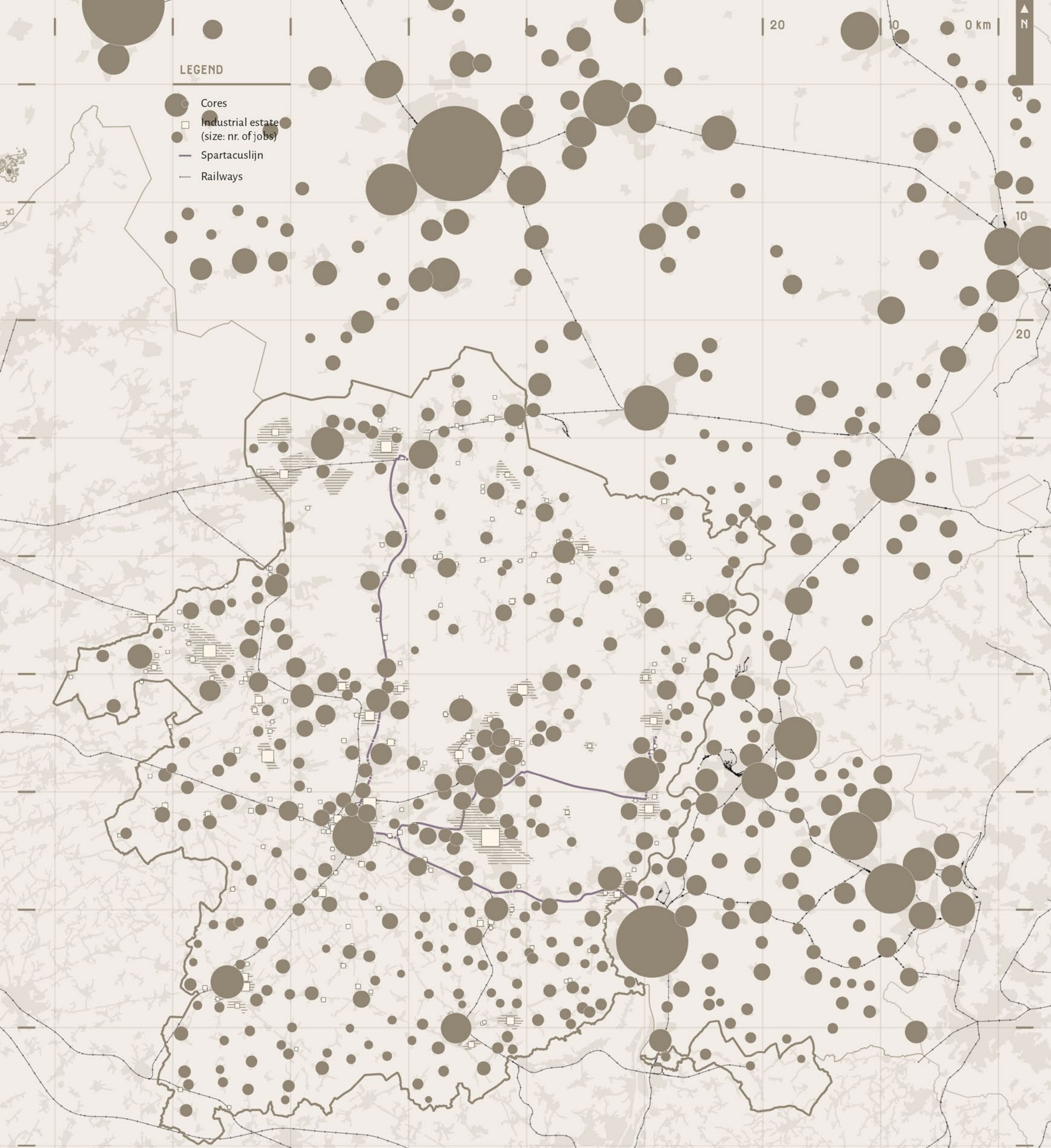
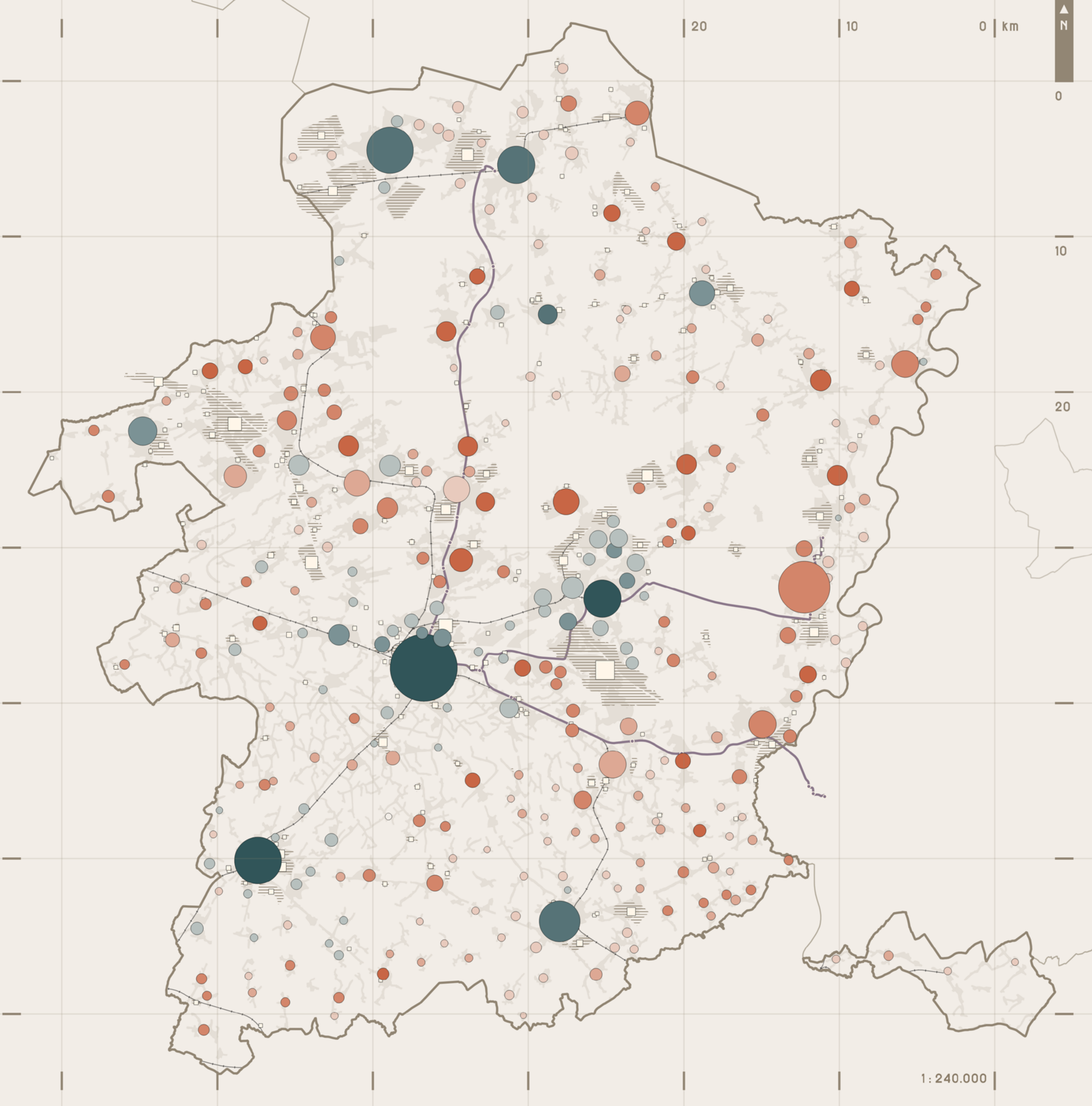


Figure 50. Image: The defined cores in Belgian Limburg and the Netherlands. The size of each core's symbol represents the size of population.

the former can include areas classified as ribbons or even dispersed buildings in the latter. Outside of this chapter, the cores would mean the cores (in contrast to ribbons and dispersed buildings) introduced in chapter 1.1.

The defined cores show that Dutch cores tend to be larger than Belgian counterparts. This is due to multiple reasons:

1. The Dutch Limburg's population density (526/sq km) is much higher than that of Belgian Limburg (364/sq km)
2. The relative lack of diffused urbanisation in ribbons and dispersed allotments let higher percentage of residents to actually live in the village cores rather than dispersed



LEGEND

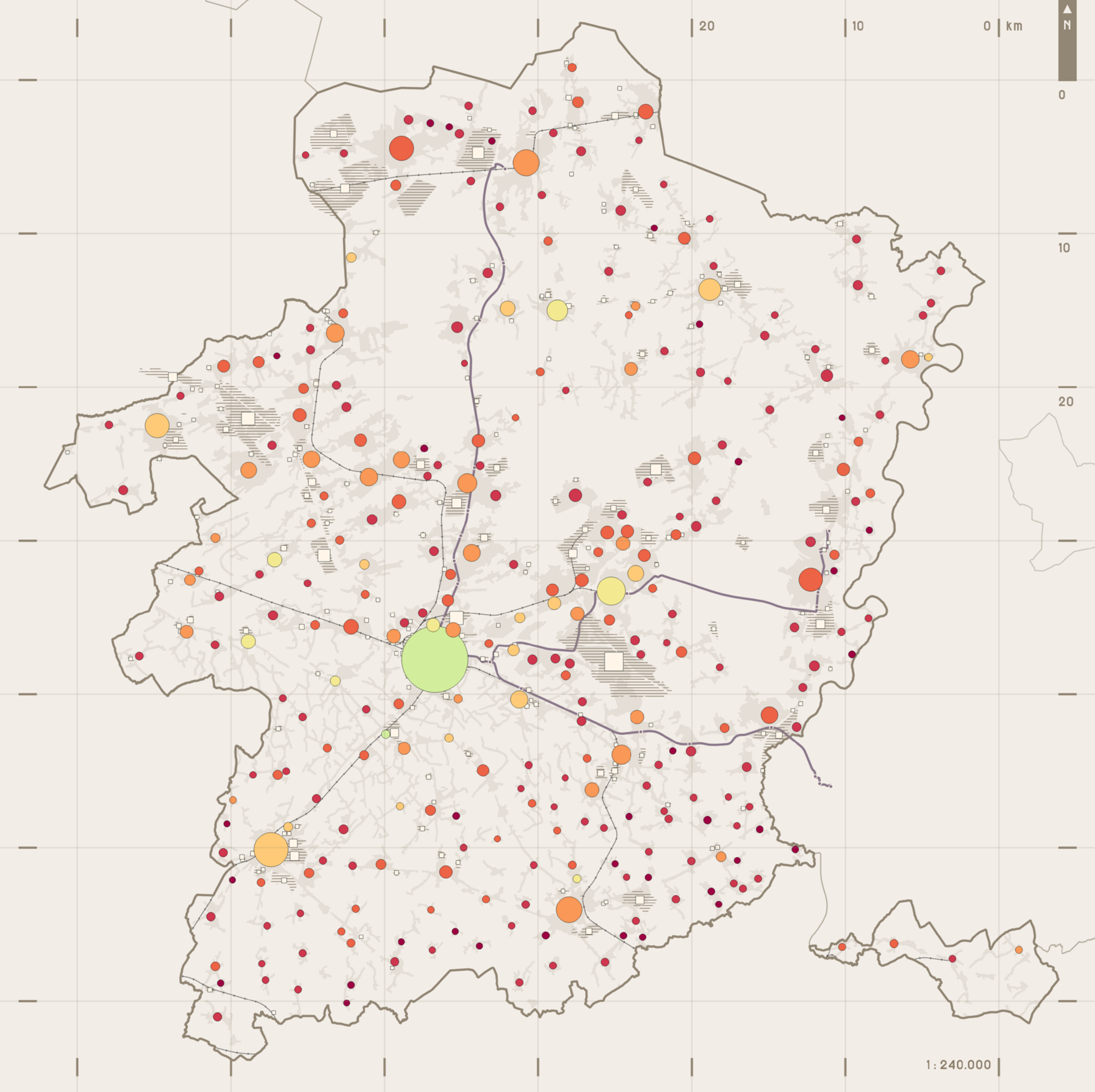
Net commuter flow
(dot size: population)

- -1200 - -400
- -400 - -200
- -200 - -100
- -100 - 0
- 0
- 1 - 500
- 500 - 1000
- 1000 - 2000
- 2000 - 20000
- Industrial estates (size: nr. of jobs)
- Railways
- Spartacuslijn

Figure 51. Net commuter flow of cores calculated with method of Vandekerckhove et al. (2018) using Steunpunt Werk data (2022).

areas. It is clearly visible through the underlay of built-up area on the map (Figure 45), where Dutch Limburg has little to no built-up area visible outside of the cores (most of them are industrial estates), while in Belgian Limburg plenty of such lands are visible.
3. The difference in scale between Belgian Statbel's statistical sectors and Dutch CBS' neighbourhoods resulted in the Dutch cores covering much wider area than Belgian cores; Belgian cores only cover the town itself without the ribbon developments from it, while Dutch cores generally cover whole area surrounding the town.

From the transportation planning perspective, however, it wouldn't be a wrong statement to say that Dutch cores can expect higher ridership than Belgian cores due to their relatively concentrated built forms.



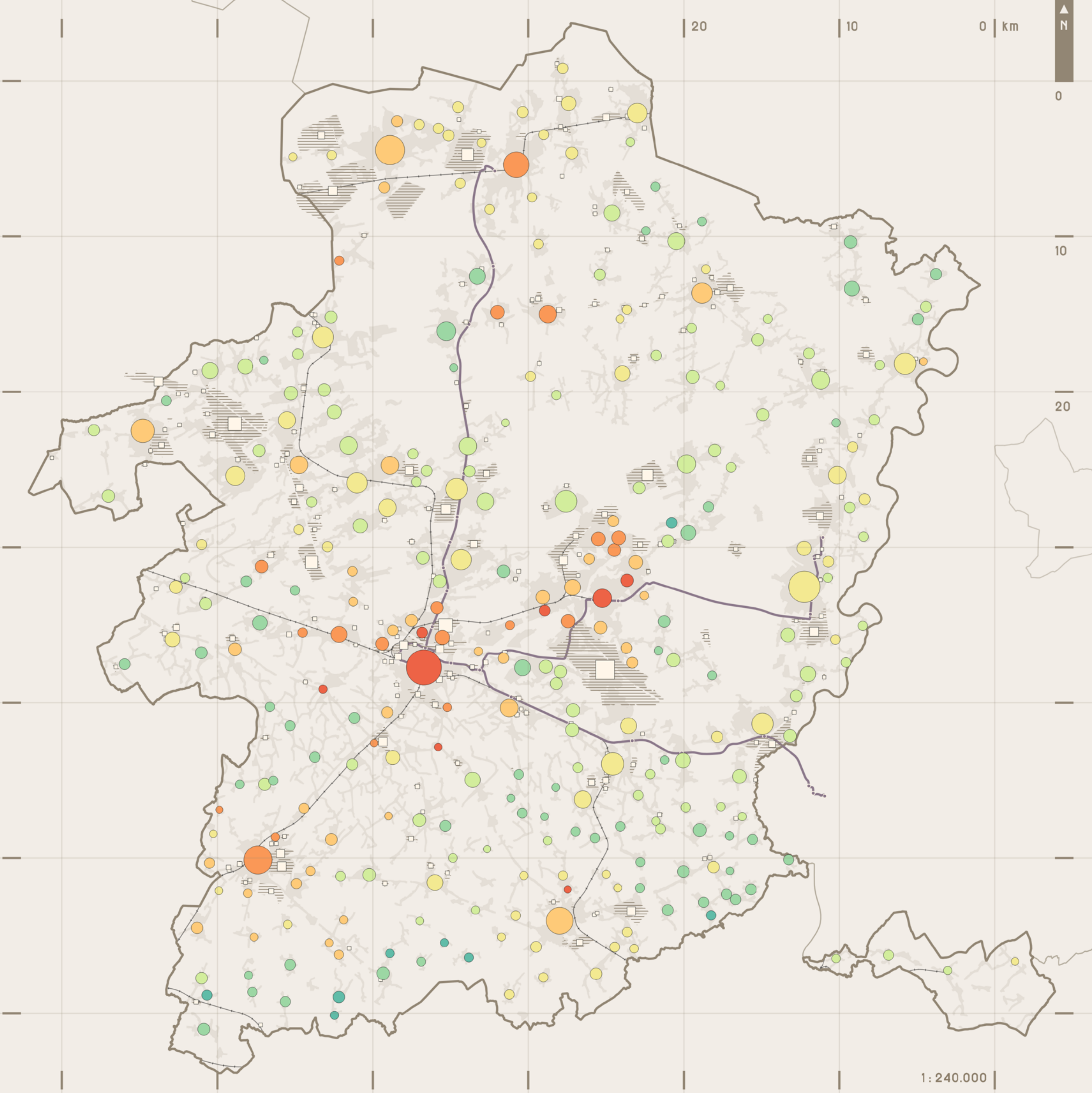
LEGEND

Percentage of incoming commuter flow
(dot size: incoming commuter flow)

- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 +
- Industrial estates (size: nr. of jobs)
- Railways
- Spartacuslijn

Figure 52. Commuter inflow of cores calculated with method of Vandekerckhove et al. (2018) using Steunpunt Werk data (2022).

The inflow of commuters is generally concentrated in Hasselt, but also mid-size clusters are visible in North Limburg and across the coal mining areas. Moreover, while Hasselt city centre attracts a large number of commuters in the region, that is only limited to "urban" economic sectors since this is only calculating the cores without industrial estates. The presence of large-scale industrial areas in Genk, Houthalen-Helchteren, and Beringen cannot be ignored.



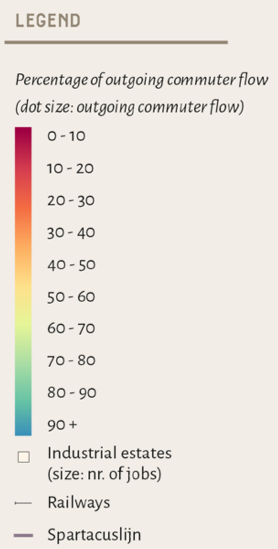


Figure 53. Commuter outflow of cores calculated with method of Vandekerckhove et al. (2018) using Steunpunt Werk data (2022).

The outflow of commuters is noticeably higher in the rural South Limburg, likely due to its rural and suburban character without significant employment opportunities inside each municipality. The relatively larger cores in the North Limburg show balanced inflow and outflow, and retain net inflow of commuters. One notable outlier is the former coal mining city of Maasmechelen, which despite its relative size remains the biggest source of outflow of commuters.

This illustrates that the concentrated service into Hasselt, as it is planned with Spartacusplan, will not be the ultimate solution; the poly-centric character of the region demands more diverse destinations and service patterns than currently planned.

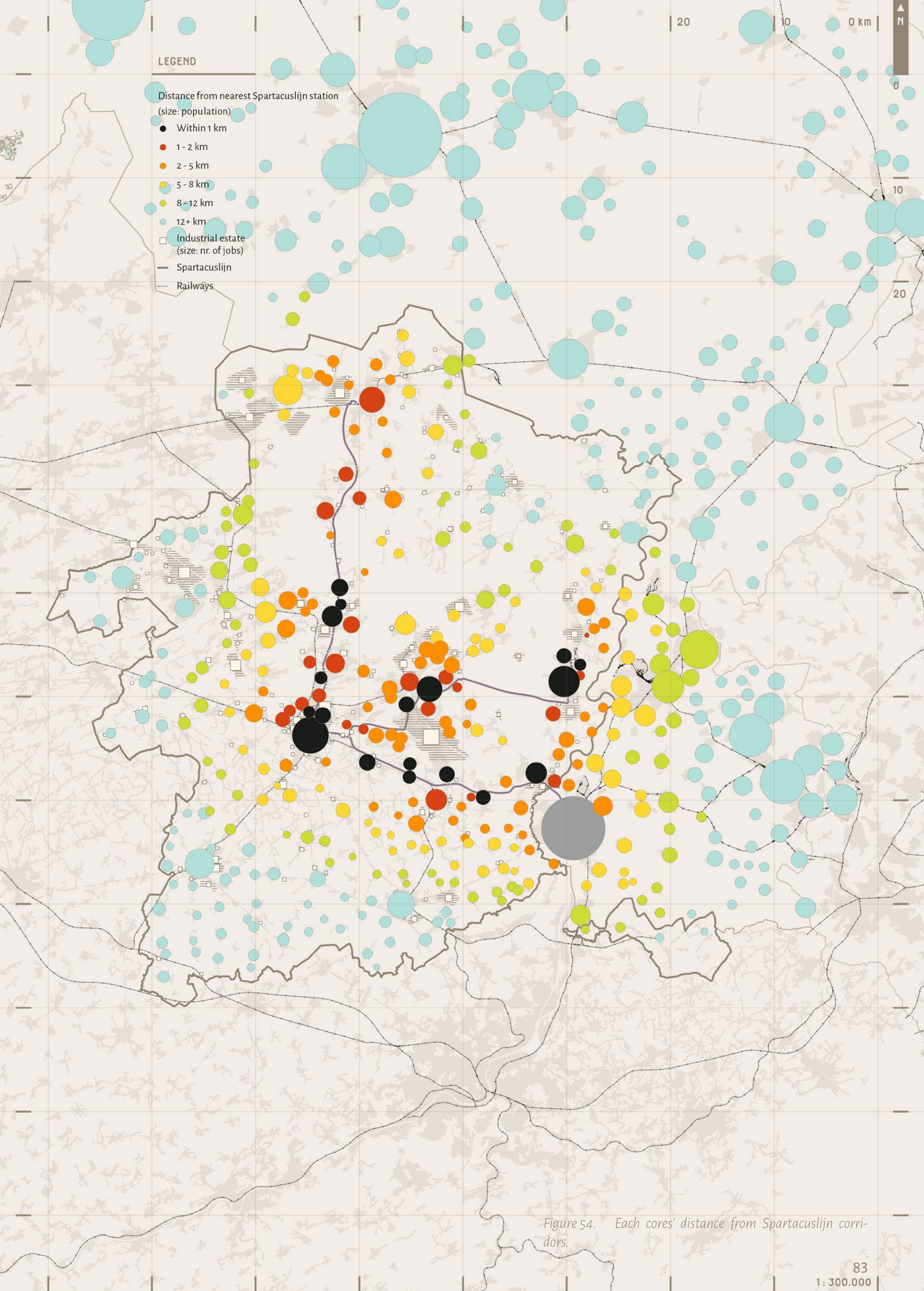


Figure 54. Each cores' distance from Spartacuslijn corridors.

The issues with Spartacusplan are further illustrated in Figure 54. Only 19 cores are directly served by Spartacuslijn, and despite serving the centre of each large city, due to the dispersed population, the share of the directly served population is extremely low. Several cities that are supposed to be served by Spartacuslijn is also not directly served in practice, due to the traject of Spartacuslijn being distanced from the actual town centre. This concerns Bilzen (Railway line 20 Munsterbilzen), Hechtel-Eksel (N74), parts of Zonhoven (N74), and Pelt (relocated station Overpelt). Moreover, in relatively poly-centric cities like Genk – where several cores are present inside the city – majority of the city's population is not directly served by Spartacuslijn.

In conclusion, Limburg is a relatively rural, poly-centric region with significant cross-border commutes with the Netherlands. The current Spartacuslijn's isolated operation would not sufficiently address the diverse needs for destinations. From this knowledge, the hypothesis will be created on Chapter 5, and the manifesto will be set on Chapter 6.

In terms of immobility, on top of the currently defined immobility presented in previous chapters, immobility that spurs from having destinations other than the current central destinations can also occur, which will significantly increase the travel time burden with transfers and possible buffers for connection risks.

4.4 MOVEMENT PATTERNS: QUALITATIVE

Not all travel behaviours and immobility are quantitatively translated. Therefore qualitative research over immobility in Limburg will provide the experiences of the users on (im)mobility into tangible form. This will result in personas and their average day of life in a week, which will be used to embody the patterns of immobility and reflect it into the design tool (pattern language), and also used to measure the design effects on Chapter 9.

4.4.1 OBSERVATIONS

Through the fieldwork and unstructured, spontaneous interviews on the users of public space, a thorough understanding of people's image of public space, transit space, and destinations is made. Observations on how they would behave in the public transport space is also made, throughout the total of 18 trips in buses around Limburg. The results are used in creating the persona and further design of the testing locations.

In fieldwork and interviews, the lacklustre public transportation offer in Limburg has been painfully apparent: majority of the countryside service were served as "school-bus", which runs twice a day, and even the urban lines were out of reach after 20:00. The poor service frequency, off-peak timetable, and (the absence of) late-hour services has been a constant topic that was unanimously reported among interviews. Another noticeable pattern of complaints were time burden, where many reported even with rail service and frequent buses present, the multiple transfer between parts of journey made the travel time burden unbearable to take public transportation.

In terms of the feelings of public transportation space, unlike my original hypothesis which expected some degree of dislike towards public transportation due to "primary emotions" (i.e. safety, hygiene), surprisingly respondents had very little complaints on primary emotions regarding public transportation. Most stated that such problems are not really an issue in Limburg, and again highlighted the aforementioned service pattern as major obstacle.

My observation was in line with that, and actually found the beaviours in public trans-

Figure 55. Map of visited sites between 2022 and 2023 by author.

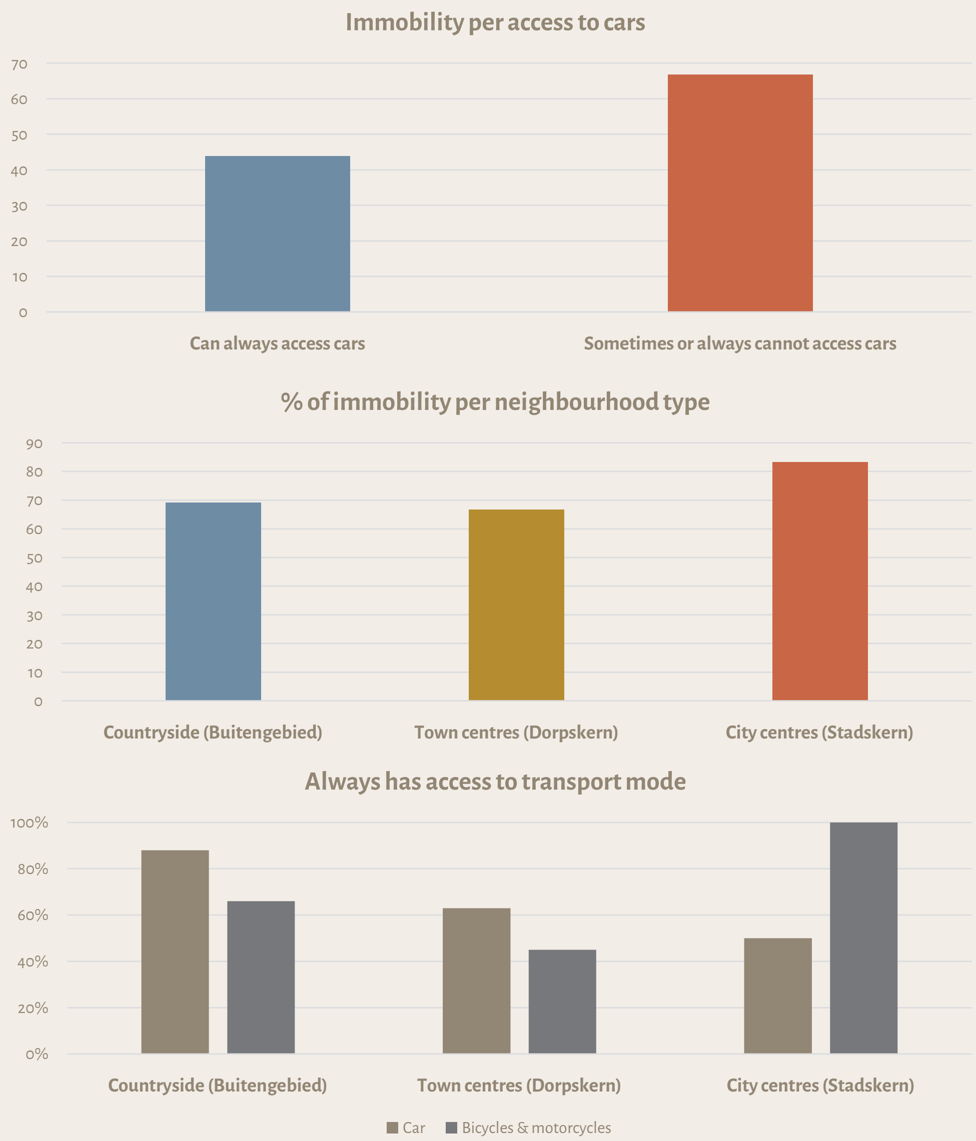
port space far more trusting and active than that of the outdoor public spaces: in outdoor public spaces, it was common to see no apparent activities other than pure traverse for 30 minutes (Stadhuisplein Hoeselt Friday 17:00, Neighbourhood park Sledderlo, Friday 11:00), and even town centres like Peer was also void of activities with noticeably older patrons. In Limburg outside of Genk and Hasselt city centre, outdoor public space (including bus stops) was relatively less used compared to that of Vlaamse Ruit, where one can spot users of public space and interactions in nearly every corner of the city. Such interactions appear to occur more often inside the public transportation vehicles where residents already know some of the familiar faces, travelling in groups, or share their purpose (travel). This is also in line with the observations of Flemish cultural anthropologist Ruth Soenen who highlighted the importance of “small encounters”: an urban encounter between strangers that does not last long nor becomes a deeper relation, which forms the social character of urban public space (Soenen, 2006). This pattern of small encounters was also found in lesser degree inside places where commuters often visit as part of their home – work travel, such as in local chip shop (Frituur) in Hoeselt.

This would mean that since the public transportation itself does not need to suffer from image problems from higher-income passengers like in Brussel / Antwerpen, which suggests that the modal shift would be far more easier to achieve in Limburg, if provided with actually viable service that does not come only twice per day, stopping after 20h. The presence of “small encounters” and relatively lower anonymity in the public sphere in Limburg in general – compared to Antwerpen or Brussel – can also support the case for mobility transition. The project’s hypothesis – using a smaller vehicles that does not feel too anonymous or busy, and a service pattern that combines the countryside with urban trunk line services into a single-seat journey, could be visioned as a pleasant and social journey full of “small encounters” if implemented.

4.4.2 ONLINE SURVEY

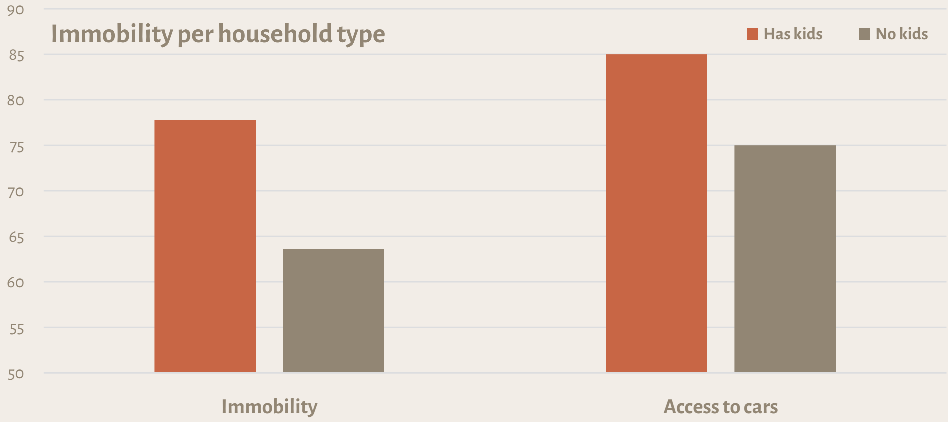
Figure 56. Survey results on immobility and access to cars (up), neighbourhood type (middle), and access to transportation per neighbourhood type (low)

On top of the fieldworks, the online survey was conducted to understand broader tendencies of immobility. Survey resulted in total of 54 responses, where 38 answered until the question of immobility, and 23 filled in the survey fully, with detailed information on their wished movement destinations and time.



Unlike the original hypothesis, immobility was more dependent with the person's access to cars, rather than the location itself; as the city centre residents had significantly lower access to cars, the percentage answered that they have immobility issues were higher in cities than countryside. However, it should be noted that the survey did not collect data from people younger than 16 to comply General Data Protection Regulation, therefore immobility in countryside may come out much higher if accounted for all age groups.

Figure 57. Immobility per household type



If looked through the household types, the immobility of the youth were indirectly reflected through this: despite having higher access to cars, immobility was much higher in households with kids than those without cars. This is likely due to them having more demands for trips, as children have their own destinations to cover (school, scouts...) that often needs to be driven by their parents.

Figure 58. Categorised purpose of desired (wished) trips

The desired trips' purpose could be classified into 4 categories: visiting someone, free time activities, exercise, and essential activities such as grocery shopping or visiting a doctor. Most Exercise and essential activities were often desired to be combined with commute, with exception of people who reported that they need to travel while their partner is at work. The other two types were predominantly wished to be done during the day and weekends.

In conclusion, from the analysis, the 6 types of personal immobility can be defined, along with 2 immobility patterns affecting the industries.

The resulting immobility patterns are assigned to persona creation (except industry-related immobility and cross-border commute) and provides insight to the creation of patterns in further chapters.

A. Immobility from spatial remoteness: lacking public transportation across the countryside, regardless of the present issues with urban forms (both ribbons, dispersed buildings, and cores).

B. Immobility from with social exclusion, poverty, and discrimination.

C. Immobility from lacking access to cars, both permanently or temporarily.

D. Immobility from travelling across national borders on public transport.

E. Immobility from poly-centricity: having non-central destinations that require extreme time burden due to transfer.

F. Immobility from dependants (i.e. kids)

G. Discrepancy in public transportation offers between **employment opportunities and people**.

H. Immobility of ideas and talent: lack of good connection and network between innovative industries.

4.5 PERSONAS

With the defined types of immobility, the persona of 4 demographic groups has been created as an personified outcome of this chapter. The resulting personas will help visualise the immobility. The resulting space-time path will be later used to evaluate the effects of the project to visualise the resident's daily life as the result of the design exercise. The 3 of them are the ones with immobility problems, and 1 without; the 2 owns a car, and 2 doesn't. Persona A, B, C is represents immobility in a cut-through family model of Limburg and its consisting members, the D represents underprivileged groups in formerly working-class, social housing districts.

4.5.1 PERSONA A

"CONTROL GROUP": LOCAL COUNTRYSIDE CAR COMMUTER

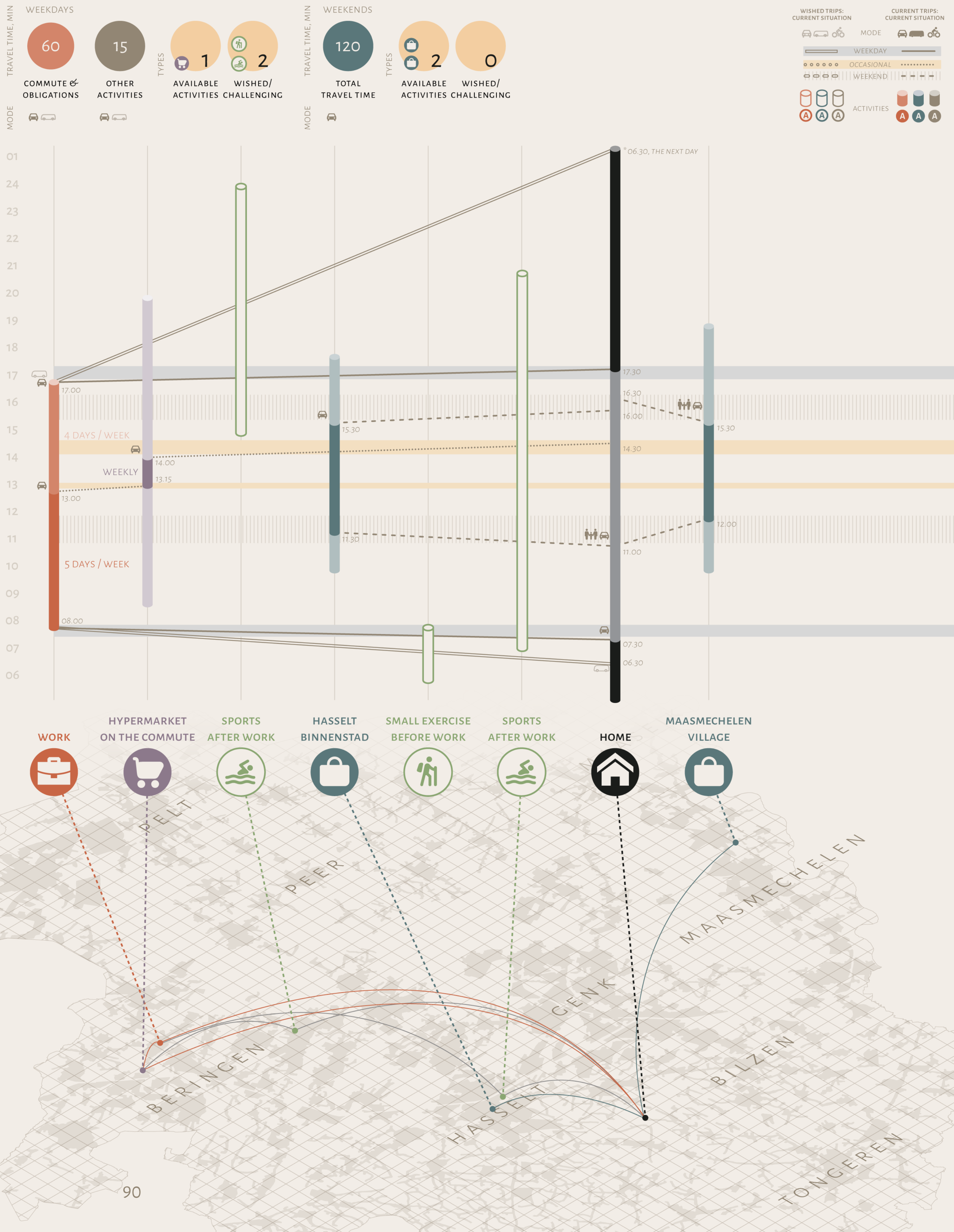


Figure 59. Time-space diagram of persona A

The first persona is a middle-aged male with wife (B) and a kid (C), living in a small ribbon development in the south of the province, who was born and raised in Limburg, and commutes exclusively with his car to west of the province using a motorway. He is the “control group” in terms of immobility: he does not suffer any significant immobility himself, thanks to full access to cars, having family and friends locally, and having no obligation to bring other family members. Instead he represents the wishes: he wishes to combine physical activities before and after his work as much as possible.

IMMOBILITY TYPES

A. Immobility from spatial remoteness

B. Immobility from with social exclusion, poverty, and discrimination

C. Immobility from lacking access to cars

D. Immobility from travelling across national borders

E. Immobility from poly-centricity

F. Immobility from dependants

G. Discrepancy in public transportation offers between employment opportunities and people.

H. Immobility of ideas and talent

4.5.2 PERSONA B

TRANSPLANTED COUNTRYSIDE CAR COMMUTER WITH CHILD FOSTERING TASKS

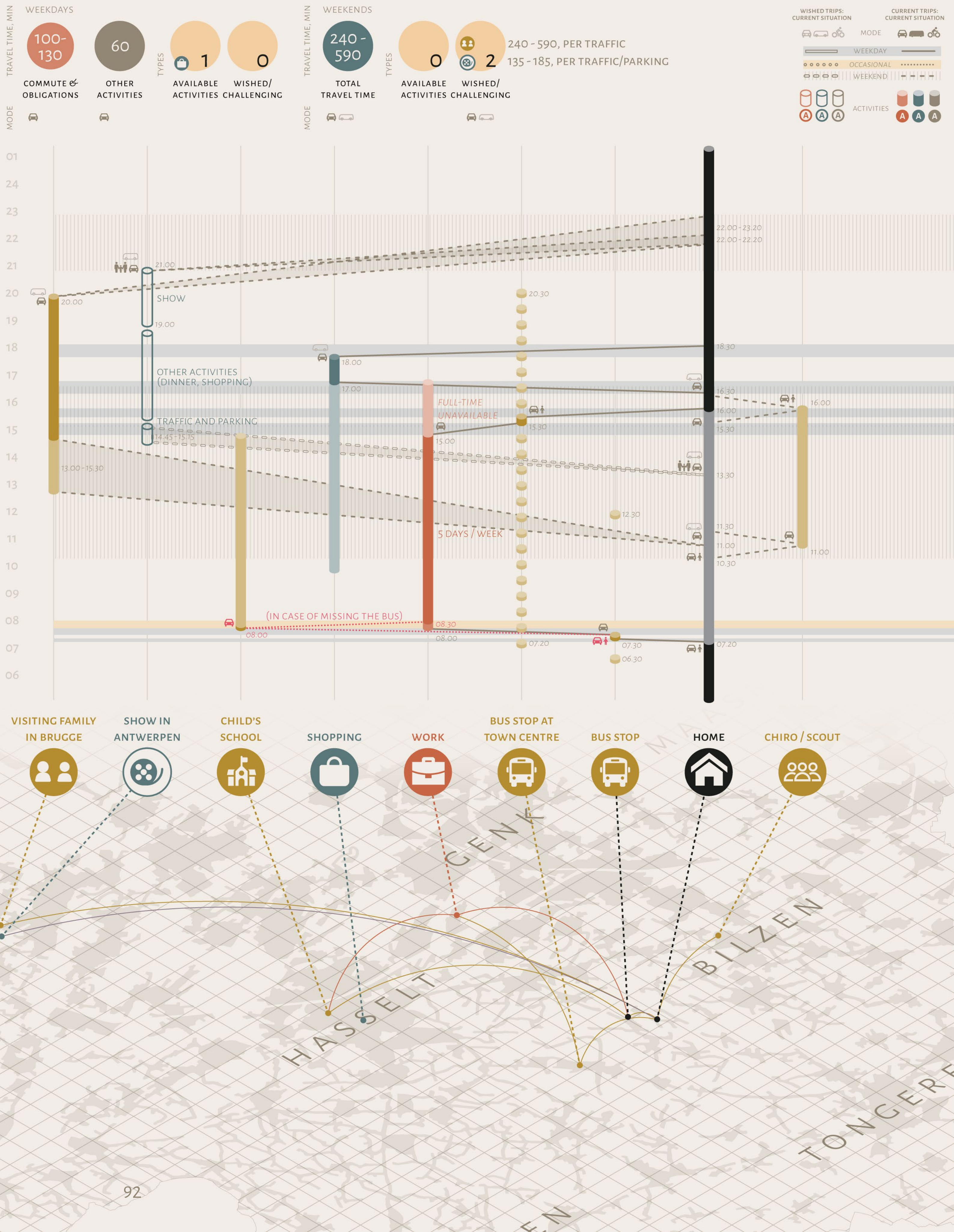


Figure 60. Time-space diagram of persona B

The second persona is a middle-aged woman with a husband (A) and a kid (C), living in a small ribbon development in the south of the province. She commutes mainly with her car, and has the daily tasks to drive the kid to destinations. She is not from Limburg, which also adds the extra task of visiting families in other provinces, and is affected by the traffic jam. She also wishes to visit restaurants and go to shows in big cities in the evenings, preferably by public transportation, to avoid the uncertain traffic jam, stressful parking, and limited options for alcoholic beverages in needing to have a designated driver (colloquially called "bob"). However, due to the lack of public transport after 20 in Limburg, such trips are strictly available by car.

While the area has a bus service twice a day, timed specifically for kids to go to school, as the timetable is fairly limited and offers limited fail-safe for her kids to go to school, she cannot work full-time; she must be able to bring her kids to and from school, just in case they miss the bus. Regardless, she feels lucky that she still has the option to work part-time, while many more in other sectors have no option but to involuntarily give up their career and become a stay-at-home parent.

Still in 2023, burdens of taking care of kids are still disproportionately affecting women more than men. Consequently, such immobility pattern sheds light for the gender justice in the mobility justice, which entails that if the transportation planning does not take their needs into account, it reduces social and economic equity for women.

IMMOBILITY TYPES

A. Immobility from spatial remoteness

B. Immobility from with social exclusion, poverty, and discrimination

C. Immobility from lacking access to cars

D. Immobility from travelling across national borders

E. Immobility from poly-centricity

F. Immobility from dependants

G. Discrepancy in public transportation offers between employment opportunities and people.

H. Immobility of ideas and talent

4.5.3 PERSONA C

COUNTRYSIDE YOUTH

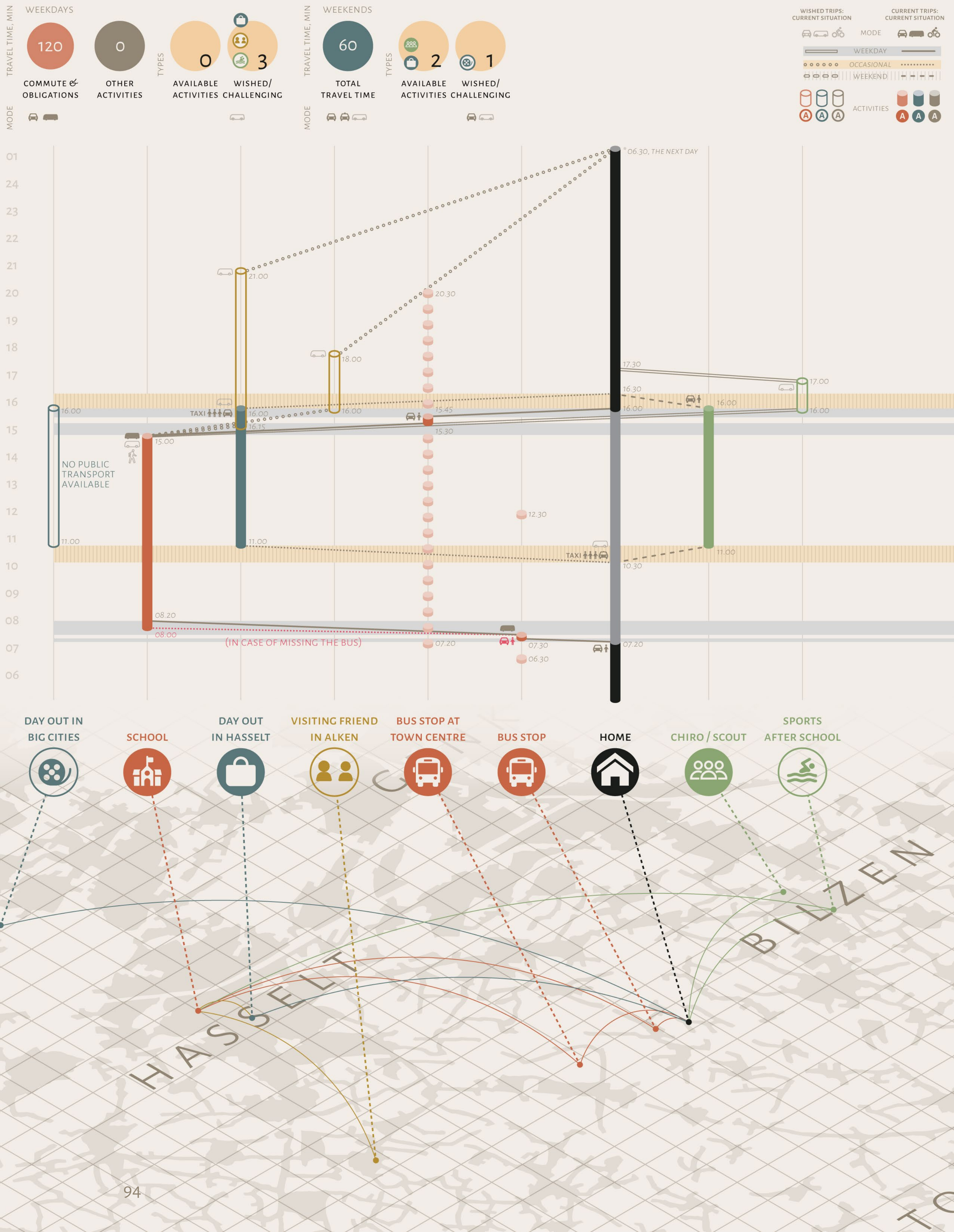


Figure 61. Time-space diagram of persona C

The third persona is a teenager living in a small ribbon development with father (A) and mother (B). Her activities and socialising are almost entirely dependent on her parents, particularly on her mother. She sometimes wishes to stay in Hasselt after school, however, as the bus going back home runs only twice per day, and the bus to the nearby arterial road also stops after 20, practically making her risk being stranded in Hasselt unless her parents come to pick her up. She also wishes to go to sports after school. She cannot do this, because while there is a bus to the sports centre, the bus from the sports centre to home does not exist.

Such patterns of immobility reduce the independence and autonomy of the kids, significantly limiting opportunities to learn and experience in their development.

IMMOBILITY TYPES

A. Immobility from spatial remoteness

B. Immobility from with social exclusion, poverty, and discrimination

C. Immobility from lacking access to cars

D. Immobility from travelling across national borders

E. Immobility from poly-centricity

F. Immobility from dependants

G. Discrepancy in public transportation offers between employment opportunities and people.

H. Immobility of ideas and talent

4.5.4 PERSONA D

BLUE-COLLAR URBAN RESIDENT WITH MIGRATION BACKGROUND

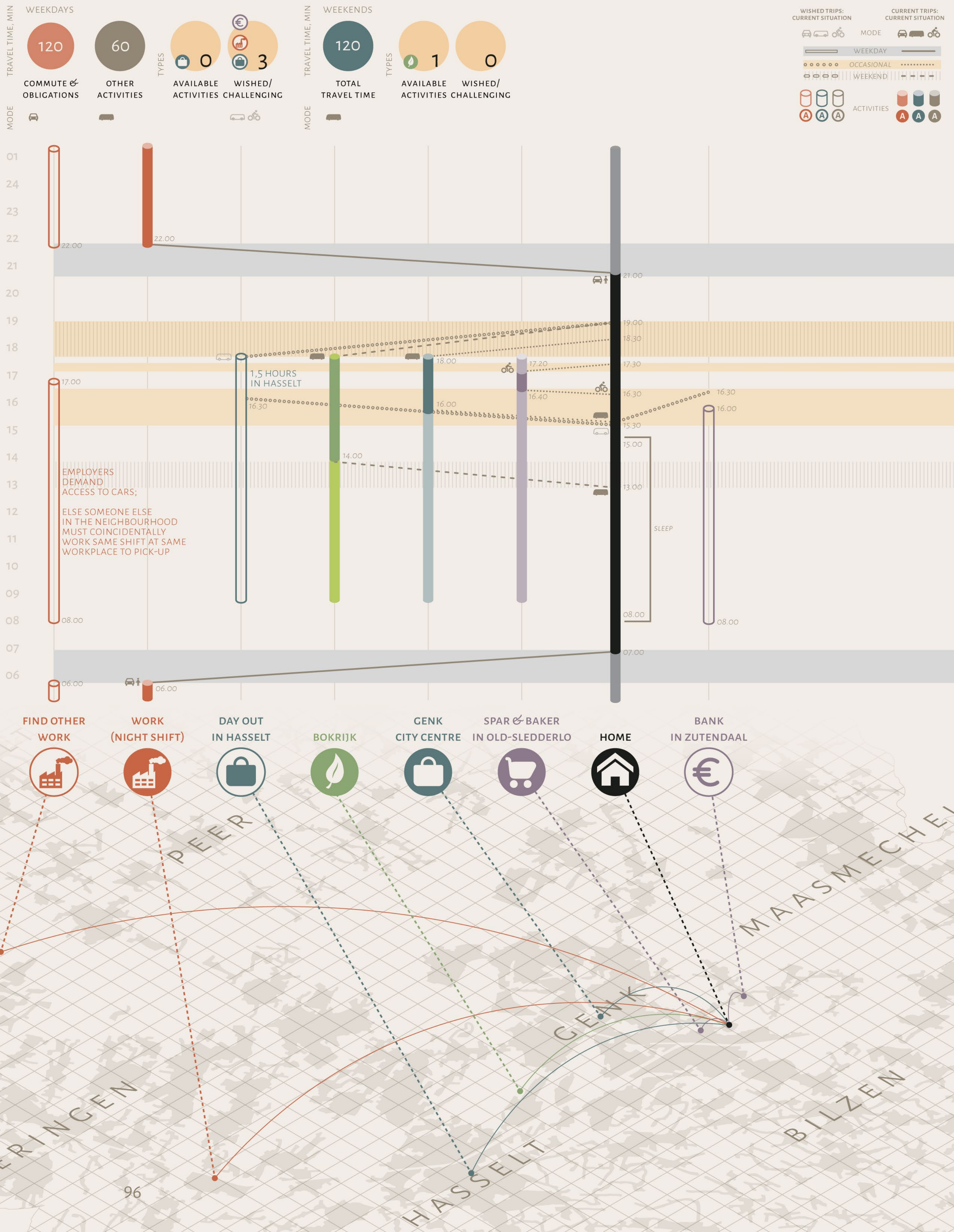


Figure 62. Time-space diagram of persona D

The last persona is a man in his mid-20s with Turkish roots. He lives in a social housing district of Nieuw-Sledderlo in Genk. He does not own a car, and works in the secondary sector in Heusden-Zolder, purely because one of his neighbours works the night shift (22.00 to 06.00) there too, and therefore can drive him together to work. After work, he sleeps during the day between 08.00 to 15.00. He often visits Genk city centre on bus, and does his daily groceries at a Turkish supermarket in Nieuw-Sledderlo, and sometimes goes to nearby towns by bike for bakeries and supermarkets. He wishes to go to Hasselt from time to time, where more diverse shops and activities are present. However, he cannot manage to do so, as it takes more than an hour for him to get to Hasselt and back. Sometimes when he needs to visit the bank in Zutendaal during the day, it is challenging to reach there, since it requires him to transfer buses, and he must wake up earlier to reach there during office hours.

Nowadays, he wishes to work in other places that offer better benefits; however, most of the second-sector jobs in industrial estates require him to have access to cars, or have someone else in the neighbourhood who works in the same shifts, the same workplace nearby to carpool with him. This significantly limits his job opportunity.

IMMOBILITY TYPES

A. Immobility from spatial remoteness

B. Immobility from with social exclusion, poverty, and discrimination

C. Immobility from lacking access to cars

D. Immobility from travelling across national borders

E. Immobility from poly-centricity

F. Immobility from dependants

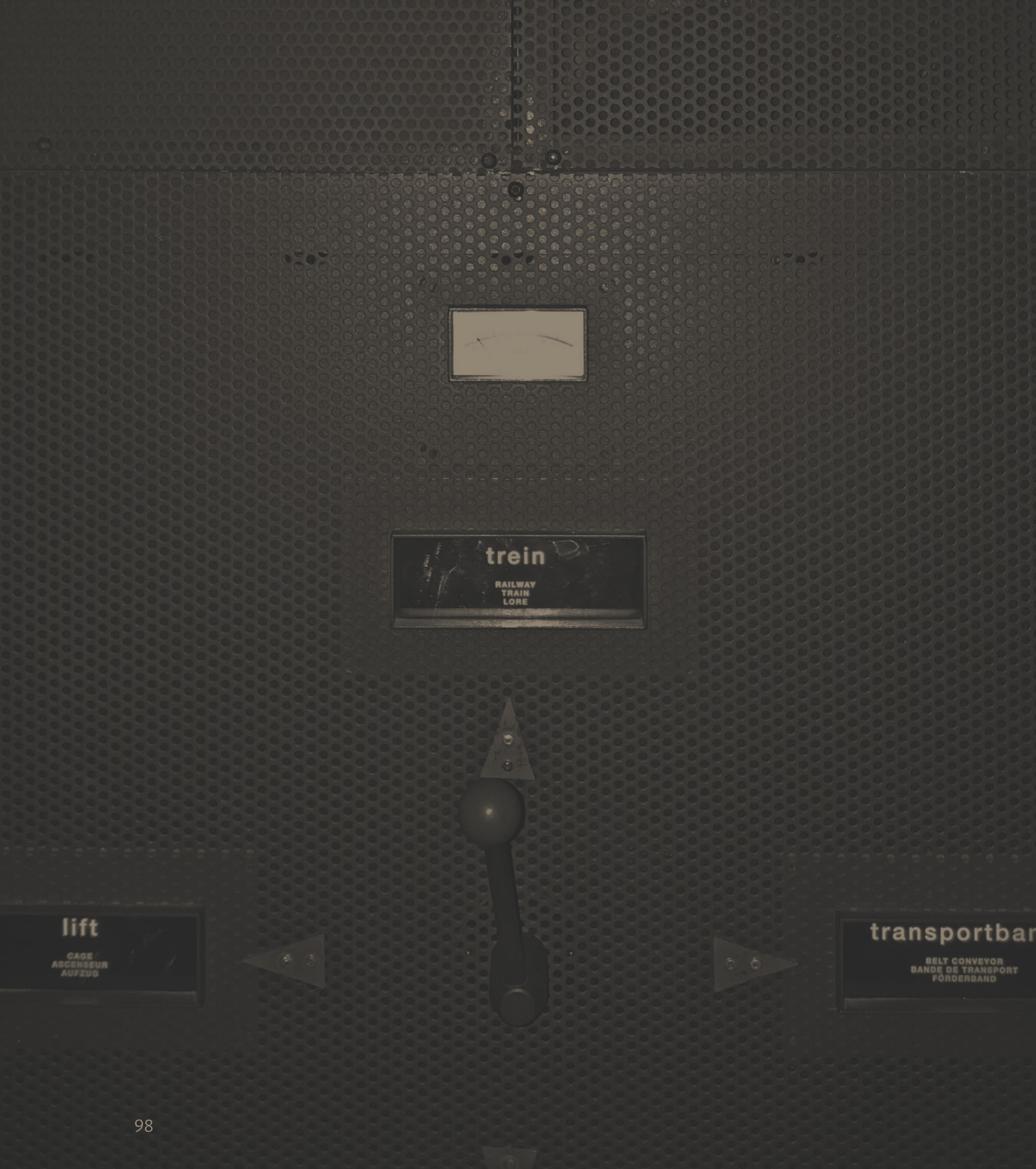
G. Discrepancy in public transportation offers between employment opportunities and people.

H. Immobility of ideas and talent

N°5

PREMISE

TECHNOLOGY CHOICE



5.1 INTRODUCTION

Right-of-way (ROW):

The right-of-way refer to multiple concepts depending on the context; but in transportation and civil engineering, it generally means priority in passage of certain places, or the total area acquired for the construction of certain infrastructure (Jamal, 2019).
In this research, the term "right-of-way" (ROW) would specifically refer to ***roadway space or infrastructure dedicated for bus rapid transit****, regardless of its alignment. For example, a separated bus lane that is 100% exclusive for buses will be considered as BRT ROW, while the curbside bus lane that allows some traffic (i.e. right-turning traffic) to be mixed will not be considered one.*

Based on the outcomes of literature reviews, the ideal mix of elements and technologies of the BRT system will be decided through a multi-criteria analysis. The resulting technology mix, and its spatial requirements and impacts, will lay the premise of the design exercise. Starting from Stakeholder analysis to clarify each stakeholder's wishes and requirements related to BRT. The wishes will be then used on the morphological analysis, in which six alternatives have been derived.

The traditional Cost-Benefit analysis will not be used in this project, as the purpose is to find out the ideal alternative for automation technology that is best suited for Limburg, not to cut the costs further. Moreover, it is already decided to build free bedding for the whole Spartacuslijn; therefore, fixed costs will not be taken into calculation, but the variable costs of operation will be taken into account to assess different impacts on labour costs at different levels of automation. However, it should be noted that for some alternatives, further upgrades in the technical specifications of dedicated BRT right-of-way (ROW), such as intersection treatment or having buffer space between lanes, may be required. The aspect of further upgrade possibility is indirectly reflected in the Suitability criteria as having a stricter standard of spatial availability.

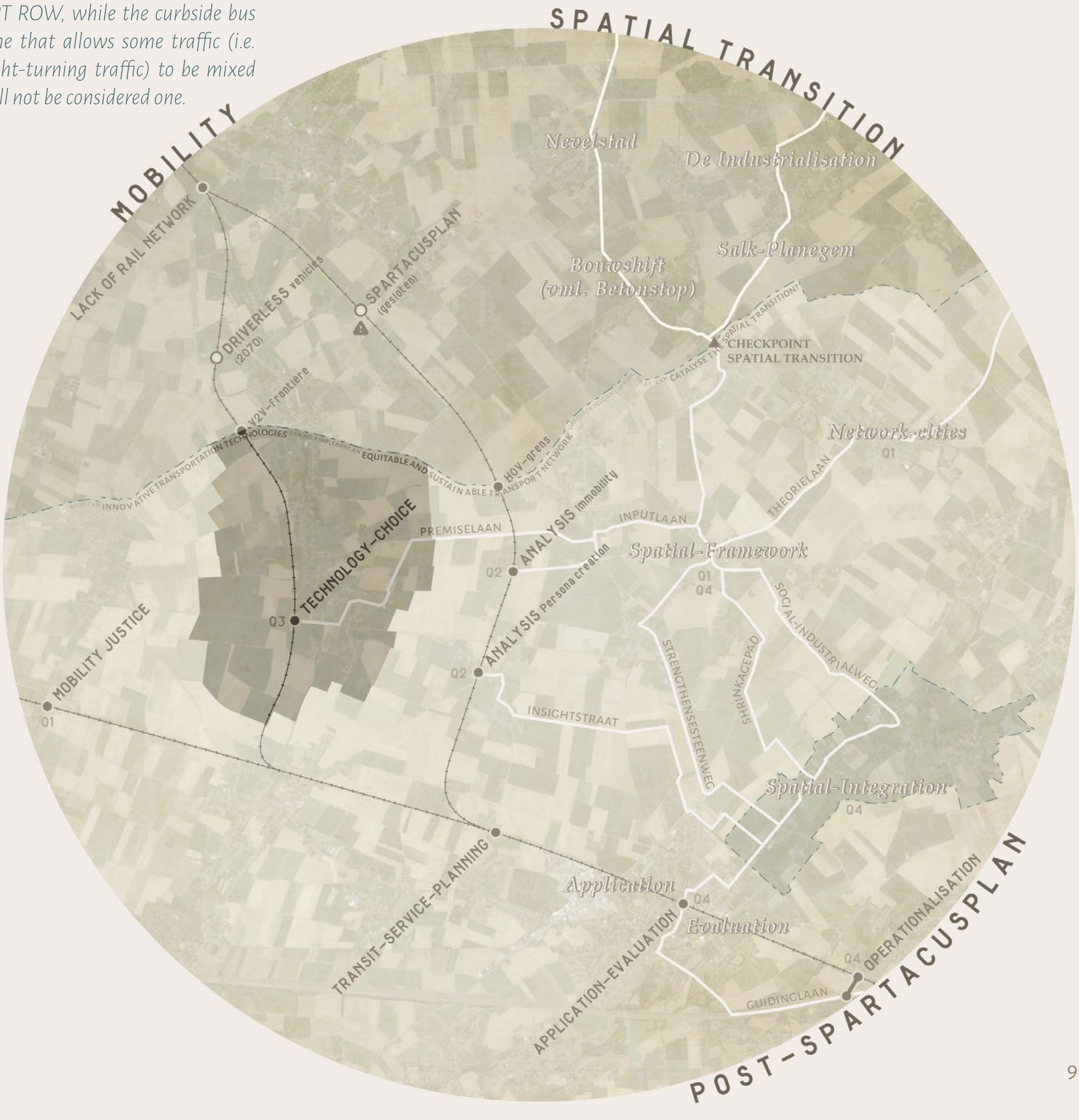
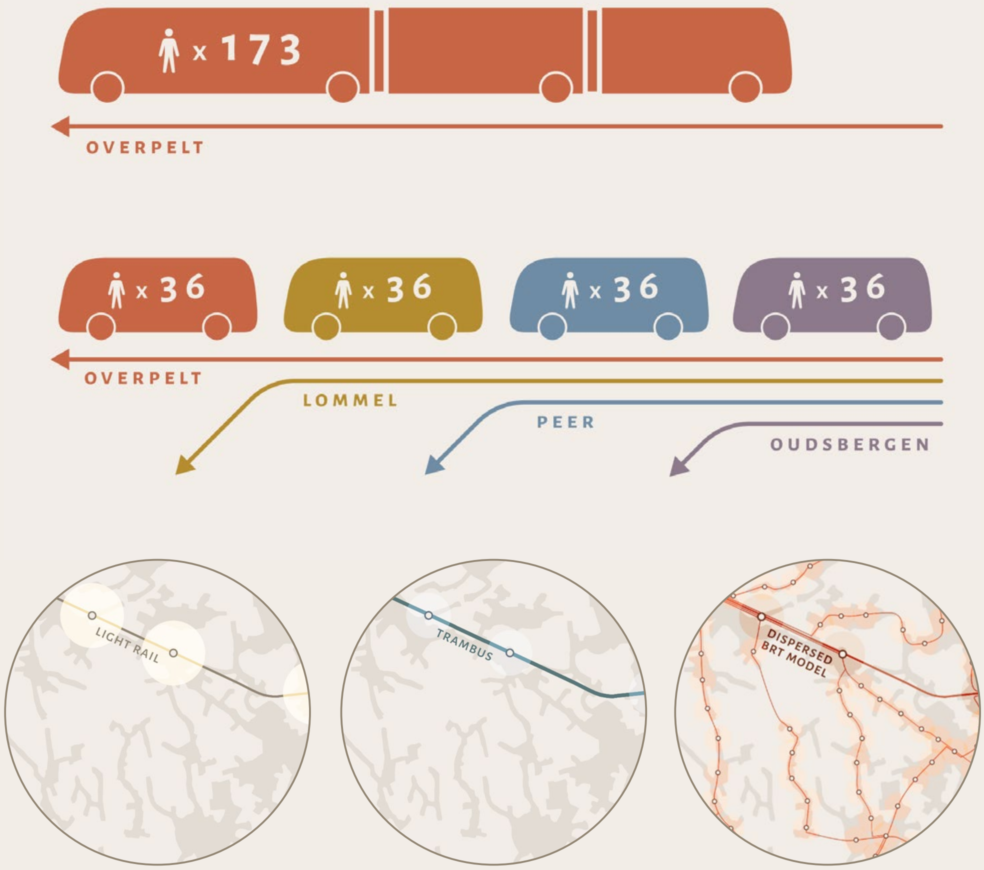


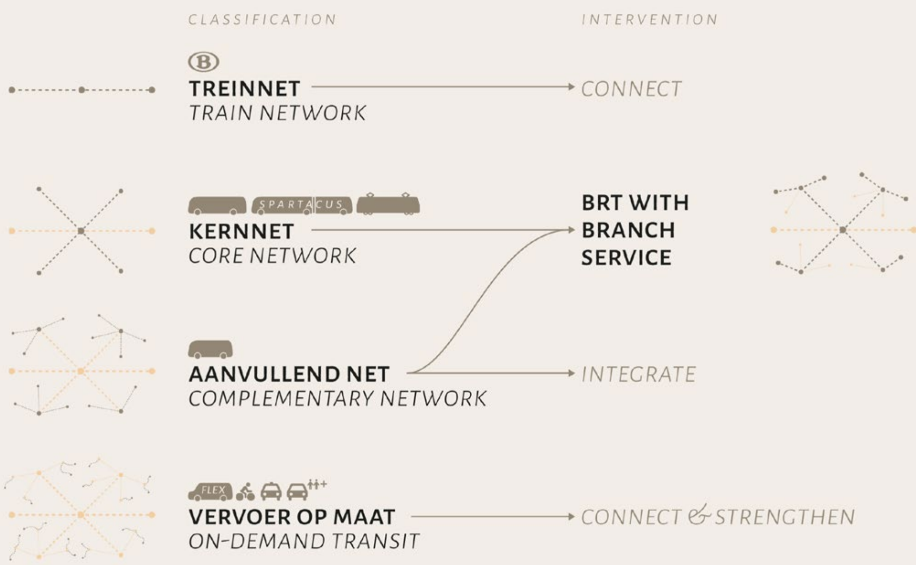
Figure 63. Concept diagram of dispersed BRT



As mentioned earlier, Spartacuslijn as a BRT is a unique case: it connects regional destinations on fully dedicated ROW. Therefore, based on the issues laid out in Chapter 1.3.3 and 1.3.4, the hypothesis for dispersed regional BRT is created. by utilising the dispersed character of BRT, a dispersed BRT model can "distribute" the capacity and frequency into the countryside, where a frequent, single-seat connection is made available.

The issue of high personnel costs will be remedied through automation inside BRT ROW. What level of automation should be applied, along with what elements, is explored in this chapter.

Figure 64. Classification of transportation system in Basisbereikbaarheid, and the project's strategy



5.2 STAKEHOLDER ANALYSIS

As a prerequisite for multi-criteria analysis, the stakeholder analysis is conducted to derive the wishes and requirements of stakeholders. The stakeholders related to this project are categorised into Governmental, Civil society, Market, and Residents. Both transport, spatial, and societal goals and wishes are taken into consideration. The level of interest and involvement is shown as dots (●●○). The governmental and civil society stakeholder's wishes and requirements are mainly based on their official plans, visions,

Table 2. Stakeholder wishes and requirements, governmental

TYPE	ACTORS	WISHES / *REQUIREMENTS*	GOALS	RESOURCES
Governmental – Inter-national	●●○ **European Union**	Faster, widely accessible public transportation connectivity between member states (European Commission, n.d.) Stronger (connection between) knowledge institutions in the region, as Eindhoven – Leuven – Aachen knowledge triangle (Stuurgroep EMR2020, 2013) Facilitate cross-border economic activities (Mirwaldt et al., 2009)	Territorial Cohesion (Mirwaldt et al., 2009)	Funding (TEN-T, CEF-T) Coordination (Interreg)
Governmental – National & Regional	●○○ **Belgium**	Regional transportation is a regional matter, therefore the interest level is lower (Infrabel) Minimise impact or conflict with rail line 34 *In case of national roads being affected, sustainability, safety, and ease of maintenance shall be guaranteed (FOD Mobiliteit en Vervoer, n.d.)*	Safety and ease of infrastructure maintenance, Cohesion between regions	Funding and maintenance for national- and international rail and national road infrastructure Influencing EU-programmes
Governmental – National & Regional	●●● **Flanders**	Public transportation should facilitate spatial transition and development regarding spatial planning issues (Department Omgeving, 2018) Secure Biodiversity and food production (Ibid.) Stronger position in European economic space (Ibid.) Transition towards circular economy (Moonen et al., 2016) *Lower budget for fiscal stability (nieuwsblad.be, 2022; Van De Werf et al., 2022)* (Basisbereikbaarheid) Multi-modal integration on the BRT with “hoppinpunten” (Departement Mobiliteit en Openbare Werken, 2021) *(AWV) Safety and ease of maintenance shall be guaranteed (AWV, n.d.)* *(AWV) For new roadways, ecological areas should be preserved, and shall not cause spatial fragmentation of nature (AWV, n.d.)* (AWV) Noise and vibration shall be minimised (AWV, n.d.)	Spatial transition, Regional economic development, Fiscal stability	Funding for regional public transportation projects, including all 3 Spartacuslijnen Spatial planning Influencing the national agendas
Governmental – National & Regional	○○○ **Wallonia**	Despite being part of Belgium and Euregio Meuse-Rhein, Wallonia is not affected in all 3 Spartacuslijnen, therefore the interest level is low.		Influencing the national agendas
Governmental – National & Regional	●○○ **Netherlands**	Lower budget for fiscal stability, in case the national funds are involved.	Fiscal stability	Funding for regional public infrastructures Influencing EU-programmes
Governmental – National & Regional	○○○ **Germany**	Despite being part of Euregio Meuse-Rhein, Germany is not affected in all 3 Spartacuslijnen, therefore the interest level is very low.		Influencing EU-programmes
Governmental – Provincial	●●● **Limburg (BE)**	Grow innovative industries in the region (Provincie Limburg, 2019) Better multi-modal accessibility in the region (Ibid.) Integrated approach between spatial planning and mobility through transit-oriented development: spatial planning and mobility as a starting point / catalyst for the economic “leverage” projects (Ibid.) *Realisation of Spartacusplan (Ibid.)*	Regional development Territorial cohesion	Spatial planning
Governmental – Provincial	●●○ **Limburg (NL)**	Better connectivity across cross-border destinations	Regional development Territorial cohesion	Spatial planning
Governmental – Local	**Municipalities**	Better integration of right-of-way in the urban fabric *Minimised adverse impacts, such as fumes, noise, and accidents* Ensure more stops available in the municipality In case of municipal roads being affected, liveability, safety and ease of maintenance shall be guaranteed Would prefer not to push Bouwshift, as it is financially burdening and can cause conflict with residents (Van De Werf et al., 2022) (Hasselt) Bring Spartacuslijn 1 to Groene Boulevard (Peeters, 2021)	Liveability Better accessibility	Spatial integration and permits of works

and other publications. Also some facts are based on informed guesses, sometimes with hints from third-party sources such as news articles.

Table 3. Stakeholder wishes and requirements, civil/private

Requirements and wishes of widespread wishes, such as (traffic) safety and sustainability, are not noted unless the stakeholder explicitly stressed it.

Civil Society	PT travellers	●●● **TreinTramBus**	Public transport should be complementary with each other, with train as major corridor Expand cross-border transport infrastructure Involve more users in decision-making Expand tram- and bus lanes and signal prioritisation Replace Trambus with better alternatives	Higher modal split of public transportation Better quality of public transportation	Political / decision-making influence
	Environmental	●●○ **Limburgse Milieukoepel**	Better spatial planning, renewable energy, bicycle infrastructure, public transport is crucial for sustainability Ecological areas of interest, such as Natura 2000 and Flemish ecological network (VEN) should be not used for any further development Critical towards the decision of changing light rail project to BRT, as BRT ROW is wider in footprint than that of light rail.	Environmental protection Sustainability	Political / decision-making influence
	Labour	●●○ **Labour unions**	Prevent sudden unemployment due to public transport vehicle automation	Preventing loss of jobs	Public opinion, protest, voting
Market Actors	Transporters	●●● **De Lijn**	Direct, regional service for dispersed spatial structure (De Lijn Limburg, 2004) *New transportation mode must be realisable, safe, reliable, and economically viable* Less labour-intensive operation to address workforce supply issues Better infrastructure and right-of-way (Sterk, 2022)	More passengers Less operating costs	Service planning
	Transporters	●○○ **NMBS**	Attracting more passengers in the multi-modal settings Better maintenance and safety on the tracks	More passengers Less operating costs	Service planning
	Transporters	●●○ **Shared mobility providers**	Ensure sufficient space and power sources around stops for facilities	More users Ease of service provision	Service provision Facility management
		●●○ **Van Hool**	Keep the trambus plan as is, or at least the alternative vehicles should be built in Belgium Adapt to innovating future mobility market	Higher market share in Global bus market	Manufacturing, Research & Development
Residents	Public transport users	●●● **Direct surroundings**	Minimised adverse impacts, such as fumes, noise, and accidents New public transportation stops in the vicinity Better service on the Spartacuslijn corridors Frequent connections to major destinations	Liveability Higher accessibility Higher property values	Public opinion, protest, voting
	Public transport users	●●○ **Outside of Spartacuslijn**	Better service outside of Spartacuslijn corridors Better multi-modal connectivity around nodes Direct, single-seat connections to deisred destinations	Liveability Higher accessibility Higher property values	Public opinion, protest, voting
	Public transport non-users	●○○ **Car users**	Minimised impact in private car infrastructure Getting a good alternative for driving	Preservation of private car infrastructure	Public opinion, protest, voting
	Public transport non-users	●●○ **Immobiles**	Provision of reliable and frequent public transportation service	Adequate level of accessibility	Public opinion, protest, voting
	Homeowners	●●○ **Countryside residents**	Worries of further declining livelihood in the area Public transportation should be also provided in the countryside Alternative housing should be comparable or better in quality, easily available, and accessible from current work, friends and social networks, leisure activities	Keeping own livelihood	Public opinion, protest, voting

5.3 REQUIREMENTS AND WISHES

Based on the wishes and requirements of the stakeholders, the constraints and objectives of the project is defined. The functional requirements are used to narrow down determine possible alternatives, and wishes of the stakeholder are later used to set the criteria for the multi-criteria analysis.

Table 4. Defined constraints and objectives

Functional constraints (must do, has to do): **Crucial functions for the new regional public transport system**	**Non-functional constraints (must have, has to be):** **Fundamental characteristics for the new regional public transport system**
Make public transport more accessible for all (Departement Mobiliteit en Openbare Werken, 2021)	Guarantee capacity, speed, and service quality desired for the high-quality public transport
Make public transport in Limburg an valuable alternative to personal cars (De Lijn Limburg, 2004)	Must be cost-effective for both construction, maintenance, and operating costs (Challans, 2022; nieuwsblad.be, 2022)
Realise the Spartacusplan of 2004 and the lines suggested in the plan inside the province (Provincie Limburg, 2019)	Must comply with existing spatial and mobility visions of the area
Transfer-free connection between diverse cores and university campuses (Meukens, 2021)	Must be reliable and realisable: applied technology must be already tested feasible or expected to be realisable in the near future (~2030)

Functional objectives (should do): **Crucial functions for the new regional public transport system**	**Non-functional objectives (should have/be, nice to have/be):** **Fundamental characteristics for the new regional public transport system**
Should provide direct service to minimise transfers for dispersed areas (De Lijn Limburg, 2004)	Should have a net-zero GHG emissions impact
Should address spatial issues, such as dispersion and fragmentation	Should not interfere in ecologically significant areas (Natuur 2000, VEN)
Should facilitate movement of knowledge, and facilitate cooperation of knowledge institutions in the region and the industries in the region (Provincie Limburg, 2019; Stuurgroep EMR2020, 2013)	Should be flexible to adapt to diverse movement patterns, by time or capacity
Should address labour shortage issues in the public transport sector (Sterk, 2022)	Should have good connectivity with other modes of transport, especially active transportation
	Adding extra built-up areas outside of existing built-up areas should be minimised
	Hindrance to surroundings shall be minimised

5.4 ALTERNATIVES

While there can be infinite sets of elements could be made, only select few sets would be feasible to be analysed. Therefore in this section, the possible elements are defined with reference case analysis on current autonomous bus projects, and the mix of elements would be created through morphological analysis.

5.4.1 REFERENCE CASES

The current progress on autonomous buses projects are analysed on their ODD, level of technology, infrastructural measures, and characteristics. The elements derived in the analysis will be used for morphological analysis.

While there are already many cases of level 4, fully driverless shuttle services in revenue service that limits ODD to dedicated busways and/or pre-determined slow-speed urban streets such as Olli, Navya, or ParkShuttle in the Netherlands, so-called “Group Rapid Transit” (GRT), such systems are excluded because driverless shuttles’ maximum speed is usually limited to 30 km/h in revenue service, and no cases as of 2019 had de-

ParkShuttle

ParkShuttle is an electric driverless bus service in Capelle aan den IJssel, between Rotterdam Metro's Kralingse Zoom station and the urban development sites in Rivium. The bus runs entirely on dedicated ROW, with crossings with other traffic completely protected with barriers. The vehicle can technically make 60 km/h (2getthere, n.d.), but operating under 30 km/h.

sign speeds higher than 60 km/h (Baggen & Van Ham, 2019). This is far lower than that of trambus (72 km/h), which is already being heavily criticised for being too slow. Therefore the analysis only includes cases that are using vehicles that are capable of speeds at least comparable or faster than trambus.

The analysed reference cases are: JR West MI-NNA, Japan; CAVForth pilot project, United Kingdom; Hitachi BRT, Japan; and Sejong BRT, South Korea. The detailed analysis and description of these cases are attached as appendix at the end of the thesis. The breakdown of ODD and other elements of BRT is listed on Table 5. From the table, the choice towards each option in morphological analysis is described.

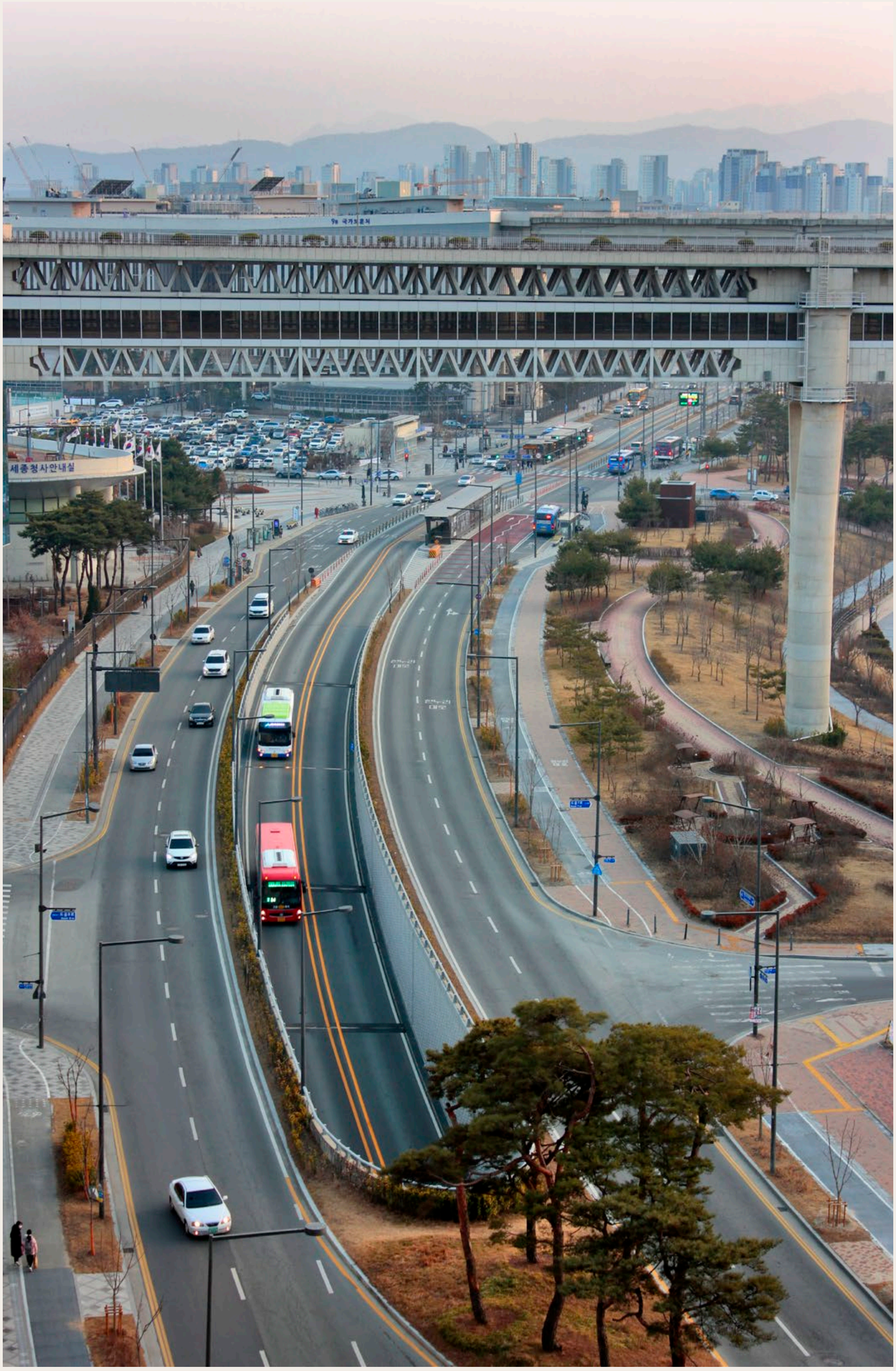


Figure 65. Sejong BRT buses entering dedicated underpass under major intersection, image taken by author

	JR West MI-NNA, Japan	CAVForth pilot project, UK	Hitachi BRT, Japan	Sejong BRT, South Korea
ODD: ROW	Dedicated road only	Pre-selected road trained on digital twin	Dedicated road + Pre-selected road with roadside sensors	Dedicated road only
ODD: Intersections	At-grade, barrier-protected on road side; only signalled crossings	All situations	At-grade, barrier-protected on ROW side; sensors on intersections	At-grade, only signalled crossings + Grade-separated crossings (viaducts and underpasses) on intersections with crossing traffic higher than 1.000/hr
Level of automation	4 on following vehicles, aimed to achieve 4 on all vehicles (undetermined)	4	3, aimed to achieve 4 (2028 ~ 2030)	3, aimed to achieve 4 (2027)
ODD specifications	Fully dedicated road; crossing with existing roads, depot, crossing on single-track sections	Motorway lane change, roundabouts, traffic lights, junctions	Roundabout, crossing with existing roads, depot, crossing on single-track sections	Fully dedicated road with no mixed traffic; dedicated median lane on motorways with barriers
Mixed traffic	No	Yes, pre-trained on digital twins	Yes, with roadside sensors installed	Yes, partially
V2V	Platooning	None	None	Traffic information sharing
V2I/I2V	Magnetic guide	Signal information	Roadside sensors and monitoring system	Traffic information communication
Current phase	Test run with journalists (2022), Real-life BRT application (2023)	Revenue service with passengers (2023)	Free service with pre-booked passengers (2023)	Revenue service with passengers (2023)
Environment characteristics	All environments, dedicated busways on roadways or former rail trackbeds	Regional character; peri-urban motorways and regional roads	Urban character, rural city with 195.000 residents; dedicated busways on former rail trackbeds	Urban and regional character, connecting new city with high-speed rail station 11 km away; dedicated busways purposely built with new infrastructure
Driver on board	Yes, aimed to remove drivers except one in the foremost vehicle of the platoon (~2023); projected to remove all drivers (undetermined)	Yes, aimed to remove drivers (undetermined)	Yes, aimed to remove drivers in dedicated road, potentially removing drivers in all conditions (2028 ~ 2030)	Yes, aimed to remove drivers (2027)
Sources	森山 (2021); 坂本 (2022); 直樹 (2022)	CAVForth (n.d.); CAVForth (2023); Russell (2022)	Michinori Holdings (2021); 日立市 (2020); 茨城交通 (2023)	최 (2022); 배 et al. (2008); 국토교통부 (2022)

Table 5. ODD specification and characteristics of reference cases

The attributes for the right-of-way (ROW) of the BRT corridor are configured based on the minimum level of elements (ROW, Intersections) to ensure safety in applying vehicle automation. Service inside the ROW is defined by two types, one simply operates exclusively dedicated BRT service inside the corridor (Linear), and the other combines several services branching in and out of the corridor (Bundle of lines).

Figure 66. Sejong BRT buses entering dedicated underpass under major intersection, image taken by author

As mentioned earlier, it is widely suggested that level 5 autonomous driving is highly unlikely to happen in the near future due to the extremely high level of safety requirements to make it work in all ODDs (Chafkin, 2022; Etherington, 2022; T. Higgins, 2022; Shladover, 2016). Kisner et al. (2017) suggest Level 4 as a “probable future”. While it is true that the two cases explore the possibility of level 4 operation in mixed traffic, however, given the complexity of including mixed-traffic sections in ODD, following the case of MI-NNA and Sejong BRT, the ODD will be limited to dedicated BRT infrastructure. The region's scale is also an obstacle for mixed-traffic level 4 operation. Therefore, the mixed-traffic capability of Hitach BRT and CAVForth will be only considered as a potential future trajectory, not a realisable option with higher probability.

It is necessary to define infrastructural requirements and ODD per technology. In the case of platooning, the reduced headways will allow less investment in grade separation. The Platooning at level 3 operation expects the drivers to be present in all cases for interventions but will allow operation on the proven environment (motorways), while platooning at level 4 operation will not require human drivers on the following vehicles. Non-platooning level 4 operation will completely no human drivers inside the corridors, which will require a much higher degree of intersection treatment and corridor capacity due to frequent operation.

Based on this, the three scenarios can be made. First is the optimistic scenario, where complete driverless operation is realised inside the ROW. To ensure the realisation until 2030, almost all infrastructural elements that can reduce ODD are applied: on all intersections, barriers (Hitachi BRT, ParkShuttle, MI-NNA) and signals (MI-NNA, Sejong) are installed, and grade-separation on major intersections to reduce conflicts are recommended (Sejong). The ROW should be fully dedicated with horizontal physical separation.

Second is the low-tech scenario, where any form of driverless operation will not be applied. In this case, barriers and horizontal physical separation would not be required. This expects the same level of automation with MI-NNA in 2022, where platooning is used, but drivers are still present in the following vehicles of the platoon.

The third is the middle ground between the two, which expects the removal of drivers from the following vehicles of the platoon. The presence of humans making the driving decisions can eliminate the need for barriers in intersections, but horizontal separation is still kept, as drivers are not present in the following vehicles of the platoon.

5.4.2 VEHICLE OPTIONS

Now the ROW options are set, the vehicle options will be formulated by analysing the existing, “off-the-shelf” vehicles that are currently available. The currently planned trambus vehicle (Van Hool ExquiCity 24) is also included.

Image				
Image source	*De Lijn (n.d.)*	*Lijn 45 / Wikimedia Commons, CC BY-SA 4.0 https://commons.wikimedia.org/wiki/File:RET_1255_te_Rotterdam.jpg*	*Switch Mobility (n.d.)*	*Stadsbus / Wikimedia Commons, CC-BY-SA 4.0 https://commons.wikimedia.org/wiki/File:StadsbusConnexxion7573.jpg*
Vehicle	Van Hool ExquiCity 24, Belgium	VDL Citea SLE-120, the Netherlands	Switch Mobility (originally called Optare) Solo, United Kingdom	VDL MidCity Electric, the Netherlands
Capacity	173 (De Lijn, n.d.)	82 (VDL Bus & Coach bv, n.d.)	Max. 36 (Switch Mobility, n.d.)	19 (VDL Bus & Coach bv, n.d.-b)
Energy types	Battery-electric, Trolley-electic, Fuel cell, Diesel hybrid (Van Hool, n.d.)	Battery-electric, Diesel hybrid (VDL Bus & Coach bv, n.d.)	Battery-electric (Switch Mobility, n.d.)	Battery-electric (VDL Bus & Coach bv, n.d.-b)
Operating maximum speed	72 km/h (Meukens, 2021)	86 km/h (VDL Bus & Coach bv, n.d.)	95 km/h (Optare, 2020)	Unknown; Original model equipped with 90 km/h speed limiter (VDL Bus & Coach bv, n.d.-c)
Current use case	De Lijn (Hybrid version)	De Lijn (Hybrid Version), Arriva Maastricht	QBuzz (U-OV) Utrecht	Connexxion Haarlem-IJmond

Table 6. Vehicle alternatives

Three options of vehicle sizes are derived from the analysis of available vehicle options: the 150+ option, assumes trambus-like operation as currently planned, the 60+ option assumes the current fleet of buses (9 – 12 m) will be used, and the 15+ option proposes smaller vehicles, such as 6 ~ 8 meter long vehicles. In terms of the impact, it is expected that smaller vehicles may provide more dispersed and frequent service, while posing higher levels of labour costs if not automated. Given the aforementioned problem with platooning with different models and types of vehicles (Mascalchi & Willemsen, 2022), the mixing of different types of vehicles should be avoided.

In terms of vehicle fuel types, given the recent market permeation of zero-emission buses, fossil fuel types (Diesel, CNG, Hybrid) are excluded to reduce emissions and noise impact. The commonly used zero-energy options of battery-electric and hydrogen fuel cell options are considered. In the case of fuel cells, the lack of significant “green hydrogen” sources in the region remains an issue, therefore, its relatively higher total emission shall be taken into consideration.

The maximum speed is also related to vehicle type. While the smaller vehicles have a marginally higher speed in comparison to standard vehicles, as they are designed for rural services and often share the design with commercial freight vans used on motorways. The largest difference is visible between trambus and other buses, since trambus is specifically designed for urban transportation.

Through this, the vehicle options can also be assigned per scenarios. For scenarios with driverless operations, the smaller vehicles comparable with Switch Mobility Solo can be used. For scenarios with human drivers, the conventional city bus comparable with VDL Citea SLE-120 can be used to reduce personnel costs.

5.4.3 MORPHOLOGICAL ANALYSIS

Based on the decisions made in the reference cases and vehicle options, the alternatives are created through the morphological chart. Aside from non-automated 0, 0+, and T alternatives, the alternative A (optimistic), B (conservative), C (platooning) each has a different level of automation and the accompanying minimum requirements of infrastructure.

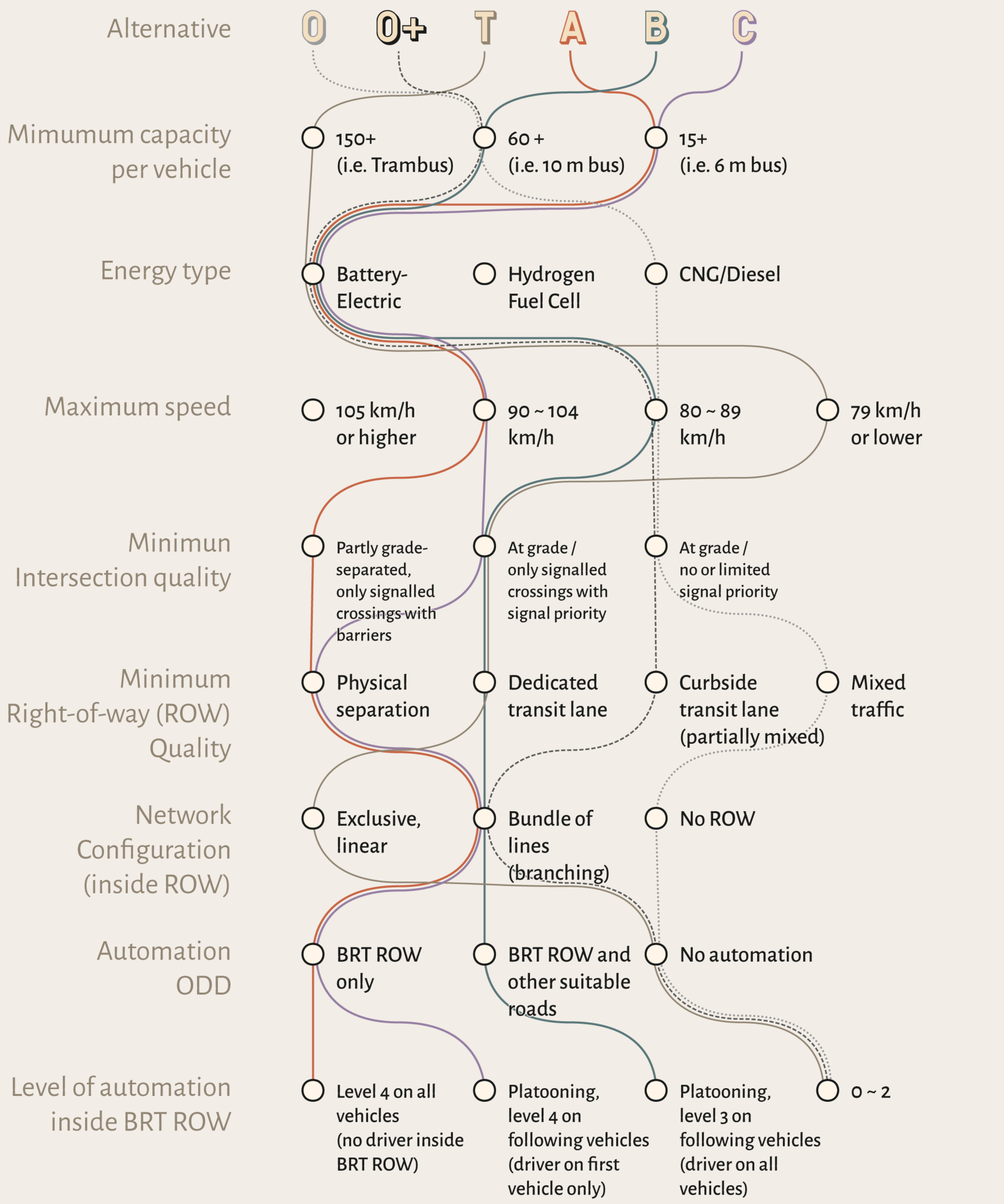


Figure 67. Morphological analysis of each alternative

5.4.4 ALTERNATIVES

The details of each alternative defined through the morphological analysis are further described.

0: No intervention
No changes are made to the current transport network.

0+: Improvement of existing bus lines
Electric buses, partial curbside bus lanes, and limited signal prioritization is used. Existing bus lines' frequency would be improved. A normal express bus line without any BRT infrastructure that emulates Spartacuslijn's frequency and stops will be introduced.

Alternative T: Currently planned trambus
Based on the currently planned trambus plan, which uses electric trambus, fully dedicated transit lane, and non-branching service.

Alternative A: Optimistic (High-tech) alternative
Assumes that level 4 operation will be available inside the BRT corridor. Buses therefore will not be required to wait in the station to join the platoon, although some level of bunching at intersections and stations would be expected. It will require signalling and barriers on all intersections to accommodate higher frequency, and grade separation would be preferred on intersections with heavy traffic. A smaller, 30-person vehicle designed for the Spartacuslijn will be used.

Alternative B: Conservative (Low-tech) alternative
Assumes that fully autonomous level 4 operation and will not be possible or spatially not feasible. Also assumes that completely removing drivers on the following vehicles are not possible due to legal or technical reasons. A standard off-the-shelf vehicle (11-metre) with limited V2V capabilities will be used. The operation will be similar to alternative T, but platooning possibility will allow some level of branching / dispersion of service while keeping higher capacity per platoon in the BRT corridor. This will require significantly higher operating costs. Buses will be able to join the platoon, but can also proceed on its own in case of delays. Buses can enter or exit the BRT corridor on any possible points, without waiting at the station.

Alternative C: Dispersed platooning alternative
Assumes that fully autonomous level 4 operation will not be possible or spatially not feasible, but the drivers on the following vehicles can be removed. A off-the-shelf minibus (6-metre) with V2V capabilities will be used. The operation will be similar to alternative A, but the platooning will allow lower degree of grade separation due to lower headways. Buses must join the platoon, therefore it requires some buffer time in the station to compensate for delays, at 1/3 of the headways (max. 5 minutes).

5.5 CRITERIA SETTINGS

Based on the wishes of the stakeholders related to the project, the defined criteria are as follows:

Table 7. List of criteria

Criteria	Sub-Criteria	Unit	+ / -
Suitability	Space unavailability for Spartacuslijn ROW	km	-
	Areas in Natura 2000 & VEN	km²	-
Accessibility	Location-based accessibility measurement (UrbanAccess)	Nr. of jobs	+
Operating Costs	Personnel hours	Hours	-
	Energy costs	€	-
Environmental impact	Sound pollution zones, built-up	km²	-
	CO_2 emission	g/km	-

5.5.1 SUITABILITY

Space unavailability is measured by the available space. The definition of available space differs based on the different levels of infrastructural elements. Therefore it is also a measurement of the spatial impact of the increased or decreased level of infrastructural investments. The criteria are as follows:

<table>
<tr><td rowspan="2">Full level 4</td><td>Alternative A</td><td rowspan="2">0: Existing separate busways</td><td></td><td></td><td></td></tr>
<tr><td>Else: follow ROW quality</td><td rowspan="4">D. Existing roads with 4 lanes or more for bi-directional; 2 lanes or more for one-way
E: Existing physically separated / median bus lanes
F. Motorways or uninterrupted traffic</td><td></td><td></td></tr>
<tr><td rowspan="4">Right-of-way quality</td><td>Physically separated</td><td rowspan="3">A: Unbuilt open space around the road
B: Former track bed of railroads, vicinal tramways
C: GTI/GNP plots</td><td></td><td></td></tr>
<tr><td>Dedicated transit lane</td><td rowspan="2">G: Existing mixed curbside transit lane</td><td></td></tr>
<tr><td>Curbside transit lane</td><td>H: Existing roads with 3 lanes or more for bi-directional; 2 lanes or more for one-way</td></tr>
<tr><td>Mixed traffic</td><td colspan="4">No criteria for available space; no penalty</td></tr>
</table>

Table 8. Infrastructure classification of space unavailability

On ROW quality, physical separation means horizontal separation from both traffic and roadside hazards, such as cyclists, pedestrians, and roadside activities. Therefore curbside transit lane is not applicable in this case, unless roadside hazards are not present. Therefore the use of shoulder lanes on motorways can be allowed, except for alternative A, where the lack of human drivers will increase the risk of manoeuvring in case of unforeseen situations on the motorway. Therefore Alternative A will require separation between existing traffic and its ROW, which the short tunnel section under Ecoduct Kikbeek may prove particularly difficult.

For Spartacuslijn 3, the design choice for the BRT corridor as part of the North-South connection (Noord-Zuidverbinding) project has already been made. Therefore sections of Spartacuslijn 3 where BRT right-of-way design is established will be classified as E. For alternative A, it will require further improvements on top of the current design for the installation of barriers and signalling.

In the case of using a dedicated transit lane, the alignment of the busway (curbside or median) does not matter. In such cases, existing mixed curbside transit lanes' right-turning traffic and cross traffic should be separated, and roadside activities should also be sufficiently separated.

For 0+ alternative, as new ROW will not be built or kept minimum, a different route that uses existing N2, N78, and N77 will be used for calculation for Spartacuslijn 1.

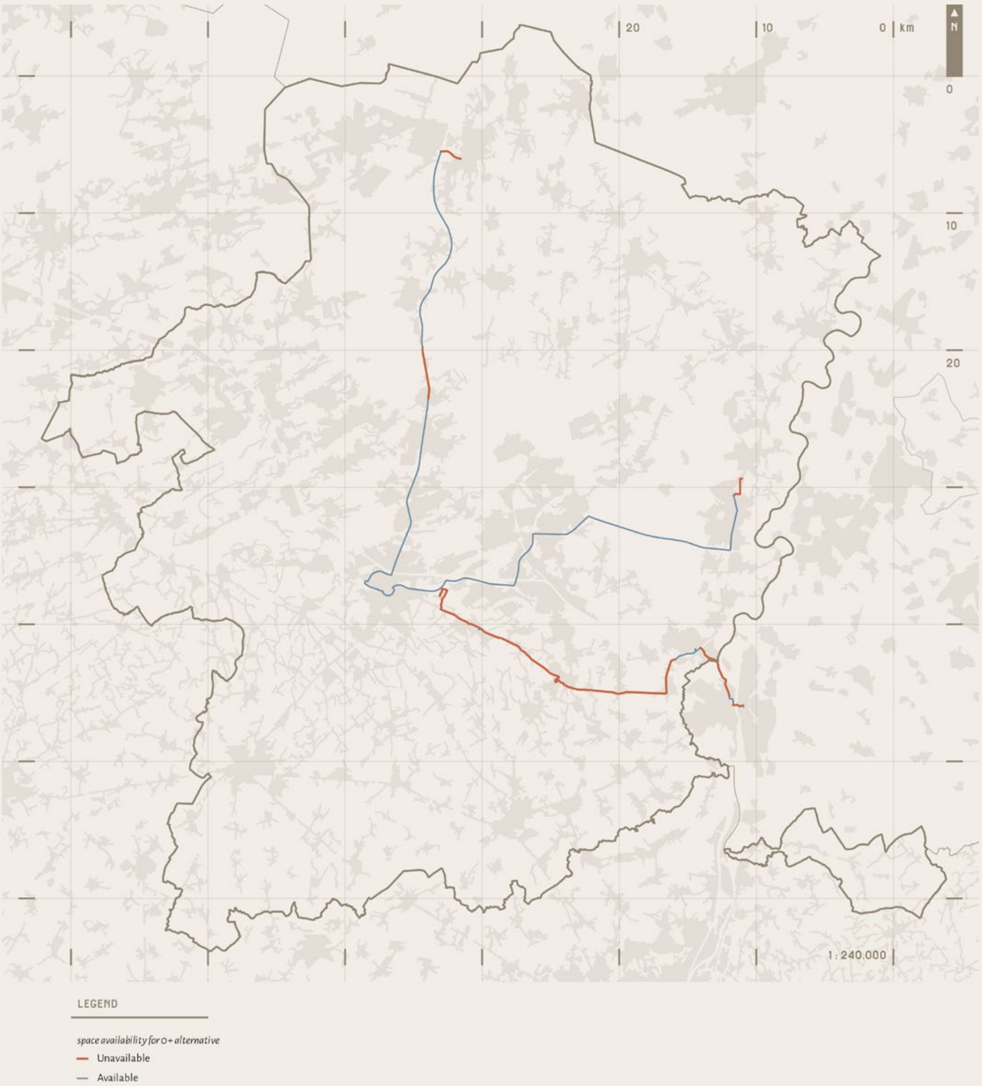


Figure 68. Space unavailability for alternative 0+

Since the study does not involve looking into route alternatives for infrastructures, Environmental Impact criteria that differ between the suitability criteria are categorised as Suitability. The Natura 2000 and VEN areas in the corridor will be counted by the overlapping kilometres for ROW construction. If the ROW cannot use existing road space in the VEN or Natura 2000 areas, this will result in a significant deduction in the scores. The corridor width of 7 metres will be used to calculate the required area of the corridor. For the 0+ alternative, as no extra ROW will be built for Spartacuslijn 1 and existing roadways can be used for other parts of the sections, there will be no Natura 2000 infringement.

5.5.2 ACCESSIBILITY

The accessibility measurements are conducted through the available open-source tool UrbanAccess for GTFS-based public transport accessibility measures (Blanchard & Waddell, 2017). In order to measure accessibility, the existing GTFS data from De Lijn will be adjusted per alternatives, with hypothetical services and patterns that can be made possible while maintaining the same maximum capacity in the Spartacuslijn corridors. Punctuality based on the intersection level and platooning will also be put into consideration by adding buffer times between stops.

0 (Nul) scenario:
No changes are made to the existing GTFS file.

0+ scenario:
To reflect the use of signal prioritisation and curbside bus lane, travel time on N702 (Dusartplein – Westerring) and (line 11 and 45) is reduced by 1 minute to reflect signal prioritisation and curbside bus lane.

Express bus that is comparable to Spartacuslijn 1 and 2 is added (1001, 1002), with same service frequency (15-minute service). The buses will only stop on stops that are closest to the planned Spartacuslijn 1 / 2 stops. There are exceptions as follows:

- Instead of using Hasselt's Outer ring (R71), express bus will make use of Hasselt's smaller ring road (R70), stopping at "Hasselt Leopoldplein" (29459, 29461) and "Hasselt Dusartplein" (29267, 29268).
- For Spartacuslijn 1, Dipenbeek station stop will be replaced by "Diepenbeek Marktplein" (27878, 27879), Beverst stop by "Beverst Nijverheidsstraat" (27028, 27029), Munsterbilzen stop by "Bilzen Station Perron 5" (105151), Eigenbilzen by "Mopertingen Mathijsestraat" (88803, 88804), and Lanaken Europaplein by "Lanaken Cultureel Centrum" (31391).
- Between Mopertingen and Lanaken, the route will make an extra stop at Veld wezelt, at "Veldwezelt Kruispunt" (31470). New Eastbound stop is created on Bilzerbaan across the street to allow buses travelling to Maastricht from Hasselt to be able stop.
- A new stop is created at Bosdel-Noord on Westering, on the location where pre-existing bus bays are visible.

Off-the-shelf electric bus comparable to VDL Citea SLE-120 would be used for the express service.

The travel time between stops are calculated using Openrouteservice. The resulting travel time for Spartacuslijn 1 replacement is 59 minutes, and Spartacuslijn 2 replacement is 51 minutes.

Line 45's trips that are overlapping with Spartacuslijn 2 will be reduced to only once per hour to emulate service hourly local service. Line 20a's hourly service will be still kept untouched to ensure local service.

Trambus scenario:
The trambus route (1001, 1002) will be introduced. The service pattern will be decided based on the available information about Spartacuslijn 1 and 2.

- For Spartacuslijn 1 (Hasselt - Maastricht), it will be running every 15 minutes, and the total travel time will be 42 minutes (Challans, 2022).
- For Spartacuslijn 2 (Hasselt - Maasmechelen), it will be running every 15 minutes, and the total travel time will be 56 minutes (De Werkvennootschap,

2022).
- Travel time on motorways and 90 km/h sections will be extended to reflect lower operating speed, which is 83% of existing buses.

Line 45's trips that are overlapping with Spartacuslijn 2 will be reduced to only once per hour to emulate service hourly local service. Line 20a's hourly service will be still kept untouched to ensure local service.

As currently planned, Van Hool ExquiCity 24 electric model (max. speed 72 km/h) is used.

Scenario A:
This alternative expects similar level of technology applied in CAVForth pilot project inside the BRT corridor. Sections outside of the BRT corridor cannot be expected to have same level of automation, and therefore will be operated fully by human drivers.

4 branching routes per travel; in testing GTFS, half will be represented, therefore two routes will be diverged every trip. Parts of line 104, 36, 10, 20a, 18, 63, 64 is replaced.

The travel time on motorways and 90 km/h sections will be shortened for parts of Spartacuslijn 1 and 2 to reflect higher operating speed, which is 132% of trambuses. Taking maximum speed differences in account, the Spartacuslijn 1 resulted in total travel time of 38 minutes, and Spartacuslijn 2 resulted in 47 minutes.

Line 45's trips that are overlapping with Spartacuslijn 2 will be reduced to only once per hour to emulate service hourly local service. Line 20a's hourly service will be still kept untouched to ensure local service.

Expected to use tailor-made vehicle comparable to Switch Mobility Solo or VDL MidCity; maximum speed specification of Switch Mobility Solo (95 km/h) is used.

Scenario B:
1 branching routes per travel; in testing GTFS, half will be represented, therefore one route will be diverged every second trip. Parts of line 20a, 18, 10 is replaced.

Buses wait at the station until the arrival of other platoon.

Line 45's trips that are overlapping with Spartacuslijn 2 will be reduced to only once inside the simulation's timeframe to emulate hourly local service.

The travel time on motorways and 90 km/h sections will be shortened for parts of Spartacuslijn 1 and 2 to reflect higher operating speed, which is 120% of trambuses. Taking maximum speed differences in account, the Spartacuslijn 1 resulted in total travel time of 38 minutes, and Spartacuslijn 2 resulted in 48 minutes.

Line 45's trips that are overlapping with Spartacuslijn 2 will be reduced to only once per hour to emulate service hourly local service. Line 20a's hourly service will be still kept untouched to ensure local service.

Off-the-shelf electric bus comparable to VDL Citea SLE-120 would be used for the express service.

Scenario C:
This alternative expects similar level of technology applied in JR West MI-NNA project inside the BRT corridor, therefore the driver will be only present in the first vehicle in the

platoon. Sections outside of the BRT corridor cannot be expected to have same level of automation, and therefore will be operated fully by human drivers.

4 branching routes per travel; in testing GTFS, half will be represented, therefore two routes will be diverged every trip. Parts of line 104, 36, 10, 20a, 18, 63, 64 is replaced.

Buses wait at the station until the arrival of other platoon. Therefore the travel time buffer of 5 minutes are added on every point the bus merges with Spartacuslijn.

The travel time on motorways and 90 km/h sections will be shortened for parts of Spartacuslijn 1 and 2 to reflect higher operating speed, which is 132% of trambuses. Taking maximum speed differences in account, the Spartacuslijn 1 resulted in total travel time of 38 minutes, and Spartacuslijn 2 resulted in 47 minutes.

Line 45's trips that are overlapping with Spartacuslijn 2 will be reduced to only once per hour to emulate service hourly local service. Line 20a's hourly service will be still kept untouched to ensure local service.

Expected to use tailor-made vehicle comparable to Switch Mobility Solo or VDL MidCity; maximum speed specification of Switch Mobility Solo (95 km/h) is used.

Figure 69. Area used for testing accessibility per scenario

Figure 70. Selected area for using the results

After each scenario's GTFS scenario are set, a location-based accessibility measurement is conducted using a Python package UrbanAccess (Blanchard & Waddell, 2017). The package will calculate jobs available to reach within 1-hour commute on foot and public transportation. The timeframe for calculation is Thursday, 07 October 2021, between 07:30:00 to 09:00:00. The difference between alternatives in the total sum of jobs in affected municipalities in the simulations (Alken, As, Bilzen, Borgloon, Diepenbeek, Dilsen-Stokkem, Genk, Hasselt, Heers, Hoeselt, Houthalen-Helchteren, Kortessem, Lanaken, Maaseik, Maasmechelen, Riemst, Tongeren, Wellen, Zonhoven, Zutendaal) is counted. Following Martens (2016)'s principle of transportation justice, the top quartile nodes will be excluded from the calculation in order to give more focus on the impacts of less accessible areas.

5.5.3 OPERATING COSTS

The variable costs will be estimated based on the Dutch regional public transport cost model by CROW-KpVV (2022) for 2021, adjusted with inflation using CBS (2023) numbers between 2021 and 2023: 21,0%. The costs will be calculated based on the hypothetical network, schedule, and timeframe (07:30:00 to 09:00:00) used in testing the Accessibility criteria.

Not all operating costs are counted in the operating costs. While aspects such as indirect personnel costs and other indirect costs may increase based on the scale of exploitation, they will be dependent on the setting of operation in practice and are far less affected by different alternatives. The vehicle costs may also change, but there is not enough literature on how different levels of automation may influence vehicle costs. Therefore, only the direct personnel costs, the number of kilometres driven, and how many personnel hours are required for driving are taken into calculation.

Energy costs are determined by the type of fuel and the amount of distance driven. Based on CROW-KpVV's cost model suggests that conventional diesel buses cost 0,39 to 0,48 euro per kilometre, and battery-electric buses cost 0,09 to 0,11 euro per kilometre; using its higher estimate and adjusting with inflation, the value of 0,58 euro/km for diesel, and 0,13 euro/km for electric buses will be applied.

In personnel hours, only hours spent in service will be used for calculation. Hours required for breaks and overhead are not calculated, as it depends on the situation. In Alternative A, Personnel hours will be zero inside the Spartacuslijn corridors, and for Alternative C, it would be counted as having one driver inside the Spartacuslijn corridors to take Platooning into account.

5.5.4 ENVIRONMENTAL IMPACT

While the analysis on environmental impact often involves the analysis on infringement on areas such as ecologically sensitive areas and culturally significant areas, this criteria would only imply a significant difference if the study's goal was to understand different route alternatives. However, for this study, the route is the same for all alternatives except 0+; only infrastructural levels dictate whether extra construction may be required or not. Therefore, it is merged into the suitability criteria, as analysing the difference based on the space unavailability criteria is required.

Moreover, because the traject alternative is the same for all alternatives except 0+, criteria that do not have any overlap with Spartacuslijn or 0+ alternative routes are excluded from consideration. This includes contours or areas that do not overlap at all, or are overlapping with sections that are classified as 0 or B in the Spatial unavailability criteria, which means that no infringement would be made, and the result will be the same for all alternatives (0). Therefore, the cultural-historically protected areas, flood risk areas, subsoil heritage sites, and protected monuments are excluded, and the remaining Natura 2000 and VEN are analysed as part of the suitability criteria.

Noise is analysed to measure the impacts on the living environments. Unlike previously mentioned criteria, the calculation of noise contours does not differ per classifications in the Spatial unavailability; instead, the creation of new roadways (where it has not been already present) will be the determining factor. Sections that involve new roadway creation are a large part of Spartacuslijn 1 and a small part of Spartacuslijn 2 around the University of Hasselt. In other words, only the alternatives that use dedicated busways – alternative Trambus, A, B, and C are affected. The Built-up areas will be determined based on the Copernicus CORINE land cover data, with areas designated as 'continuous urban fabric' and 'discontinuous urban fabric'. The created noise zones will be calculated as a 2-lane road, which a noise zone distance of 200 metres for the built-up areas, and 250 metres for outside of the built-up areas applies (InfoMil, 2019, as cited in Baggen & Van Ham, 2019). Since the section of new roadway creation does not differ between alternative Trambus, A, B, and C, the criteria will be black and white (0 – 1) between 0 / 0+ and Trambus / A / B / C.

As the purpose of the multi-criteria analysis is to understand the impacts of different elements, the different vehicle types' CO_2 emission is also used as criteria. CO_2 emission is calculated for their exhaust emission per fuel type. For conventional diesel buses, 0,835 kg per vehicle km is applied, based on CROW-KpVV's data (CROW-KpVV, 2019). For electric buses, theoretically the exhaust emission would be 0; however, it is necessary to calculate the emissions directly related to its exploitation is very hard to define for electric buses, as the exhaust emission will be zero for electric buses. The well-to-wheel analysis takes other factors, such as energy production methods (M. Verbeek & Van Grinsven, 2021) into account, but in this case, Flemish bus operator De Lijn claims that they only purchase “green electricity” (Groene stroom), therefore the buses have completely zero emissions (De Lijn, n.d.-b). Based on De Lijn’s claims, electric buses’ CO_2 emissions will be calculated as 0. This makes the criteria black and white.

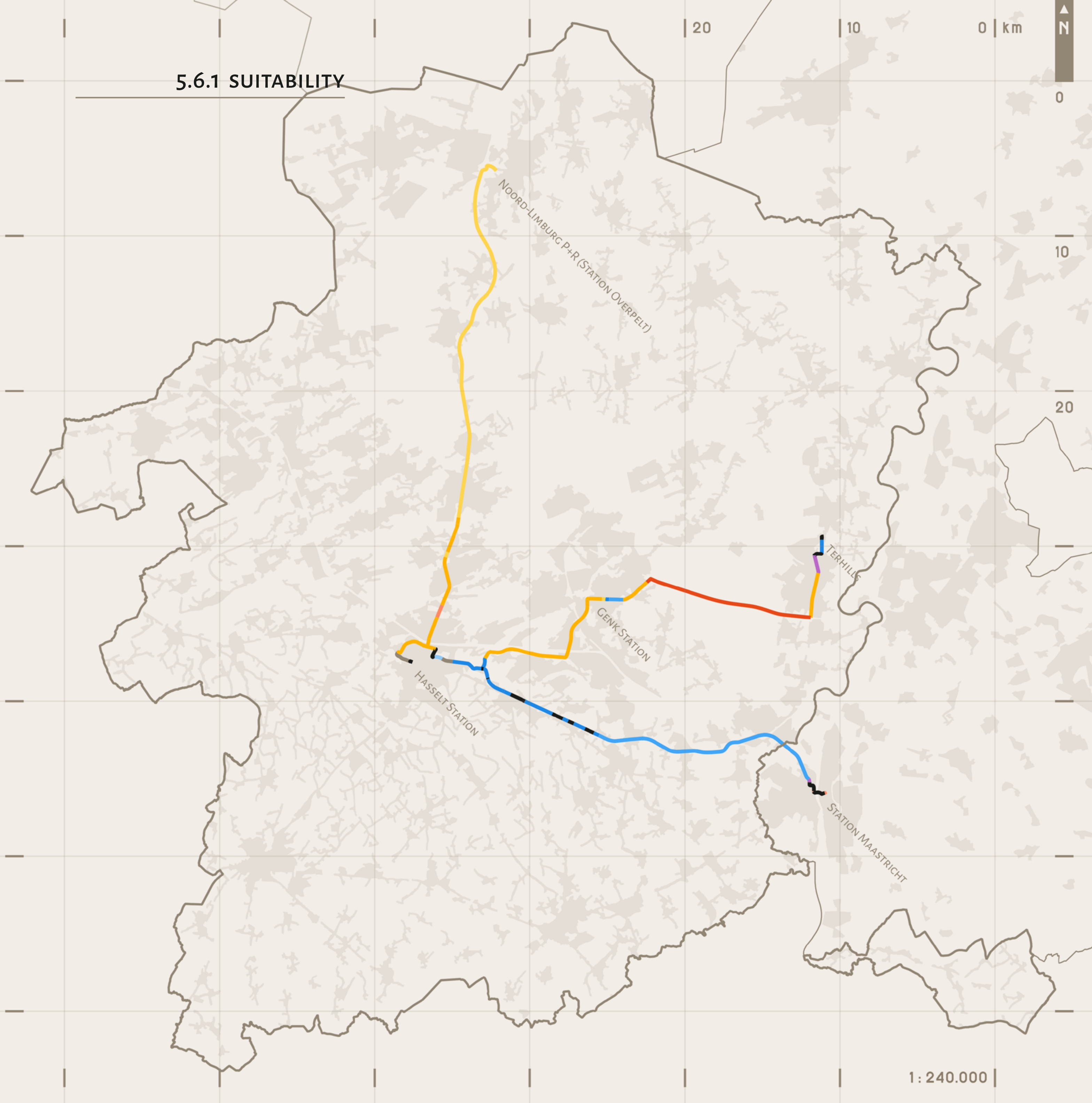
5.6 MULTI-CRITERIA ANALYSIS

The results of each criterion analysed are shown in Table 9. The results of the analysis are discussed in the chapter.

Criteria	Sub-criteria	Unit	0	0+	Trambus	A	B	C
Suitability	Space unavailability for Spartacuslijn ROW	kliometres	0	38,32	7,57	70,75	7,57	8,58
	Areas in Natura 2000 & VEN	square kilometres	0	0,014851	0,000329	0,06545	0,000329	0,020216
Accessibility	Location-based accessibility measurement (UrbanAccess)	Number of jobs	148232606	447803266	444467543	643489020	481060502	569905881
Operating costs	Personnel hours	Hours	6,76	13,76	13,9	7	23,15	21,33
	Energy costs	€	162,98	83,69	86,81	216,45	148,51	216,45
Environmental Impact	Sound pollution zones, built-up	Square kilometres	0	0	14,92	14,92	14,92	14,92
	CO_2 emission	g/km	835	0	0	0	0	0

Table 9. Raw results of criterias

5.6.1 SUITABILITY

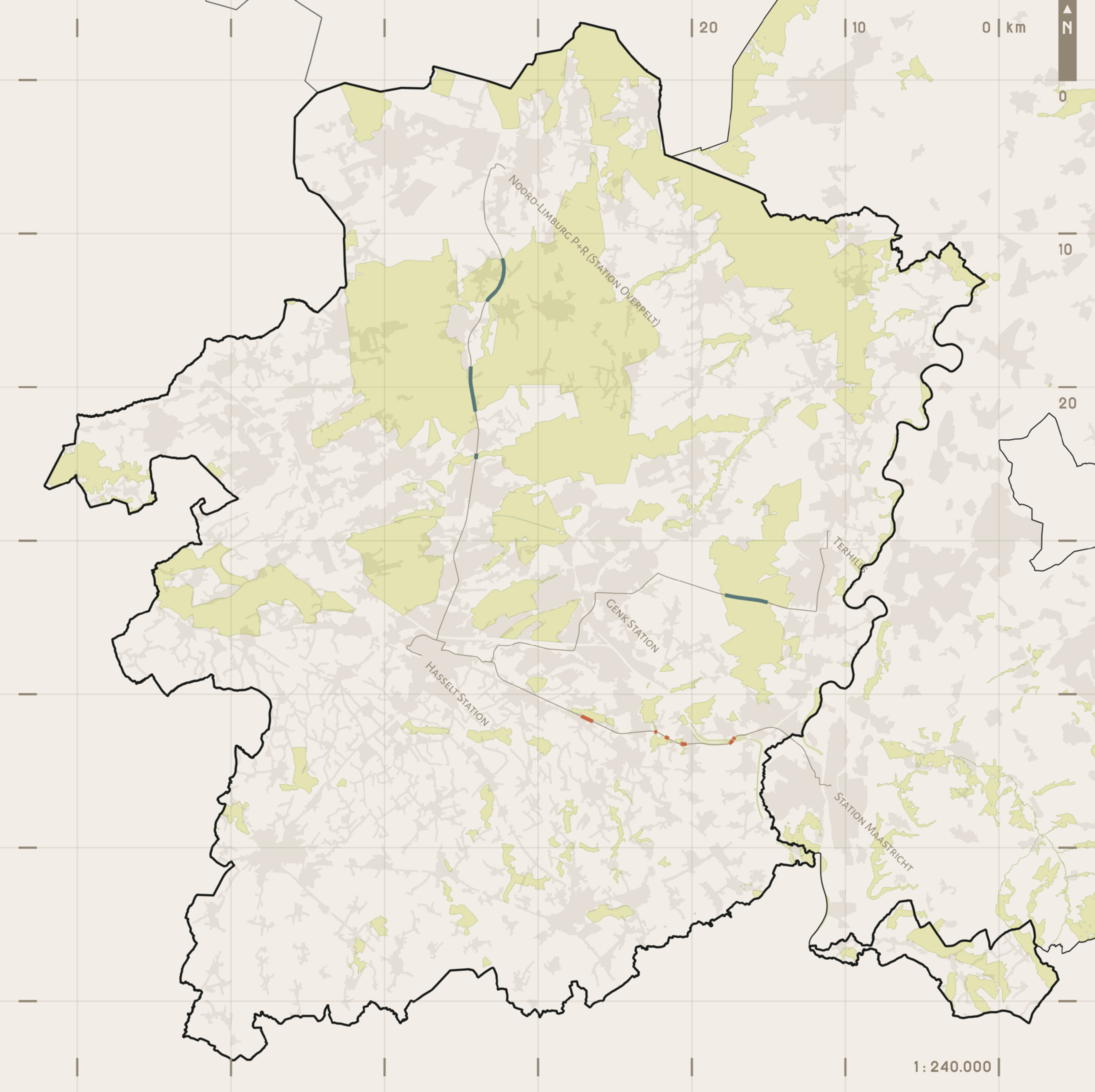


LEGEND

- 0: Already built busways
- A: Unbuilt open space around the road
- B: Former track bed of railroads, vicinal tramways
- C: GTI/GNP plots
- D: Existing roads with 4 lanes or more
- E: Existing physically separated / median bus lanes
- F: Motorways or uninterrupted traffic
- G: Existing curbside transit lane
- H: Existing roads with 3 lanes or more
- Built up

Figure 71. *Classification of space unavailability*

Due to the high level of infrastructure standards required for alternative A, the space unavailability was the highest on alternative A; this is mainly due to the section between Genk and Maasmechelen, where buses must run on the existing A2 motorway. Depending on the design on a spatial configuration, or the possible advancement in vehicle automation, this may not become a problem by the time of the implementation; CAVForth's pilot project already do include motorways as their ODD, however, whether the completely unmanned higher-speed operation in mixed traffic will be possible is still unclear, therefore it can be concluded that for now the A2 section will require the manned operation, or to have physical separation in order to reduce the ODD.



LEGEND

OVERLAP WITH NATURA2000 AND VEN
- Needs extra space (A,B, Built-up)
- Can use existing road space (E,G)
- No overlap
- Natura 2000

Figure 72. *Classification of Natura 2000 / VEN space use*

5.6.2 ACCESSIBILITY

After all, the primary goal of the transportation projects remains accessibility; especially in Limburg, with the spatial dispersion, providing a good level of accessibility remains a challenge. Therefore accessibility is given the most weight. Surprisingly, Trambus has shown almost the same or even worse accessibility than the 0+ alternative, where normal buses will be run on existing roads, making limited stops similar to Spartacuslijn with comparable service frequency. This is likely due to the higher maximum speed for normal buses compared to Spartacuslijn, and its possibility to stop near the city centre on the smaller ring of Hasselt.

Due to the higher level of branching services, alternatives A and C scored best in this regard. Alternative C scored relatively less than alternative A due to buffer time at the stops required to join other platoons. Alternative B scored fairly similar to Trambus 0+ alternative, and scored accordingly with its amount of branching services (1 per trip) compared to A and C (4 per trip).

Figure 73. Results of accessibility analysis

Following Martens (2016)'s transportation justice principles, excluding areas that were on the 25% quartiles in Alternative 0 (= currently well-served areas) appears to have little impact on the result if both sides are normalised. However, the dispersed variants (A, C) performs relatively better in the less accessible areas than in already accessible areas.

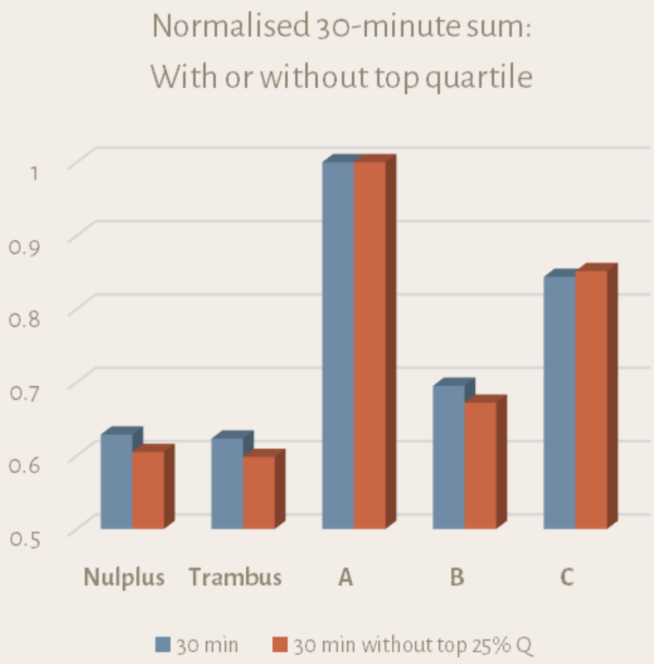


Figure 74. Normalised 30-minute sum of accessible jobs with / without top quartile

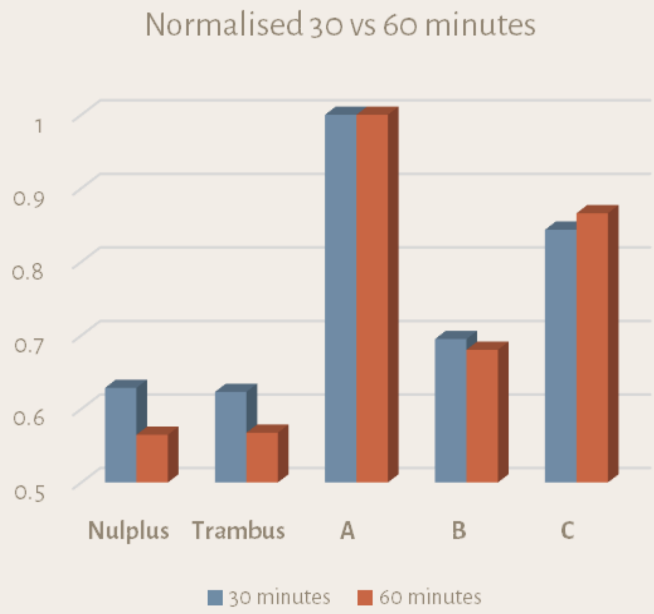
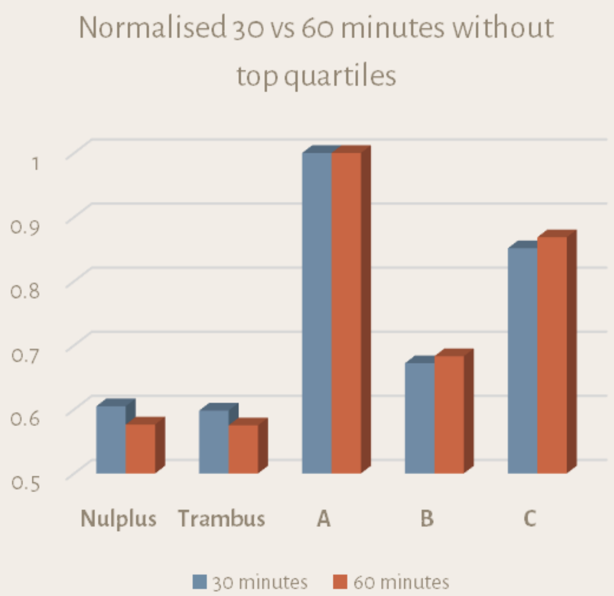


Figure 75. Difference between normalised 30 vs 60-minute sum of accessible jobs

Figure 76. Difference between normalised 30 vs 60-minute sum of accessible jobs with top quartile removed



When normalised, alternative A, B and C fared relatively better if calculated for 60 minutes travel time limit instead of 30. This is likely due to the relatively longer distance the residents in the branchig service area would have to travel to major employment centres. With the top quantiles removed, the Alternative B also scored better, again due to the presence of direct branch services outside of Spartacuslijn corridor.

Nevertheless, the differences after normalisation was fairly marginal with no change in ranking between alternatives. Therefore it can be concluded that the choice of 30 minutes over 60 minutes, or the choice to remove top quartiles did not significantly influence the results, regardless of the theoretical reasoning to choose so.

5.6.3 OPERATING COSTS

Costs for personnel is one of the stakeholder demands, as De Lijn is increasingly facing a labour shortage for human drivers (Sterk, 2022). Moreover, it is by far the most determining factor in the long-term operating costs: it takes roughly half of the whole costs involved in an average service hour (CROW-KpVV, 2015). Despite having far longer driving distance and serving 4 branches per trip, alternative A keeps personnel demand in line with Alternative 0 by eliminating driver needs inside the BRT corridor. Alternative C has higher demand for personnel than trambus or 0+ alternatives indeed, as it practically addes extra labour demand on top of trambus or 0+ scenario for branch services. However, despite having only 1 branch service per trip, alternative B requires the highest amount of drivers per trip, making it a financially risky choice in the long term.

Energy costs were in line with the total distance served per alternative, almost directly translating into accessibility. However, since Alternative 0 is reflection of the current operation that uses fossil fuel buses, it scored higher than trambus, 0+ and alternative B, despite adding no service.

5.6.4 ENVIRONMENTAL IMPACT

Both sound pollution zones and CO2 emissions were 1 – 0, which for the latter owes to De Lijn's policy to only purchase "Green electricity" for its whole fleet of electric buses and trams, eliminating possible tailpipe CO2 emission from usage. The sound pollution zones were already 1 – 0, since only difference between alternatives was whether the alternative required building own roadway for Spartacuslijn or not.

5.6.5 NORMALISING

In order to compare the differences between alternatives, all values are normalised between 0 and 1. Criteria for which smaller values would mean better would be inverted to uniformly compare the results. For example, for energy costs between simulation timescale, the highest value is Both A and C's 216,45, and the lowest value is 0+'s 83,69. For Alternative B, the value is 148,51. Therefore the following formular will be used: (148,51 – 83,69) / (216,43 – 83,69) = 0.48824947273. Since for energy costs, smaller values would mean positive, therefore it is inverted by 1 - 0.48824947273 = 0.51175052727. In the report, only 2 digits will be shown for normalised values, and 3 digits for final values.

5.6.6 WEIGHTING

The costs and suitability in spatial reality are also important factors, as one can determine long-term financial feasibility, and the other can tell how much extra intervention to the physical infrastructural is required for automation. Therefore these are given 20% of weight each.

Since both sub-criteria are 1 – 0 for environmental impacts, the criteria are given only 10% of weight.

Criteria	Criteria Weight	Sub-criteria	Unit	+/-	Sub-criteria weight
Suitability	20%	Space unavailability for Spartacuslijn ROW	kliometres	-	90%
		Areas in Natura 2000 & VEN	square kilometres	-	10%
Accessibility	50%	Location-based accessibility measurement (UrbanAccess)	Number of jobs	+	100%
Cost	20%	Personnel hours	Hours	-	67%
		Energy costs	€	-	33%
Environmental Impact	10%	Sound pollution zones, built-up	Square kilometres	-	10%
		CO2 emission	g/km	-	90%

Table 10. Criteria and their weights

5.6.7 RESULTS

Criteria	Sub-criteria	**0**	**0+**	**Trambus**	**A**	**B**	**C**
Suitability	Space unavailability for Spartacuslijn ROW	1	0,45	0,89	0	0,89	0,87
	Areas in Natura 2000 & VEN	1	0,77	0,99	0	0,99	0,69
Accessibility	Location-based accessibility measurement (UrbanAccess)	0	0,6	0,59	1	0,67	0,85
Cost	Personnel hours	1	0,57	0,56	0,98	0	0,11
	Energy costs	0,4	1	0,97	0	0,51	0
Environmental Impact	Sound pollution zones, built-up	1	1	0	0	0	0
	CO2 emission	0	1	1	1	1	1
		0,38	0,635	0,703	**0,737**	0,632	0,704

Table 11. Results of multi-criteria analysis

The result of the MCA turned out that alternative A is the best option, which is followed by alternative C and Trambus. The low-tech alternative B has shown worse results than 0+ alternative.

5.7 SENSITIVITY ANALYSIS

In order to test how the results are sensitive (dependent) on the weights, each set of criteria is given twice the weight of the intended weight set per scenario except for accessibility, which already takes 50% of the weight. For the accessibility scenario, accessibility was given 75% instead. The unweighted standard weight scenario is also added, where all sub-criteria get equal weight regardless of their importance.

Standard weight		**Suitability 40%**		**Accessibility 75%**		**Operating Costs 40%**		**Environmental Impact 20%**	
0+	0,77	Trambus	0,74	A	0,82	A	0,77	A	0,75
Trambus	0,71	C	0,71	C	0,74	0+	0,65	C	0,70
0	0,62	B	0,69	B	0,64	Trambus	0,65	Trambus	0,63
B	0,58	0+	0,60	0+	0,64	C	0,51	0+	0,61
C	0,50	0	0,53	Trambus	0,62	B	0,47	B	0,61
A	0,42	A	0,49	0	0,10	0	0,46	0	0,20

Table 12. The results of 5 weight scenaios.

In 3 out of 5 scenarios, Alternative A lies fairly far ahead of other options, and Alternative C was the runner-up in 3 out of 5 scenarios. If all criteria are taken equally, the 0+ alternative comes ahead, and if suitability (ease of implementation) took twice the weight, trambus and alternative C come first. In both scenarios, alternative A becomes the least favourable, likely due to its relatively higher potential obstacles with stronger infrastructural requirements.

However, Given that this analysis is aimed at understanding the impacts of automation on accessibility and operations, not deciding a traject alternative for infrastructure, accessibility, and operating costs should be given more weight. On the other hand, suitability and environmental impacts shall be given less weight, given that these are to estimate the potential risks, rather than a certain risk in the implementation; they can change drastically in the actual design process of the ROW itself. With that in mind, if accessibility is given 75% weight, A and C comes in first with a huge margin. If cost is given double weight, while A still comes in first thanks to its lower operating costs. Alternative 0+ and trambus follows with nearly identical results.

While accessibility and costs are important measurements and the only "directly relevant" criteria, however, depending on stakeholder's needs and changing situations, other criterias and scenarios may can be used in situations such as local opposition (environmental impact) or ease of spatial implementation (suitability).

5.8 CONCLUSION

In the choice between 'low (infrastructural) investment, low return (0, 0+, Trambus, B)' and 'high (infrastructural) investment, high return (A, C)' options, it can be concluded that the high-investment, high-return alternatives have taken the upper hand. Therefore the application of alternative A, an option with a higher level of automation and subsequently a higher level of infrastructural investment, would be the ideal solution for Spartacuslijn, considering the huge benefits in accessibility and lower operating costs, despite other potential obstacles are relatively higher. And in case the fully driverless operation (Level 4) inside ROW cannot be realised or spatial integration proves too difficult, then it can still be realised with alternative C, with a reduced number of human drivers in the cost of having slightly higher waiting time at the stations. The low-tech option B, which operates a limited number of branching services without applying automation technologies, shall not be considered a valid option, as the risks in operating costs far outweigh the relatively small benefit it provides. If spatial integration of alternative C would prove impossible or removing drivers from the following vehicles were not possible, it would be rather beneficial to operate frequent express buses on roughly the same route as Spartacuslijn.

The implementation of alternative A would mean that more infrastructural investments will be required, such as more separation of the BRT corridor. Therefore, based on the case studies and the results of the multi-criteria analysis, spatial measures for ROW design and service planning are defined.

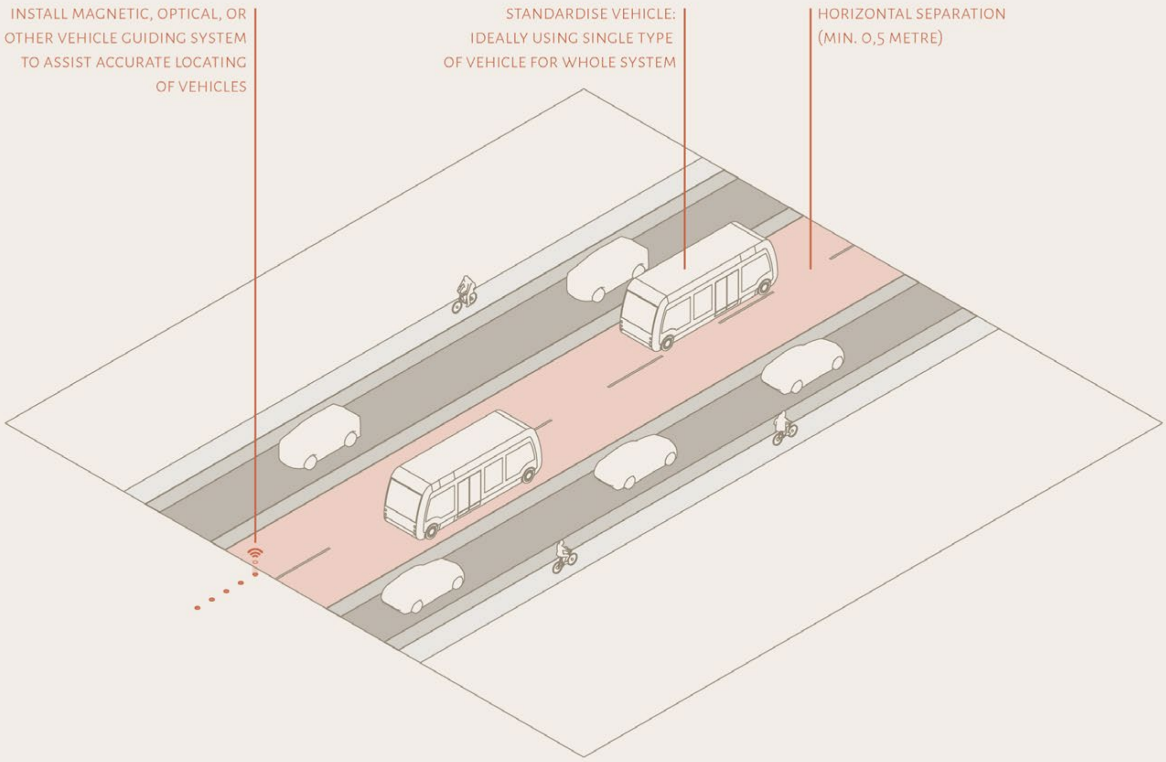


Figure 77. Design example of BRT corridor for alternative A

1. Right of way
A higher degree of separation between BRT and non-BRT vehicles horizontally. The human-driven buses shall ideally be also prohibited from entering the BRT ROW to reduce ODD. The curbside lane should not be used, unless given enough separation between all other potential hazards (vehicles, activities). For flexibility in maintenance situations, the median should not be located between two directions of ROW.

2. Vehicles
Vehicles should be standardised as much as possible, preferably using only 1 type of vehicle across the whole system. This is necessary to keep the potential for cooperative driving capabilities, such as platooning as addressed in Chapter 1.3.4.

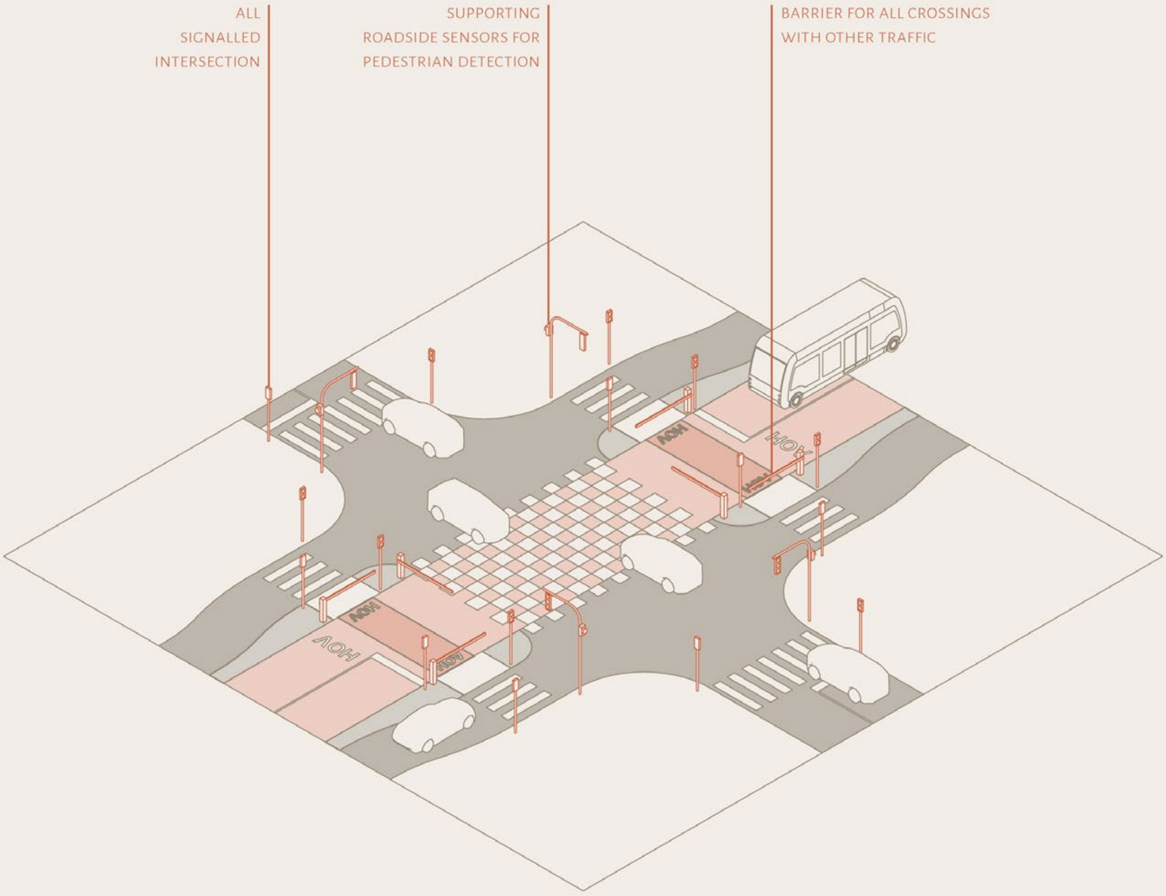


Figure 78. Design example of BRT corridor for alternative A

3. Intersections

Each crossing with car traffic should be signal-controlled and barrier-protected. If the median bus lane enters an intersection shared with other traffic, the left-turning or crossing traffic must be separated inside the given signal cycle, or preferably, BRT should be given separate, prioritised signal cycles. The continuity of BRT ROW should be clearly given to other road users to avoid. Given the high frequency of buses, in urban areas and major intersections, grade separation should be considered if possible. All pedestrian and bicycle crossings, with exception to median bus lanes that share intersection with other traffic, should be also equipped with barriers.

4. Supporting equipment

In order to assist vehicle locating functions, it would be strongly recommended to install magnetic, optical, or other guideway infrastructure to assist in locating of vehicles inside the corridor. Moreover, at intersections, installing sensors for detecting incoming pedestrians and vehicles could be installed.

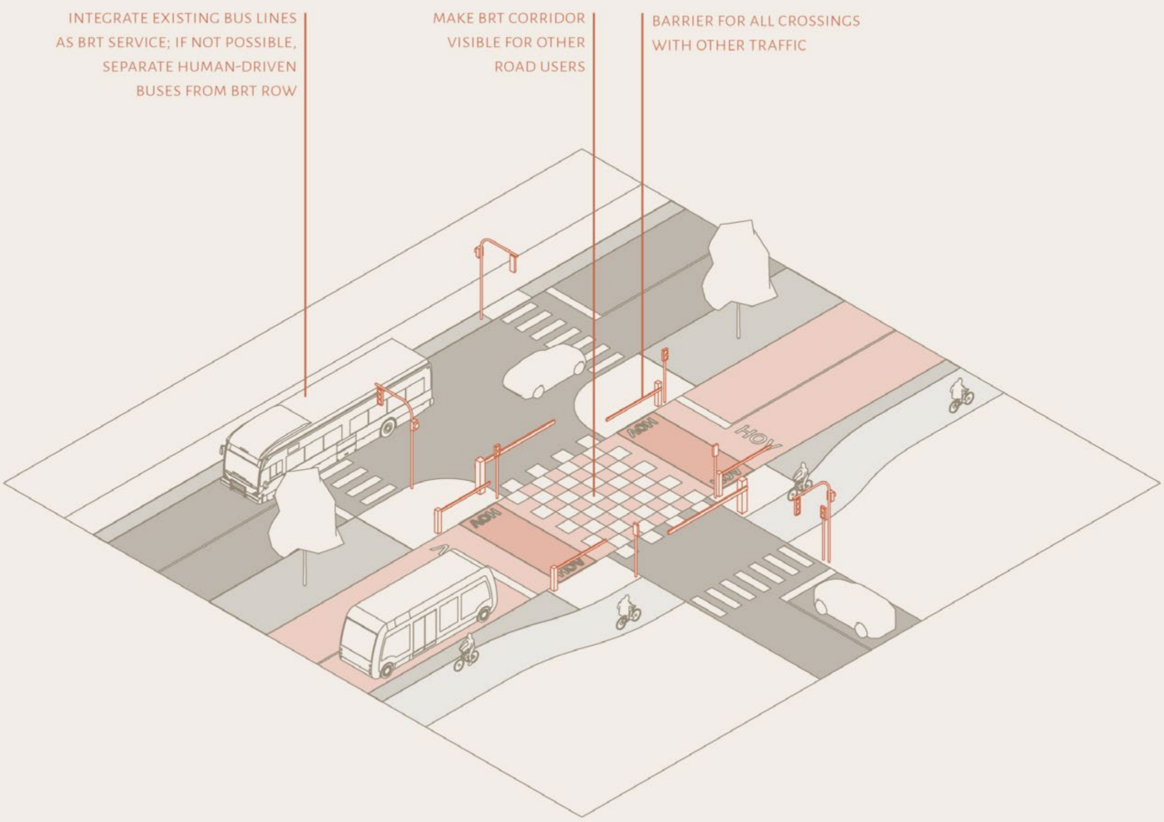


Figure 79. Design example of BRT corridor for alternative A

5. Stations

Platforms and ROW must be separate from existing bus stations. Enough length should be available for platforms, and preferably given extra passing lane and designated stops if spatially possible. Since buses can join and leave the ROW in any moment, the "bunching" of buses may occur (and designed to do so in Alternative C). Therefore enough platform length should be guaranteed. Passenger information for each route's stopping positions in the platoon should be also provided. As human drivers will operate to and from Spartacuslijn stations, the amenities for the drivers waiting at the station should be also installed.

6. Service planning

More existing lines shall be integrated into BRT as branch services as much as possible. Since the operating costs inside the BRT corridor is dramatically reduced, more line configuration and service patterns are possible. This will also compensate the risks involved with prohibiting conventional buses inside the ROW. In terms of planning the network itself, while generally the grid-based network is recommended over traditional radial networks for autonomous bus service planning (Kisner et al., 2017) (in other words: point-to-point network over hub-and-spoke model), since applying driverless operation outside of BRT corridor is still risky, this principle shall be partly adopted as to integrating smaller point-to-point demands into branching services.

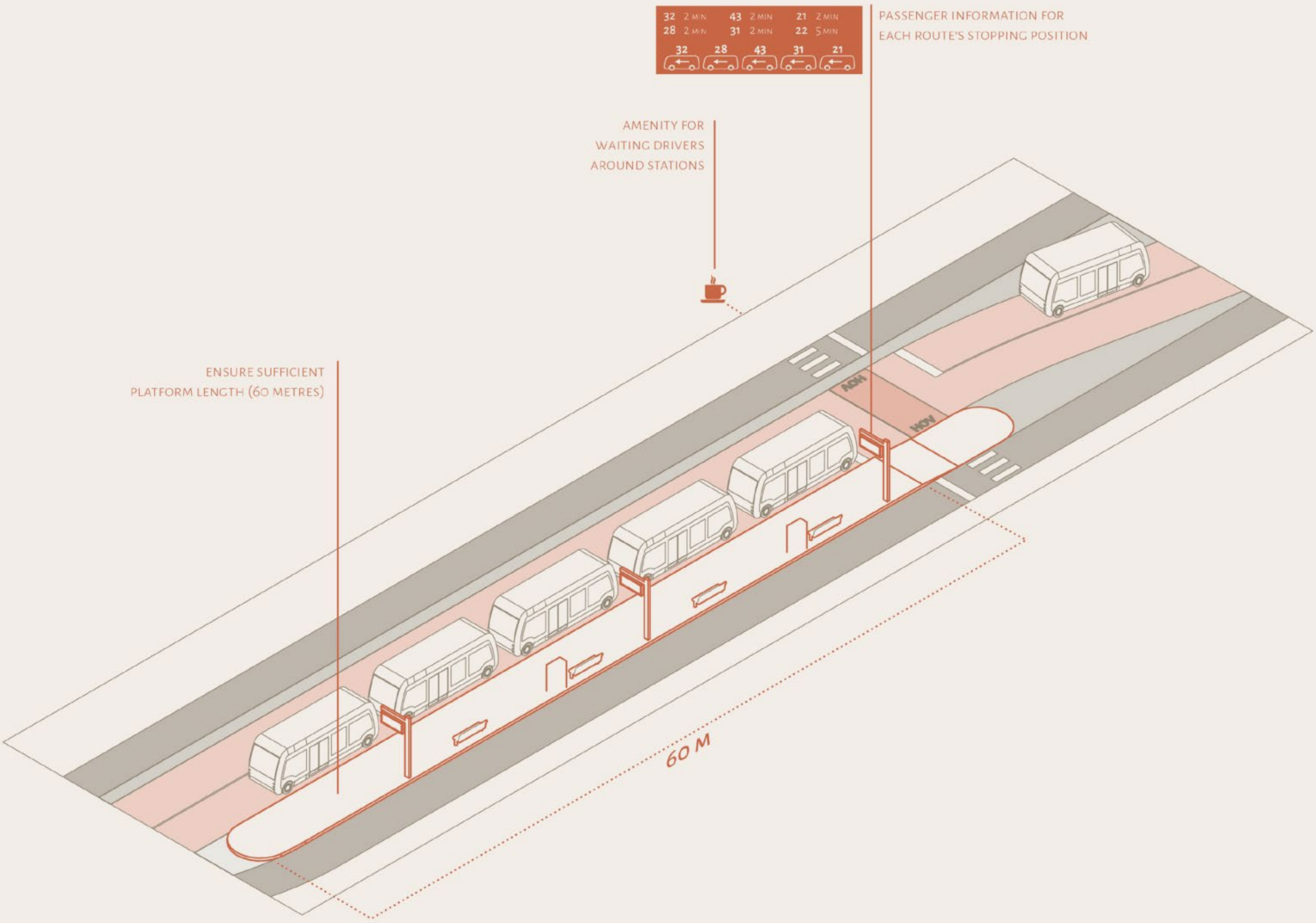


Figure 80. Design example of BRT station for alternative A

In addition, kerb guidance tracks can be installed on certain sections if available. This can significantly reduce the width of ROW while increasing the operating speed, which can help integrate the corridor in limited space, such as motorways or tunnels.

Overhead electric wires inside BRT ROW can also be considered, which can reduce the size of the battery required. Trolley wires should not be used, since the addition of trolley wires and inevitable dewirement problems may cause an extra challenges for driverless operation.

While there are indeed tangible results of autonomous bus projects across the world, even operating on pre-determined, pre-trained public roads as seen in CAVForth pilot project, the full driverless operation without dedicated infrastructure still holds some uncertainty. Therefore it is recommended to still reduce the ODD as much as possible (Chafkin, 2022; Etherington, 2022; T. Higgins, 2022; Shladover, 2016), by designing the infrastructure suited for autonomous buses. If compromise in infrastructure is necessary in case of downgrade to alternative C, the presence of human driver can reduce most of the fail-safe designs, except the key principle of horizontal separation of BRT ROW and controlled intersections.


PEPPE'S

N°6

VISION

NEW SPATIAL FRAMEWORK

6.1 INTRODUCTION

What would then this new mode of public transportation mean for the spatial transition in Limburg? Can this increased flexibility and accessibility be used as leverage?

In this chapter, the current policy of bouwshift is analysed on whether it can drive the spatial transition, and what its implication would be for urban and transportation planning. After that, in order to use the newly found transport accessibility as leverage in neighbourhood development, a guiding framework that clarifies the development potential of the neighbourhood and provides a guidance towards the future is created by classification of built-up areas in Limburg using indicators related to the built environment and accessibility of the area, such as walkability, accessibility, and density. In addition, as public transportation is expected to have a higher level of impact on the liveability of the neighbourhoods, the indicators are aimed to address the amenity level and function mix of the areas too.

Some areas need different approaches apart from the built environment and liveability indicators: areas with socioeconomic challenges, and areas undergoing industrial transition. Such areas are designated as their own types, overriding the existing type designations.

6.2 BETONSTOP, OR BOUWSHIFT

Core strengthening (Kernversterking)

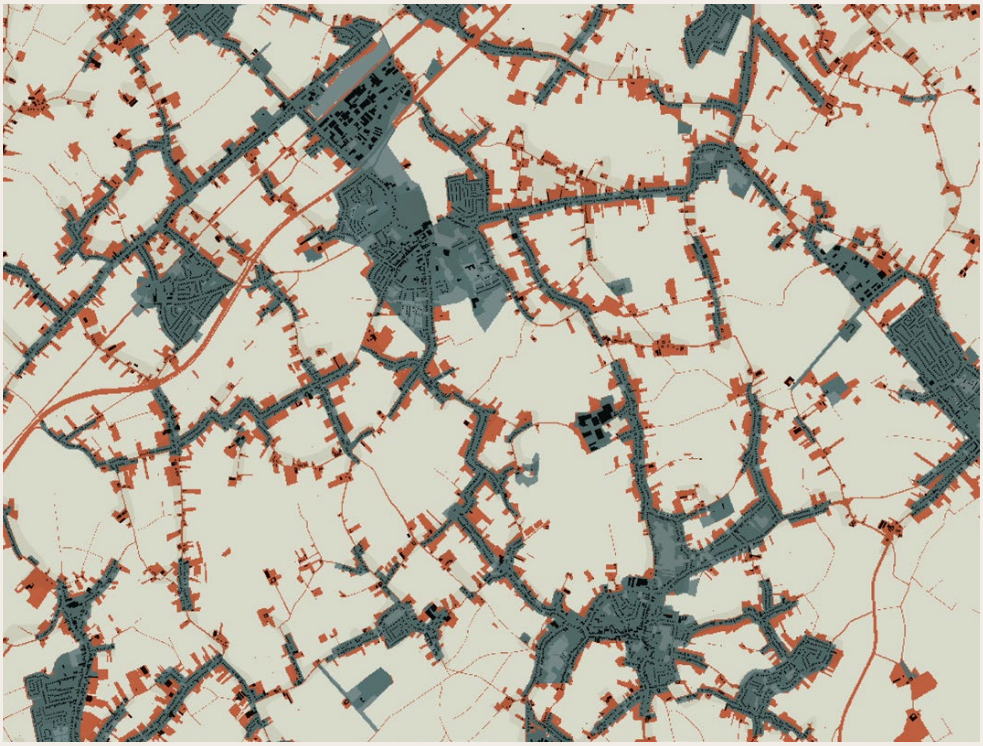
Core strengthening is a policy of revitalising and densifying existing town / city centres. This can includes interventions such as densification, permeable surfaces, and greening of streets (K. Verachtert et al., 2021). In general, it aims to create a quality town centres that are liveable and sustainable.

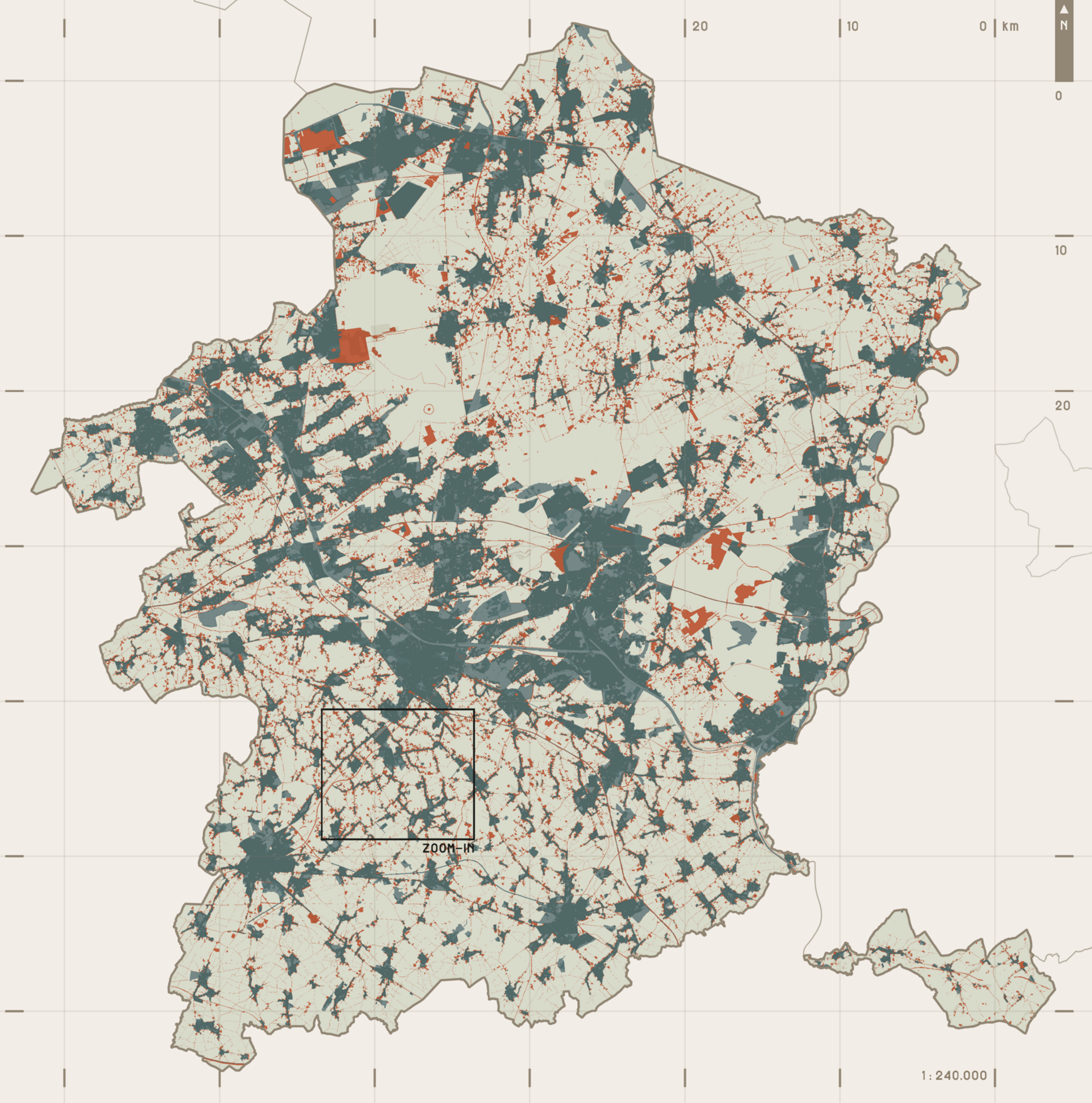
Before the start of design, the current solution of Bouwshift (construction shift) needs to be analysed further. Formerly known as Concrete stop (Betonstop), later changed into Construction Shift (Bouwshift), the Flemish government has set a timeline until 2040 when net-zero land consumption should be realised for development in open space (Vlaamse Regering, 2022). It aims to prevent the building up on open spaces, and push the developments into designated areas by 2040. Therefore the two-track, "push and pull" strategy of strengthening of urban areas and cores on the one hand (core strengthening: Kernversterking), and stopping the land consumption of other areas, on the other hand, will be applied (Taskforce bouwshift, 2021).

Existing land owners in residential expansion areas who now cannot build anymore due to bouwshift will also be compensated for the "planning damage" (planschade) according to its market value, which the funds will come from Construction Shift Fund of the Flemish government. While this sounds feasible, the construction shift policy met with criticism all across the board: Flemish Association of Space and Planning (VRP) called it the "assassination of open space", in their joint statement with Network Architecten Vlaanderen, Natuurpunt, Bond Beter Leefmilieu, and Boerenbond. Since the financial burden for compensation is moved from the Flemish (regional) level to the municipal level, not to mention that it will hinder the crucial supra-local solidarity and coordination, but also make the spatial transition voluntary and burdening for municipalities with already insufficient capabilities (Van De Werf et al., 2022).

Moreover, according to VRP, the yearly 100 million euro budget of the Construction Shift Fund of the Flemish government is insufficient to achieve a large-scale spatial transition involving 30.000 hectares (Ibid.); this is roughly the size of municipality Hasselt, Genk, Diepenbeek, and Maasmechelen combined across Flanders. The compensation to planning damage will also reward ongoing speculations on land that were deliberately left undeveloped.

Figure 81. Built-up areas inside "soft use" lands and zoom-in of dispersed areas. Almost all ribbon developments are already given "hard uses", and little buildings fall under bouwshift (soft use). Data source: Ruimtebeslag versus ruimteboekhouding van het RSV - Vlaanderen - Toestand 2019





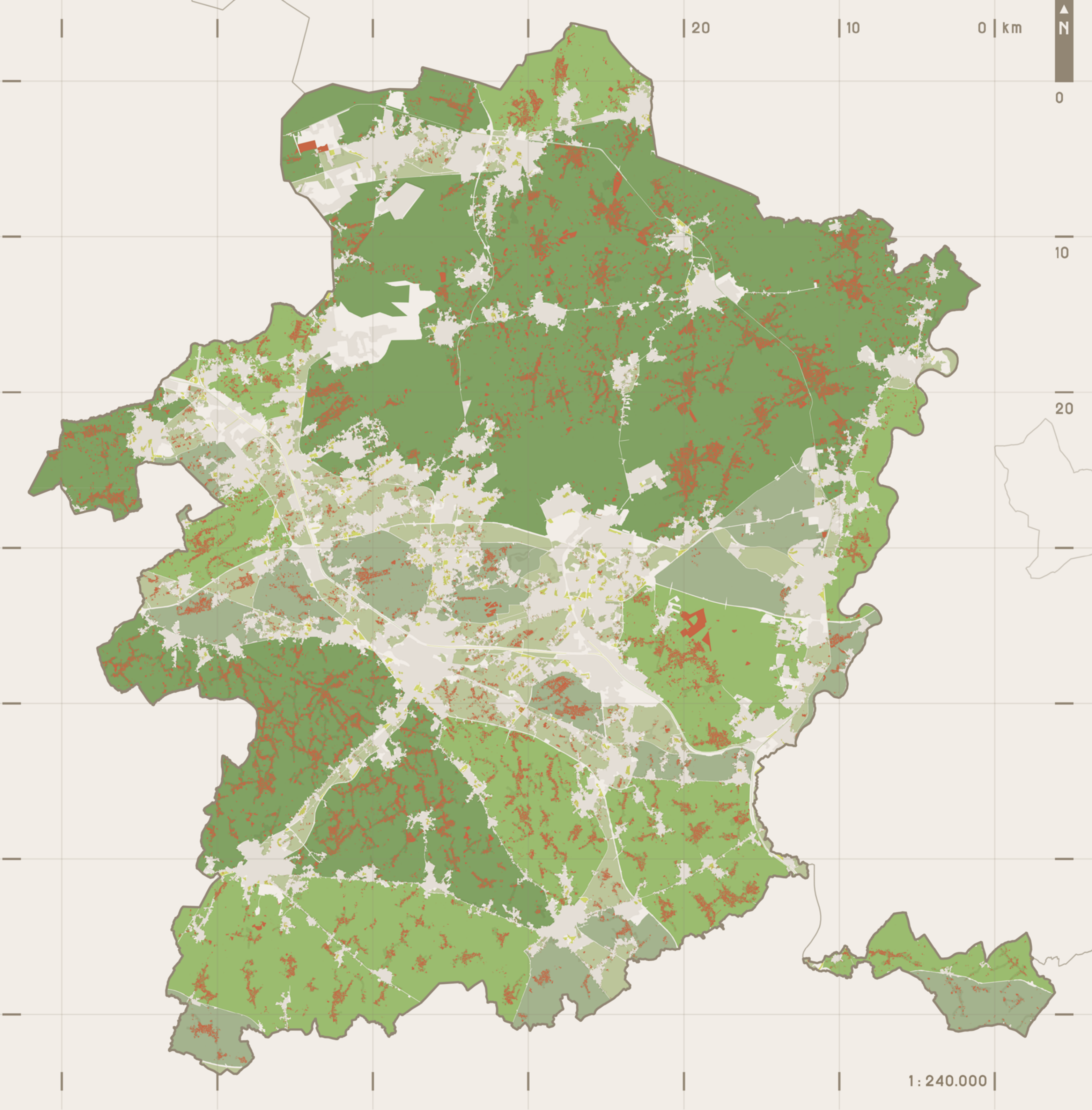
LEGEND

Built-up areas inside soft uses

Soft use = nature, agriculture;
Hard use = residential, commercial, industries, enz.

- Built up - hard uses
- Built up - soft uses
- Unbuilt - hard uses
- Unbuilt - soft uses

Figure 82. Built-up areas inside "soft use" lands in Whole Limburg and the zoomed in area (Figure 80). Data source: Ruimtebeslag versus ruimteboekhouding van het RSV - Vlaanderen - Toestand 2019



LEGEND

COHESIVE OPEN SPACE AREAS (SAMENHANGENDE OPENRUIMTEGEBIEDEN)

- Large rural open space
- Small rural open space
- Large linear and (peri-)urban open space
- Small linear and (peri-)urban open space
- Small pieces
- Built-up areas inside open space areas

Figure 83. Built-up areas inside cohesive open space blocks (red)

Bouwshift is not intended to, nor designed to tackle the existing spatial dispersion already made. The oversupply of "hard uses" like residential or industrial use during the 60s and 70s into the regional plans have legitimised the dispersed settlements, mainly ribbon developments (Lacoere et al., 2023). This is more visible when compared to the Flemish government's cohesive open space area study, which identifies the clusters of open spaces in Flanders (Van Den Berg et al., 2021). The vast majority of the ribbon developments that are inside the open space areas are simply acknowledged in the plans. Bouwshift simply focuses on putting a brake on the future consumption of open space, which mostly focuses on residential expansion areas (woonuitbreidingsgebied) that are not yet realised.

This means that existing ribbon developments and dispersed buildings will remain a reality for the foreseeable future; bouwshift will certainly reduce their attractiveness, but further measures to gradually thin the ribbons are required to actually tackle it must follow.

This is still bad news for the people living in the ribbon developments and dispersed settlements – which ribbon developments alone account for ¼ of the whole Flemish population (Pisman et al., 2021) – two things will be made sure through bouwshift: that the current trends in deteriorating amenities in their area will continue, and eventually the shrinkage will follow in the neighbourhood.

This raises three questions: How to gradually and voluntarily move existing people out of the countryside to towns and cities, and where will they go, and how to provide public service (especially accessibility) for those in the countryside, which are not going anywhere for the foreseeable future and will gradually see their liveability deteriorate?

In conclusion, the current policy on spatial transition in Flanders will stop future consumptions, albeit the implementation itself is flawed. The existing dispersed settlements will certainly not go away in the foreseeable future, unless extra efforts to attract people out of the ribbons and dispersed areas on top of existing betonstop/bouwshift are taken. During the process, the livelihood of those still living in the countryside should not be neglected.

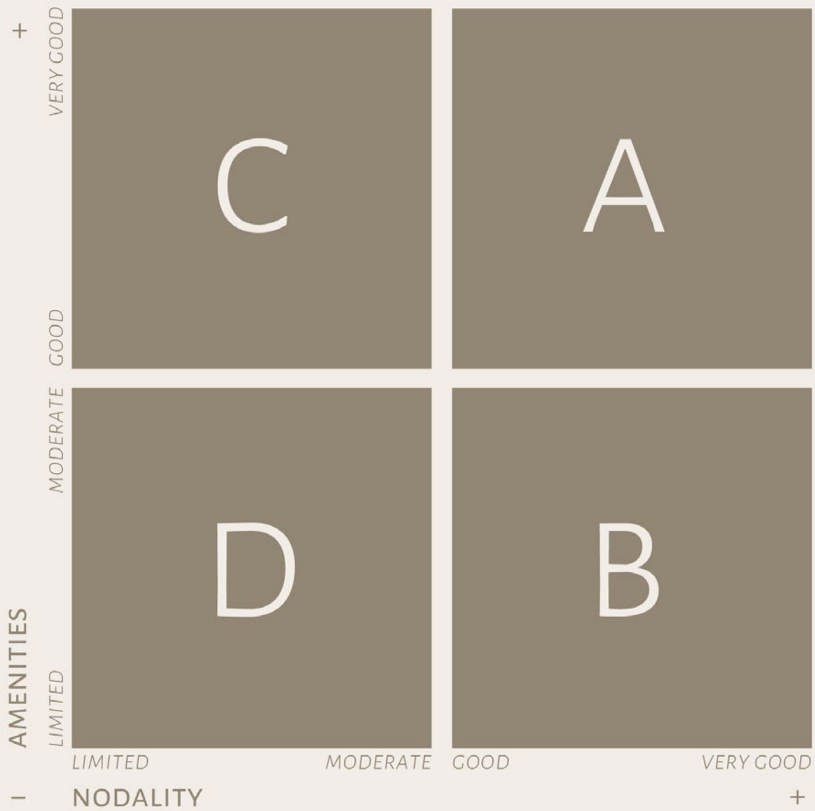
6.3 SPATIAL FRAMEWORK: INDICATORS AND APPROACH

As mentioned earlier, the Flemish discussion of Concrete Stop / Construction Shift involves not only stopping the additional building footprints, but also strengthening existing cores (kernversterking). Therefore, the strategy goes both ways: certain areas can be transformed back to open spaces and green areas, while some areas may need strengthening of certain aspects (public transportation, amenities, density...), and some areas can be already strong enough as is. The spatial framework created in this chapter defines what needs to be done in a certain area based on the potential of a given area, and provide the local-level future goal and strategy for spatial transition. The design interventions designed in the project will be therefore based on the results of the Spatial Framework.

The key instruments in the spatial intervention are the transportation service, investments in amenities and services, and land exchange / reparcelling, or in other words, the "land swap" of plots; it is known under the Flemish planning system as "ruilverkaveling" – officially as reparcelling by force of law with planning exchange (Herverkaveling uit kracht van wet met planologische ruil). In this study, both forced and voluntary land swap is concerned, however, it is important to facilitate voluntary measures as much as possible before opting for forced options, by creating attractive transit-oriented neighbourhoods that people can relocate with ease.

The transportation service can be supplied temporarily or permanently. If the service is provided temporarily, it can be gradually reduced in the course of spatial transition.

Figure 84. The VITO Nodality and Amenities matrix. Image source: Verachtert et al. (2019), adapted by author.



In most of the spatial planning decisions, the Nodality and Amenities data (Verachtert et al., 2019), which provides a framework for future spatial development potentials through the synthesis of nodality and amenities, is used as one of the criteria for understanding the spatial potential of the region. The first quadrant is well provided with both transportation and amenities, the second quadrant is rather limited in terms of their level of facilities, the fourth quadrant is where high-quality public transport is lacking (quadrant C), and the third quadrant is lacking both amenities and transport, making it less suited for development (Vito, 2019).

While it will be used as a starting point of the spatial framework, however, the Nodality and Amenities study calculates accessibility on trains, trams, and "A-line" buses of De Lijn, which connects major destinations and has at least four services per hour during the off-peak hours (Ibid.). This is a good metric for identifying already well-served dense urban environments, but not a good measure for this project, where a new transportation service is created for the spatial transition. Therefore, in this project, more criteria related to the built environment (density, typology) and use (mix of functions) will be assessed alongside Nodality and Amenities data in order to understand the impact of the dispersed public transportation in the region, and Nodality is limited to define areas that are already well-served.

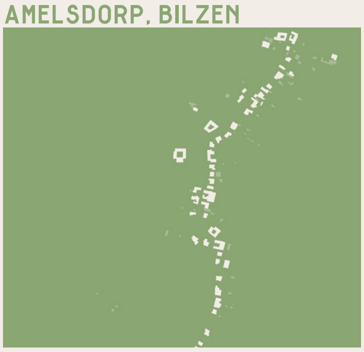
Figure 85. Defined spatial types on the quadrant

CRITERIA	AMENITY	NODALITY	# OF JOBS ACCESSIBLE	HOUSING DENSITY	FUNCTION MIX	CRD (KLV)	NEAR SPARTACUSLIJN	INSIDE COHERENT OPEN SPACE AREA
	CURRENT LEVEL OF AMENITIES	CURRENT LEVEL OF CONNECTIVITY ON RAIL & FREQUENT BUSES	JOBS ACCESSIBLE ON FOOT OR PUBLIC TRANSPORTATION IN 30 MINUTES	CURRENT LEVEL OF HOUSING DENSITY	CURRENT LEVEL OF FUNCTION MIX	CORES, RIBBONS AND DISPERSED BUILDINGS	FUTURE: WITHIN 500M OF SPARTACUSLIJN STOPS	CURRENT: WITHIN COHERENT OPEN SPACE AREAS
		MUST FULFIL BOTH					*MAY OVERRIDE OTHER CRITERIA*	
DATA SOURCE	*Verachtert et al. (2019)*	*Verachtert et al. (2019)*	*by author*	*VITO & Vlaams Instituut Gezond Leven vzw (2021)*	*VITO & Vlaams Instituut Gezond Leven vzw (2021)*	*Pieters et al. (2021)*	*by author*	*Ruimtebeslag versus ruimteboekhouding van het RSV - Vlaanderen - Toestand 2019*
TRANSFORM: NATURE	2 OR LOWER	2 OR LOWER	3000 OR LESS	0 OR LOWER	–	CORE, RIBBON, DISPERSED	–	TYPED BY DEFAULT (UNLESS OTHER TYPES APPLICABLE)
STRENGTHEN: TRANSIT	2 OR HIGHER	2 OR LOWER	5000 OR LESS	0 OR HIGHER	0 OR HIGHER	CORE, RIBBON, DISPERSED	RULES OUT	–
STRENGTHEN: AMENITIES	2 OR LOWER	2 OR HIGHER	3000 OR MORE	–	0 OR LOWER	CORE, RIBBON, DISPERSED	–	–
STRENGTHEN: HOUSING	2 OR HIGHER	2 OR HIGHER	3000 OR MORE	0,5 OR LOWER	–	CORE, RIBBON, DISPERSED	TYPED BY DEFAULT (UNLESS OTHER TYPES APPLICABLE)	RULES OUT
CONCENTRATE	2	2 OR HIGHER	5000 OR MORE	0,5 OR HIGHER	0,5 OR HIGHER	CORE, RIBBON, DISPERSED	–	RULES OUT

EMPOWER: SOCIOECONOMIC — *OVERRIDING CRITERIA: AREAS WITH MODERATE TO SERIOUS SOCIOECONOMIC CHALLENGES, AS ADDRESSED IN TOTTÉ & SOENEN (2019) AND VANDERSTRAETEN ET AL. (2021).*

INDUSTRIAL TRANSITION — *OVERRIDING CRITERIA: LARGE INDUSTRIAL SITES (USED TO BE) BASED ON MANUFACTURING AND COAL MINING ALONG WATERWAYS, IJZEREN RIJN, AND COAL MINING AREAS IN CENTRAL AND WESTERN LIMBURG. AREAS WITH INCUBATORS PRESENT ARE ALSO INCLUDED OUTSIDE OF AFOREMENTIONED AREAS.*

AMELSDORP, BILZEN



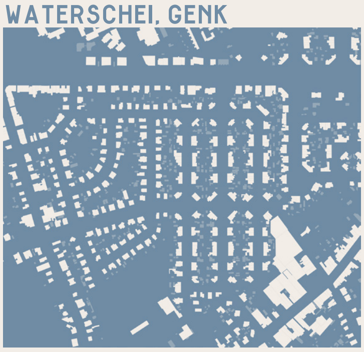
MOPERTINGEN, BILZEN

EIGENBILZEN, BILZEN

MUNSTERBILZEN, BILZEN

BILZEN (CENTRE), BILZEN

WATERSCHEI, GENK



GENK-ZUID, GENK

UNCLASSIFIED: GINGELOM

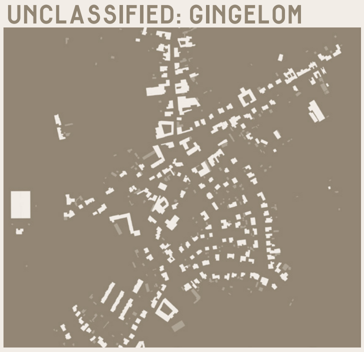


Table 13. Criteria for categorising each types

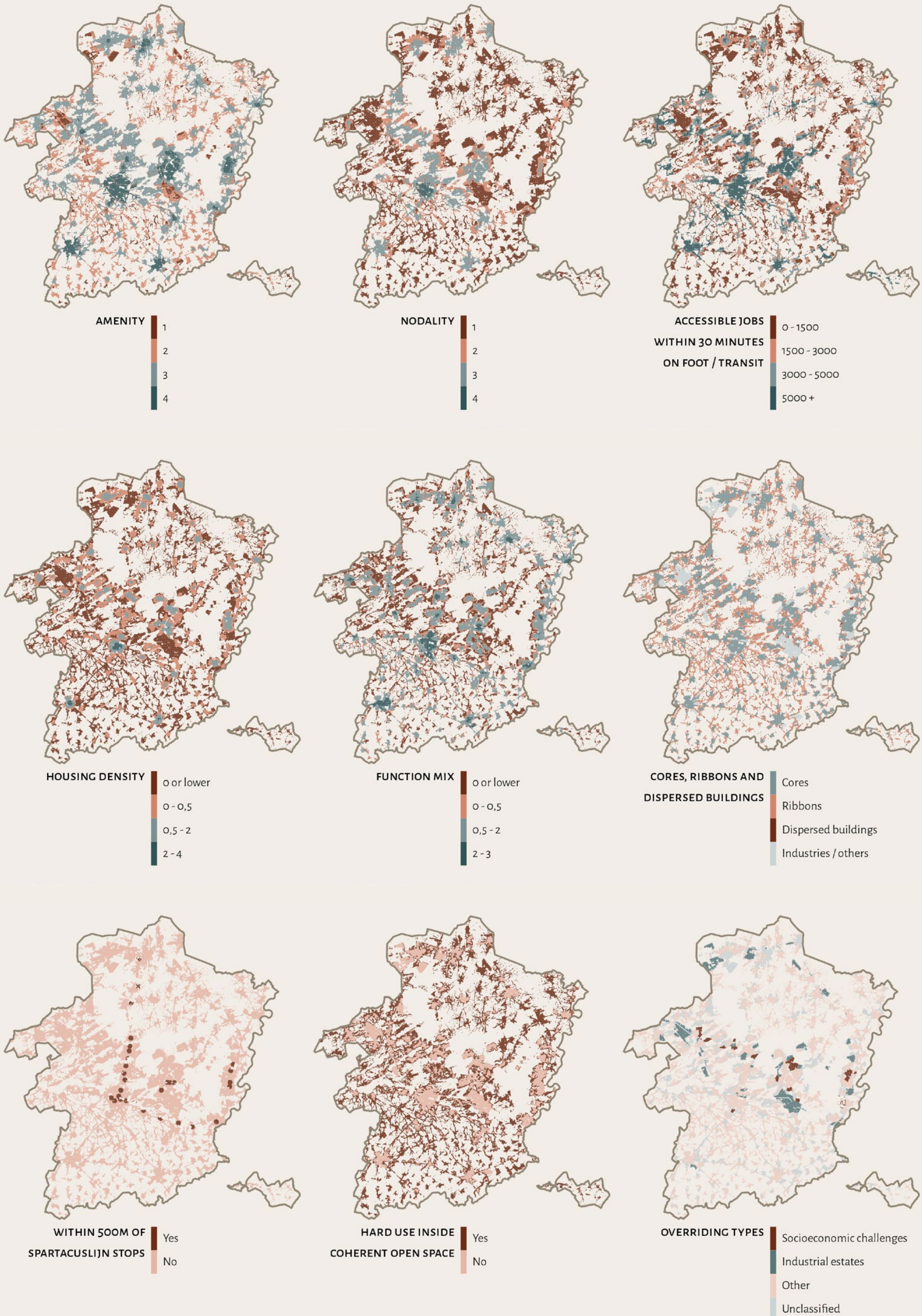


Table 14. Data used in each criteria

To determine the typology of every hectare in Limburg, threshold values are set for each types. On top of the commonly used Amenities and Nodalities criteria, the accessibility data calculated in Chapter 4.2.1 is used to supplement the relatively limiting Nodality. Therefore the threshold value for Nodality is relaxed, and actual accessibility through non-A-line buses would be measuring current accessibility, which reflects the ease of providing public transportation service in its current form. On top of the values suggested, being located within 500 metres of planned Spartacuslijn stops also reflects future accessibility, which being inside 500 metres from Spartacuslijn stop types them as "Strengthen: Housing" areas by default, unless typed otherwise already.

The Housing density and CRD (KLV) classification (core, ribbon, dispersed buildings) were used along with Amenities data to filter the suitability of the built environment. Function mix is also used to rule out suburban warehouse stores typed as Strengthen: Transit, and determine Strengthen:Amenities areas.

Moreover, being inside a coherent open space area rules out certain types, or types them by default: for example, being inside the coherent open space area rules out being "Strengthen: Amenities" area, and types it as "Transform: Nature" by default.

On top of that, as a result of de-industrialisation as introduced in chapter 1.3.1., areas with socioeconomic challenges have been determined by Steunpunt Wonen (Vanderstraeten et al., 2021). Among those neighbourhoods, areas with moderate to serious socioeconomic challenges are designated as Empower: Socioeconomic areas. Certain industrial areas along the canal and IJzeren Rijn that are based on coal mining and manufacturing, such as Port of Genk, are designated as areas for industrial transition regardless of their designated spatial type. These are therefore "overriding types".

Table 15. Defined spatial types and their instruments

	TRANSIT	INSTRUMENTS			
	APPROACH	TIMEFRAME	INVESTMENT PRIORITY	FOCUS	LAND SWAP
TRANSFORM: NATURE	TEMPORARY, DISPERSED	LONG-TERM (BUILT FORM)	#1 PRIMARY	INTRODUCING NATURE AND OPEN SPACE BACK INTO THE AREA	OUT
STRENGTHEN: TRANSIT	PERMANENT & FREQUENT	SHORT-TERM (TRANSIT)	#2 SECONDARY	IMPROVING TRANSIT SERVICE IN THE AREA	IN
STRENGTHEN: AMENITIES	PERMANENT	SHORT-TERM (LAND USE)	#2 SECONDARY	PROVIDING AMENITIES BY INTRODUCING FUNCTION MIX	IN
STRENGTHEN: HOUSING	PERMANENT	LONG-TERM (BUILT FORM)	#1 PRIMARY	HOUSING SUPPLY AS A DESTINATION FOR LAND SWAP	IN
CONCENTRATE	PERMANENT	LONG-TERM (BUILT FORM)	#3 MINIMAL	LIVEABLE URBAN CORES AS DESTINATIONS	IN
EMPOWER: SOCIOECONOMIC	PERMANENT	SHORT-TERM	#1 PRIMARY	SPATIAL & MOBILITY JUSTICE: EMPOWERING DISADVANTAGED AREAS	-
INDUSTRIAL TRANSITION	PERMANENT (FLEXIBLE)	LONG-TERM	#2 SECONDARY	STRENGTHENING EXISTING INDUSTRIES AND SUPPORT TRANSITION TO KEY GOAL AREAS (LOGISTICS, INNOVATION, KNOWLEDGE)	-

6.4 AREA TYPES

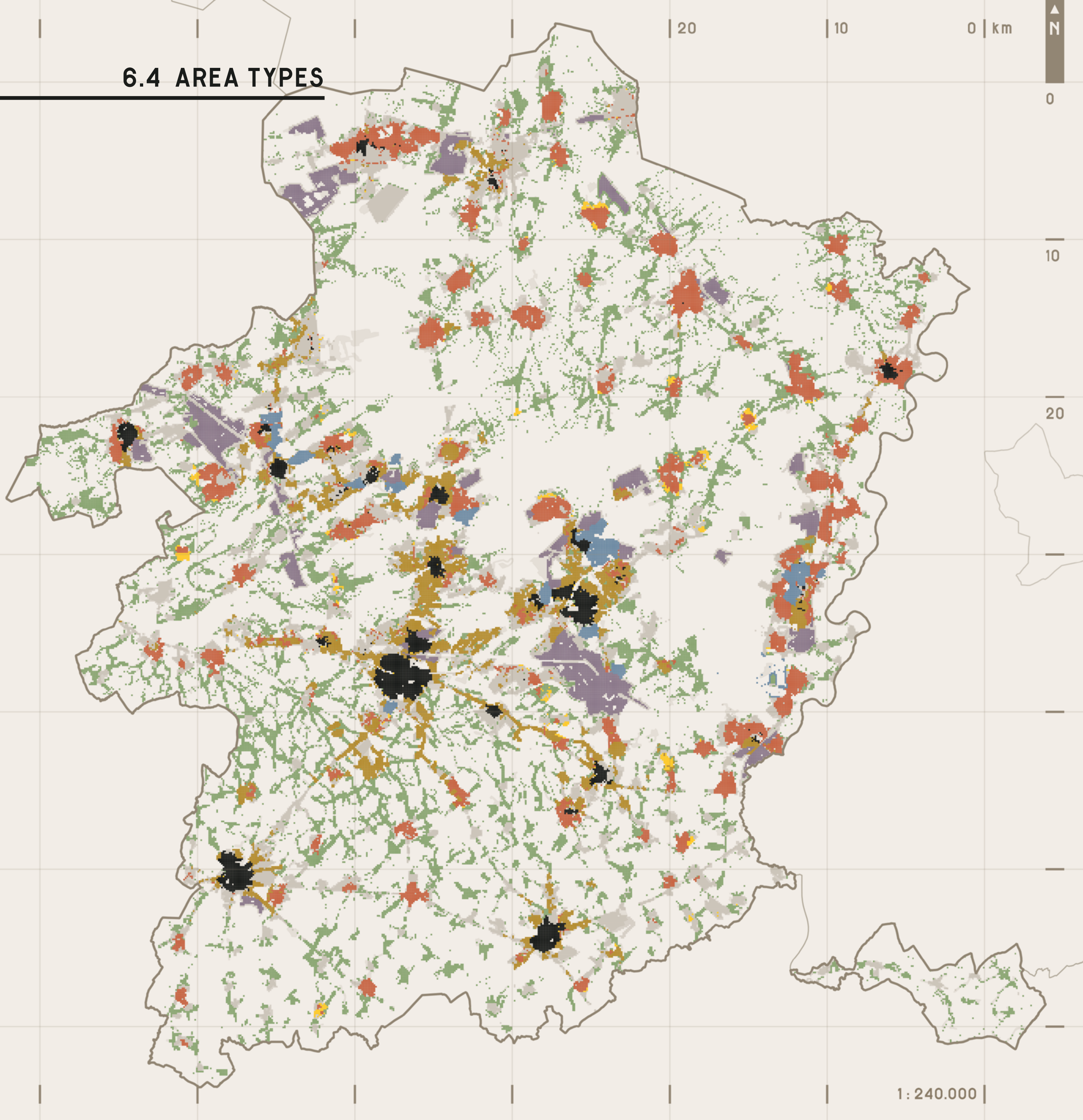
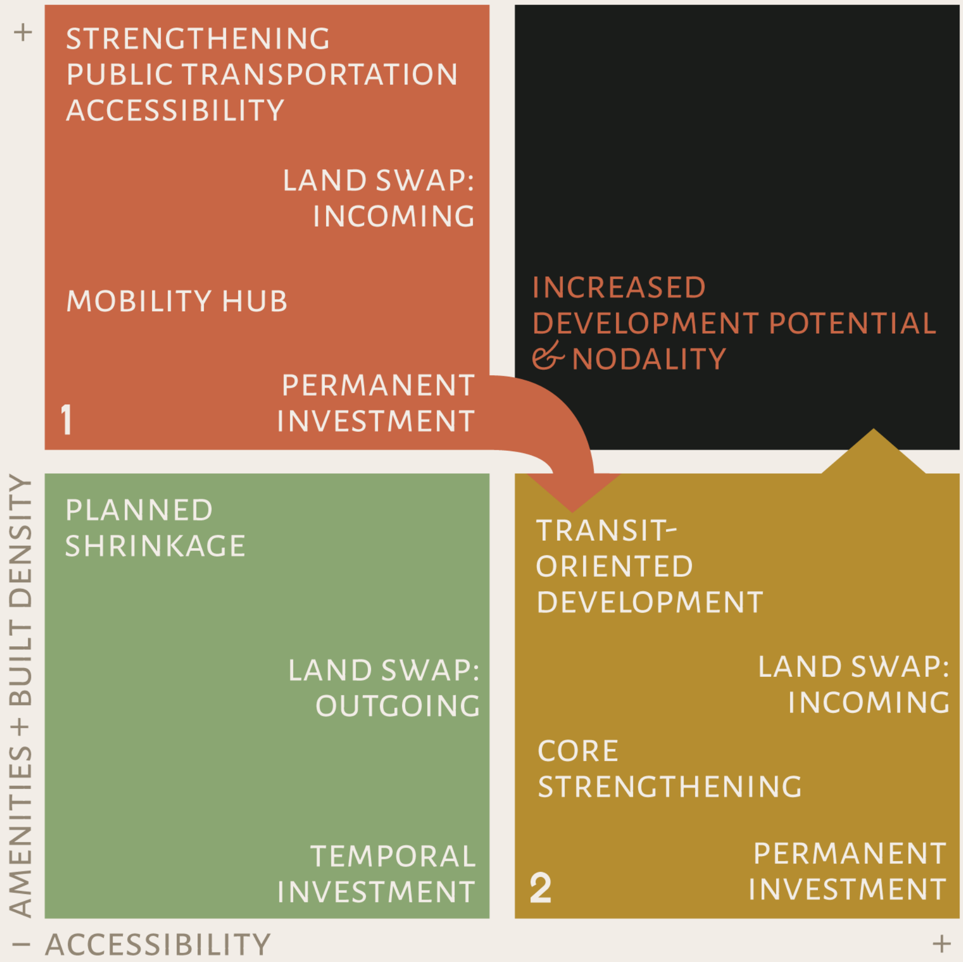


Figure 86. The resulting spatial framework with types of each hectare shown.

There resulting spatial intervention types are shown in the map. This will work as the framework for the following smaller-scale interventions. The each spatial types' approaches and visions will be discussed on the next page.

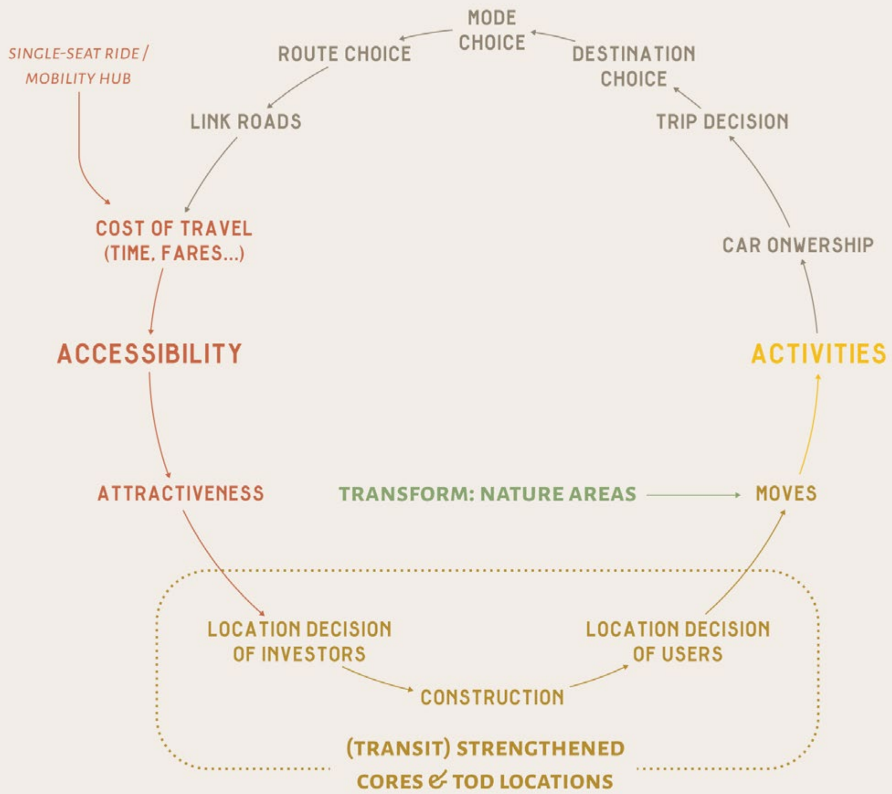
Figure 87. Transit and urban developmenmt approaches by each spatial types



Concentrate

These are generally existing city centres. The area is already well-served by existing transit network, and shows no signs of issues related to spatial dispersion in the built environment. In other words, they are already doing very well on its own, compared to other areas. With ideal potential (connectivity and density), these areas can sustain, densify, and grow on its own regardless of the interventions designed for them. Therefore development tools and pathways for these areas will not be designed in this project, however they will be frequently served and in higher capacity in order to improve connectivity between important cores in the region, such as Hasselt, Genk, Maasmechelen, Houthalen, Diepenbeek, Pelt, Sittard, and Maastricht. Such locations will be also served as the 'destination' for those living along the branch services.

Figure 88. Wegener (2004)'s circle adapted to depict the possible strategy in Strengthen areas



Strengthen – Housing

These are generally areas served by Spartacuslijn, or peri-urban areas with good connectivity to existing network yet has low density. They pose little danger to spatial fragmentation, and possess high potential for development. They can be offered as a destination for land swap from the countryside, therefore offering relatively lower density housing with good public transport access would be the key. The assessment framework's spatial transition parts should be focused, especially on built footprints.

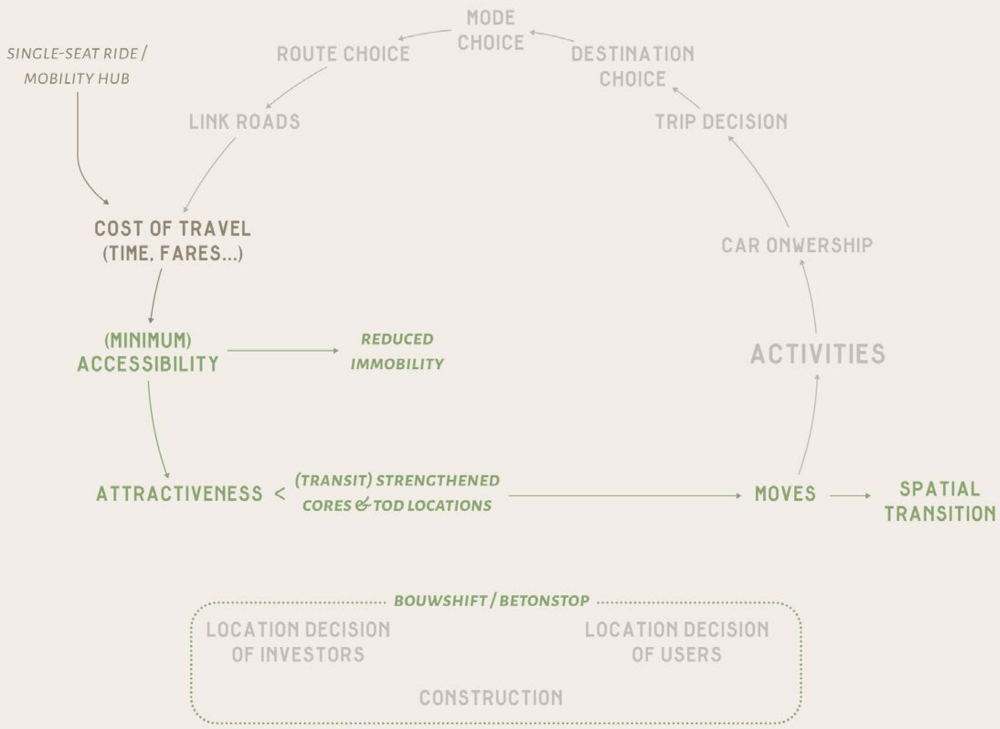
Strengthen – Amenities

Small set of locations that has good enough density and connectivity but lacking in amenities are classified as this type. Spartacuslijn 1's Eigenbilzen station area is an example of this. In these areas, the focus should be placed on providing amenities and access to amenities, instead of focusing on built footprints. Therefore in the assessment framework, the Liveability criteria should be focused.

Strengthen – Transit

These are often healthy town centres across the province, with good urban form and amenities yet lacks proper public transportation accessibility. In these areas, the context of core strengthening should be applicable; the provision of transportation service should be prioritised to better connect the cores with the rest of the province, through providing new connections, more frequent service, and mobility hubs. Therefore in the assessment framework, the Accessibility criteria should be prioritised. In the longer term, improving the transit service would increase the development potential of the area, and therefore same approach with Strengthen – Housing can be used.

Figure 89. Wegener (2004)'s circle adapted to depict the possible strategy in Transform areas



Transform – Nature

These are often the "ribbon developments" and "dispersed buildings": these areas are the key targets of spatial transition. Land swap should be aimed at moving built footprints from these areas to Strengthen-Housing areas. The process shall take long-term efforts, therefore during the process, the public transport should be only provided to ensure the very minimum level of service for those living in the area; investment in permanent structures should be also kept minimum, and the service should be gradually phased out as the population at the area declines.

Empower – Socioeconomic

These are often social housing areas built to house workers that were invited to Belgium to work in key industries of the past. As the neighbourhoods face socioeconomic challenges, providing good access to economic opportunities, and improving social cohesion should be the priority in these neighbourhoods. The Accessibility and Socioeconomic metric should be therefore focused in the assessment criteria.

Industrial Transition

These areas require tailor-made approach, with thorough understanding of the underlying industrial ecosystem and flows of goods and resources. In many cases, the industries should transition into logistics sector or more knowledge-based, innovative industries, according to the Province's vision. Therefore in Industrial transition areas, the goal should be defined per location based on thorough analysis of the industrial ecosystem and future perspectives of the site, and then the desired aspects to focus in the assessment criteria can be decided upon.

6.5 MANIFESTO: POST-SPARTACUSPLAN

It is very clear that we cannot simply let those in the dispersed settlements to be left inaccessible during the course of decades of spatial transition; on the other hand, it is also important to encourage people to (voluntarily) move from the dispersed settlements into the cores and cities, without resorting to stronger planning tools. While nowadays in Flanders, the cycle of "construction" is blocked through bouwshift and betonstop, keeping the countryside accessible for the sake of reducing immobility would theoretically mean that they will have less incentive to move to the city.

In this project, the direction for this should be replicating the Accessibility – Attractiveness – Investment and construction chain available in more parts of the province to relieve the burden of densification in the city centres, and to easily attract the people in the countryside. On the other hand, the surplus attractiveness and accessibility should be minimised in the dispersed settlements.

Compared to the original Spartacusplan, the provision of branch services would ensure accessibility to previously poorly served cores and ribbons. The urban design and transportation planning intervention will then differ, for the cores, the intervention will ensure that the development is accelerated, through frequent services with permanent urban design interventions; the ribbons will, on the other hand, receive temporary urban design measures to mitigate effects of transition (shrinkage, vacant structures...) through de-densification, and the transportation service is provided to ensure minimum accessibility.

This will also provide extra space and capacity for densification and TOD into small towns that were previously not well-connected, and thus had low potential for development. This will then gradually absorb the ribbons, which then the transit service would also be gradually phased out.

This strengthening of low-nodality cores spread across the province is particularly suited for attracting people from ribbons. As addressed earlier, the Belgian countryside is a highly sedentarist place: they do not want to move away from the familiar town, where they live alongside familiar faces and familiar environments. On the other hand, their life is now (physically) mobile, where most of the groceries, work, and activities require driving great distances to nearby towns. This suggests higher ties to the nearby towns but not necessarily to cities; for many, living in the countryside is part of a conscious choice specifically to move away from dense cities, as they wish to move away from old, busy, and noisy cities and areas with a high share of migrants (Reijndorp & Pilet, 1998, as cited in Pisman et al., 2001). Pisman et al. (2011) identified the preference of housing environment difference between residents of the city centre and suburbs in Gent. In the study, the low-density suburban area of southern Sint-Denijs-Westrem has shown a significantly higher percentage of preference in the current community (80%, in city centre 31%), and 95% reported detached single-unit houses as the ideal quality of a house (in city centre: 38%), although the desire to move to more rural areas were much lower (15%, in city centre 30%).

In other words, the small cores that were not well-served by transit previously, can be the middle ground for countryside residents between (dense, sustainable) cities and (unsustainable) dispersed buildings, with more capacity to supply the housing type that the countryside residents desire. The branch services from Spartacuslijn can flexibly create such cores by providing accessibility.

SPARTACUSPLAN (TRAMBUS)	ASPECTS	DISPERSED REGIONAL BRT
Frequent	**Public transportation: on Spartacuslijn**	Frequent
Transfer required; infrequent	**Public transportation: towns outside of Spartacuslijn**	Single-seat ride to desired destinations; frequent
On high-nodality locations	**Where new developments take place**	Both high-nodality locations and low-nodality cores (where Branch service would increase nodality)
High-density densifications and redevelopments	**Spurred development types**	Both high- and low-density developments

Table 16. Comparison of Dispersed regional BRT with current Trambus-based Spartacusplan

Ultimately, after the spatial transition is complete, the transit service can further focus on (strengthened) cores and further destinations, and the transit service can be reduced or completely pulled from dispersed settlements. The BRT ROW would also be gradually expanded on key corridors. From that phase, the aim can also further shift towards a modal shift.

The conceptualised network structure during the transition phase and its ultimate form is spatially illustrated through three maps in next pages.

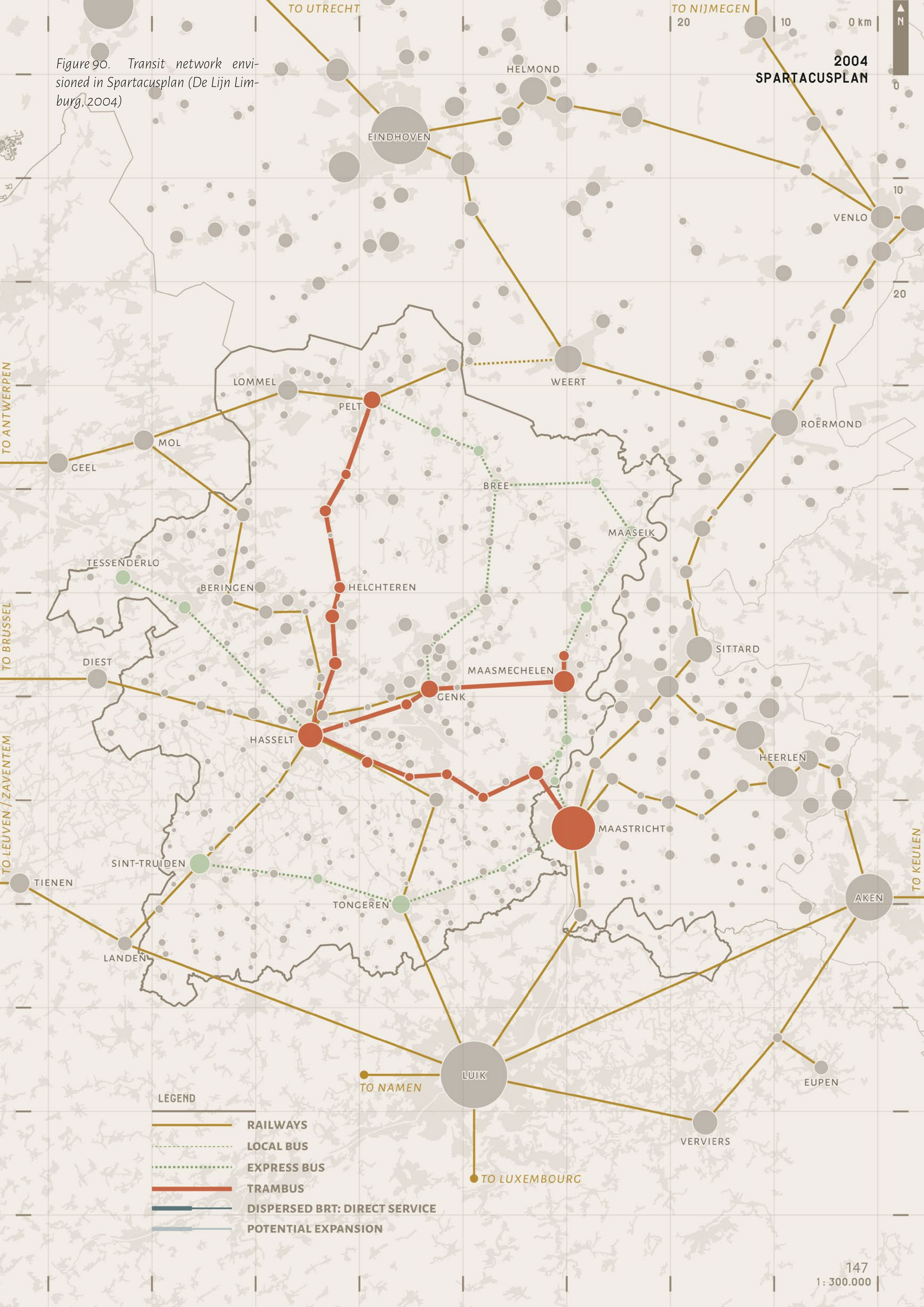


Figure 90. Transit network envisioned in Spartacusplan (De Lijn Limburg, 2004)

Figure 91. Post-Spartacusplan: Dispersed BRT network for the transition period (2030 – 2060) and classification of each cores

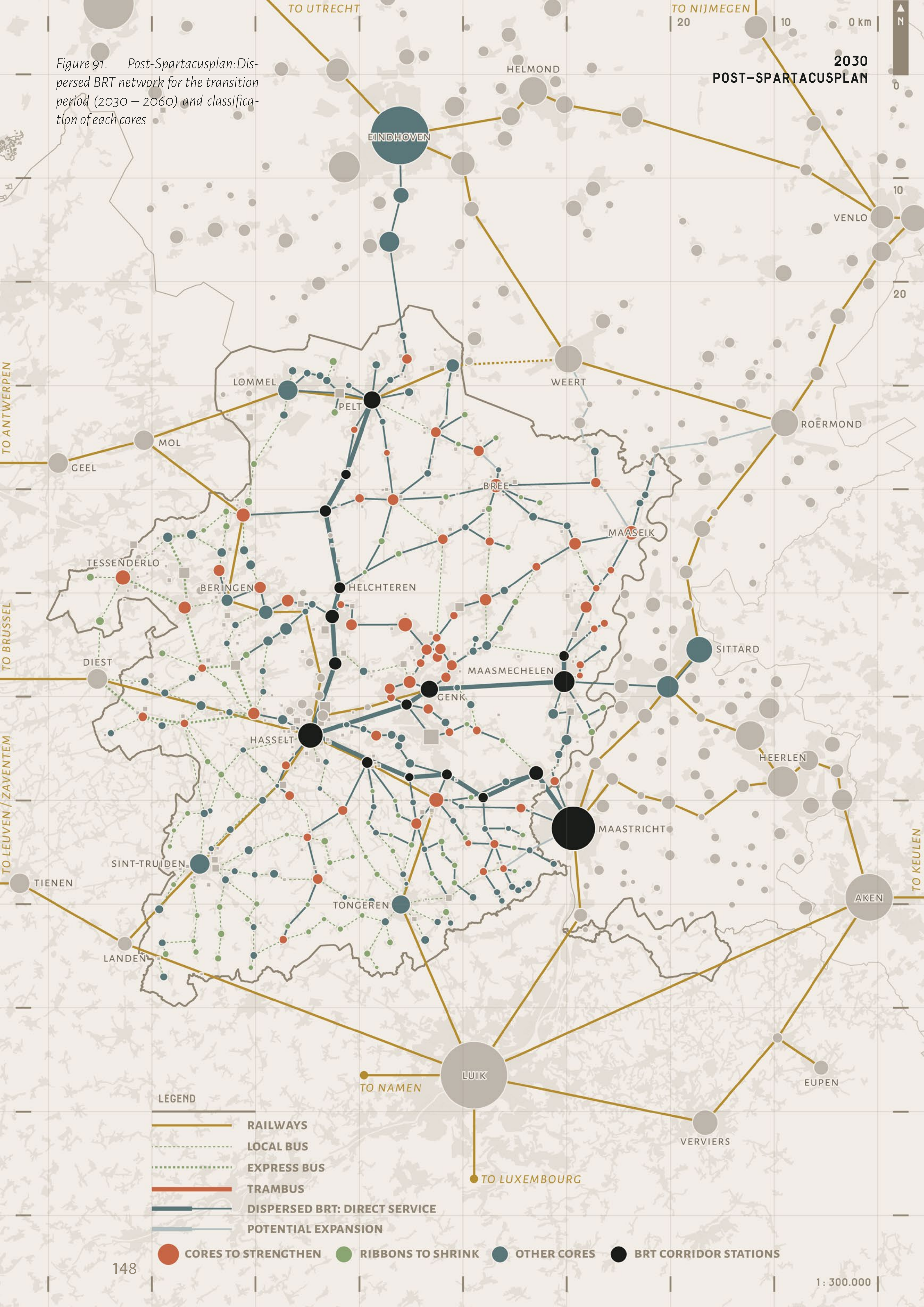
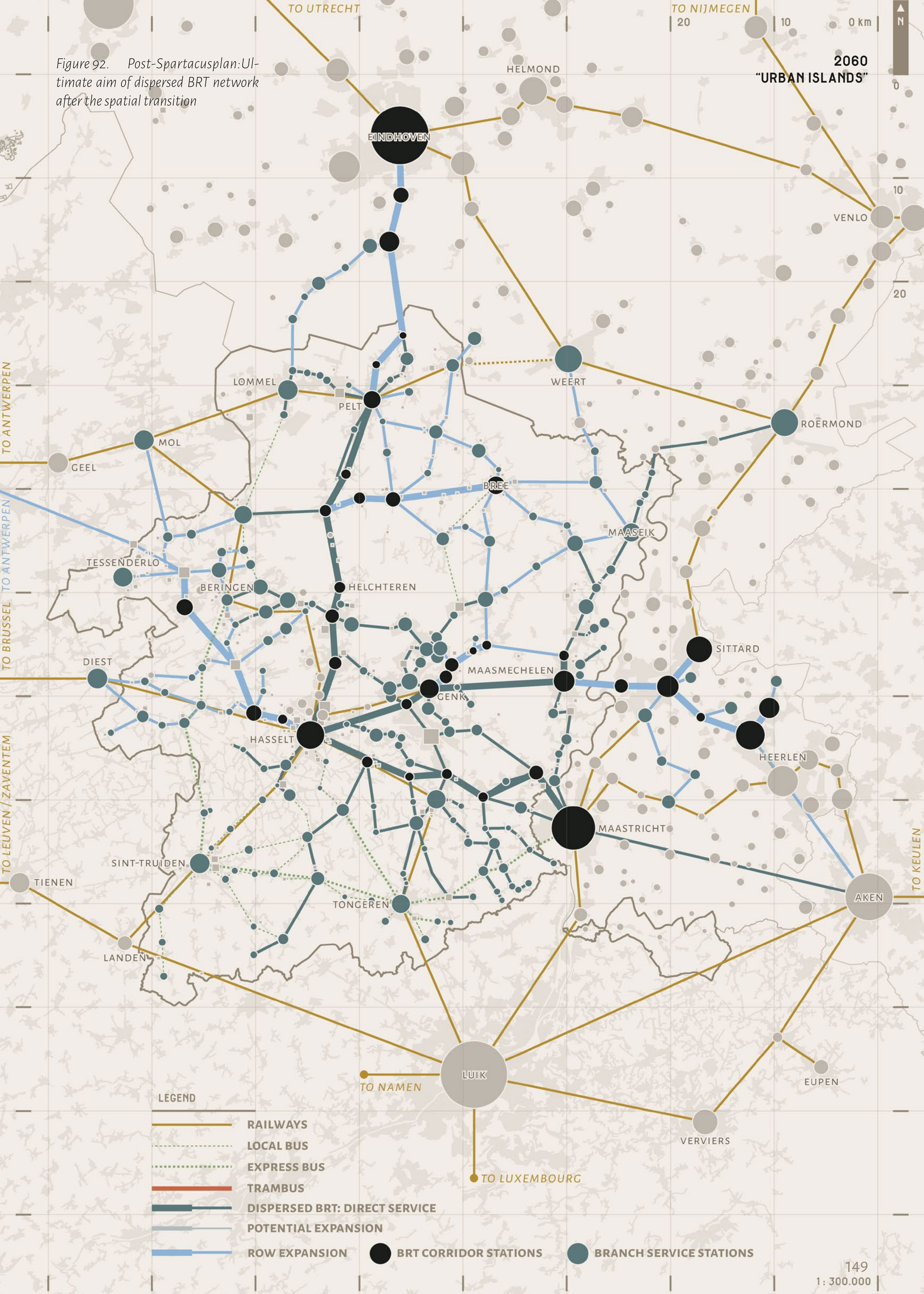


Figure 92. Post-Spartacusplan: Ultimate aim of dispersed BRT network after the spatial transition



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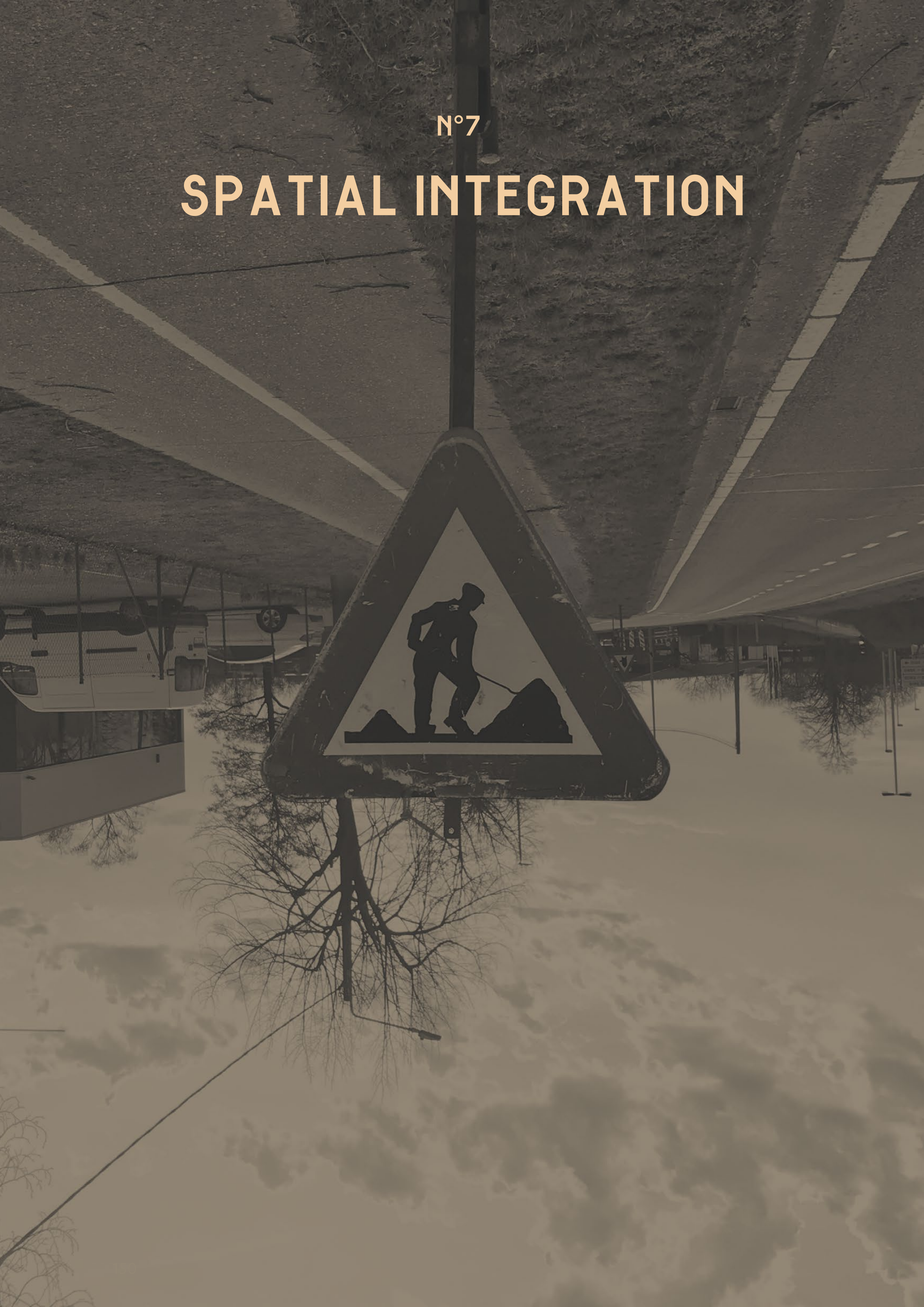
N°7

SPATIAL INTEGRATION



7.1 INTRODUCTION

Now that the spatial framework has given the strategy to follow, the tools to realise that strategy will be developed. This chapter concerns the built environment measures related to the new BRT system and facilitate the ultimate goal of spatial transition.

In order to facilitate stakeholder engagement in the design process of integrating the Spartacuslijn and its branching services into neighbourhoods, following Alexander et al. (1977)'s method of pattern language, the set of patterns are created for public use.

Patterns contain the principle of design or instruments that can be used in implementing the spatial objectives in the area. They are connected to other patterns, synergising, conflicting, or excluding other patterns. Patterns are created to be understood by all stakeholders participating in the design process, and it allows different design solutions to be created for different types of places and context. Details such as specific functions of each location and placement of patterns can be further determined by the stakeholders and designers themselves according to the applied patterns and their knowledge of each location's context and situation.

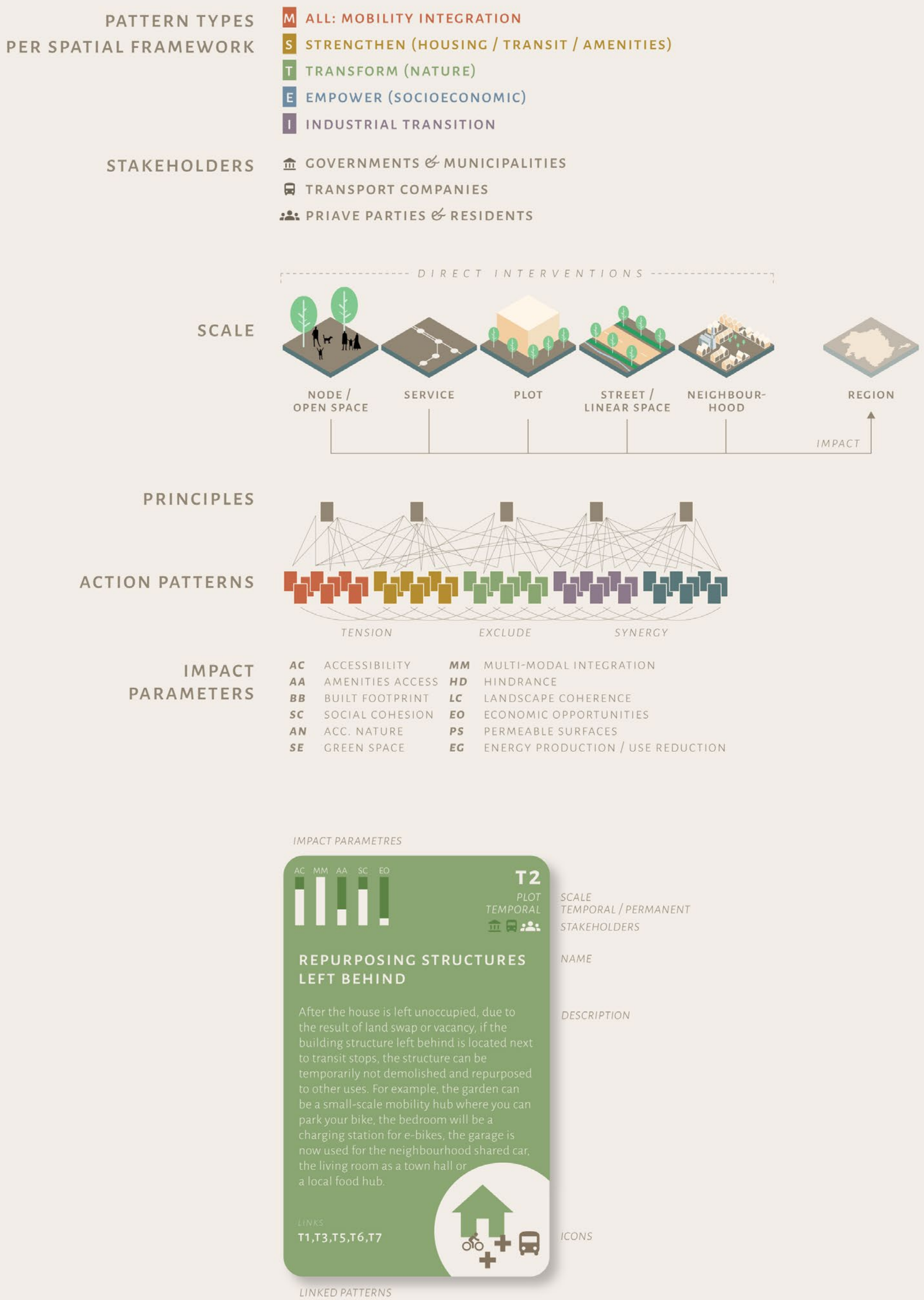


Figure 93. Pattern language structure in the project

The patterns are derived from the theoretical embeddings (Chapter 2) and immobility analysis (Chapter 4), and partly from policy documents and theories that are widely used in urban planning and transportation planning. The patterns consist of principles and actions: the principles encompass multiple action patterns, and are used to inform and guide the designers and professional parties on their ideal direction of decisions. The action patterns are then categorised by the type of strategies defined in the spatial framework: Transform, Strengthen, and Socioeconomic/Industrial transition. On top of the four types, the mobility integration patterns are also added as the universal category that can be applied in all types of locations.

Each pattern that corresponds to each spatial type is designed to achieve each type's goals. For example, in Transform patterns, more temporal interventions that are aimed to ultimately turn back into nature are offered; on the other hand, patterns related to densification are offered in Strengthen patterns.

Each pattern affects the evaluation framework differently. They can also be categorised per stakeholders, and scale levels ranging from nodes to neighbourhood level. Each action pattern links to principle patterns, and has a different impact on each metric in the assessment framework. Between the patterns, a synergetic relation or conflict/tensions would be possible, and sometimes, choosing one pattern in a certain location may exclude the application of certain other patterns.

The list and image of all patterns are provided from next page. The descriptions of each patterns are as following:

MOBILITY INTEGRATION

It is geared to "welcome" the arrival of transit in the neighbourhood: it concerns measures that better prepare the area's built environment towards transit use, and potentially expand the transit infrastructure. It is a "neutral" type as it is designed not to add density nor subtract it, so it only concerns the transportation infrastructures and only the function of buildings. Patterns that require densification or re-developments are categorised as Strengthen patterns. Therefore it can be used in all area types. Mobility measures that can be only used in certain areas are therefore categorised as their respective category.

STRENGTHEN

The category concerns built environment measures that aim to create liveable neighbourhoods. It is designed for all Strengthen types, but due to the difference in aim, extensive use of Mobility integration patterns is recommended for Strengthen: transit types. The key objective of this pattern is to improve liveability and facilitate spatial transition. Do mind that this is not designed for a one-way increase of density; it is designed for spatial transition, as some patterns would reduce density as far as it is beneficial for spatial transition and improve liveability.

TRANSFORM

The category is mainly based on the de-densification model introduced in Chapter 2. It concerns mitigating the effects of spatial transition in the countryside, such as vacant houses and public services. Its objective is also aimed at spatial transition, but unlike Strengthen patterns, it does not aim to directly reduce it; instead, it aims to mitigate the adverse effects on infrastructure and public service provision, through re-introducing agaric uses, promoting self-sufficiency, and repurposing plots and structures.

INDUSTRIAL TRANSITION

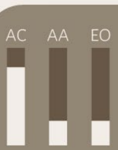
The category is aimed at promoting innovation in the region. It aims for the creation of quality space around industries and workspaces. The socioeconomic metrics, particularly economic opportunities, are focused.

EMPOWER

The empower category is aimed at empowering disadvantaged neighbourhoods through urban design and transportation planning. It is aimed at improving socioeconomic metrics.

+ PRINCIPLE PATTERNS

The principle patterns do not suggest single, specific action. Its purpose is to make (often tacit) field knowledge in urban planning and transportation planning explicit for stakeholders by conveying it as norms and ideas, guiding stakeholders in a certain direction. Therefore the possible measures are not limited to example actions named in the description itself.



P1

UNIVERSAL URBAN DESIGN

All people regardless of their ability or identity must be able to access the facility with ease. Design the space with different groups in mind!

Sheller (2018) argues that universal design must be required for all facilities, to ensure accessibility for all people, in all modes of transport. This not just means barrier-free access, but also designing the space with different groups in mind: a toilet may not matter for most passengers, but lack of it may equal inaccessible for elderly.

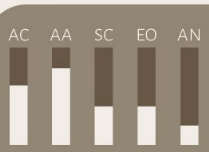
P2

LEGIBLE SPACES

Design the facilities of the station and connection to other transport modes easy to navigate and understand. Can a 7-year-old kid also use the bus with ease?

The transit stop and its surrounding areas should not be overly complicated in the wayfinding, but also . The access to the station should be clearly identifiable and easy to navigate (An et al., 2019). The user must be able to understand the structure of the stop and where a bus may stop, where a bus may locate, and where their desired destinations are located.

P3



STOPS AT THE CENTRE OF ACTIVITIES

Transit stops outside of BRT corridor should be located close to where people will want to go, even if it means having to make a little bit of detour.

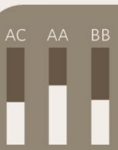
When determining the location of stops and placement of activities around the stops, many end up isolated from the actual centrality of activities in the neighbourhood, often for the sake of speed or transportation performances. Such a situation should only occur in design when it's truly inevitable; the stops should be organically connected to people's activities.

P4

STARTING FROM EXISTING URBAN FABRIC

Instead of large-scale redevelopments, start with small-scale developments. If large-scale redevelopment is done, then make sure it can adapt if some locations are not available.

Radical, large-scale redevelopment with significant urban fabric changes should be avoided. The development should happen incrementally, and in case of redevelopments, must be adaptable to situations where certain plots are not available. This will not only reduce the project risk, but also reduce displacement from accessibility. However, the trade-off between the benefit of density and rights of residents must be well discussed.



P5

INCREMENTAL TRANSITION

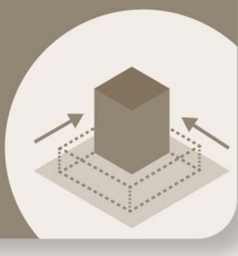
Try to plan a slow-paced, gradual steps towards the end goal, instead of designing a one-time solution.

Leemans (2021a) and De Meulder et al. (1999) both recommend focusing on incremental change instead of radical urban form changes. Approach the spatial transition through incremental, systemic changes to different layers of urban systems, such as infrastructure, movement, or amenities.

P6

MINIMISING BUILT FOOTPRINTS

Reduce the building's footprint as much as possible, even inside the cities, as far as the quality of the space doesn't get sacrificed.



As the goal of Bouwshift/Betonstop suggests, reducing the built footprint is a must. Even inside densely built cities, it is still recommended to reduce the built footprints if it does not sacrifice other aspects, in order to increase permeable surfaces and open spaces.

AC MM

P7

COMPLETE STREETS

Design the streets for all road users, and do not let one type of road users (i.e. cars) dominate the street space.

The streets must be safe for all users, and its space must not be dominated by one mode – often, that being automobiles (Sheller, 2018). Existing roadway space should be reallocated, and new roadways must be accommodating for all users, and its space must be fairly allocated.

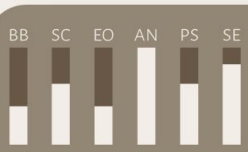
AC AA SC EO

P8

FUNCTION MIX

Encourage introducing diverse functions in the neighbourhood, especially close to the transit stops.

The introduction of diverse functions can not only improve amenities and create destinations for the passengers, but also catalyse reduction in car dependency. New developments should be not designed to have only one functions, and preferably mix functions across scale levels, from building level to the city level.



P9

BRINGING NATURE AND PEOPLE CLOSER

Bring the products of nature close to people, so that people can enjoy the benefits of it with ease.

As suggested Horizontal Metropolis (Viganò et al., 2018), the (healthy) dispersion can be a strength: the nature can be brought closer to citizens, not only for leisure and pastime, but also for a beneficial relationship – such as producing food, materials, energy, and other resources. Possible strategies include promoting local food production and consumptions and creating space for recreation, and also providing accessibility to nature areas.

P10

COHERENT LANDSCAPE

Connect large patch of nature with other patch of nature, and avoid cutting those patches and green space connecting patches.

With the landscape ecology principles of patches and corridors, the large patches of nature should be connected through green/blue corridors (Dramstad & Olson, 2013). For example, cutting through the patches and green spaces should be avoided, and if inevitable and/or already occurred, then remedial measures should be taken.

P11

CLIMATE-RESILIENT CITIES

Give more space for nature, biodiversity, and water to pass into the ground, along with the design for public transport.

Limburg is no longer free from the impacts of climate change: flooding, heat waves, and abnormal weathers are getting more common. While implementing the public transportation networks, more permeable surfaces, more green spaces, and more biodiversity should be also achieved (Gies, 2021)., in order to address the ultimate challenge of the climate change.

P12

SOCIALLY RESPONSIBLE DEVELOPMENT

Engage diverse group of people to make transit-oriented developments inclusive for all social class and identities.

Sheller (2018) argued that the provision of transit-oriented development should take social impact into account. It should be made sure that the development around transit does not become a bubble of luxury properties, through engaging diverse group of people in the decision making process.

AC EO

P13

CONNECTING KNOWLEDGE AND PEOPLE

Connect innovative industries with other industries, knowledge institutions, and potential customers and workers to accelerate innovation.

According to the “Network Cities” theory by Batten (1995), good connection between people and places is a perquisite for knowledge-based industries. Connect innovative industries with other innovative industries, knowledge institutions, customers, and talent. While they are often located in peripheral locations, Urban design measures should attract transit, or provide good permeability to such areas.

AA SC EO

P14

FACILITATE NIMBLE AND DIVERSE ECONOMIC ENVIRONMENT

Promote the small businesses and create business environment and opportunities friendly to new businesses to come.

The innovation stems from the contacts and network of people: they share ideas, different disciplines are met, they collaborate, and therefore innovate (Dall’Orso, 2019). A nimble and diverse business environment that supports small businesses is important to facilitate innovative economy in the region (Vandecasteele et al., 2019).

P15

ACCESSIBILITY AS LEVERAGE FOR NEW OPPORTUNITIES

Accessibility can be used as a leverage in attracting new developments, economic opportunities, and also resolving stakeholder conflicts.

The improved accessibility should be facilitating the new opportunities in the area. Introducing new functions, economic opportunities, and creation of residential areas can be supported by providing good connectivity with desired destinations (Wegener, 2004). The accessibility can be also used as a "carrot" for resolving stakeholder conflicts.

AC MM AA

M1

NODE
PERMANENT

MAKING TRANSIT VISIBLE

The presence of the public transportation should be visible for everyone. The urban design around the stops, the clear signage from the public space, and the clear marking on the roads can be used.

LINKS
P2 P3 P4 M8 T5

AC MM AA HD

M2

STREET
PERMANENT

PERMEABLE PEDESTRIAN NETWORK, DISCONNECTED AUTOMOBILE NETWORK

The pedestrians and cyclists should be able to access the station as directly as possible, while the circulation for cars should aim for the opposite. A new pedestrian shortcuts, cul-de sac with cut-through for pedestrians (Williams et al., 2004), one-way system, or disconnecting link for cars inside the neighbourhood or through traffic can be used.

LINKS
P1 P2 P7 P15 S1
S5 I5 M3 M4 M9 M10

AC AA HD

M3

STREET
TEMPORAL

ONE-WAY CIRCULATION / PEDESTRIANIZING STREETS

By changing the circulation of the neighbourhoods from two-way to one-way for cars, or redirecting car traffic completely from sections of road, extra space could be created for safer pedestrian access and vibrant streets.

LINKS
P1 P7 P15 S1 S5 I5
M2 M4 M9 M10

AC AA SC EO AN

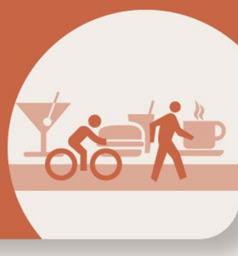
M4

STREET
PERMANENT

LIVELY PEDESTRIAN & CYCLING ACCESS

The pedestrian access routes shall be aligned with existing functions and destinations in the neighbourhoods, and diverse functions and programmes would be located / created along the access, so that the access to the station becomes less monotonous.

LINKS
P2 P3 P7 P8 P9
M2 M3 M9 M10 S7 T5



MM HD AN SE EG

M5

STREET
PERMANENT

MULTI-FUNCTIONAL BUFFER SPACE

Due to the high operating speeds and the higher aimed level of automation, a buffer space along the BRT right-of-way is recommended. Moreover, around the arterial roads or between the buildings, there can be plenty of in-between spaces to be found. These spaces can be used for many things: Solar panels can produce energy, Trees can fight urban heat island effects and can work as an sound barrier, and around the station or amenities, bikes and shared personal mobilities such as electric scooters (step) can be stored.

LINKS

P11 M6 S4

AC MM AN SE

M6

STREET
PERMANENT

REPURPOSING GNW/GTI PLOTS

In Limburg, there's no lack of unfinished, or underutilised infrastructures; jokingly called a "large useless projects". Moreover, there are also plenty of former tramways and rail trackbeds are found across the province. Such plots are ready to be turned into bicycle paths, ecological corridor, and busways.

LINKS

P4 P9 S1 I5 M5

SE

M7

NODE
PERMANENT

ECOTUNNEL

Large parts of Spartacuslijn will cross through patches of green spaces. In order to ensure passage for smaller animals present in the area, a small tunnel can be built underneath.

LINKS

P10 P11 S8 S11

AC MM AA EO

M8

PLOT
PERMANENT

MULTIFUNCTIONAL MOBILITY HUB

The mobility hub should not only serve its function as a space for movement; rather, it should be designed and function like a normal mixed-use building that also serves mobility as one of its features. It can be an apartment, public building, sports centre, hospital, shops, maker spaces and mobility hub combined.

LINKS

P3 P8 M1 S5

AC MM HD

M9

STREET
PERMANENT

TRAFFIC CALMING

Pedestrian and bicycle access routes to transit stops will naturally get higher level of foot traffic. To ensure safety and pleasant access to transit, the speed and density of motorised traffic should be drastically reduced. Therefore multiple traffic calming measures can be used, such as horizontal deflection measures (chicane, narrowing streets), speed humps, and using different surfaces - including permeable surfaces.

LINKS

P1 P7 S1 S5 I5
M2 M3 M4 M10

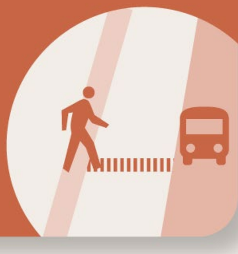
AC AN

M10

STREET
TEMPORAL

CREATING PEDESTRIAN SHORTCUTS

In areas with low street connectivity, pedestrian path leading to transit stops or major destinations can be created using space between plots or through the open space. In case of open space, permeable pavement should be used, or completely not paved.



LINKS

P2 P3 S13
M2 M3 M4 M9 S8

AC BB

S1

STREET
PERMANENT

GRADUAL BRT INFRASTRUCTURE EXPANSION

While Spartacuslijn will remain as a key corridor in Limburg for the foreseeable future, the gradual shift in mobility behaviour would mean that there's more capacity for introducing BRT in other corridors: more political support, less burden on road space.

LINKS
P5 M2 M3 M9 S3

AA BB SC

S2

PLOT
PERMANENT

DIVERSE HOUSING TYPE

The types of housing supplied should be diverse, from alonestanding houses to apartments – in order to accommodate diverse needs and made attractive to countryside dwellers, which should settle closer to transit through land swap.

LINKS
P12 T2

AA BB

S3

NEIGHBOURHOOD
PERMANENT

LINEAR DENSIFICATION

Provide infill developments or densification in cores along high-frequency transit corridors, such as Spartacuslijn or bundled multiple branch services. Due to relatively lower density, such these areas have better capacity to receive densification. Ensure good access to vital amenities (groceries, GP...) in the current and future services, and other amenities and activities spread along the transit line.

LINKS
P5 P15

HD

S4

PLOT
PERMANENT

ACOUSTIC FACADES

Spartacuslijn 2 and 3 is in large part built on arterial roads and motorways. When densifying such areas, the issue of noise pollution often arises; therefore designing a block facing the big roads with soundproof-ing towards the road's side is recommended.

LINKS
P11 S12 M5

AC MM AA

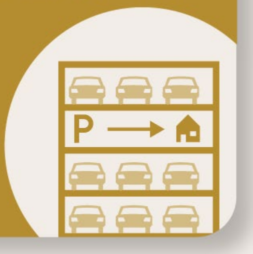
S5

PLOT
TEMPORAL

CONVERSION-READY PARKING BUILDINGS

The behavioural change in mode choice does not happen overnight; especially areas outside of Hasselt and Genk city centre, reducing parking demand requires long-term efforts. However, often such outdoor parking spaces are the only possible place for densification. Therefore densification can first happen including few floors dedicated for parking, but with structures designed to accommodate future conversion to intended purposes.

LINKS
P4 P5 P8 M2 M3 M9 S6 S7



AA BB EO

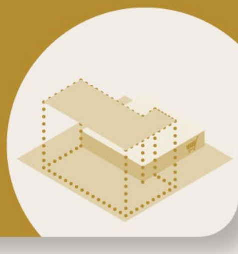
S6

PLOT
PERMANENT

INTEGRATING SUBURBAN COMMERCIAL ACTIVITIES

In the ‘Strengthen: Housing’ or ‘Strengthen: Transit’ areas, often the suburban commercial warehouses, car dealerships, or garages are present. These functions can be integrated by building on the frontages facing the streets and integrating the parking space above it. Such functions should be aimed to be gradually replaced by more suitable functions.

LINKS
P4 P5 P8 S12 I3



AA EO

S7

STREET
PERMANENT

ACTIVATING PLINTHS

Along the main access routes for pedestrians, the plinth of the buildings shall be activated with diverse functions and amenities. This will make the plinths less monotonous, and can improve the safety along the walkways by introducing natural surveillance.

LINKS
P3 S5 S6 M4

HD AN PS SE

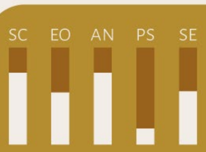
S8

PLOT
PERMANENT

GREEN FINGERS

The green fingers can be integrated into the neighbourhood as a corridor between patches. This can improve biodiversity while also creating accessible or productive green space for people.

LINKS
P10 P11 M7 S11 S9 I4



S9

NEIGHBOURHOOD
PERMANENT

INTERFACE FOR LOCAL FOOD (STRENGTHEN)

In urbanised areas, local food can be integrated as to raise awareness of local food for the urban residents and experience it, bringing the agaric countryside closer to the city. The farmer's market can be placed around the stations, and community garden can be introduced in the neighbourhood.

LINKS

P9 P14 T4 T6 T7
S8 S11

S10

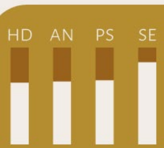
NEIGHBOURHOOD
PERMANENT

INFILL DEVELOPMENT OF PERIMETER BLOCKS AND URBAN FRINGES

The perimeter blocks and urban fringes as typed by De Meulder et al. (1999) has a large potential for densification. The interior of the blocks can be filled up in a coherent manner with the surroundings, however the permeability in the blocks shall be guaranteed.

LINKS

P4 P10



S11

NEIGHBOURHOOD
PERMANENT

GREENING INSIDE PERIMETER BLOCKS AND URBAN FRINGES

When lacking sufficient accessible green space, the interior of the perimeter blocks / urban fringes can be made into an accessible green space.

LINKS

P10 P11 S8 S9 M7

S12

PLOT
TEMPORAL

ADAPTABLE DENSIFICATION

When completely re-developing parts of the area through densification, the urban design should be able to withstand the changes if parts of the plots become unavailable for development. Therefore a good plan for long-term transformation should be designed, with possible adjustments in mind.

LINKS

P4 P5 S4 S6 I2

BB EG

S13

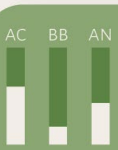
PLOT
PERMANENT

DENSIFYING EXISTING STRUCTURES AND IN-BETWEEN SPACES

The additional built footprint and the impact of densification in the urban fabric can be minimised by using existing structures and built-up plots. This can include methods such as top-up densification and infill densification.

LINKS

P4 P6 M10



T1
PLOT
TEMPORAL

EMPTY PLOTS AS GATEWAY TO NATURE

In Flemish countryside, finding an access to an open space is limited. Empty plots can become a public passageway to the nature behind the ribbon developments, increasing the accessible nature.

LINKS
P6 T4

T2
PLOT
TEMPORAL

REPURPOSING STRUCTURES LEFT BEHIND

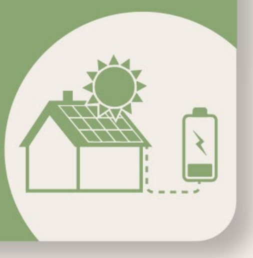
After the house is left unoccupied, due to the result of land swap or vacancy, if the building structure left behind is located next to transit stops, the structure can be temporarily not demolished and repurposed to other uses. You can be creative about this: the garden can be a small-scale mobility hub where you can park your bike, the bedroom will be a charging station for e-bikes, the garage is now used for the neighbourhood shared car, the living room as a town hall or a local food hub.

LINKS
P4 P5 S2 T3

T3
PLOT
TEMPORAL

ELECTRICITY PRODUCTION AND STORAGE

Empty plots can be used for energy production. Moreover, existing structures like emptied houses or a garden houses can accommodate neighbourhood energy storage systems, which can reduce the burden on electricity network.



LINKS
P9 T4 T2

T4
PLOT
TEMPORAL

1 EURO FARMS

The vacant plots can be temporarily or permanently provided to the local residents as farmland for a symbolic amount. Commonly done in many declining North American cities. This way, local food production is introduced to the area, and the originally visioned agricultural lifestyle can be also gradually introduced to the countryside.

LINKS
P5 P9 T1 T3 S9

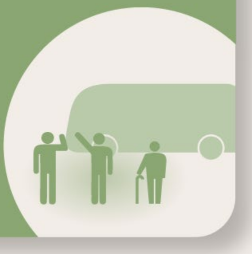
AA SC

T5
NODE
TEMPORAL

MEETING SPACES AROUND THE STOPS

The service pattern in dispersed settlements will be improved, but won't reach that of the cities. The waiting time should be combined with the interpersonal interactions in the community, though a pleasant and open waiting space that can accommodate spontaneous encounters between residents.

LINKS
P3 P12 M1 M4



SC BB EO AN PS SE

T6
NEIGHBOURHOOD
TEMPORAL

INTERFACE FOR LOCAL FOOD (TRANSFORM)

Although the area lacks amenities for shopping and groceries, the vast surrounding agricultural land can be a great asset. By making local food available in the neighbourhood, the neighbourhoods can reduce dependency to outside facilities. A retail space for local food in communities, distribution system for distributing the local food across the rural communities and into the cities, and community organisation for promoting local food production for both professional and non-professional farmers should be promoted.

LINKS
P9 T3 S9

AC MM AA EO AN

T7
SERVICE
TEMPORAL

LOGISTIC INTEGRATION

The off-peak service through dispersed neighbourhoods will be harder to sustain by only carrying passengers; by integrating cargo (i.e. local food, parcel, mail, food delivery...) capabilities, it can financially help sustain the bus service outside of peak hours, and help in the provision of public service in the countryside.

LINKS
P9 MP3 S9

AC MM SC EO

E1
SERVICE
PERMANENT

24H SERVICE / FLEX-TRANSIT

Large parts of residents in social housing areas work in secondary sectors, often working shifts; for them, a traditional 7 to 20 service pattern would significantly limit their access to opportunities. A 24-hour service and/or flexible transit options during the night should be provided.

LINKS
P1 MP3 MP4 E2 E3

AC MM EO

E2
SERVICE
PERMANENT

CARPOOL AND SHARED CARS

Due to lower level of car ownership in the areas combined with diverse commuting patterns, provision of carpool and shared cars are crucial. A place for carpooling and shared cars should be provided, in combination with electric car charging spots, bicycle shed, and neighbourhood level energy storage.

LINKS
P1 MP4 E1

AC EO

E3
SERVICE
PERMANENT

CONNECT WITH EMPLOYMENT OPPORTUNITIES

Access to opportunities should be crucial in empowering communities through transit. A transit service should also focus on providing access to locations with large employment opportunities, such as industrial estates.

LINKS
P1 MP4 E1

AA SC EO

E4
NEIGHBOURHOOD
TEMPORAL

SMALL-SCALE BUSINESS OPPORTUNITIES

Empower the economic opportunities in the area by providing small-scale, ad-hoc spaces for small business in the neighbourhood. This can be done by means of adding temporary structures, allowing small addition to the frontage, and markets in the vicinity of the stop. The improved access with surrounding areas will provide a good stream of patrons for the business.

LINKS
P14 P15 I2

7.7 INDUSTRIAL TRANSITION

AA SC EO

I1

NEIGHBOURHOOD
PERMANENT

FACILITATE "STREET LEVEL CULTURE"

Florida (2002) defines the "creative class" as people engage in "street level culture", meaning people enjoy authentic, indigenous services or products, such as going to local chocolatier instead of national brands, for example. Their separation between work and private life is rather blurry, thus such cultural, quality environment is recommended to be placed around the place they work.

LINKS
P3 P8 P13

AA BB EO

I2

PLOT
TEMPORAL

TEMPORARY STRUCTURES

Temporary structures, such as shipping containers, can allow ad-hoc realisation of required office and making space, and can easily adapt to the growth of the business. This can be used during constructions, or situations where planned buildings cannot be built due to failure to acquire plots.

LINKS
P5 P6 P14 E4 S12

AA BB EO

I3

PLOT
PERMANENT

REPURPOSING WAREHOUSES

Warehouses that occupy the vast majority of the current industrial landscape in Limburg, often has many salvageable elements. The high ceiling and openness makes it ideal for makers, and the products can be kept for the makers in the neighbourhood. The sports facilities can be also placed inside.

LINKS
P4 P5 P13 S6

HD AN PS SE

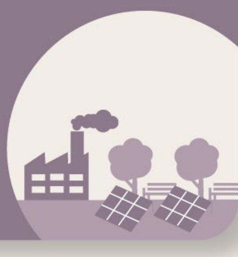
I4

NEIGHBOURHOOD
PERMANENT

IINDERZONE AS OPEN SPACE & ENERGY PRODUCTION

Some industries inevitably can cause hindrance around the facility. In such cases, the hinderzone can be used as an open space, or used to introduce energy production, such as solar farms or large-scale windmills.

LINKS
P5 P10 S8



HD EO

15

STREET
PERMANENT

SEPARATE NETWORK FOR LOGISTIC AND LIVING

As innovative industries require quality environment around their workplace, providing both the liveable streets and well-functioning access space for logistics is crucial. This can be done by designating certain sections of streets for humans, and provide new network dedicated for the smooth flow of logistics, often at the other side of the block.

LINKS

P1 M2 M3 M6 M10

7.8 OVERVIEW: PATTERN RELATIONS

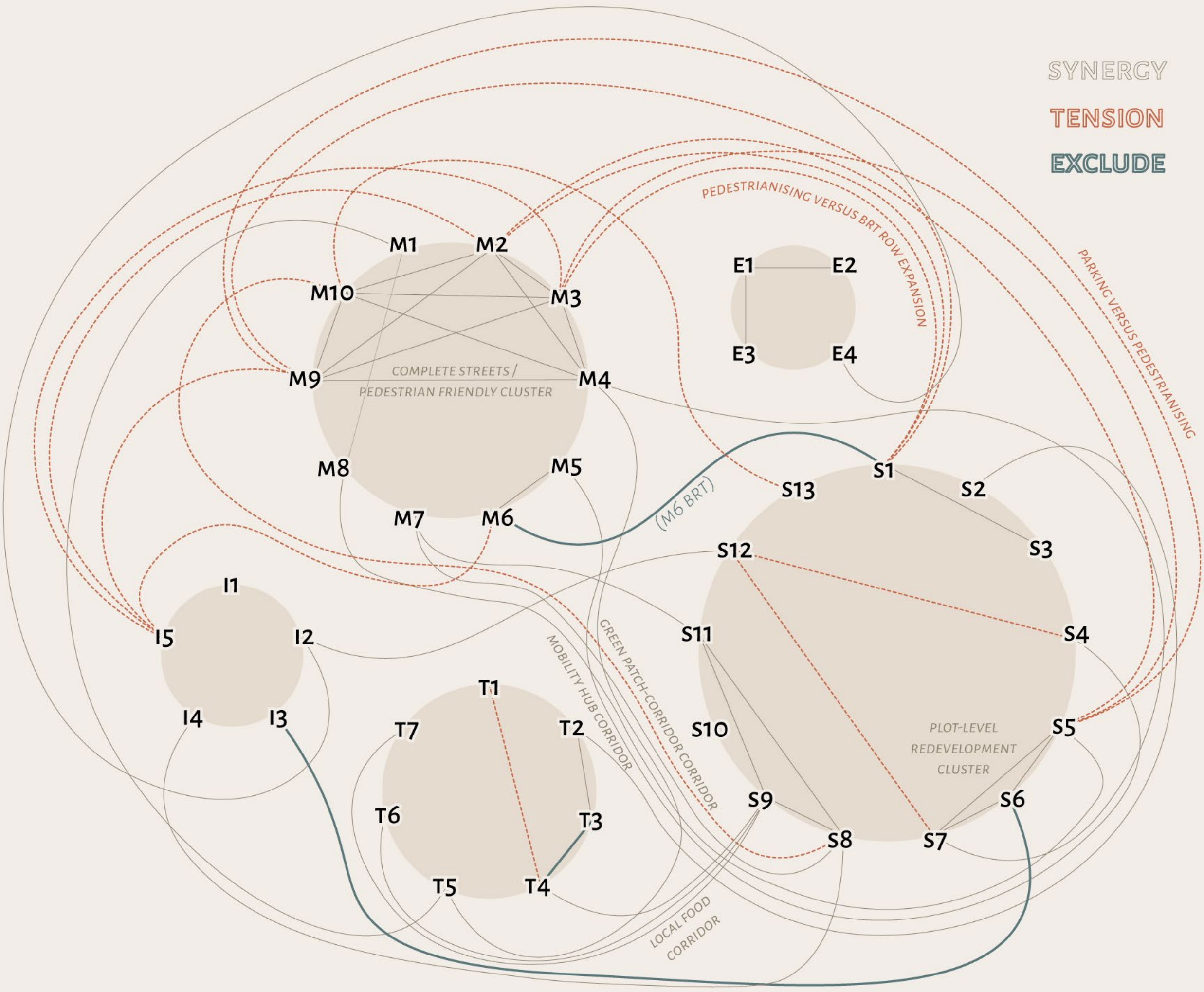


Figure 94. Relation between patterns

Not all patterns are applicable at once, in all locations; while most of the pattern relations are synergetic, some patterns can cause tensions with other patterns, and some patterns can completely exclude certain patterns from being applied.

Therefore, between patterns, a-pattern-of-pattern-relations can be identified: a synergetic clusters can be found between pedestrianizing and complete street-related patterns, synergetic plot-level redevelopment patterns, ecological patch-corridor related patterns, mobility hub patterns, and local food patterns. On the other hand, the pedestrianizing patterns collide massively with parking supply and BRT right-of-way expansion.

The patterns defined in this chapter will be applied and tested for effectiveness in chapter 9, along with the patterns and digital tool created in the next chapter.

N°8

TRANSIT SERVICE PLANNING

8.1 INTRODUCTION

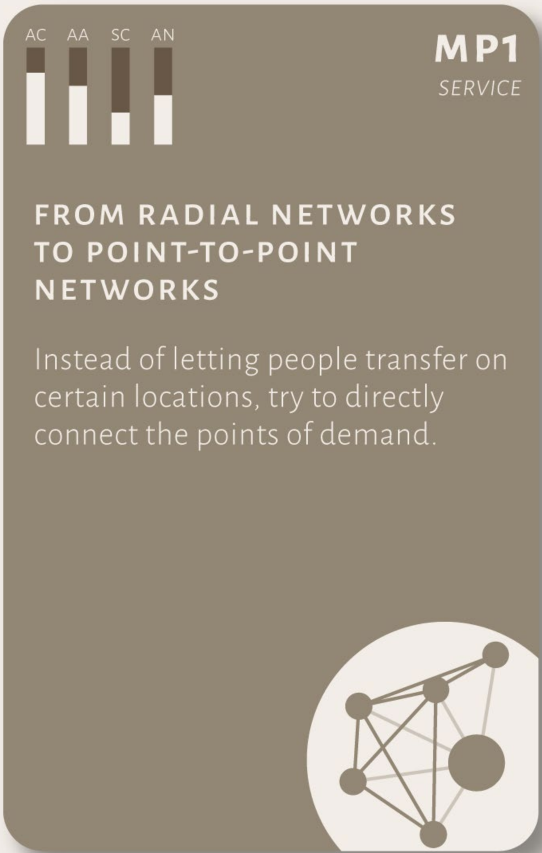
As the catalogue of urban planning measures to support the implementation of BRT is designed through Pattern Language, the same is also created for transportation planning measures. Alexander et al. (1977)'s Pattern Language, which has been used in the previous chapter, can also be partly applied to transportation service planning to streamline the participatory design process. However, in this case, instead of principle patterns and action patterns, the action patterns will be replaced with any possible locations where a stop can be located.

In this chapter, the principle patterns of transport service planning and the interactive digital tool that provides a catalogue of possible locations along with relevant parameters are discussed. Ultimately, this chapter's outcomes are aimed at letting stakeholders create a new transit line that branches out of the BRT corridor based on the principle patterns, which they can maximise, balance, or set threshold of the parameters according to their wishes.

8.2 PRINCIPLES

The characteristics of mobility principle patterns are the same as spatial integration principle patterns. They are created from theoretical underpinnings, insights on immobility, and widely used transportation planning theories. However, they do not have action patterns underneath; as mentioned earlier, the action patterns are replaced with potential destinations that the transit service can connect to.

Therefore, the principle patterns mainly focus on where and whom to serve. The list and image of patterns are provided below.



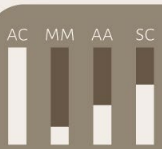
Poly-centric regions need poly-centric travel patterns and networks. Getting away from the traditional radial networks is recommended, especially with the introduction of vehicle automation (Kisner et al., 2017).

MP2
SERVICE

REFLECT THE NEEDS OF EVERYONE

Take the travel needs of elderly, migrants, children, women, and other groups, not just 9 – 5 commuters.

Not only commuters, but the travel needs of the elderly, migrants, children, women, and other groups should be taken into account in the service planning by engaging diverse groups in the planning process.



MP3
SERVICE

PRIORITISE UNDERSERVED AREAS

Prioritise serving the less accessible areas should be prioritised, even if it means prioritising it more than areas where you can expect higher ridership.

Serving the less accessible areas that are below the threshold of minimum accessibility should be prioritised than serving already well-accessible areas with high potential ridership (Martens, 2016).

AC SC

MP4
SERVICE

ACCESSIBILITY AS A MEANS OF RESTORATIVE JUSTICE

Use public transportation to heal the damages done for the histori-cally marginalised people.

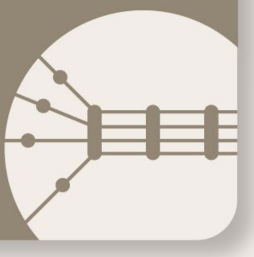
Public transportation can be an instrument for re-storative justice by providing better accessibility for historically marginalised people, as suggested by Sheller (2018).

AC AA

MP5
SERVICE

BUNDLING BRANCH SERVICES

If a section of the corridor has higher demand, than create multiple lines that serves surround-ing areas and also the high-de-mand corridor.



When large demand is expected at certain section of the corridor, multiple branch services diverging from the corridor should be introduced to expand service areas while guaranteeing sufficient capacity and fre-quency for the high-demand corridors, so that the smaller per vehicle capacity can be compensated.

AC BB

MP6
SERVICE

SINGLE-SEAT RIDE

For areas typed as strengthen areas, provide a single-seat ride to major destinations as much as possible.

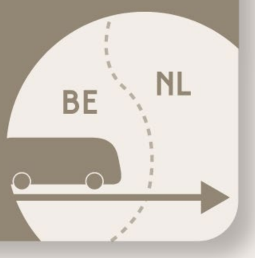
For areas typed as strengthen areas, the bus service serving the area should be designed to provide single-seat ride to the major destinations as much as possible to improve attractiveness of the area, and ultimately stimulate development.

AC MM AA EO

MP7
SERVICE

CROSS-BORDER SERVICE

Freely connect the destinations in the Netherlands and Germany, as BRT can run anywhere as far as the driver is present.



The national borders surrounding Limburg shall not become a barrier anymore, particularly since the BRT does not need dedicated infrastructure to run. More cross-border destinations should be created as a branch service, even if there's no dedicated infrastructure present.

8.3 BRT PLANNING SUPPORT TOOL

As an action pattern for transportation service planning, I created an interactive ArcGIS storymap that visualises amenities available in the 500-metre radius and also the core classifications (as defined in Chapter 4). The OpenStreetMap point of interest (POI) data was used to show and calculate amenities. The POI data was extracted using OsmPoisPbf, and re-classified amenities based on the code conversion chart (Peetz & Garg, 2013). Some action patterns in the spatial integration patterns are also applicable in service planning.

On the regional level, all cores defined in Chapter 4, and industrial estates will be represented as a dot. Users can click on the dots to see the commuter flows (incoming, outgoing, net), demographics data (population, number of jobs, population change between 2011 and 2022, median income, average number of cars per household), Nodality and Amenity, and public transportation accessibility from chapter 4. Spatial types and Spartacuslijn are also shown when zoomed in. Users can click on the menu to visualise the cores based on each parameter.

On the local level, the aforementioned amenities data is displayed. Users can click on any point on the map where they want to place the new stops. Then the list of types of amenities present within 500-metre distance will be displayed, along with the number of types of amenities, number of jobs and population around it, built environment metrics (walkability, function mix), and demographic data (mobi-score, median income, average number of household cars). The Spartacuslijn with Spatial types defined in Chapter 6 is also provided in the tool.

Based on this information, users can plan the transit service by prioritising, minimising, maximising or balancing certain metrics, or actually by setting the threshold of the parameters. As a usage example, each principle pattern can be applied (but not limited) by following ways (except MP7 cross-border service):

- MP1: Connection between areas that were not the centre of radial network can be considered by looking for demands between areas with nodality 3 or lower.

- MP2: For certain groups of people, access to certain types of amenity can be crucial. Provide service to that type of amenity.

- MP3: Prioritise cores with accessible jobs under 5.000.

- MP4: Prioritise cores and areas with less number of cars per household or low income.

- MP5: When connecting between large cores with population higher than 2.000 around Spartacuslijn, expand the service between them towards surrounding smaller cores.

- MP6: Maximise pull factors such as number of jobs, number of types of amenities, and commuter inflow for connecting Strengthen: Housing areas.

The existing amenities per 500m border are pre-calculated on hectare level on GIS: a grid of 100 m x 100 m squares are created, and amenities that are within 500 metres from each grid's centroid have been calculated. Therefore, depending on which part of the square a user may intend to look into, some amenities may lie maximum 641 metres (500 + 141 metres, because √(100+100) = 141.14 = diagonal length of the 100 m x 100 m square.) from the stop, or some amenities that are between 358 metres (500 – 141 metres) and 500 metres from the intended point may was not calculated. Nevertheless, it is suitable for its purpose: providing information on the level of amenities available in the neighbourhood of the station.

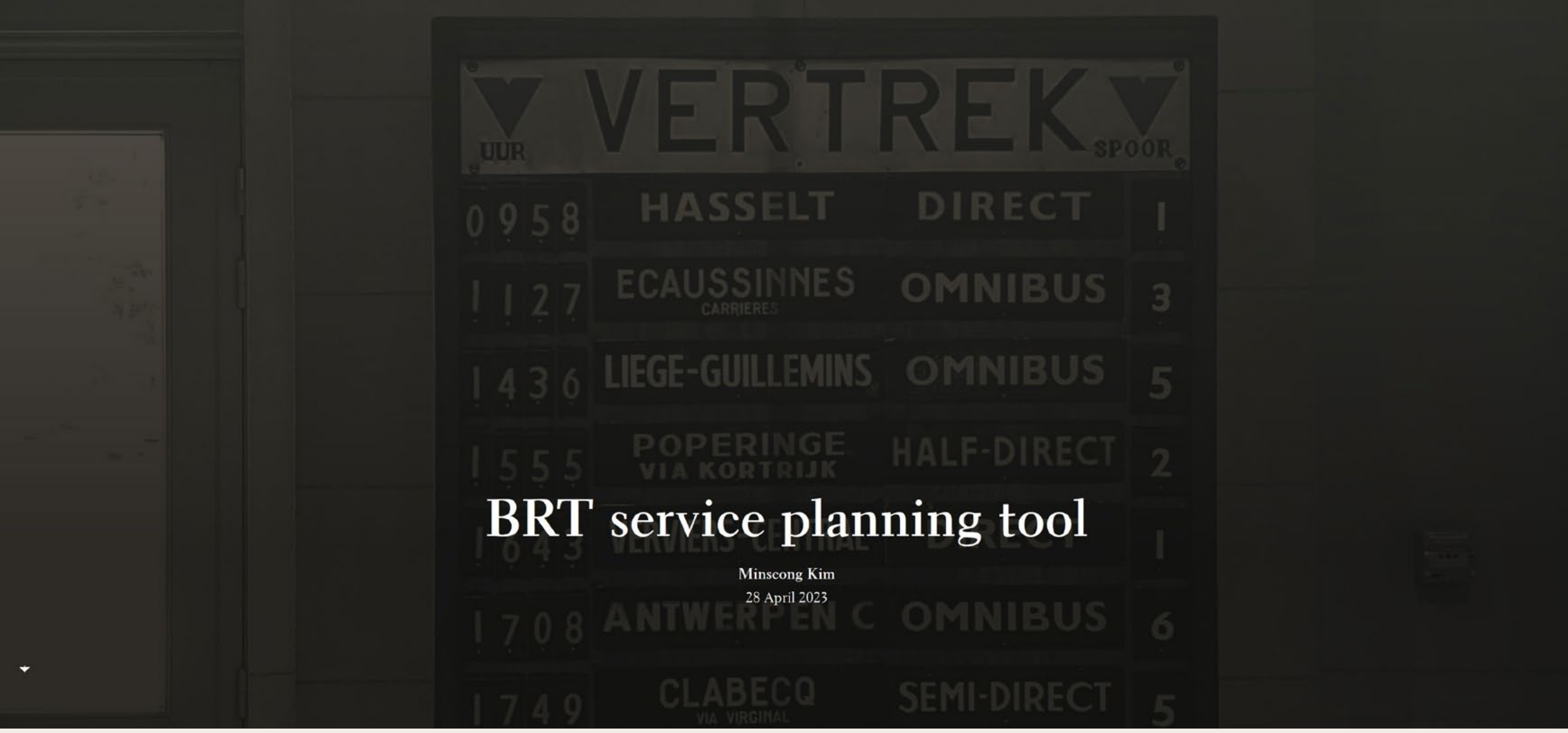


Figure 95. Service planning tool's entrance page.

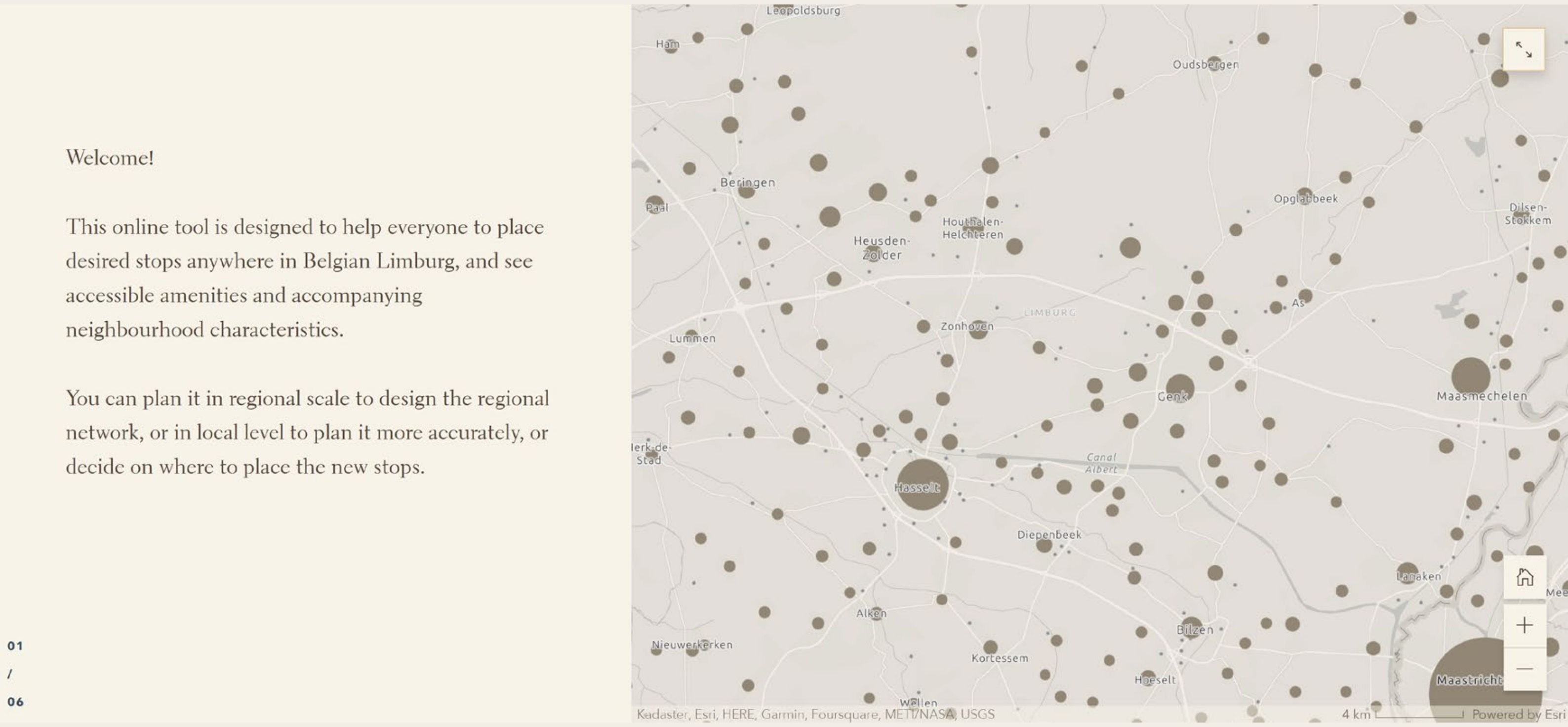


Figure 96. The user can scroll through the tool's introduction.

Figure 97. *The user guide page. The page reads: "On the regional scale, what you see are the "cores". Cores are basically a continuous area of settlements - corresponding to a town, or a part of a city."*

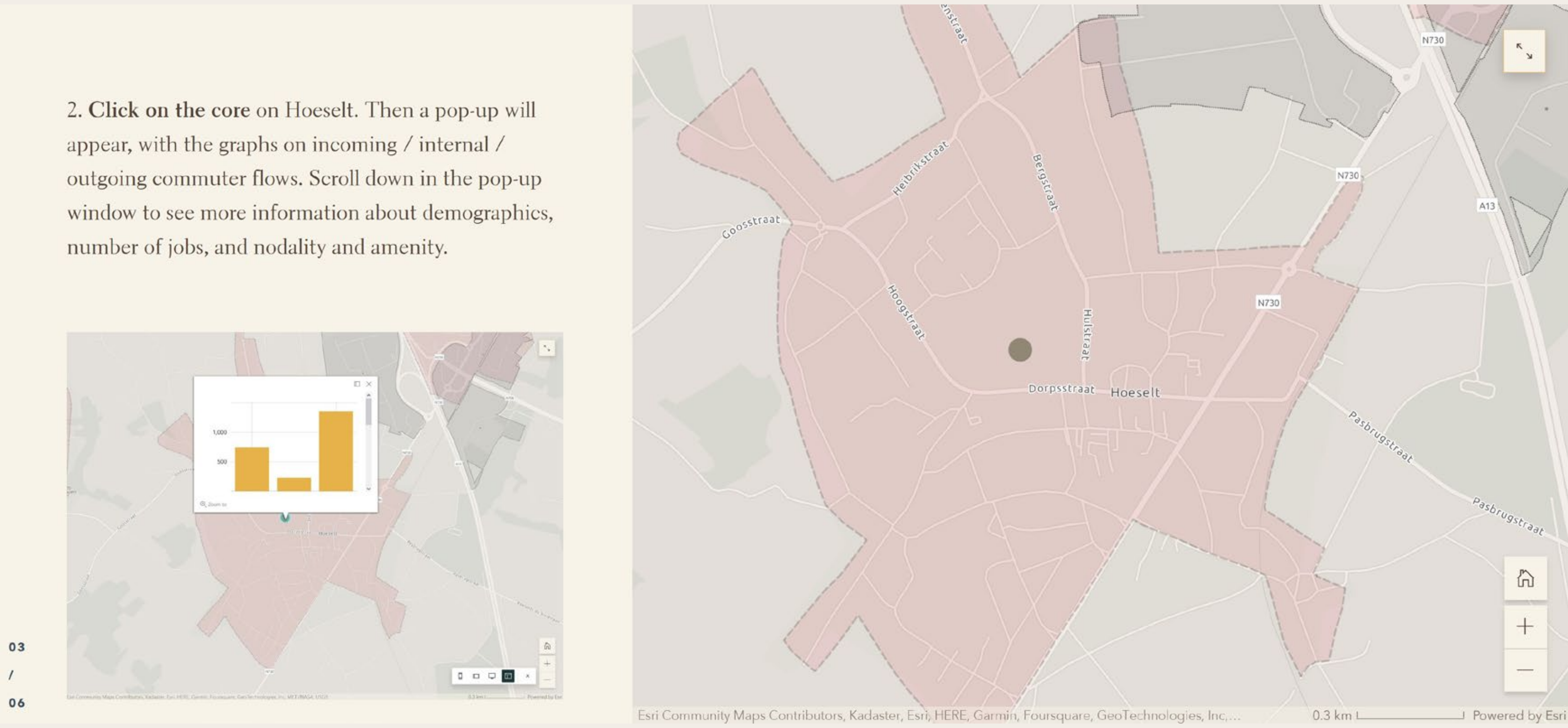
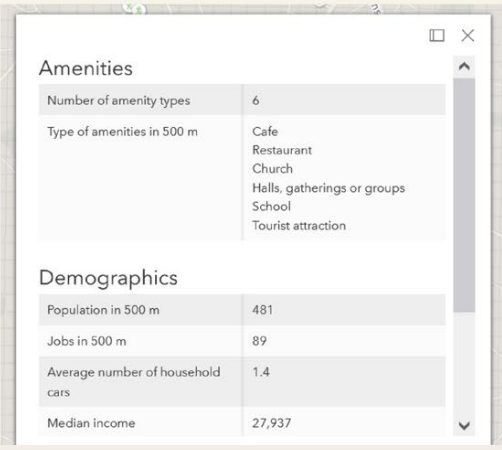
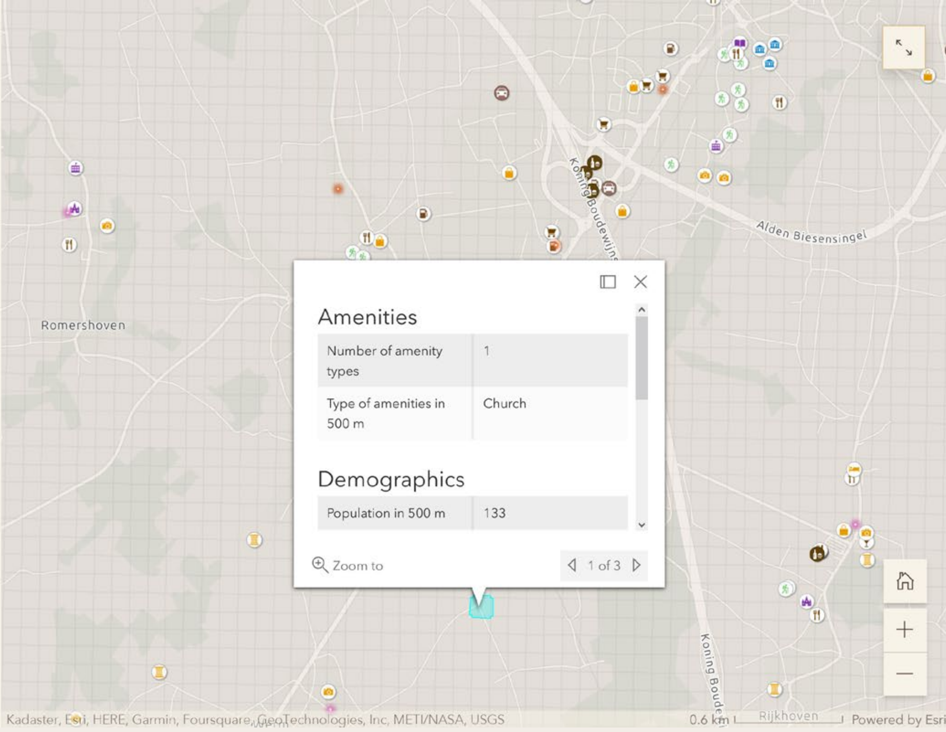


Figure 98. *The user guide page. The page reads: "Click on the core on Hoeselt. Then a pop-up will appear, with the graphs on incoming / internal / outgoing commuter flows. Scroll down in the pop-up window to see more information about demographics, number of jobs, and nodality and amenity."*

3. On the **local scale**, what you see are the map of amenities in Limburg.

You can now **click on any location on the map** where you would like to place a potential bus stop, or **click on the amenities** to see its name.

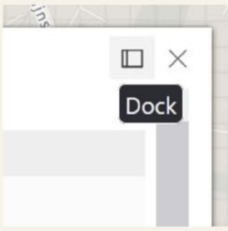




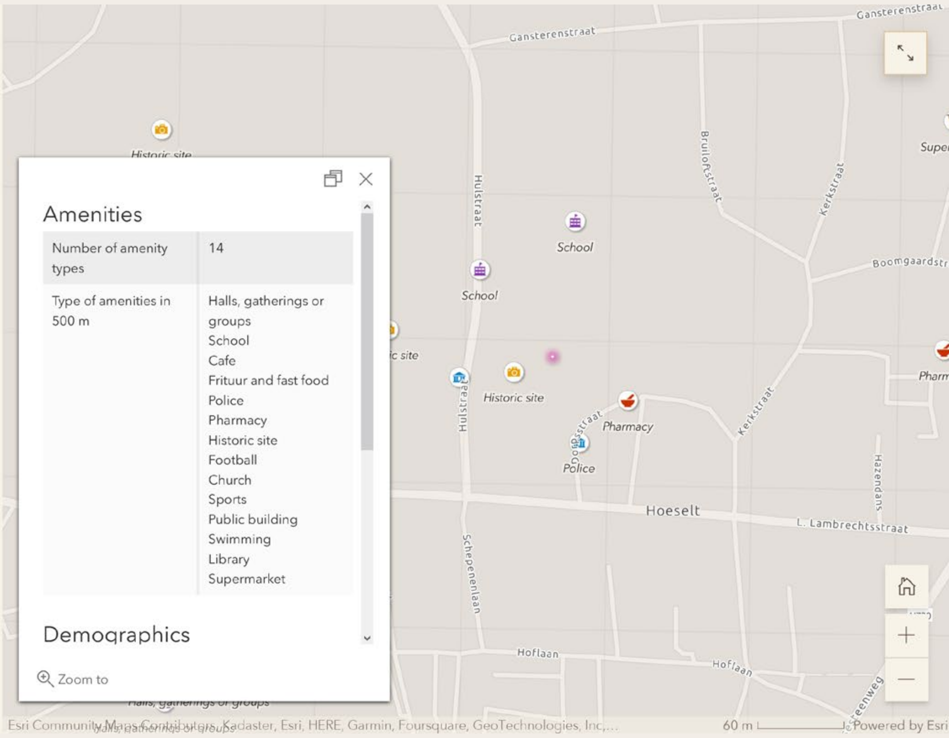
04
/
06

Figure 99. "On the local scale, what you see are the map of amenities in Limburg. You can now click on any location on the map where you would like to place a potential bus stop, or click on the amenities to see its name."

4. Tip: you can click on the **"dock" button in the top right corner** to view the details more easily.



Now you are ready to use it!



05
/
06

Figure 100. The user guide page. The page reads: "Tip: you can click on the "dock" button in the top right corner to view the details more easily."

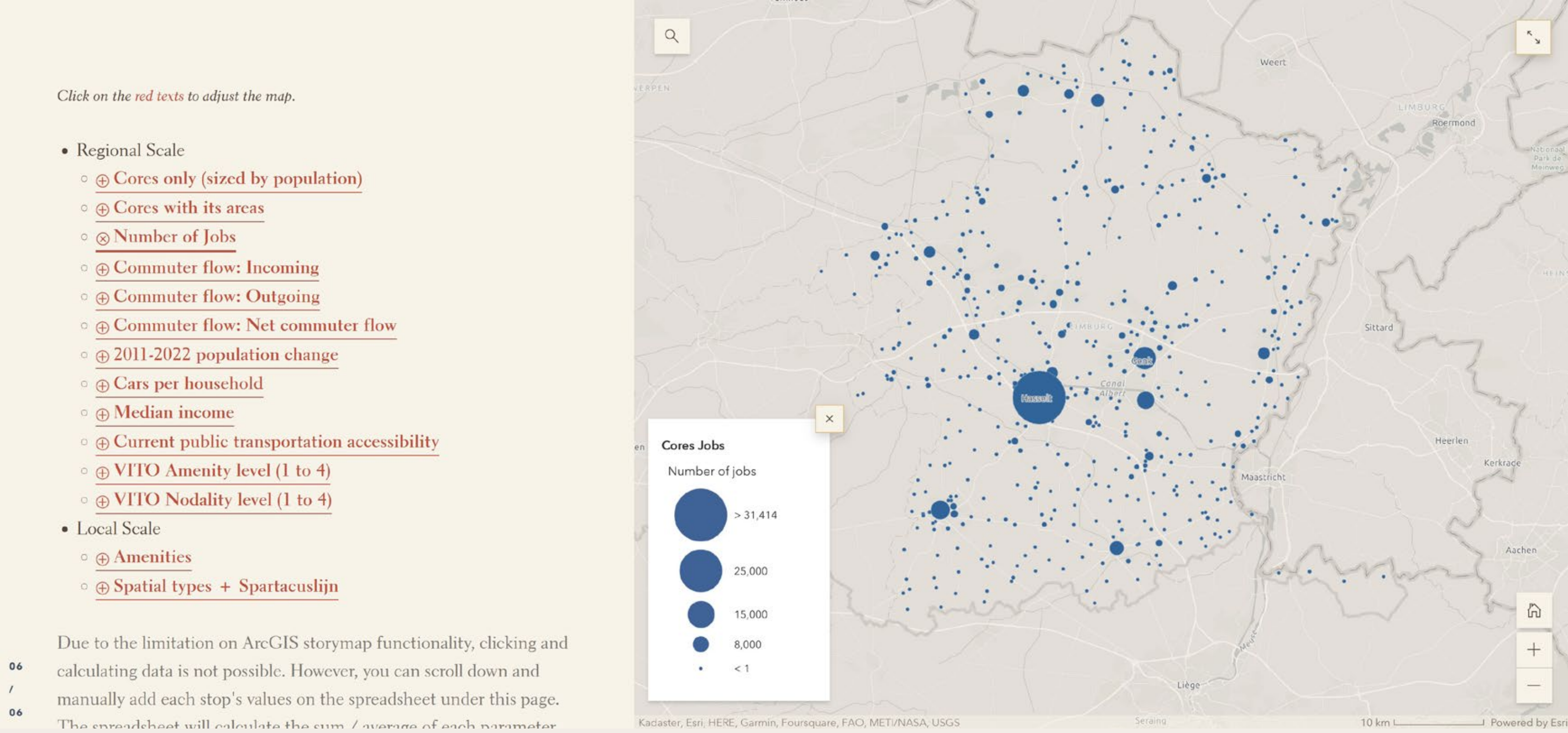


Figure 101. The tool page. Users can click on each red text on the left to change the map's visualised data, and easily zoom and navigate the map.

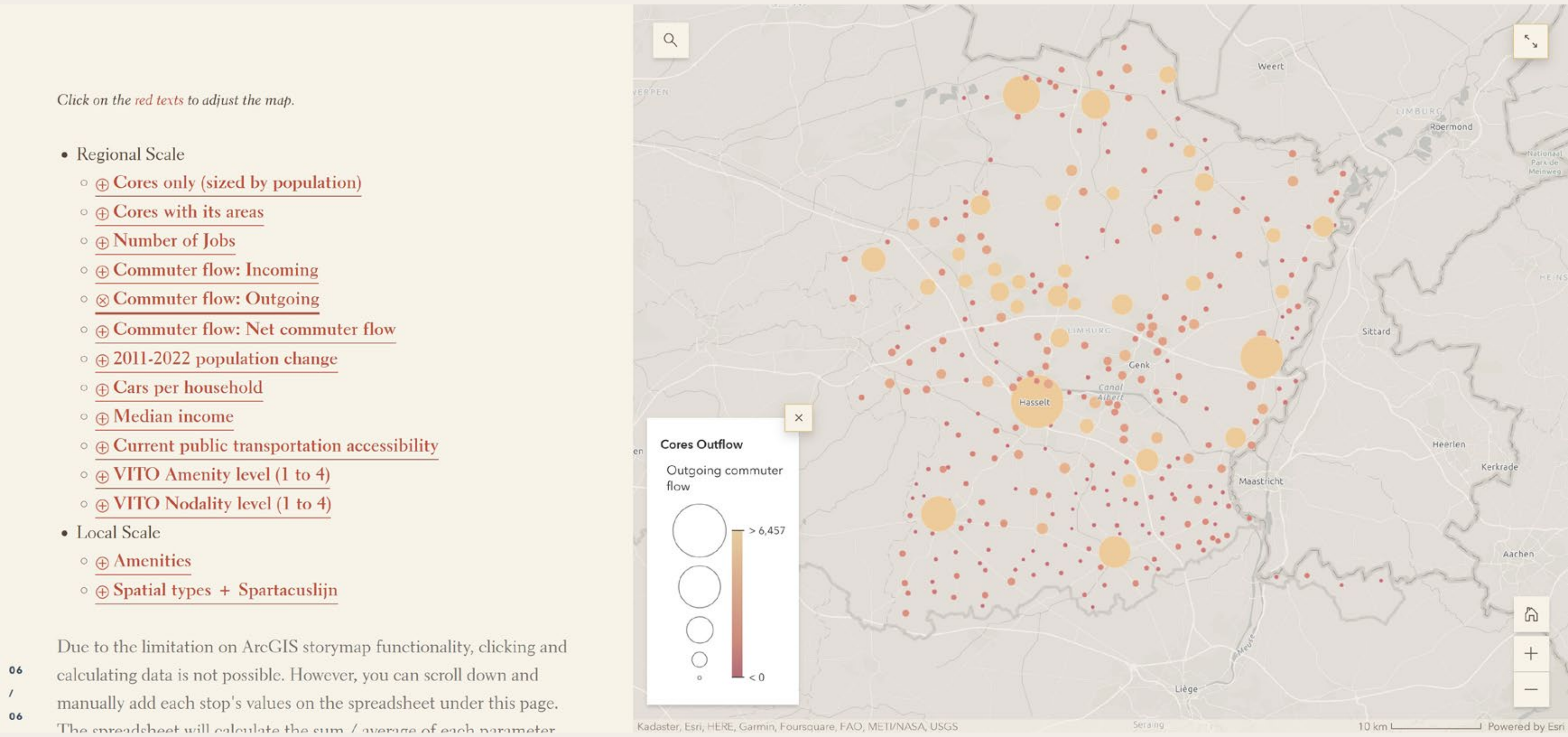


Figure 102. Commuter outflow is visualised. The legend is set to open by default, which users can close freely.

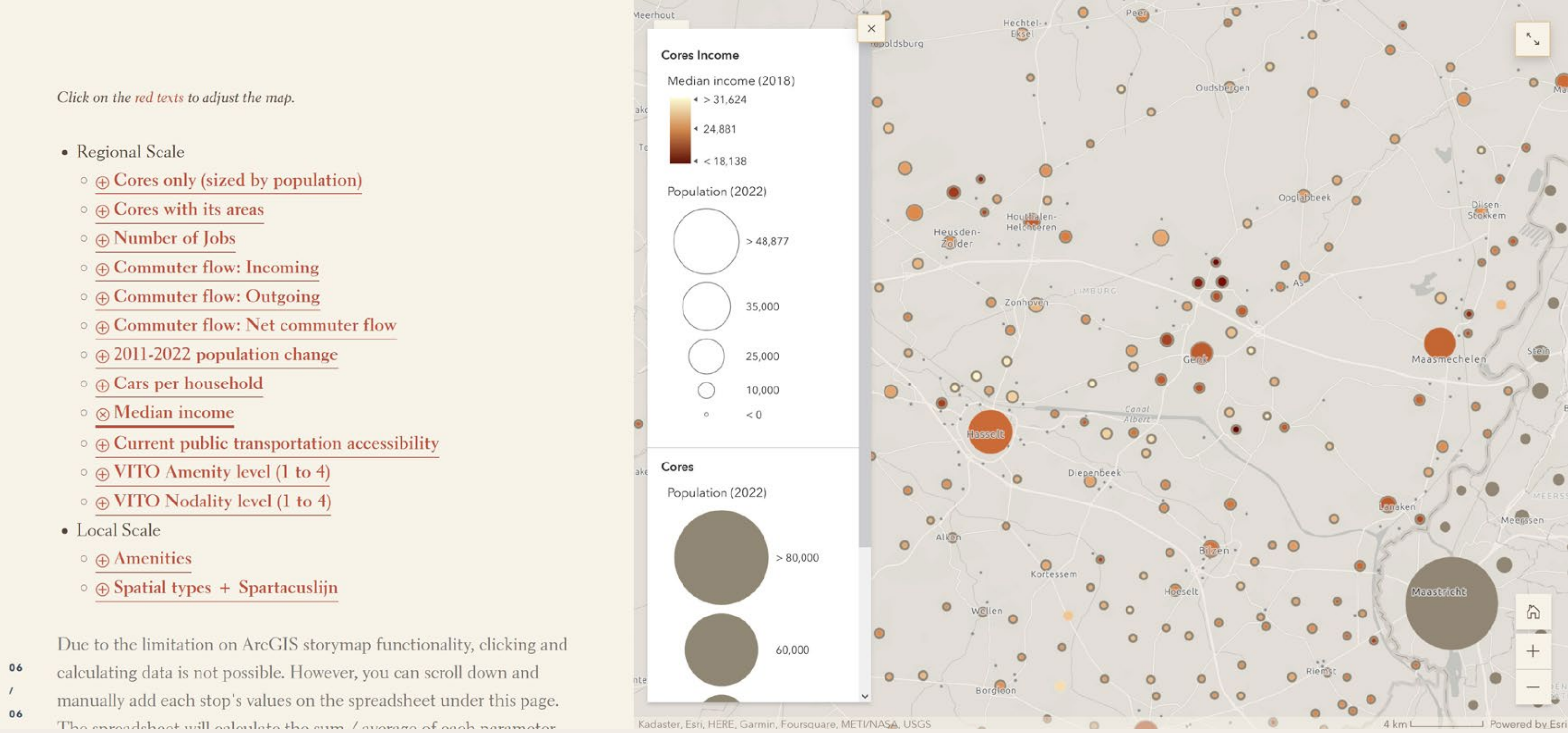


Figure 103. Income levels are visualised along with population of each cores. This can be useful in applying principle pattern MP4.

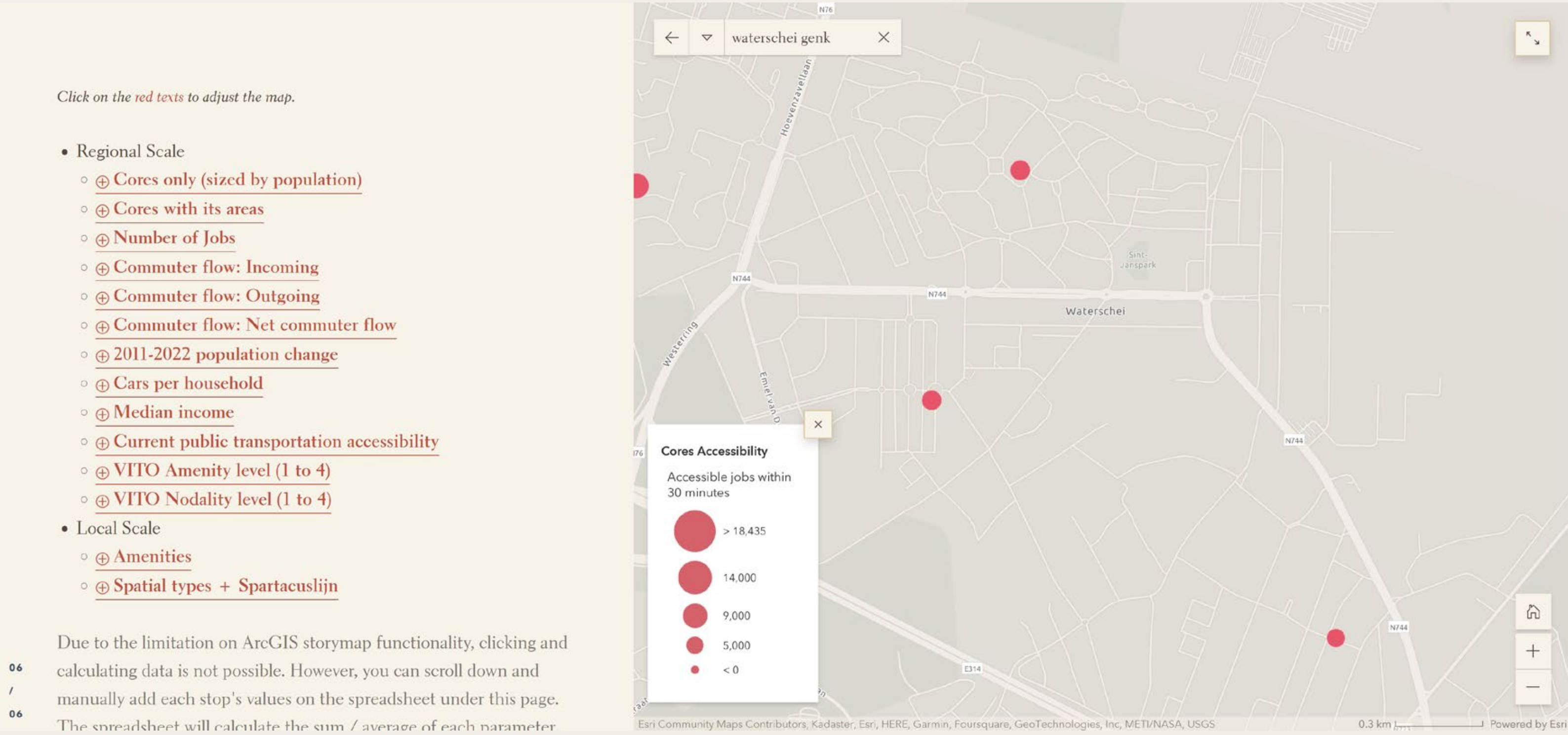


Figure 104. Accessibility (per core) is visualised. Users can search on the location inside the tool.

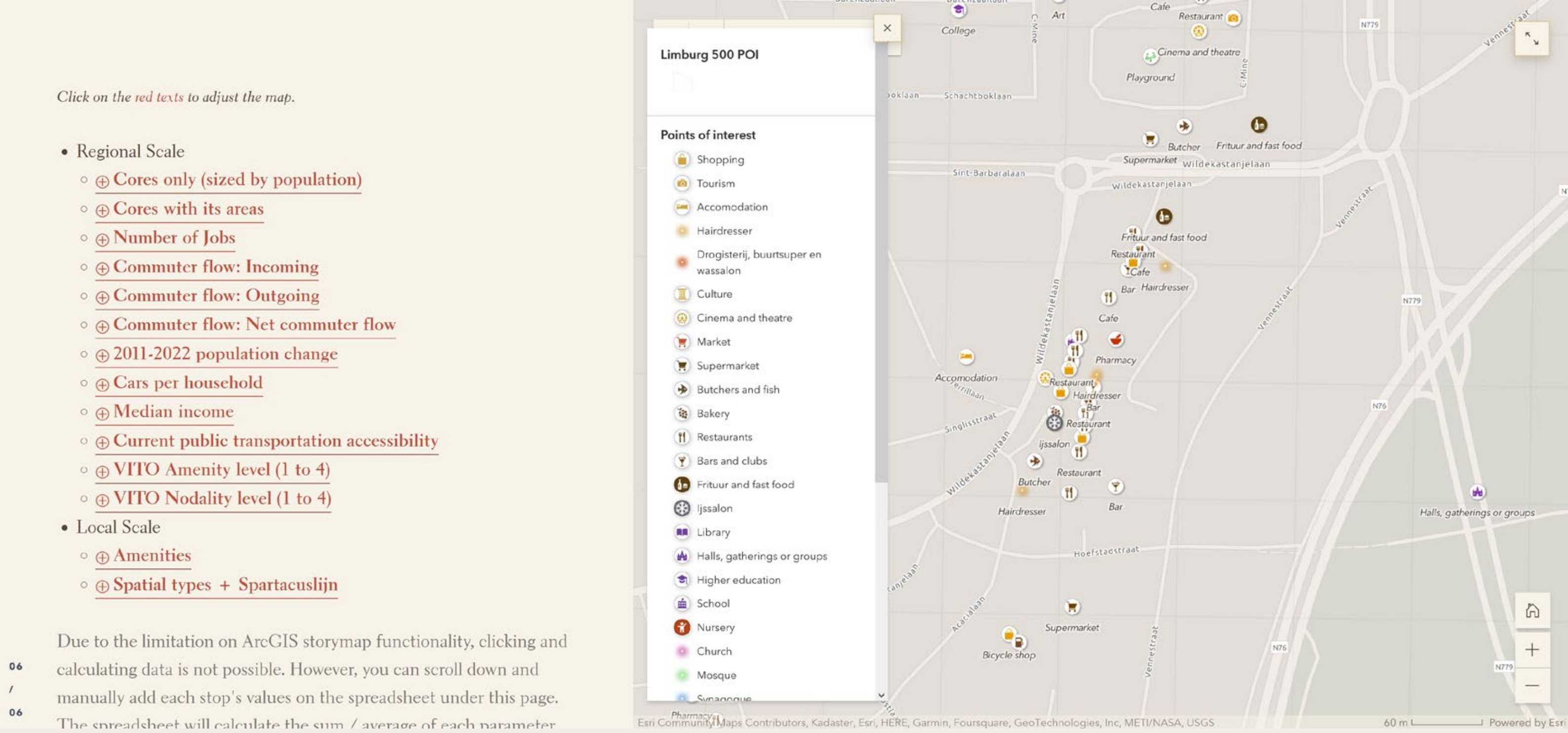
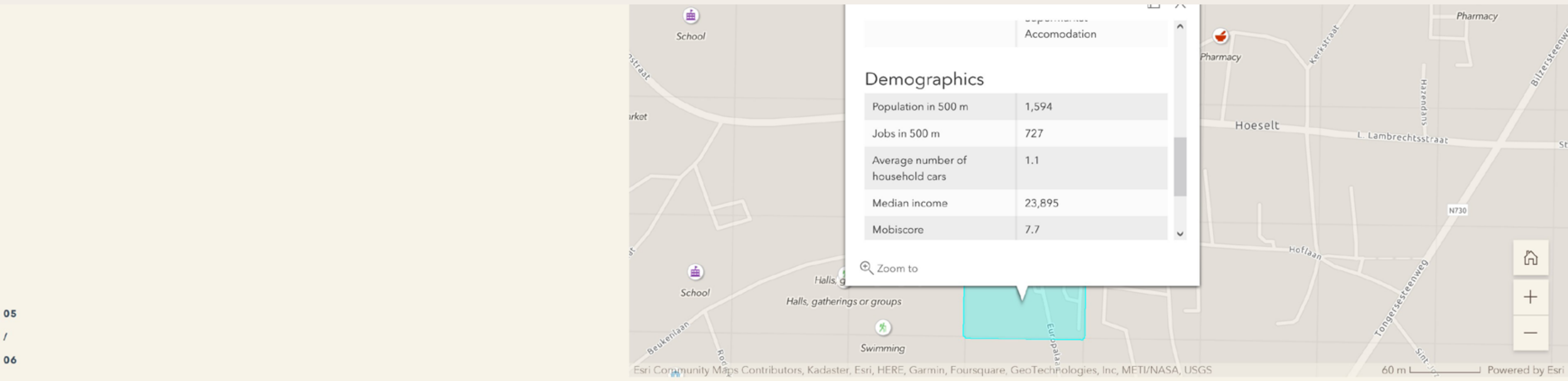
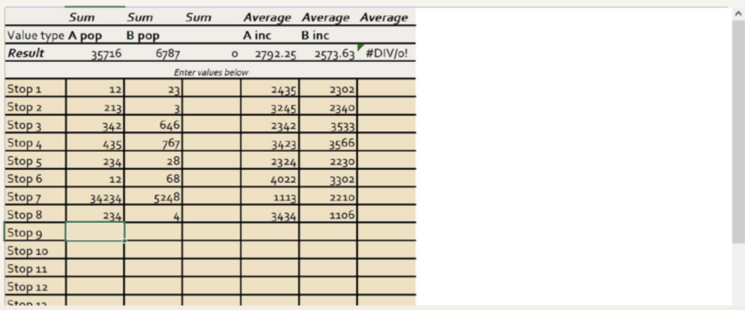


Figure 105. *Local-scale amenities are visualised. Amenities are set to not displayed on regional scale, and shows its type in text when zoomed in. When clicked or zoomed in further, the name of the place is also displayed.*





	Sum	Sum	Sum	Average	Average	Average
Value type	A pop	B pop		A inc	B inc	
Result	35716	6787	0	2792.25	2573.63	#DIV/0!
			Enter values below			
Stop 1	12	23		2435	2302	
Stop 2	213	3		3245	2340	
Stop 3	342	646		2342	3533	
Stop 4	435	767		3423	3566	
Stop 5	234	28		2324	2230	
Stop 6	12	68		4022	3302	
Stop 7	34234	5248		1113	2210	
Stop 8	234	4		3434	1106	
Stop 9						
Stop 10						
Stop 11						
Stop 12						

Figure 106. *Screen when scrolled halfway down through the end of the tool. Underneath the tool is an embedded excel-sheet. Some example values are typed in by the author for testing. By default the values on the "Value type" and Stop 1 – 8 are empty, where users can fill in the values themselves.*

Since ArcGIS Storymap does not support calculation nor communicating selected values on the map, which limited the function to a "catalogue" of potential locations. To remedy this issue, a spreadsheet is embedded at the end of the page, right below the tool. The spreadsheet calculates the sum or average of the values filled in. Users can manually fill in the values by retrieving the values from the tool by looking up at the map above, which can be seen on Figure 105. It can be used for comparing different route alternatives as the screen example of Figure 105 shows, for example.

The spreadsheet is not necessary in an workshop setting, which then participants can look up the values on the map and list the necessary values on the table for discussion. In that environment, the spreadsheet will serve purely supplementary function.

Demographics data	*Statbel (2021)*
Amenities data	*OpenStreetMap contributors. (2017). Planet dump retrieved from https://planet.osm.org*
Walkabilitytool data	*VITO & Vlaams Instituut Gezond Leven vzw. (2021). Walkabilityscore-tool Berekeningswijze en data. Vlaams Instituut Gezond Leven vzw.*
Nodality and Amenities data	*Verachtert, E., Mayeres, I., Engelen, G., Van Der Meulen, M., Vanhulsel, M., & Engelen, G. (2019). Ontwikkelingskansen op basis van knooppuntwaarde en nabijheid voorzieningen.*
Created by	Minseong Kim / TU Delft

Figure 107. The credits page with data sources.

The interactive online tool has been published for public use. https://arcg.is/11Li5e

The interactive tool can be used to support (non-transportation planners) stakeholder participation. It is also suited to apply principle patterns too, as suggested with example cases presented in this chapter. Further in this thesis, the interactive tool will be also applied in the workshop strategy in chapter 10 (operationalisation). In the next chapter, the principle patterns and the digital tool will be used to create transit interventions (lines) alongside the urban design exercise to demonstrate the synergetic relationship from coordinating urban design and transportation planning.

N°9

APPLICATION & EVALUATION

9.1 INTRODUCTION

The urban design patterns and the public transportation planning tool will be tested on the 4 example locations. Locations are selected to cover diverse aspects: Spartacuslijn stop / Branch, South Limburg / North Limburg / Central Limburg, and its type in the spatial framework. 4 personas will be assigned to each location, and will be tested on how their daily life may change. The interventions will be then assessed using the assessment framework for their effectiveness.

A quick context scan will be conducted on each sites. The quick scan will therefore emulate the local knowledge in the actual workshop settings, which cannot be present in this design demonstration. And based on the findings of the context scan, a strategy of general mesoscale intervention and corresponding patterns will be applied to each location according to it. Each location will also design 1 branch service in accordance to its strategy, except for Peer, which already functions as a gathering point for bus lines in the Northern Limburg.

The goal of the exercise is to see whether the patterns proposed in Chapters 7 and 8 are applicable and effective, and also to make an example case that urban designers and

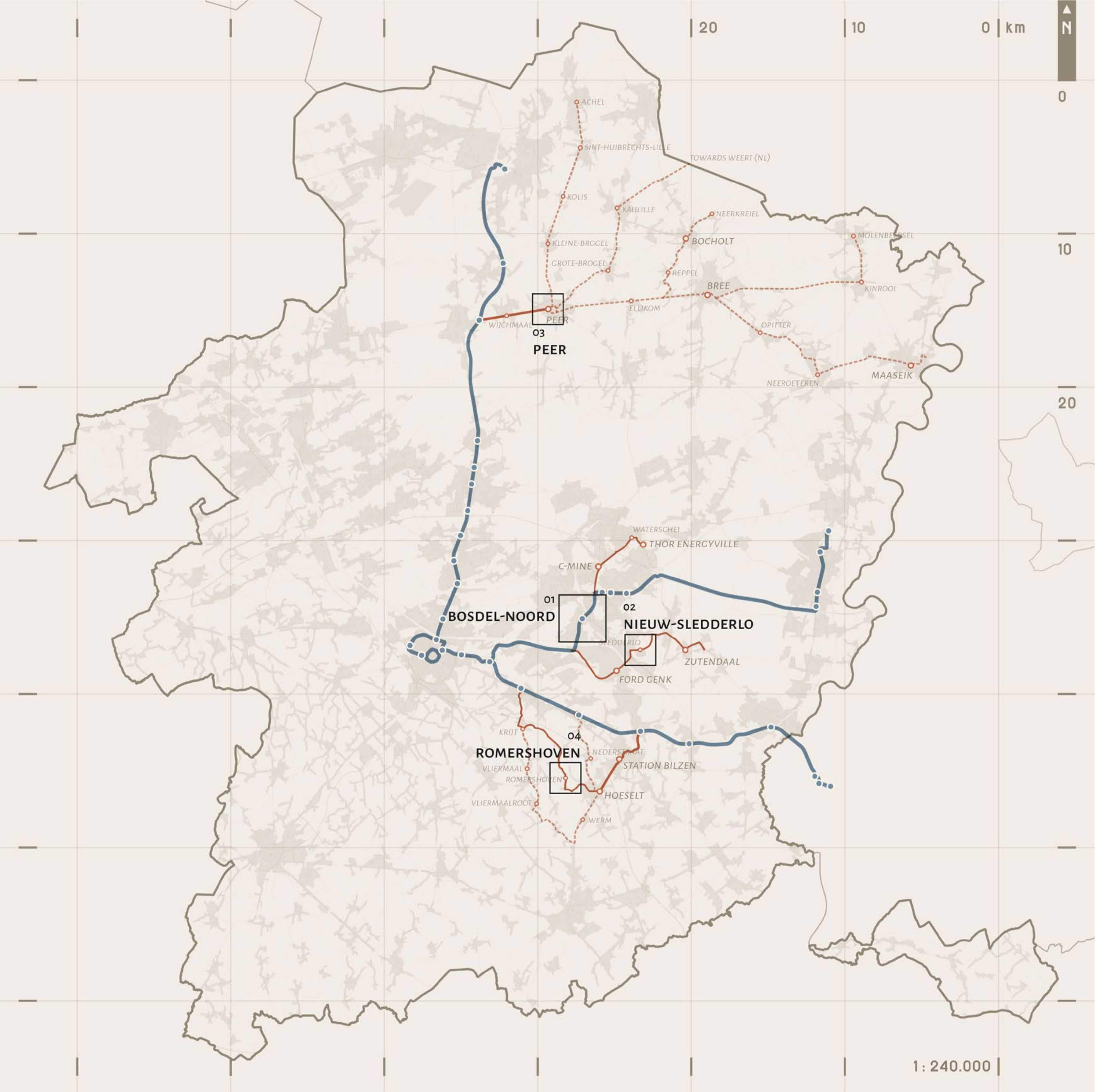


Figure 108. The 4 testing locations and the proposed branch services.

transportation planners can refer to. The visualised effects, artists' impressions, and the guidelines for application will provide direction for urban planners and urban designers to be informed about the process, purpose, and goals of the strategy in a spatial manner.

Secondary goal of the urban design exercise is to apply and test as many patterns as possible, as far as the spatial conditions allow for them. In a real application, not all patterns are required to be applied, and coordination between neighbourhoods would be required, which the process will be further clarified in the Operationalisation chapter.

Location	*Spartacuslijn*	*Sub-region*	*Spatial type*	*Dominant fabric type*	*Representing persona*	*Description*
Bosdel-Noord	Corridor	Central	Strengthen: Housing & Industrial transition	Urban Fringe	A	Potential infill and densification along Spartacuslijn
Peer	Branch	North	Strengthen: Transit	Perimeter block	C	Transformation of town centre for better public transportation access
Romershoven	Branch	South	Transform: Nature	Ribbon	B	Transformation of ribbon development for temporal provision of public transport and incremental shrinkage
Nieuw-Sledderlo	Branch	Central	Strengthen: Socioeconomic	Garden city (as in planned neighbourhood)	D	Public transportation as a leverage for socioeconomic challenges in an isolated neighbourhood

Table 17. Four testing sites and their characteristics

Figure 109. Urban fabric of each testing locations

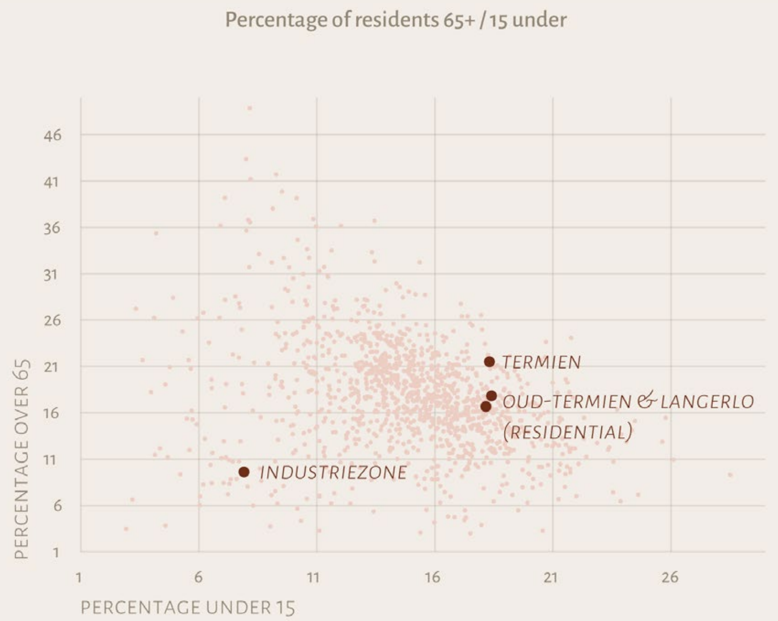
9.2 BOSDEL-NOORD

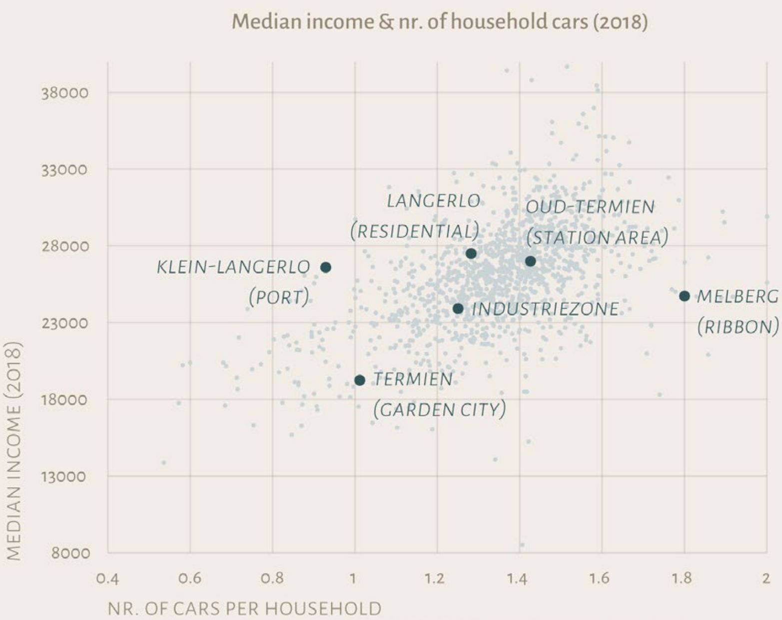
Bosdel is the "flagship" case: it is the only site located next to a new mainline Spartacuslijn stop, and unlike the other 3 sites where the patterns generally concern nodal interventions focused on specific issues, Bosdel-Noord case presents a neighbourhood-scale TOD design on an urban fringe near the station that is ready for infill development. Bosdel-Noord gives an example of a future strategy where less densely built lands along Spartacuslijn stops could be developed into an attractive transit-oriented neighbourhood that can facilitate active land swaps from the countryside.

Bosdel also presents the potential design of the industrial transition in the region. The proximity to the Port of Genk while also being a Spartacuslijn stop gives an interesting context: Bosdel is where the Port of Genk meets the city, and also where the Spartacuslijn 2's many dispersed services congregate between Hasselt and Genk in high frequency. As stated in Chapter 1.3.1, it is also important to create quality space around the working environment, which the urban design measures are crucial to realisation.

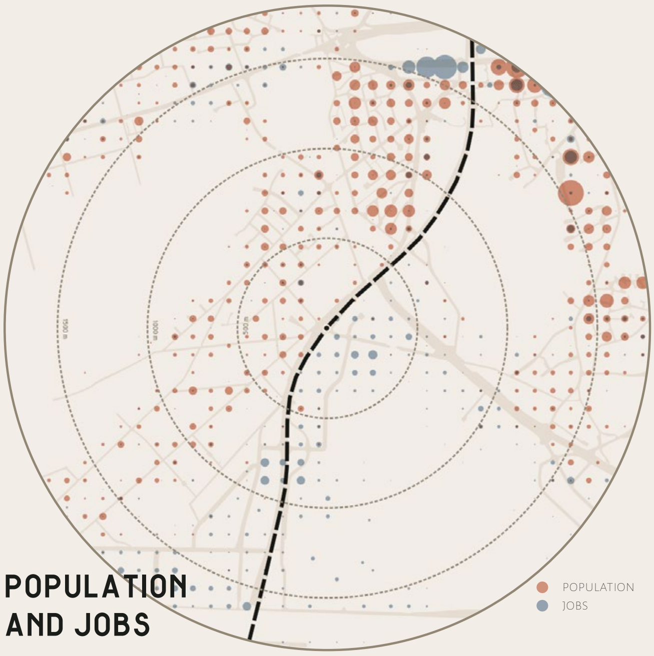
9.2.1 CONTEXT SCAN

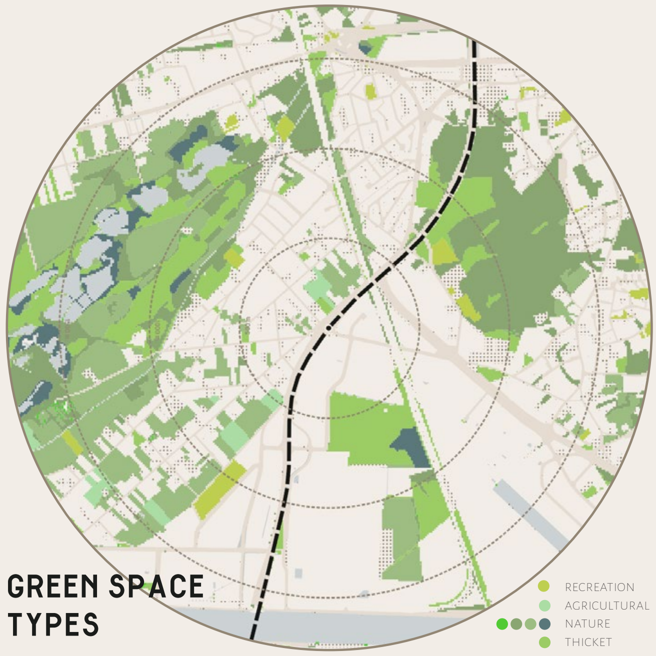
Figure 110. Demographic analysis of Bosdel. Age composition (above), income and household car ownership (below), Data source: Statbel (2021)

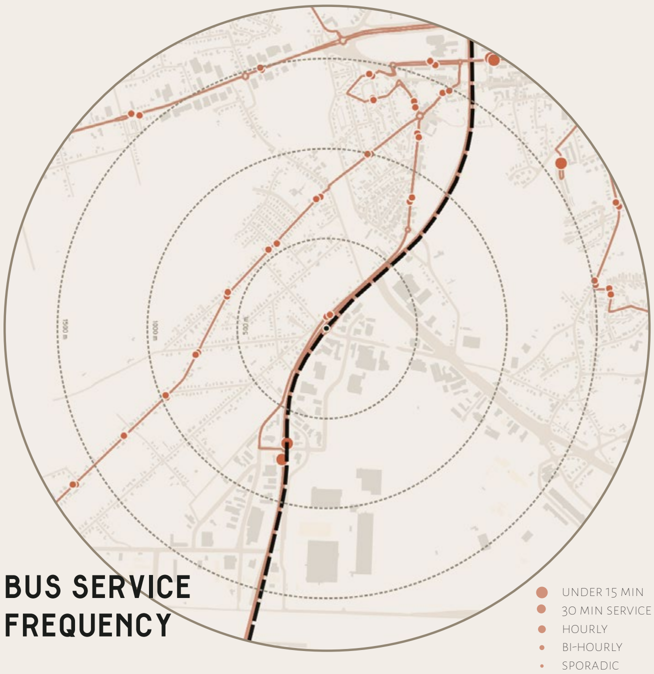


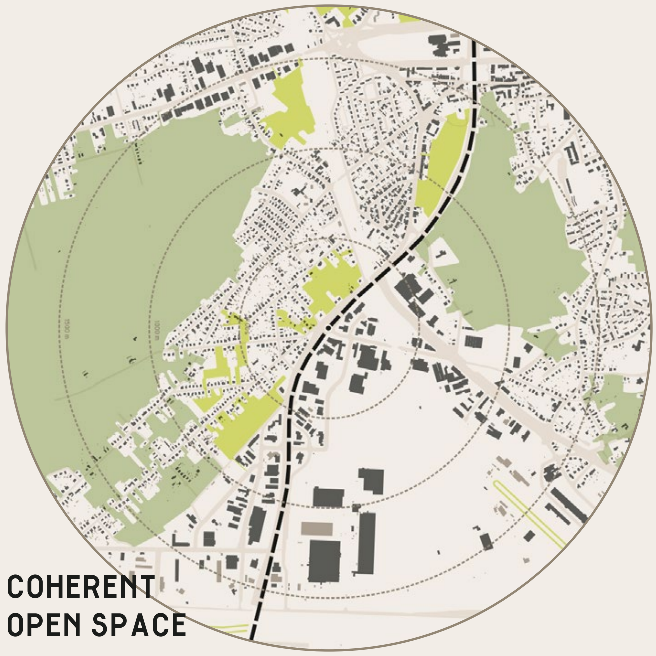


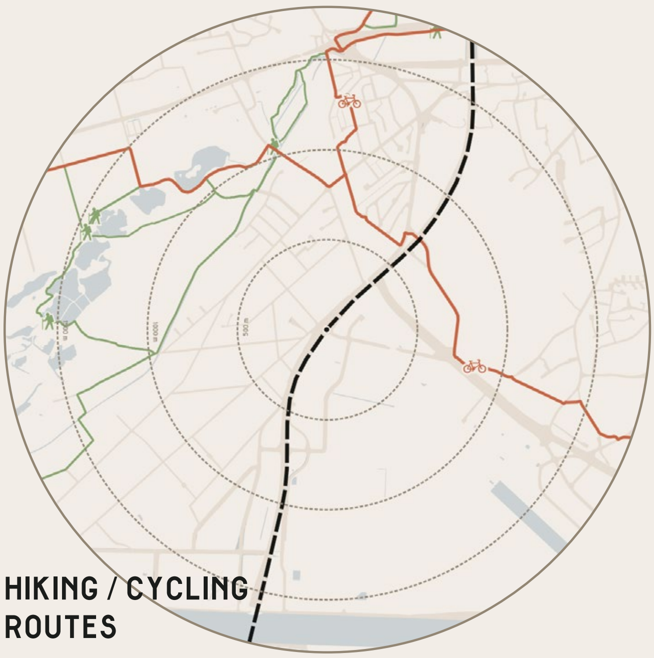
In terms of demographics, the surrounding residential areas of the station (Oud-Termien) can be considered as an median representative of Limburg neighbourhoods. On the other hand, the mining garden city neighbourhood north of the station (Termien) shows noticeable sign of socioeconomic challenges, which is also classified as an neighbourhood with light socioeconomic challenges by Vanderstraeten et al. (2021), suggesting need for connecting station with Termien.

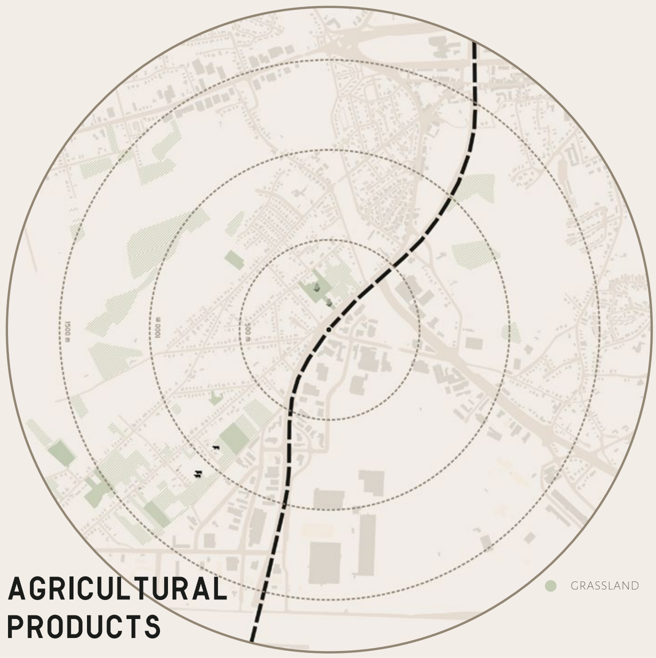

POPULATION AND JOBS
POPULATION
JOBS

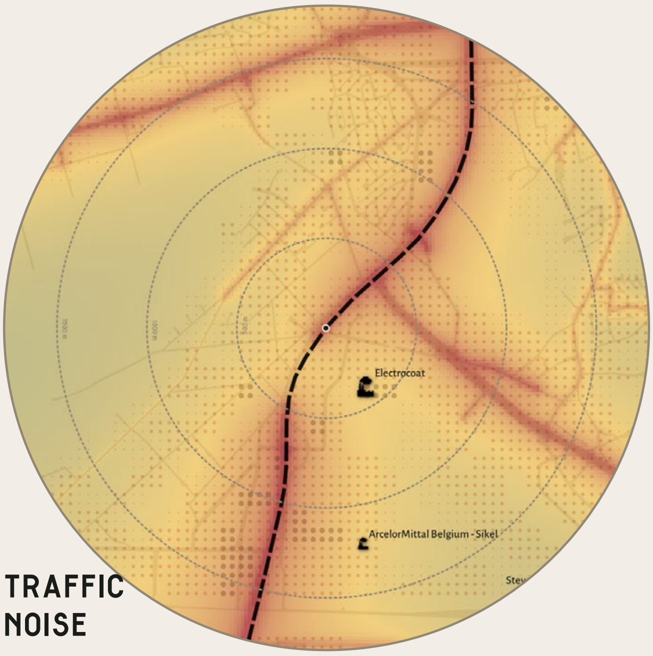

GREEN SPACE TYPES
RECREATION
AGRICULTURAL
NATURE
THICKET


BUS SERVICE FREQUENCY
UNDER 15 MIN
30 MIN SERVICE
HOURLY
BI-HOURLY
SPORADIC

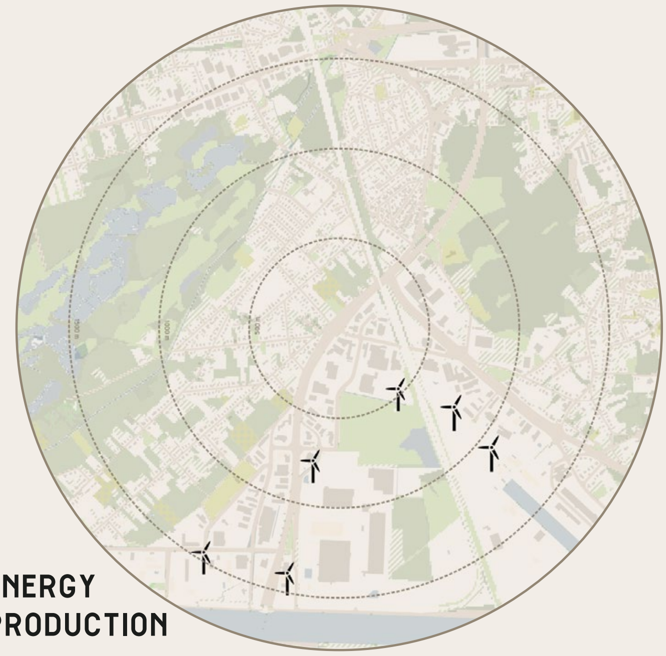

COHERENT OPEN SPACE


HIKING / CYCLING ROUTES


AGRICULTURAL PRODUCTS
GRASSLAND



TRAFFIC NOISE



ENERGY PRODUCTION

NEARBY AMENITIES

Figure 111. Quick scan of the site

9.2.2 INDUSTRIAL ECOSYSTEM

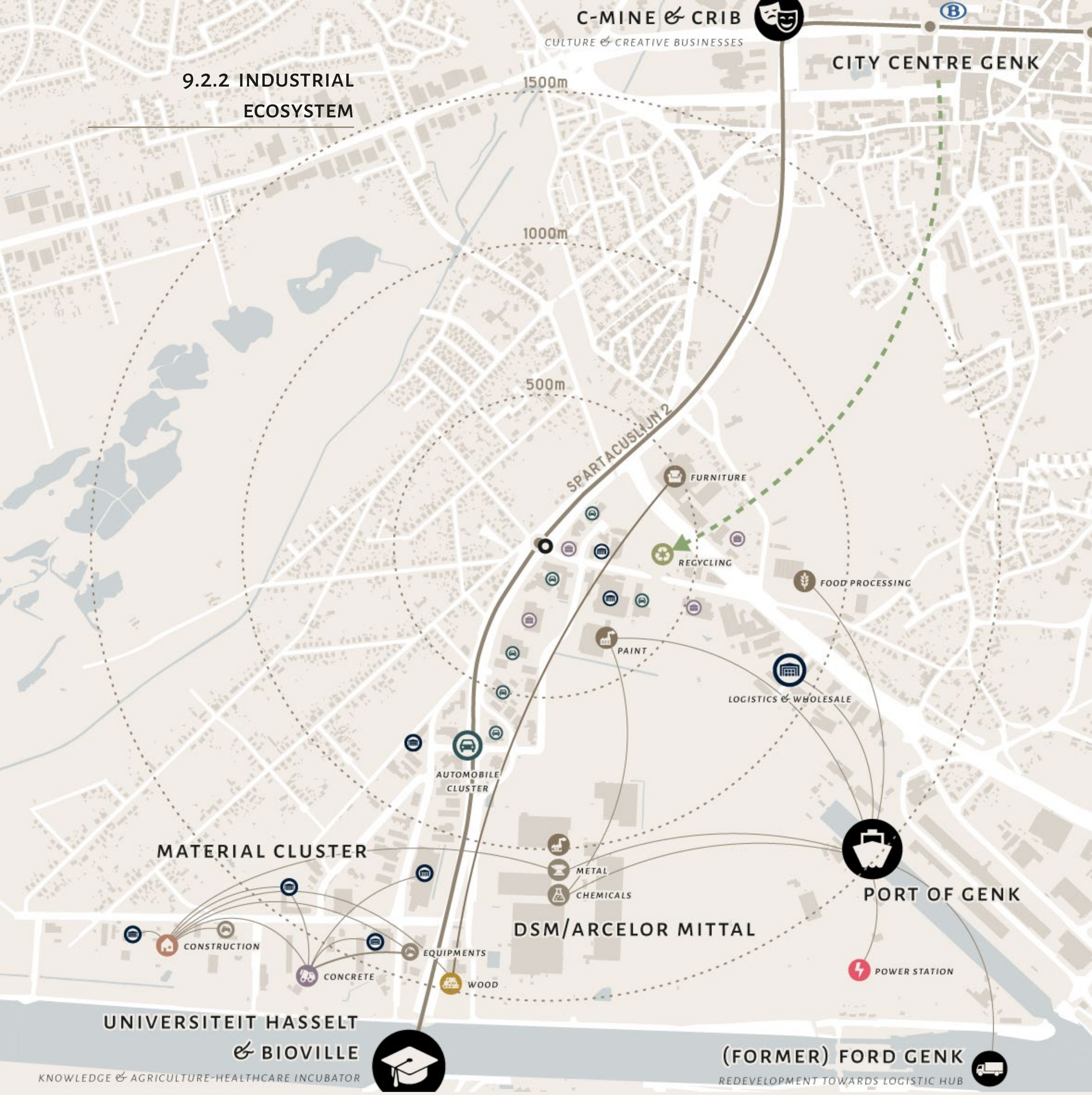


Figure 112. Current industrial locations and their relations around Bosdel-Noord.

As suggested in the spatial framework, the industrial transition area type requires the analysis and understandings on the industrial ecosystem of the area. The site is situated between the material cluster along the Albert Canal and the logistic cluster on the Port of Genk. The two clusters have little interaction between, and forms an relatively isolated system, due to the presence of large-scale DSM facility and a power plant. The area is occupied by suburban commercial activities, such as car dealerships, garages, and warehouses. One thing noticeable in the site is the presence of recycling industry and a second-hand store. Such land use is attributed to the fact that the site is the closest industrial estate from the Genk city centre.

Figure 113. The Proposed industrial strategy around Bosdel-Noord.

The area lies between Genk and Hasselt, being accessible from both. The knowledge and innovation incubators of C-Mine (creative), UHasselt, and Thor EnergyVille lies nearby. The Spartacuslijn and its potential branches generally would also gather between Hasselt and Genk: this means superb accessibility from large part of the region than nearby Ford Genk site or Port of Genk – which can position Bosdel as a "public façade" of the Port and Ford Genk: the Ford Genk can be positioned more as the B2B, industry oriented makerspace and innovation space where large-scale, technical innovations are made, while Bosdel becomes a "public façade" for the port of Genk: focusing on makers in end-user products, and innovations in circular materials that involves societal application and products.

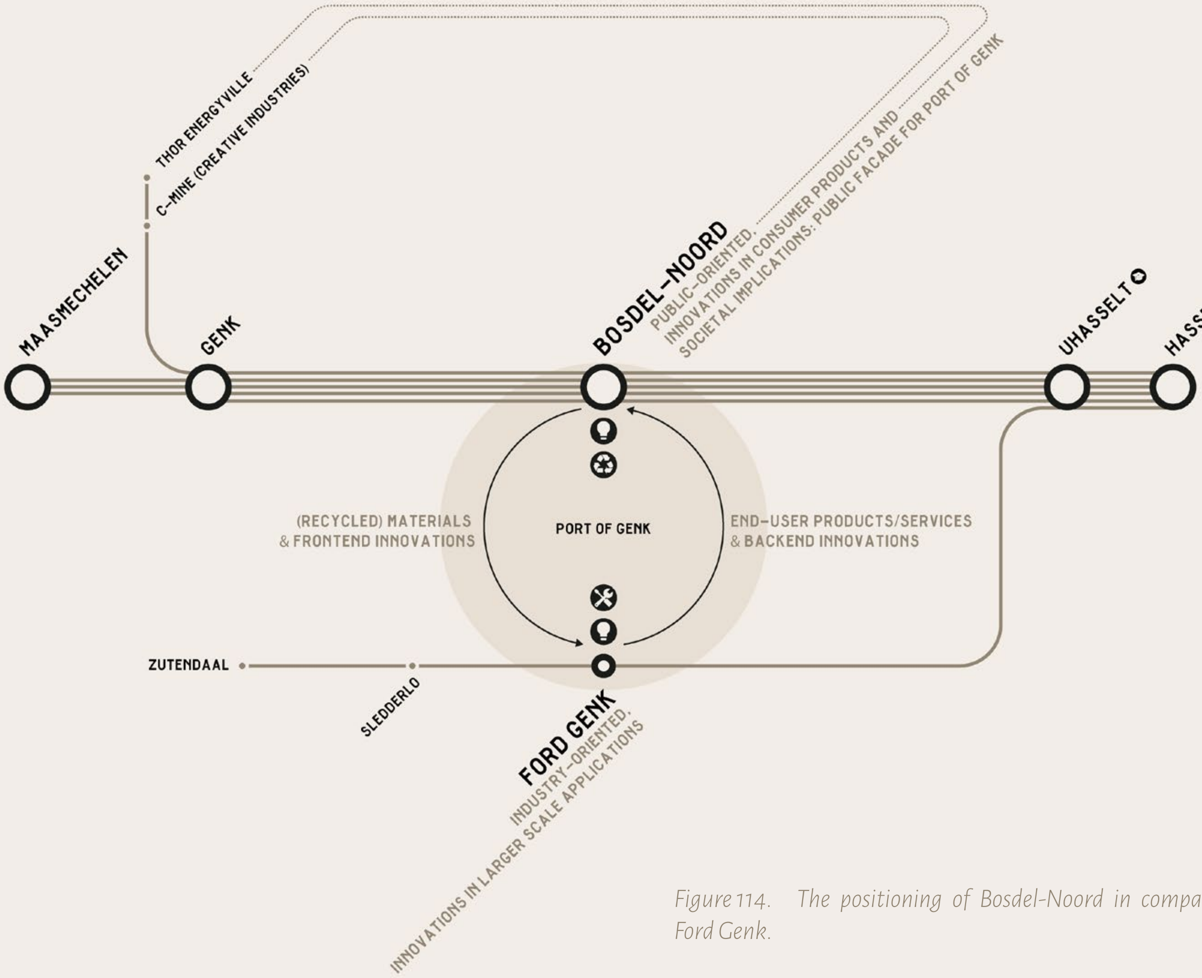


Figure 114. The positioning of Bosdel-Noord in comparison with Ford Genk.

9.2.3 TRANSPORT SOLUTION

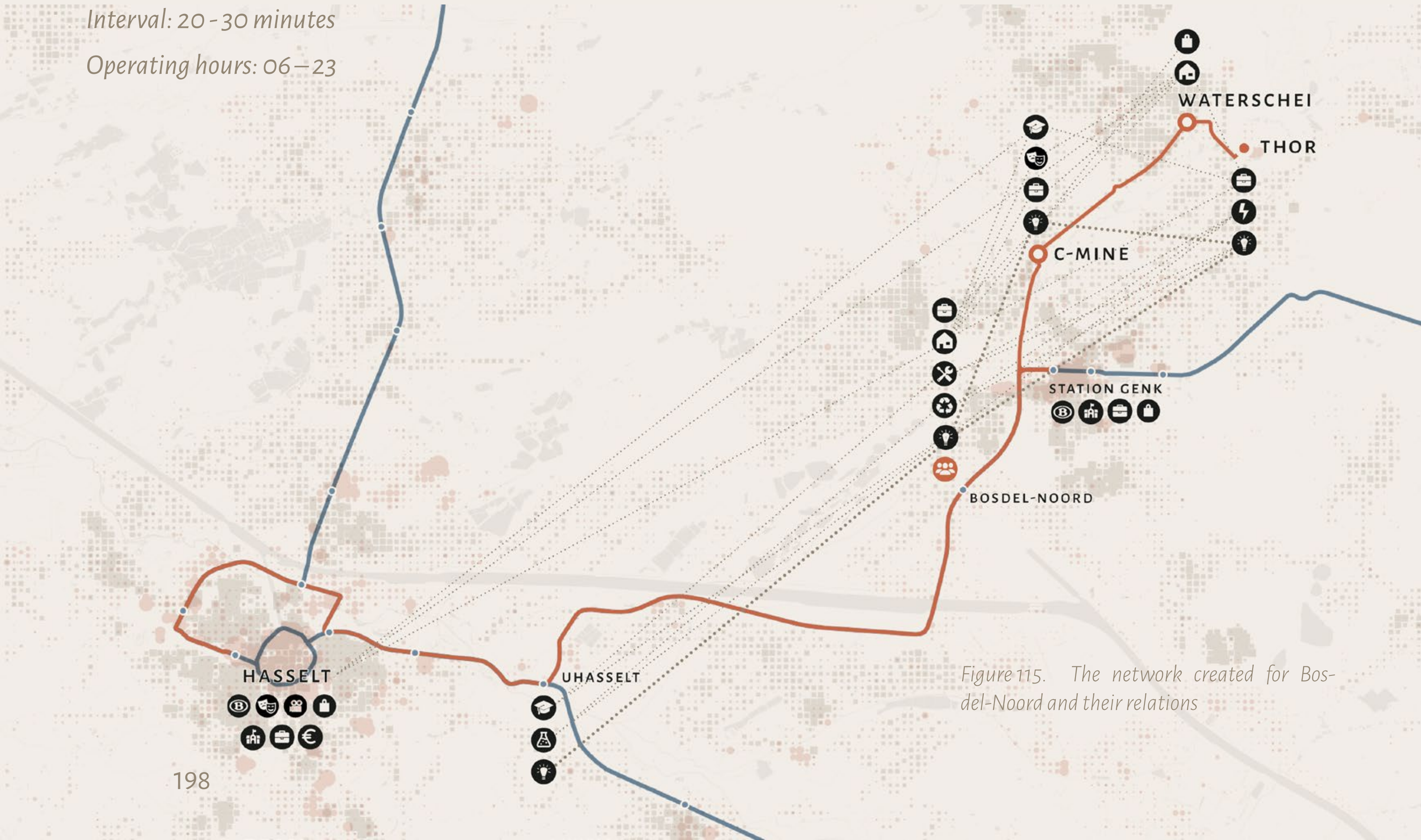


Figure 115. The network created for Bosdel-Noord and their relations

While University of Hasselt, Bosdel, C-Mine, and Thor Energyville are locations aimed at introducing innovative businesses in the region, the transportation link between them has been lacking. By creating a branch service connecting the knowledge institutions and innovation incubators, the transfer of ideas and people can be facilitated. On the route, the socioeconomically deprived neighbourhood of Waterschei will also be served as one of the intermediate stop, connecting the neighbourhood with job opportunities.

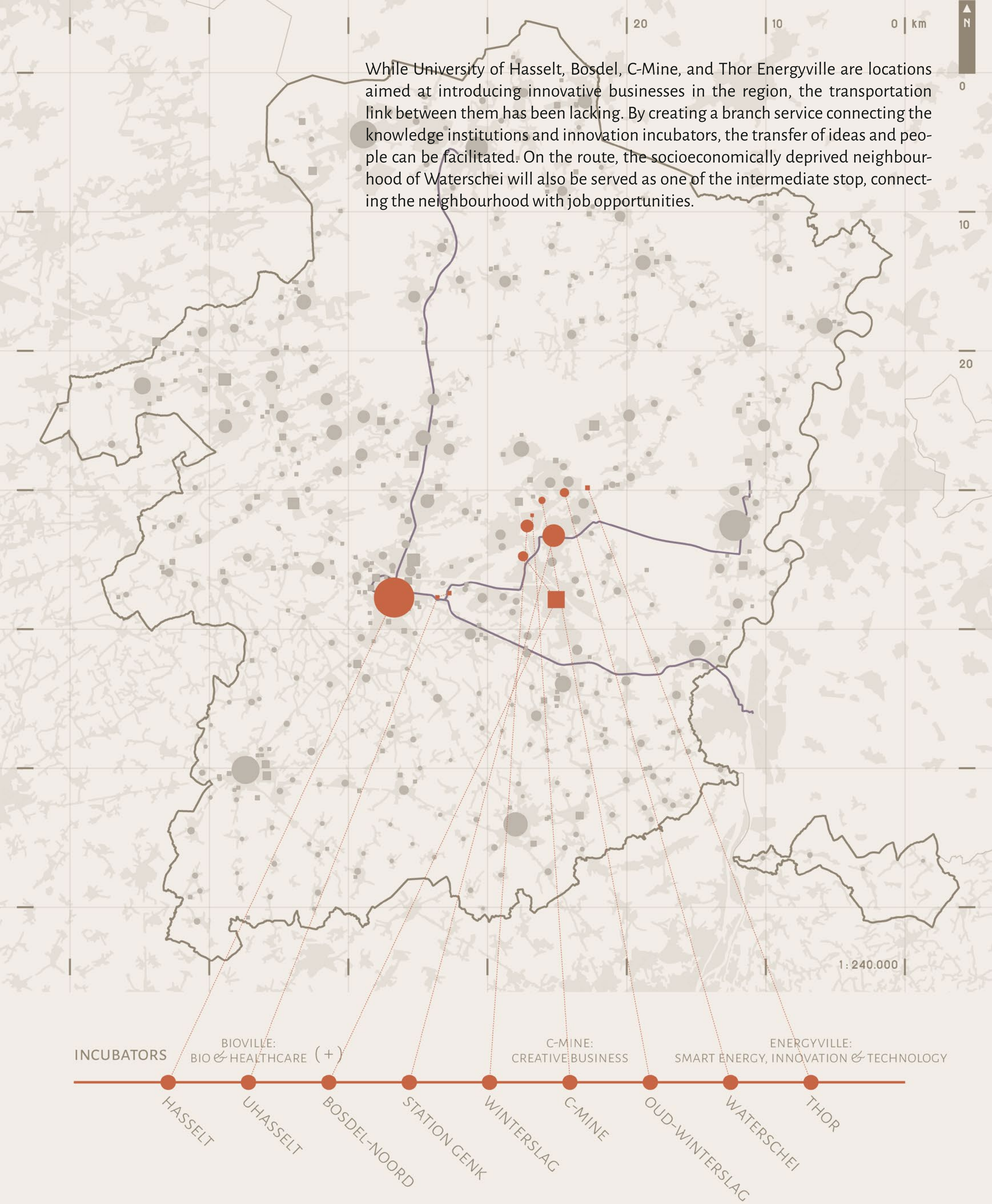
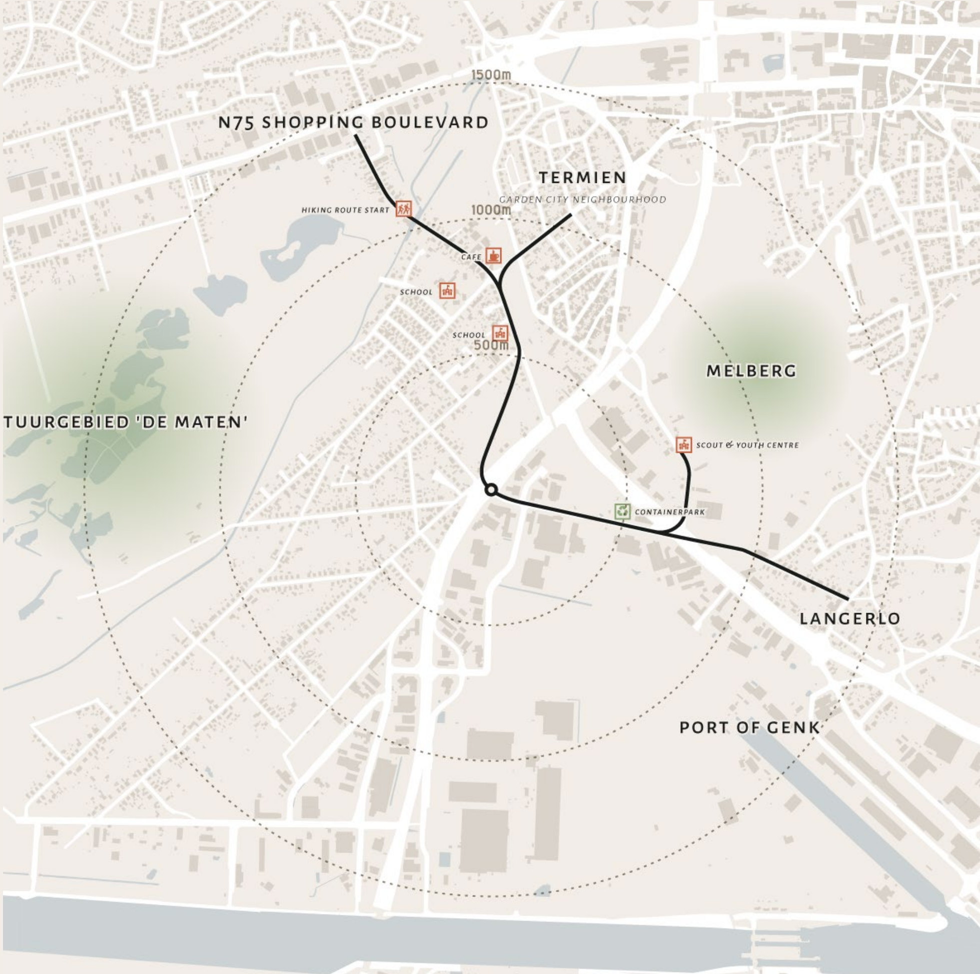


Figure 116. The network created for Bosdel-Noord and the characteristics as defined in Chapters 4 and 8

The line could be designed based on the principles of MP1 (point-to-point) and MP6 (single-seat ride), along with the results of the industrial context of the area. Therefore, it is aimed to offer direct service between key knowledge and innovation institutions in the region as much as possible.

9.2.4 APPLIED PATTERNS

Figure 117. Urban design objective for Bosdel-Noord based on local context



Based on the context scan, the urban design would aim to create a living axis connecting the shopping boulevards in N75, Termien, and De Maten on the north, through the Spartacuslijn station and to the Melberg and the Port of Genk. The relatively empty urban fringe block north of the station will be also re-developed.

Figure 118. Applied patterns and not applied patterns with the reason of non-application

BOSDEL-NOORD

Applicable pattern types

APPLIED			NOT APPLIED	
M1	S2	I1	M6	NO GNW/GTI
M2	S4	I2	M10	PATH IS NOT INTENDED TO SOLVE CONNECTIVITY ISSUE
M3	S5	I3	S1	BRT CORRIDOR ALREADY PRESENT
M4	S6	I4	S3	INSIDE URBANISED AREA
M5	S7	I5	S11	URBAN FRINGE BLOCK GOT RE-DEVELOPED; PARTLY APPLIED
M7	S8			
M8	S9			
M9	S10			
	S12			
	S13			

The spatial type (Strengthen: housing and Industrial transition) dictates that Strengthen and Industrial Transition patterns will be applied. Given the scale levels of the urban design, almost all patterns were applicable. One notable perk of Bosdel is the already rejected residential expansion area. Since the ruling was made, the rejected area will be kept as a green space.

9.2.5 TRANSIT-ORIENTED DEVELOPMENT

Figure 119: Ground plan of Bosdel-Noord

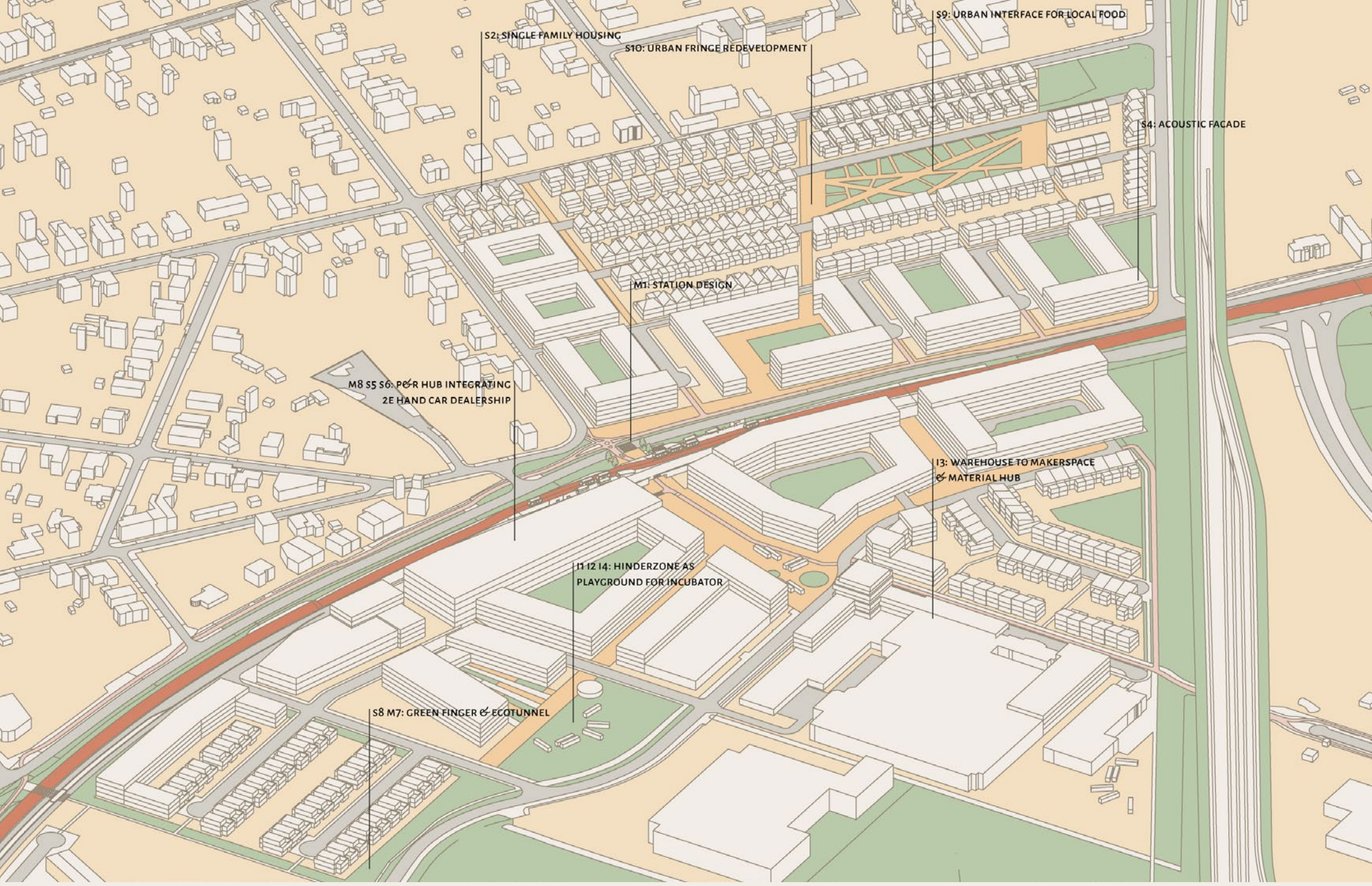


Figure 120. Applied patterns on bird's eye view (only when location specific)

In Bosdel, the application of patterns in the neighbourhood scale would be tested. Figure 119 shows selection key patterns in neighbourhood. The most notable case is the re-development of the urban fringe to the north of the site. It could be re-developed along with the diagonal axis through the block as a pedestrian access to the station, which is suggested from the verdict based on quick scan of contexts. However, as for Bosdel's case, the creation of direct diagonal axis would be not possible due to the undevelopable area in the centre, so the undeveloped land could be turned into a park, and another diagonal axis could be instead created, giving diversity of the programmes and rhythm to the access route through the block.

Following the principle patterns P4 and P5, the re-development could be designed upon the existing plot structures to ensure adaptability in the application, in case parts of the plots become unavailable for use. This means that even if the plot is not available for development, no changes are needed to be made in the existing urban fabric of the particular area.

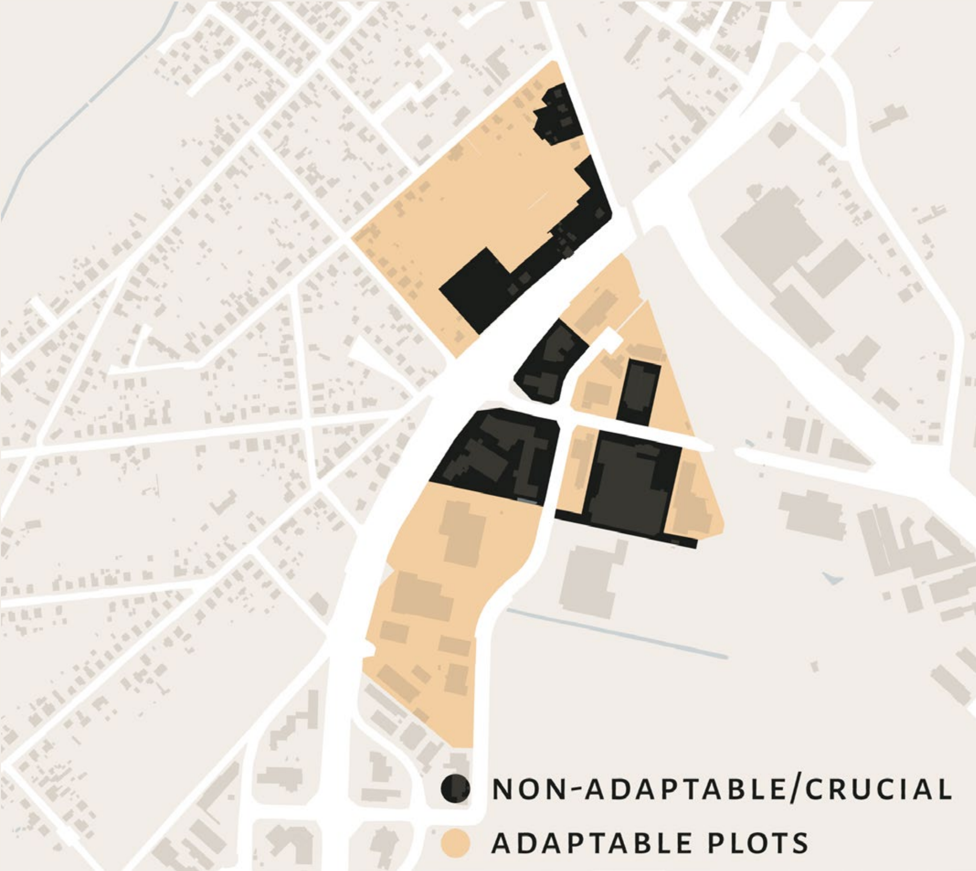


Figure 121. Map of adaptable and unadaptable plots

The acoustic façade of 4 – 6 storey high flats could be created along the BRT corridor (N76) to provide mitigation to noise and air pollution from the road, and could also provide an urbanised atmosphere for passengers entering the area.

Figure 122. Section of sound barrier flats and BRT ROW; reducing sound pollution with both acoustic facade (flats of 4 - 6 stories) and line of trees

The important aspect of the housing supply is that a certain amount of housing supply should consist of what countryside residents would find attractive, namely free-standing, single-family houses in quiet streets. The free-standing single-family housing is provided on the further parts from the station to ensure attractive housing offers for the countryside residents willing to swap their land with housing in an accessible area. While such houses are not ideally the most sustainable form of housing supply, it is important to set the balance between the impact of dispersed settlements versus the reduced density of housing supply. This should be well-adjusted per local situation in the process, taking the development pressures and amount of surrounding dispersed settlements into account. In Bosdel's case, the following aspects are considered:

- Genk has uniquely less dispersed settlements surrounding it
- Bosdel is located near new industrial areas of Bosdel
- Station on the main corridor of Spartacuslijn 2
- Good access to Both Hasselt and Genk
- Creating vibrant spaces near incubators

Therefore, it would make sense in Bosdel's case to supply more denser housing, and lower the percentage of single-family houses. The immediate vicinity of the station can be developed into a relatively higher density to facilitate activities near incubators.

Figure 123. Bird's eye view of Bosdel-Noord

Through this, the urban planners can make conscious decisions to provide denser housing in Bosdel, and offer more housing that is more fitting for countryside residents in other smaller cores outside of Spartacusplan; transportation planners can also support this by connecting such cores with branching services, alleviating the burden of single-family housing supply in Bosdel.

The urban fringe block at the north of the station could be re-developed along with the diagonal axis through the block as a pedestrian access to the station. As for Bosdel's case, however, the creation of direct diagonal axis would be inefficient due to the un-developable area in the centre, the undeveloped land could be turned into a park, and another diagonal axis could be created instead, providing diversity and rhythm to the access route through the block.

Figure 124. Network of public space in Bosdel-Noord

Figure 125. Ground-level programmes of Bosdel-Noord

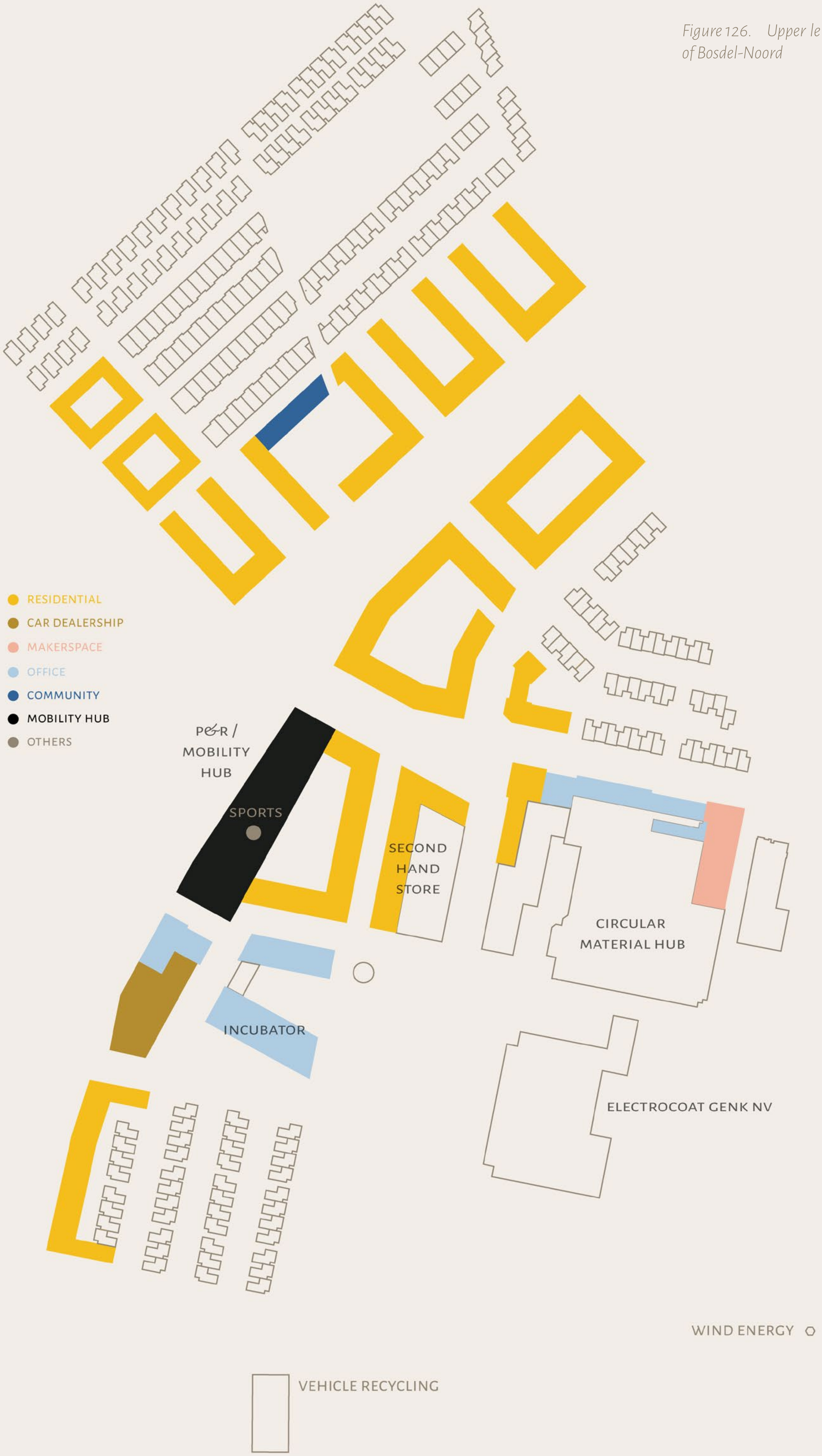


Figure 126. Upper level programmes of Bosdel-Noord

In this exercise, the industrial area of Bosdel is re-developing into a mixed-use maker district containing housing, a second hand store, a material hub, and an incubator geared for consumer-oriented circularity and materials (Figure 113). Existing used car dealerships can be integrated into the mobility hub by creating extra park & ride space that can be converted into housing in the future. The design of the building therefore needs to reflect this possibility in structure. The Figure 127 depicts the possible scenarios of transformation of the parking spaces in mobility hub in Bosdel.

Since a large portion of De Lijn drivers will now operate branch service to and from Spartacuslijn stations, amenities for De Lijn drivers should be created along with the mobility hub. The proximity of the mobility hub with the station would allow less space to be allocated for the station, which is built on limited road space.

Figure 127. Transition of use in Park & Ride function

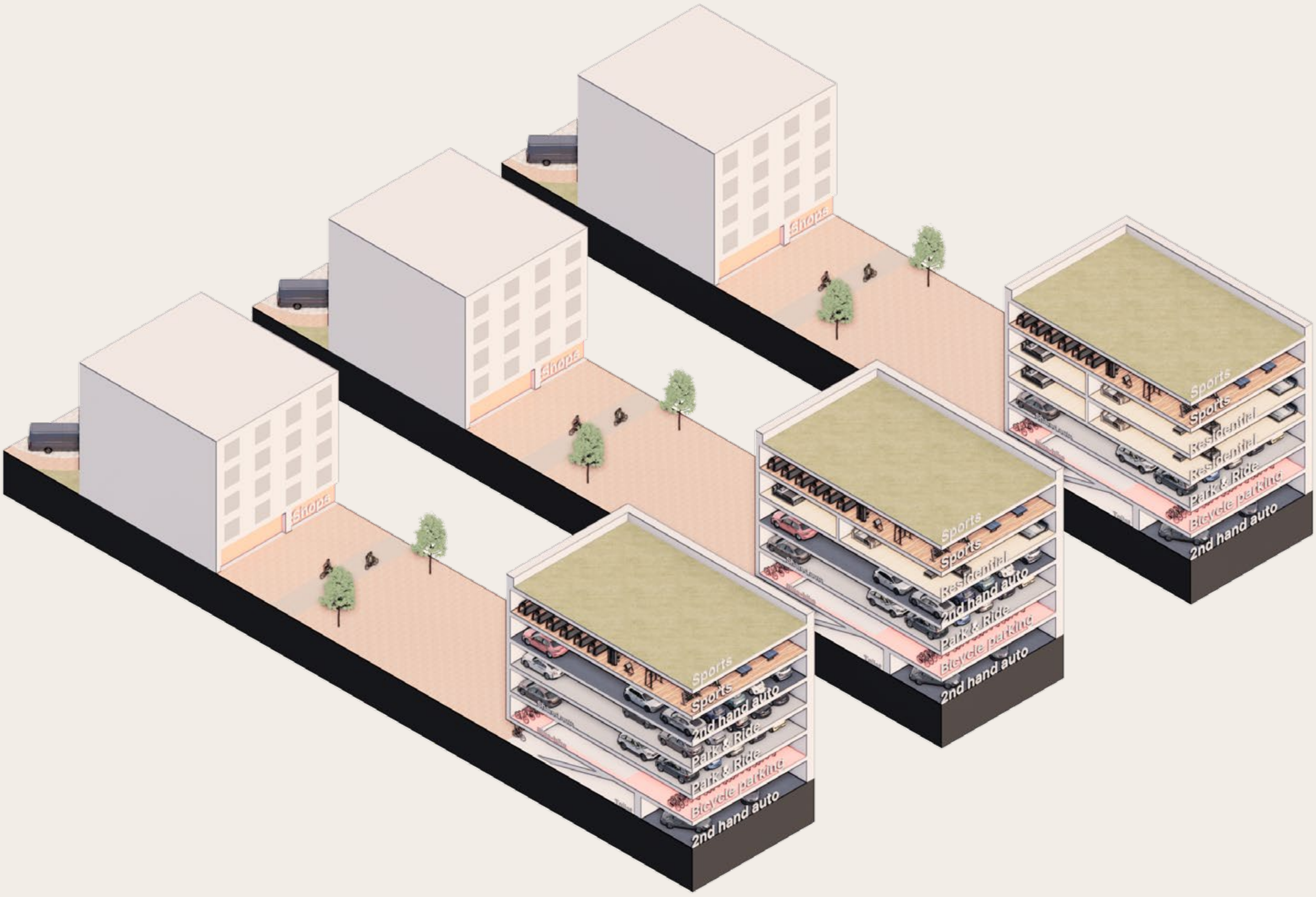
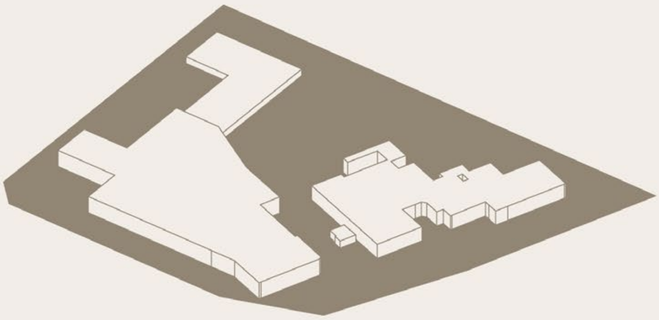


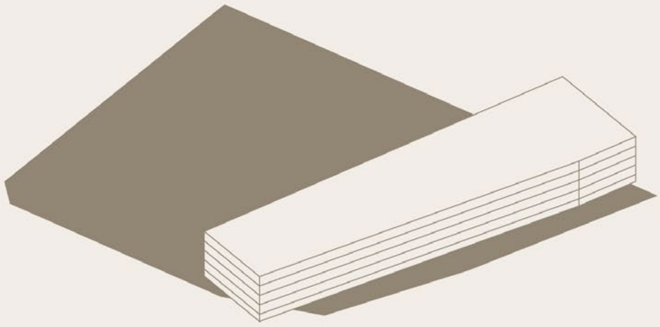
Figure 128. Integrating existing functions into mobility hub

USED CAR DEALERSHIP

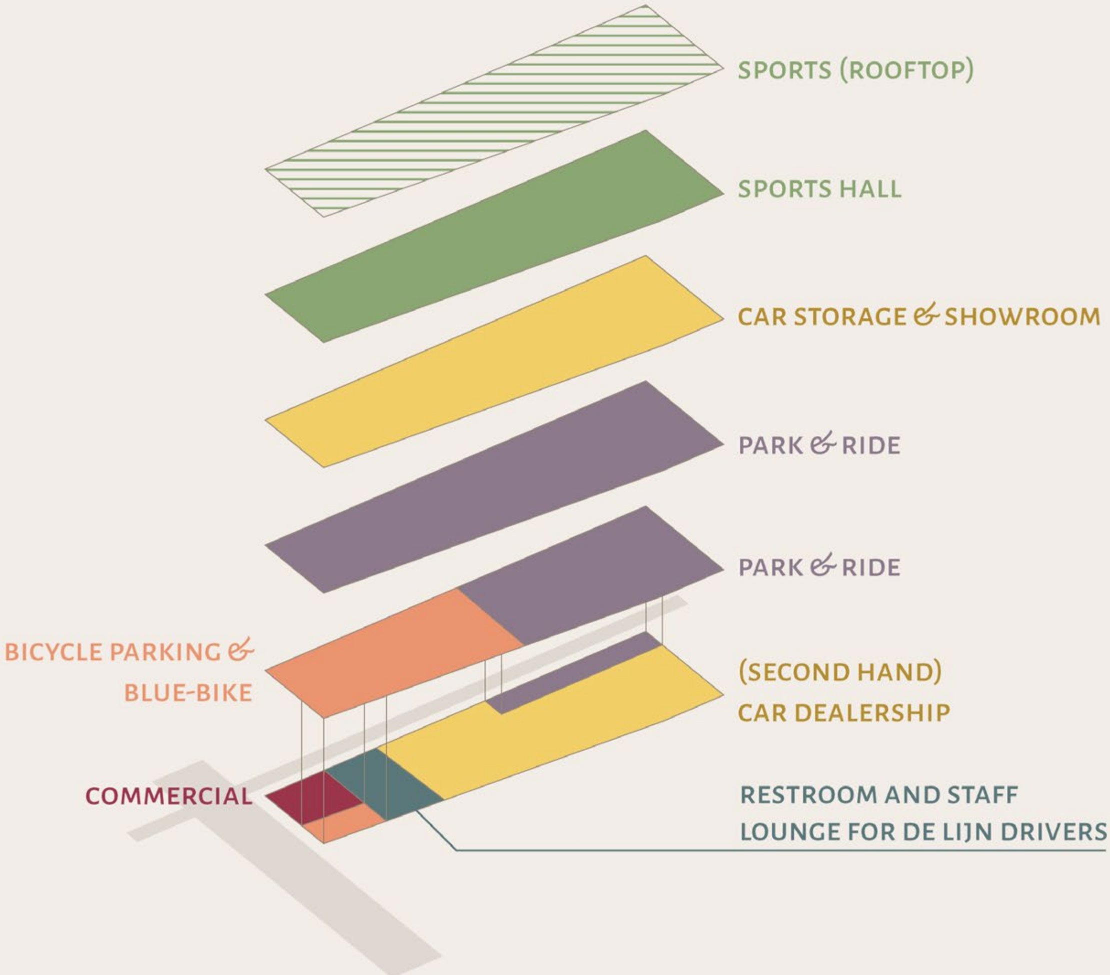


LOT AREA	21.091 SQM
BUILT FOOTPRINT	7.264 SQM
FLOOR SPACE	11.176 SQM

PARK AND RIDE BOSDEL



LOT AREA	21.091 SQM
BUILT FOOTPRINT	5.751 SQM
FLOOR SPACE	28.758 SQM



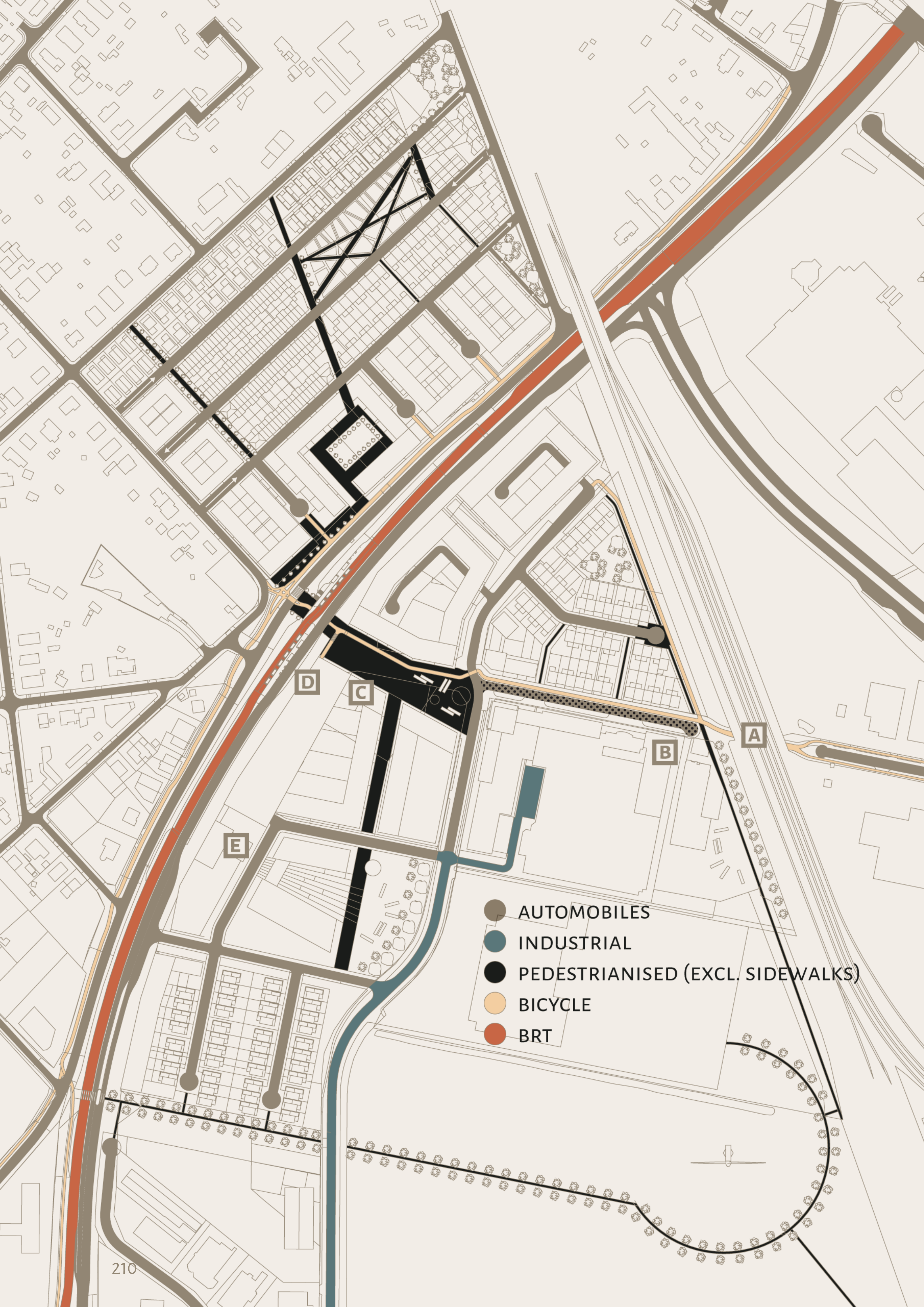

A
B
C
D
E
AUTOMOBILES
INDUSTRIAL
PEDESTRIANISED (EXCL. SIDEWALKS)
BICYCLE
BRT

Figure 129. Circulation diagram of Bosdel-Noord

The circulation surrounding the station can be dramatically modified. The starting point of urban design should be that after the introduction of BRT, especially with the introduction of branching services, the Spartacuslijn and its services can be used as leverage towards radical re-structuring of road space.

In the context of Bosdel, the single-sided onramp from the road could be removed (D), rendering the section of Bosdel between the station and N76e (C) dead-end; that area will become a pedestrianised plaza, welcoming visitors as a gateway for the Port of Genk. The underpass below the railway line has already been closed for cars and only available for bikes even as of 2022 (A). Therefore, the remaining part of Bosdel can be also made pedestrian-friendly (B), realising the initially proposed living corridor.

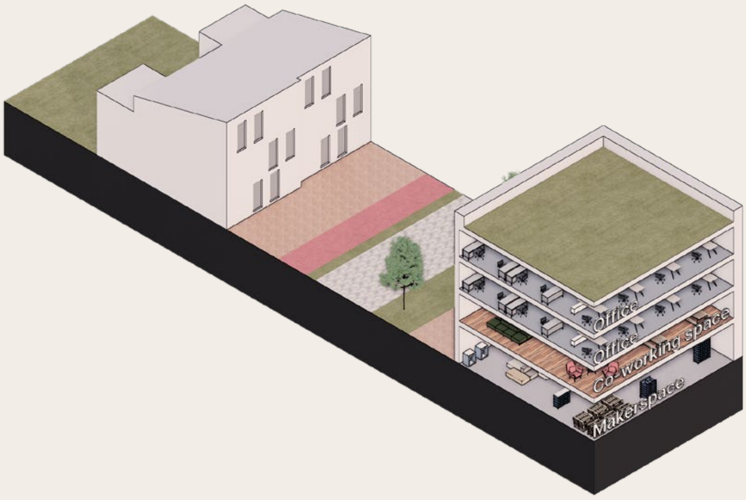


Figure 130. Section of B: Co-working space on upper floors, maker space on the ground level; machineries can operate free from vibration, and delivery logistics get far smoother.

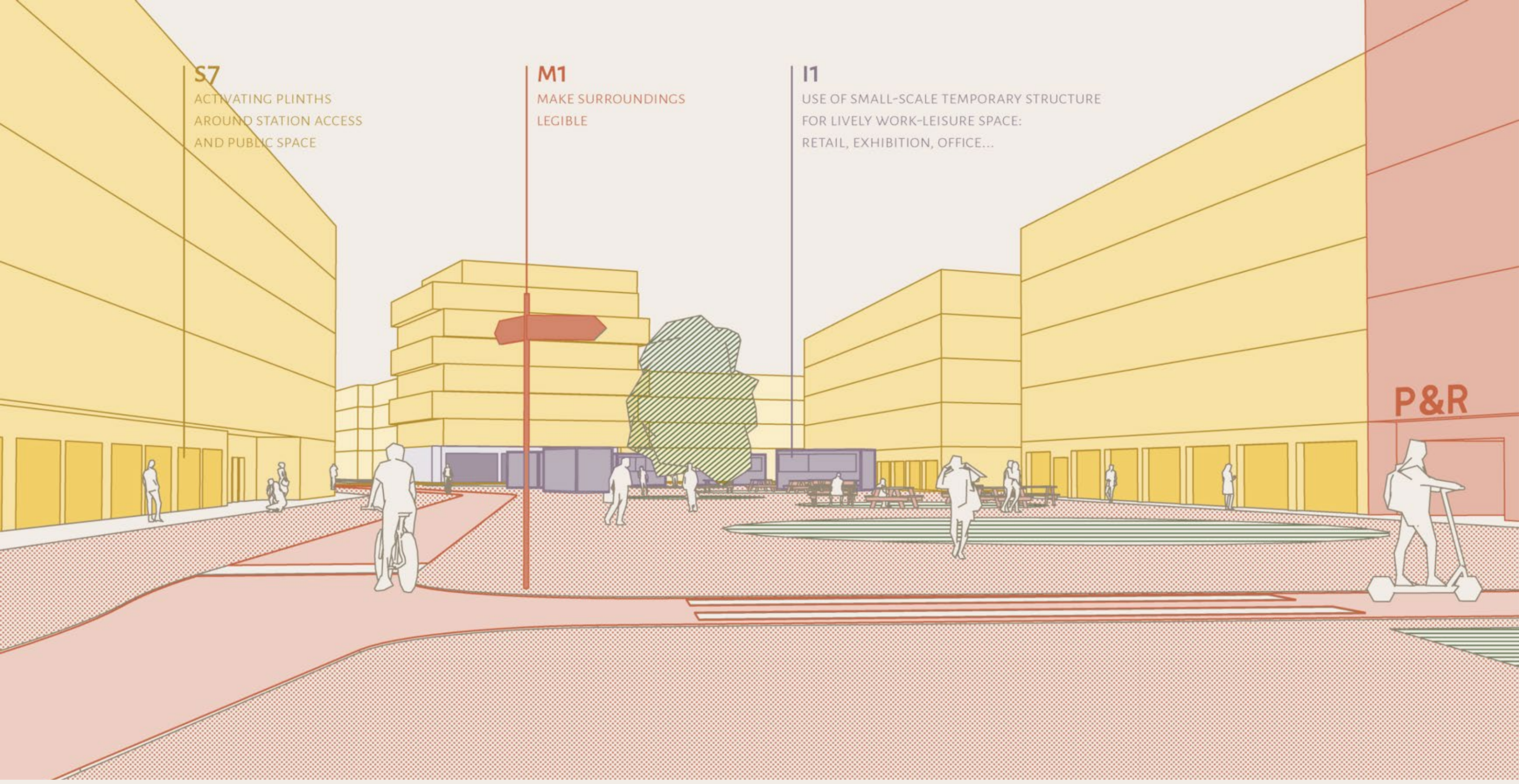


Figure 131. The street-level view of public space created on former Bosdel road

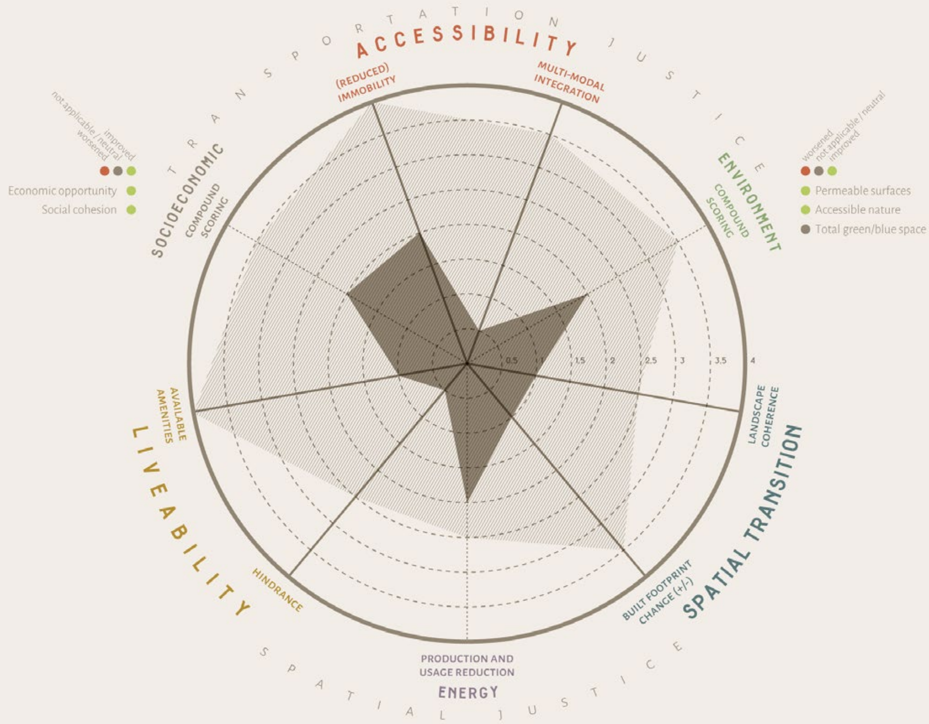
Figure 132. Example design of Bosdel Station

On a smaller scale, the visibility and presence of transit should be clearly manifested in the public space. In Bosdel's context, the branding of the system should be clearly visible, and the vehicle's movement should be clearly noted and visible from the street level. In terms of materials and design elements, as far as the visibility of the station is guaranteed, it can be freely decided upon the urban designers and residents. It is recommended to use the pre-existing context, in Bosdel's case the circular economy and second-hand store's vintage atmosphere would be possible to be used as the theme of the neighbourhood for urban designers.

It is recommended to create a lively neighbourhood near where innovative industries take place. In Bosdel's context, the large public space lies between innovative industries, BRT station, mobility hub, and second-hand shops. The plinths surrounding this space should be activated with commercial activities to create an lively feeling, and temporary structures that holds exhibitions, shops, and small-scale offices could be added to introduce more nimble changes into the space.

9.2.6 ASSESSMENT FRAMEWORK

Figure 133. Assesssment framework



As almost all of the patterns has been applied, the patterns have shown balanced effect in all criteria. The largest benefit came from multi-modal integration, and the built footprints and amenities also improved. The total green/blue space remain neutral, despite creating new green spaces, the redevelopment on the northern fringe block offset the gains. In practice, however, given that the green space inside urban fringe was not accessible, it can be argued that it has ultimately provided benefit in that regards.

The expected effects on the problem fields are as follows:

Spatial dispersion and spatial transition	The synergy of urban design and the proposed line provides positive effects on the spatial transition in general, by being the magnet for the dispersed settlements of Nebular city: it attracts the dispersed households by offering attractive, well-connected living environment at the cost of reduced density.
Deindustrialisation & Innovation	The synergy of urban design and the proposed line can accelerate innovation by creating attractive working areas, which are well-connected with other industries, creatives, and knowledge institutions.
Spartacusplan & Mobility Justice	The urban design indirectly benefits the transportation issues by providing more passenger base through development and mobility hub. The proposed line can connect relatively disadvantaged area with potential employments.

Table 18. Design's effect on the problem fields

9.2.7 DAY OF LIFE: PERSONA A

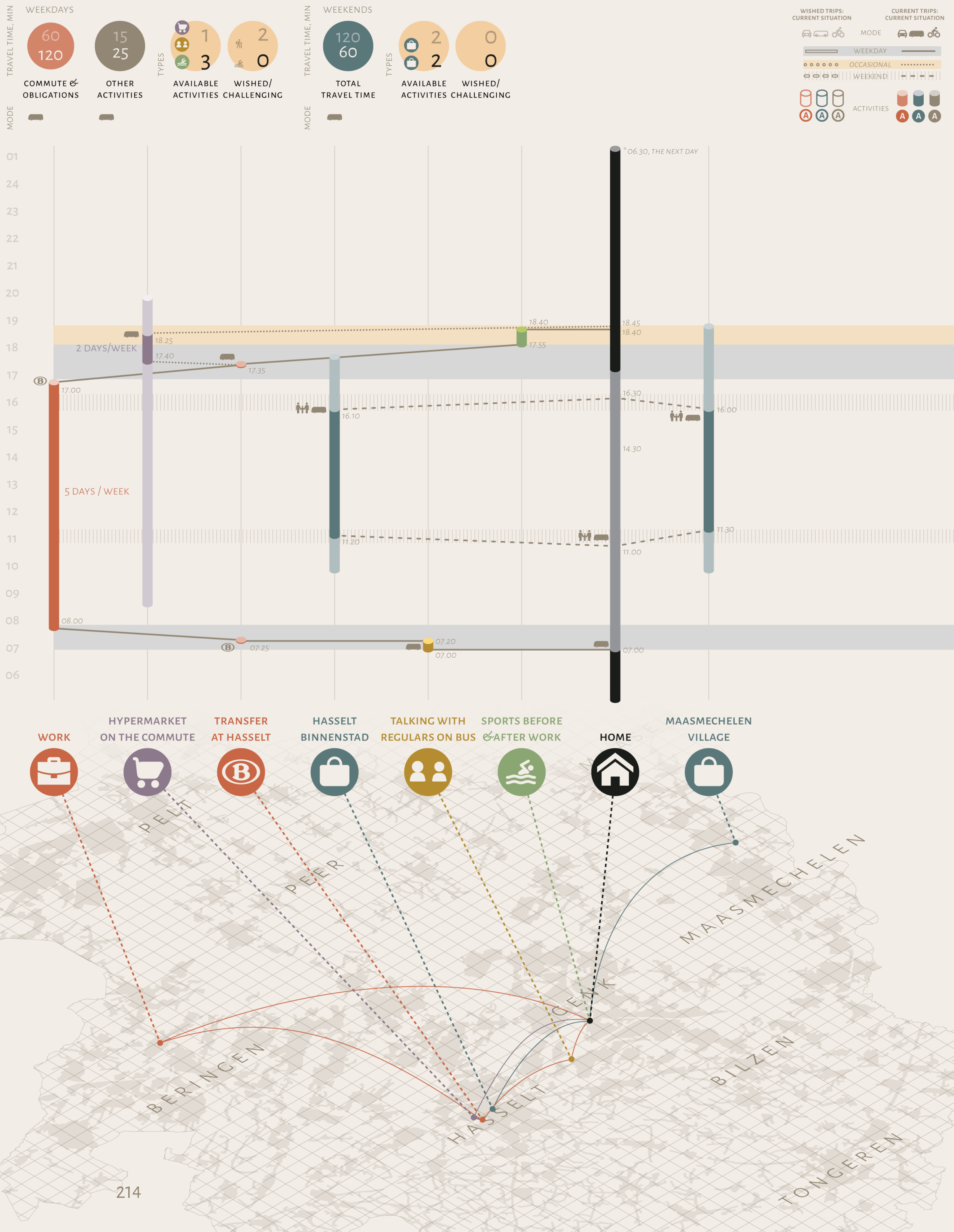


Figure 134. New time-space diagram of persona A living in Bosdel

The situation assumes persona A choosing to move to Bosdel from nearby Gelieren-Hoogzij, where he was already quite familiar with Genk. He can visit the sports centre at the mobility hub next to the stop after the work, and can easily visit where he used to visit by car, including Maasmechelen Village and Hasselt. He can now take the bus and train to his work, and on the way back home, he can visit the hypermarket, which lies 1 stop away from Hasselt station. He hops off the bus and do the groceries and hop on the next bus without thinking too much about the timetable. Although it takes longer with public transportation, he can enjoy the convenience of not driving anymore. Moreover, the smaller vehicles feels cosy and familiar, and during the commute, he is already familiarised with new regulars on the bus and met some former neighbourhs that he already knew in his previous home; because one of the buses in Spartacuslijn 2 also runs through his old neighbourhood, albeit not as frequent, he could still see visit his old friends, and actually see them more often, nearly every morning. This way, he doesn't feel disconnected from his old community, and the commute times are combined with social activities.

9.2.8 DESIGN RECOMMENDATIONS

1. Housing supply to attract countryside residents by **offering minimum amount of free-standing house** should be prioritised over marginal density gains, as the adverse effects of the former far outweighs the latter. Do note that this decision also requires conscious, regional-scale decision to focus on density on certain locations, and single-family house on the other. Such decisions are highly dependent on the surrounding context of the area.

2. The **branch service** to smaller cores that are classified as "Strengthen: Transit" or "Strengthen: Housing" is crucial to alleviate the burden of providing to alleviate the burden of supplying single-family house in urban areas.

3. Start the urban design from **existing urban fabric** and avoid radical changes in urban form; the urban design should be flexible on both plots and the trajectory of future demands.

4. Use the newfound accessibility as a **leverage to impose radical restructuring of road space.** This can achieve the benefits of radical urban form changes without making such risky choice.

5. Create an **attractive, lively public space** with variety of activities where innovative industries should take place. The offer of space should be also made nimble through **temporary structures.**

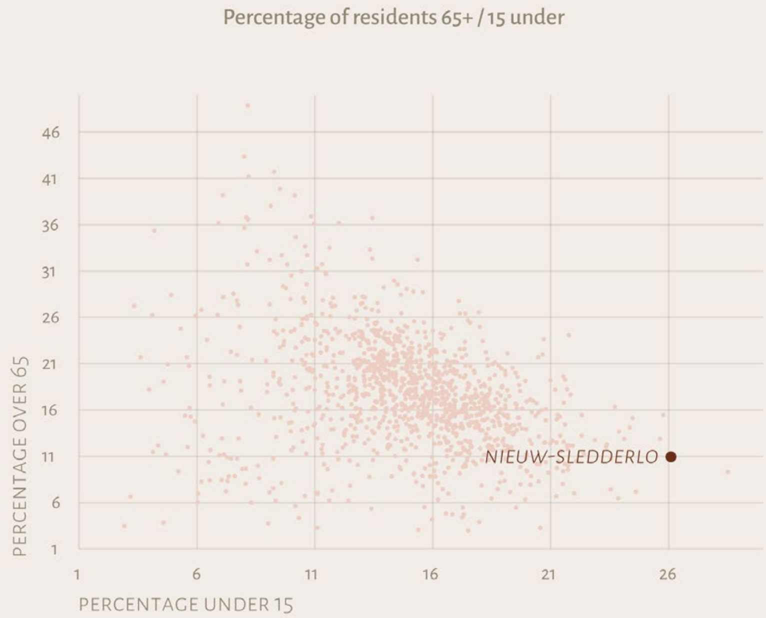
6. Place **amenities for De Lijn drivers,** as each Spartacuslijn stations will become a operation base for human drivers operating branch services to and from Spartacuslijn stations.

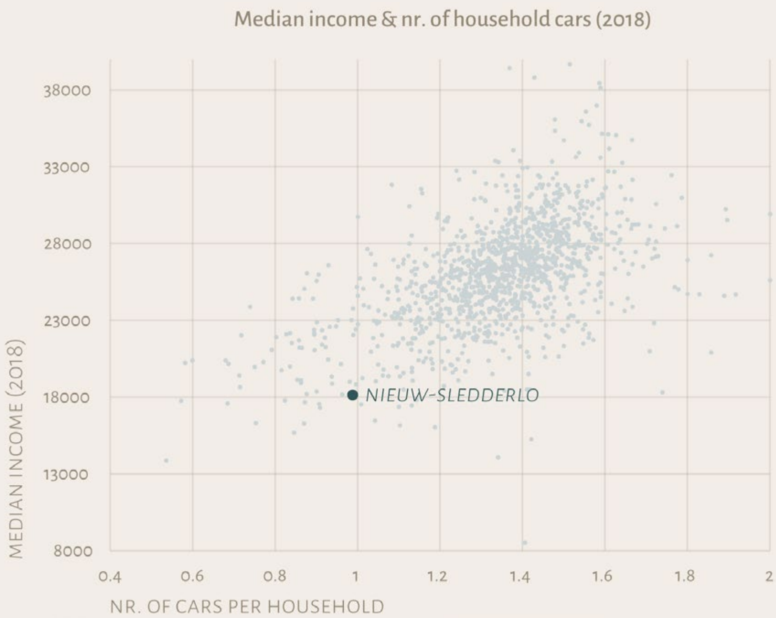
9.3 NIEUW-SLEDDERLO

The design example on Nieuw-Sledderlo presents a possible urban design and transportation planning trajectory for designers and planners to address the economically deprived areas across the province. Nieuw-Sledderlo is a social housing district near the port of Genk and the former Ford Genk site. Being a neighbourhood with residents with predominantly migration backgrounds – predominantly Turkish (70%) and Moroccan (15%) – the neighbourhood faces socioeconomic challenges such as poverty, unemployment and unstable employment (Verstraete et al., 2016). Not only is it isolated spatially, but also it is isolated spatially: on the current route, G1, Sledderlo is practically the dead-end of the line; as many research on the site has noted, solving the spatial isolation remains an issue. This is especially important for transportation planners to address through this chapter.

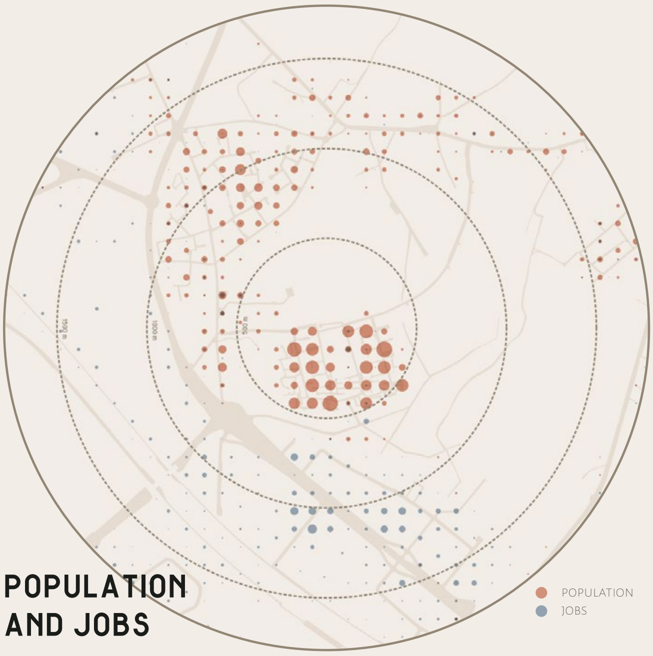
9.3.1 CONTEXT SCAN

Figure 135. Demographic analysis of Nieuw-Sledderlo. Age composition (above), income and household car ownership (below), Data source: Statbel (2021)

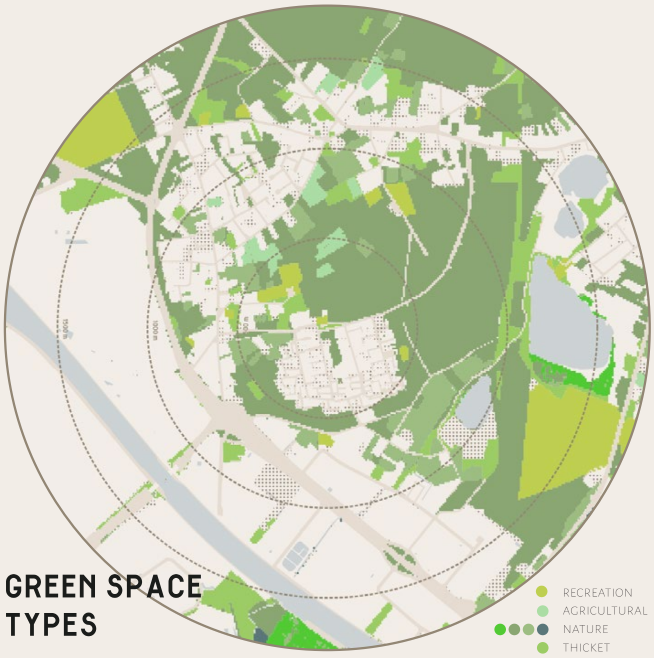




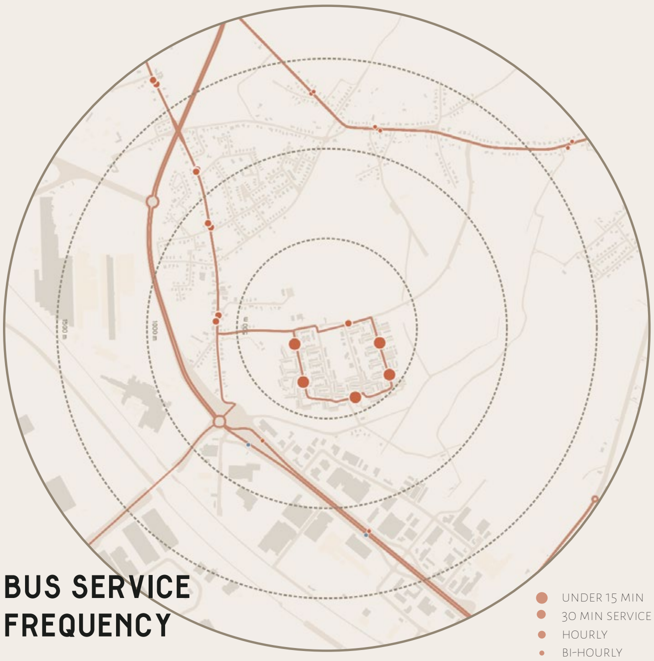
Being a neighbourhood with mainly social housing with serious socioeconomic challenges (Vanderstraeten et al., 2021), the area has low income and access to cars; however, demographically, it is one of the youngest neighbourhoods of Limburg, with a quarter of its residents being under the age of 15.



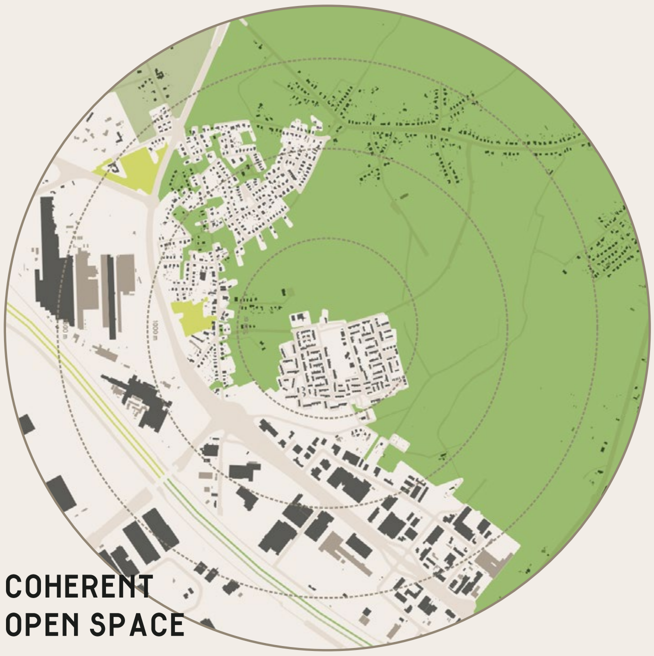
POPULATION AND JOBS



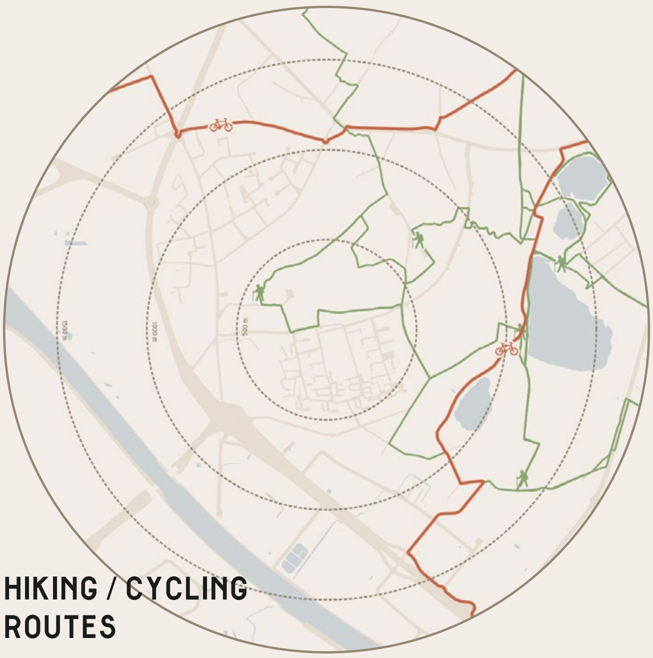
GREEN SPACE TYPES



BUS SERVICE FREQUENCY

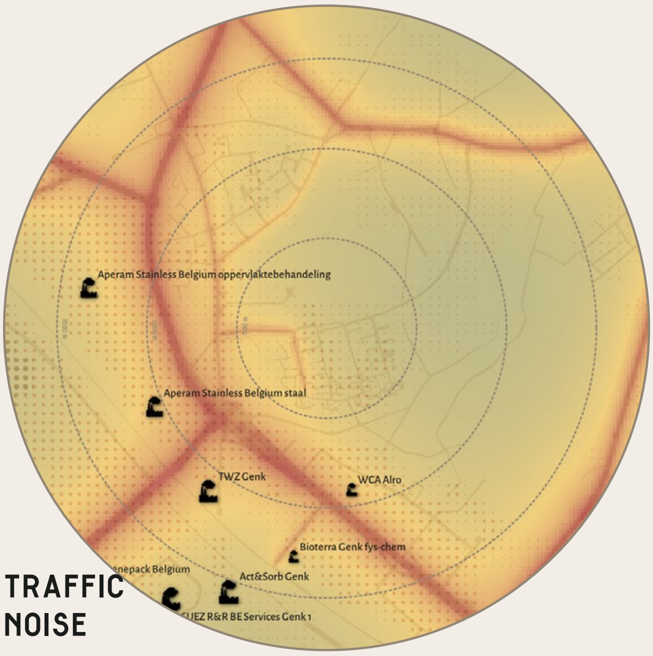


COHERENT OPEN SPACE

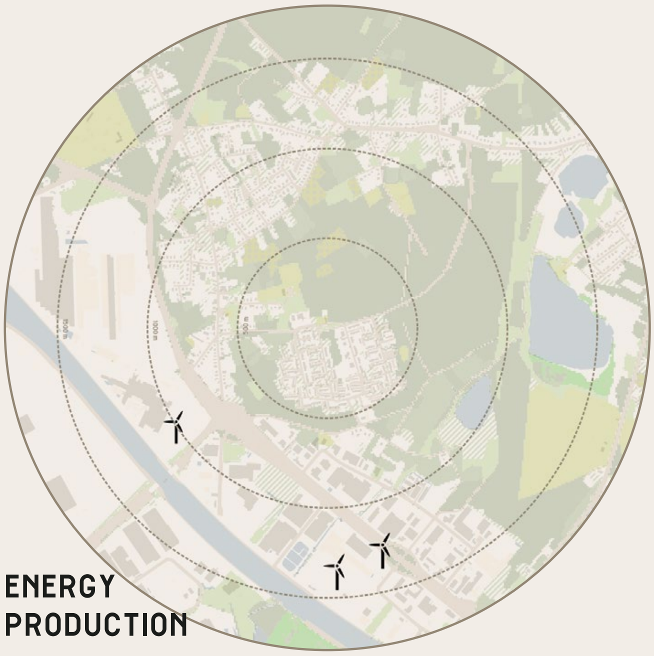


HIKING / CYCLING ROUTES

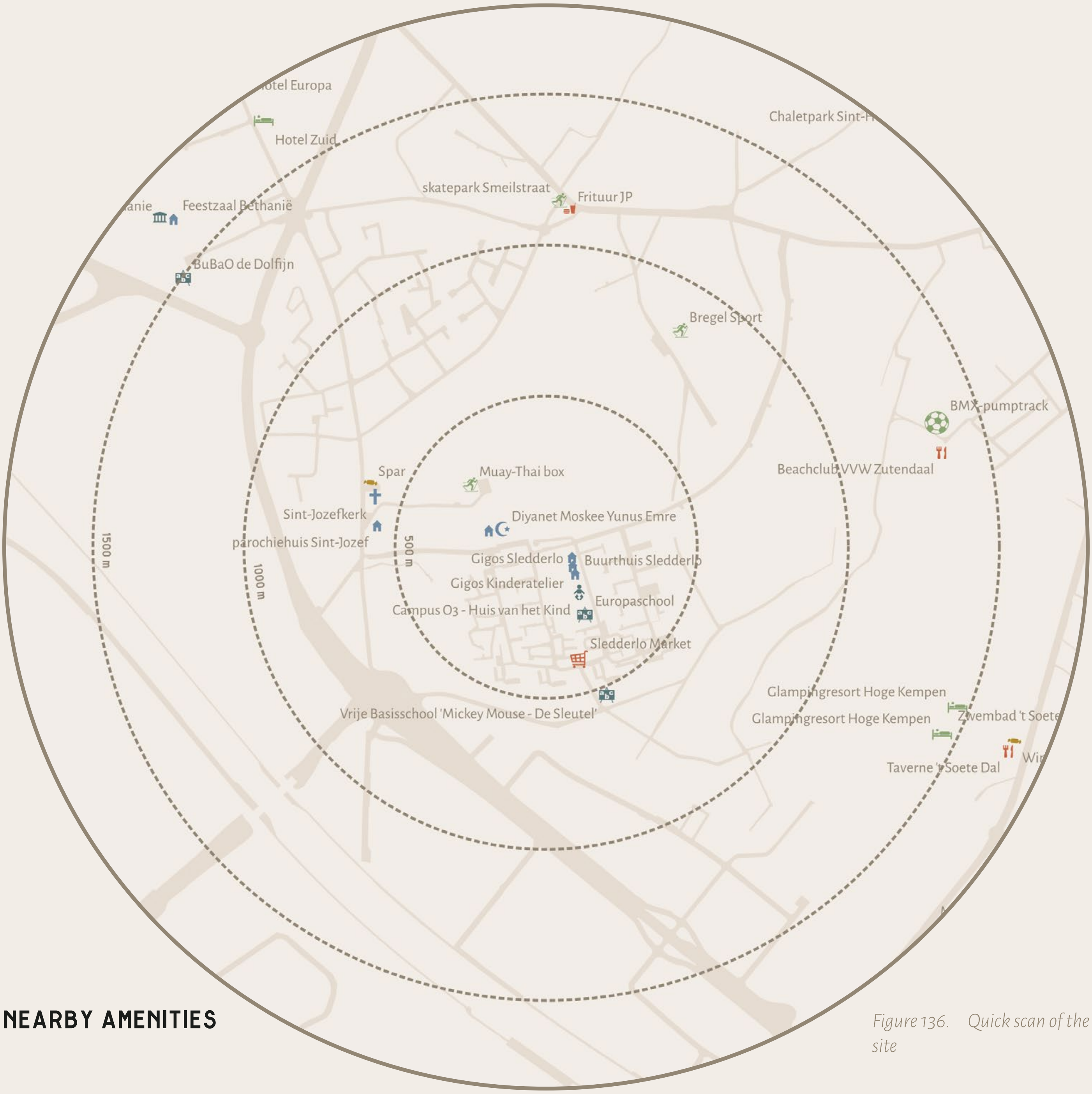
AGRICULTURAL PRODUCTS



TRAFFIC NOISE



ENERGY PRODUCTION



NEARBY AMENITIES

Figure 136. Quick scan of the site

9.3.2 TRANSPORT SOLUTION

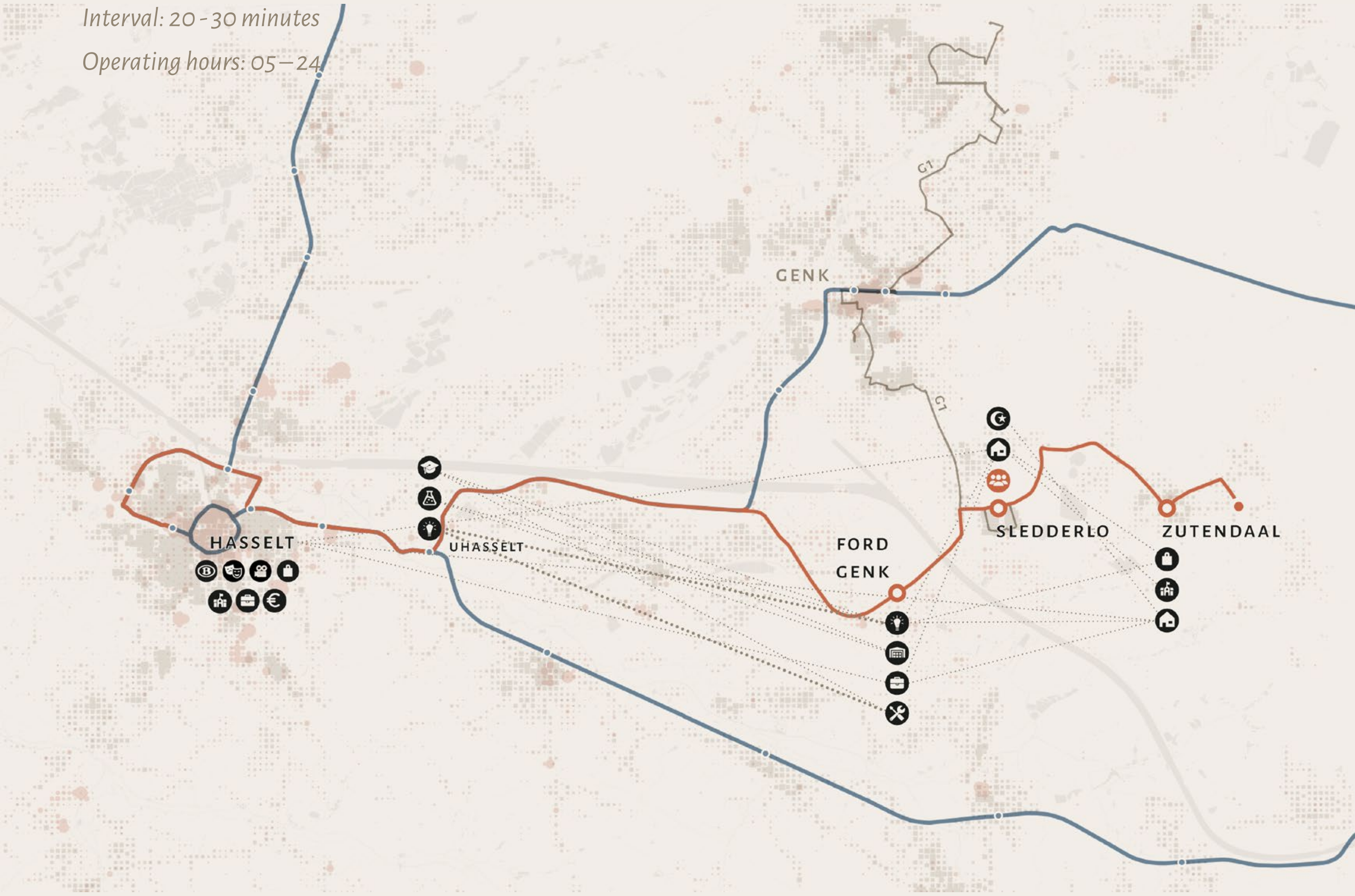


Figure 137. The network created for Sledderlo and each stop's relations

In combination with the redevelopment of Ford Genk site, Sledderlo can be put into the map as the intermediate destination between Zutendaal, Ford Genk, UHasselt, and Hasselt. The Ford Genk site can be connected with knowledge institutions in University of Hasselt, financial institutions in Hasselt, and the working-class neighbourhoods of Sledderlo. Zutendaal, where many interviewed residents of Sledderlo rely on for daily amenities, will be connected with Hasselt and Sledderlo with direct service for the first time.

In Sledderlo, the principle patterns of MP2 (reflect needs of everyone; in Sledderlo's persona D, the shift workers), MP3 (prioritise underserved areas), MP4 (restorative justice), MP6 (single-seat ride, in Sledderlo's case, to Hasselt) is applied, with the focus on income and number of jobs in the online planning tool.

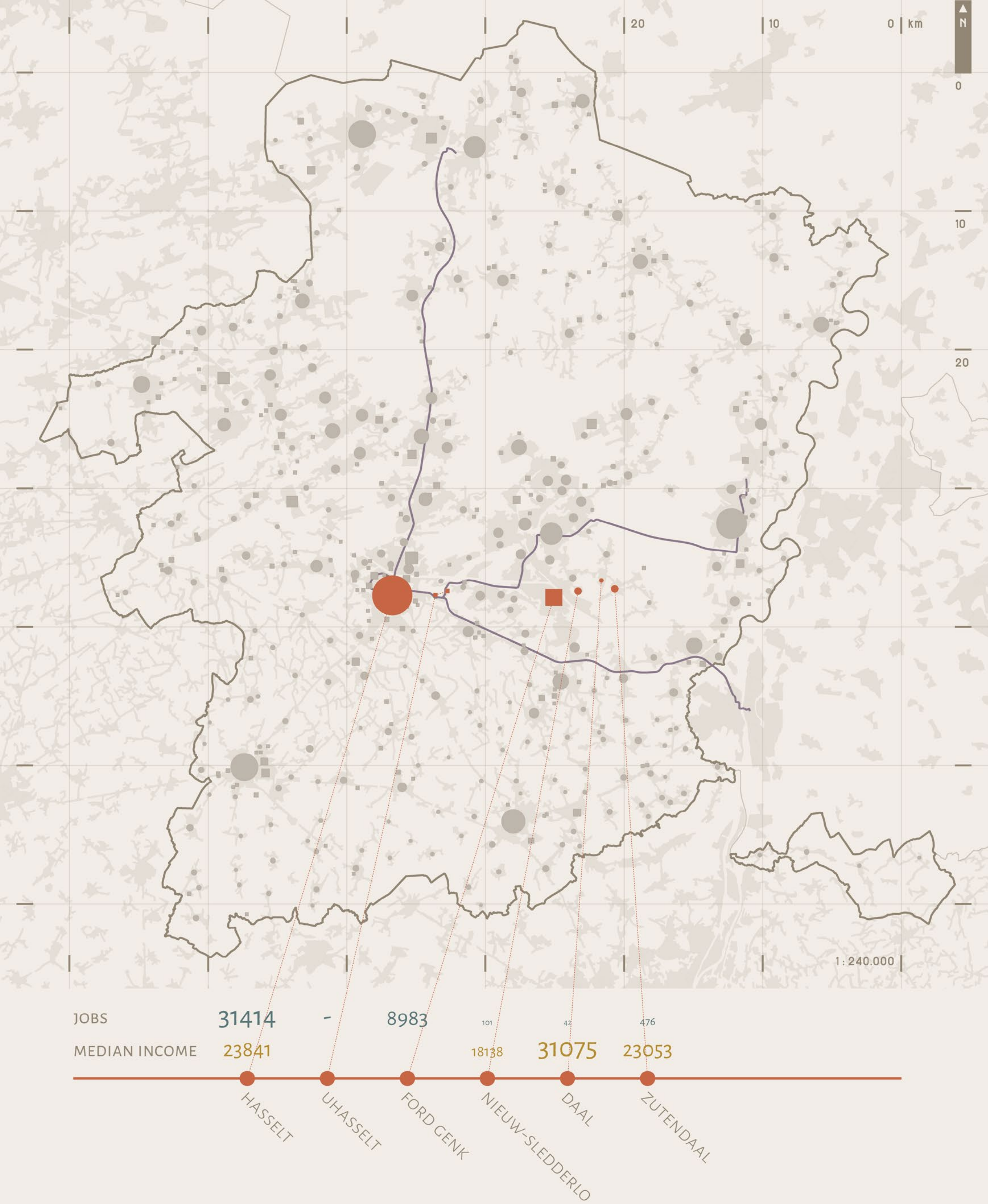


Figure 138. The network created for Sledderlo with the key metric (jobs and income) retrieved from the online BRT planning tool created on Chaper 8

9.3.3 APPLIED PATTERNS

Based on the context scan and site visit, the local strategy could be formulated.

The recently opened road between Nieuw-Sledderlo will accommodate new bus service between Zutendaal and Hasselt; as Sledderlo became an intermediate stop and a connecting point for G1 and the new line, the currently empty green space on Wintergroenstraat will be transformed into a small-scale local mobility hub, Central point combining Carpool, shared car, and the new bus service.

Figure 139. Mobility strategy

The "Groene Hart" at the centre of the neighbourhood is connected with every corner of the neighbourhood, along with the sports centre, buurthuis, school, and a GP along the eastern edge of the park. The new stop will be placed at the centrality between the mosque and the neighbourhood amenities, and on the endpoint of the green axis from the Turkish supermarket and Moroccan mosque. On the southeast side of the neighbourhood, a new footpath through the forest will be created to improve connectivity with the industrial area in the south.

Figure 140. Circulation strategy

Figure 141. Applied patterns and not applied patterns with the reason of non-application

NIEUW-SLEDDERLO

Applicable pattern types

APPLIED		NOT APPLIED	
M1	E1	M2	PLANNED NEIGHBOURHOOD
M4	E2	M3	PLANNED NEIGHBOURHOOD
M8	E3	M5	NO BRT ROW
	E4	M6	NO GNW/GTI
		M7	NO BRT ROW OR MOTORWAY
		M9	PLANNED NEIGHBOURHOOD
		M10	NO PERMEABILITY ISSUE
		S ALL	PLANNED NEIGHBOURHOOD

In Sledderlo, all patterns of Empower: Socioeconomic patterns has been applied. As the neighbourhood is a already planned neighbourhood, several mobility integration patterns were not applied, and all Strengthen patterns were also not applied.

9.3.4 OPEN SLEDDERLO

Figure 142. Making space for mobility hub

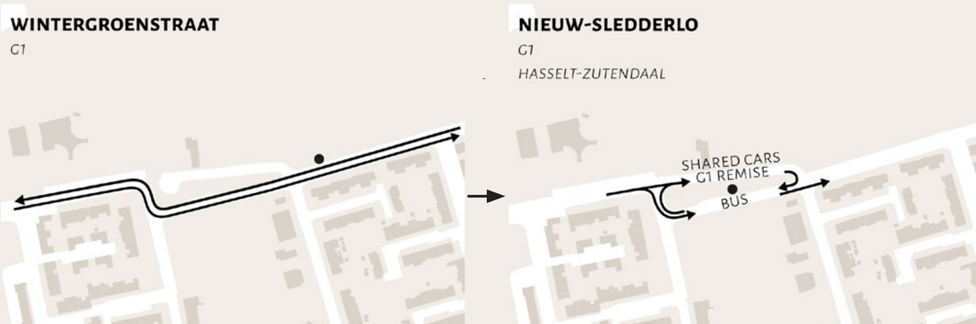
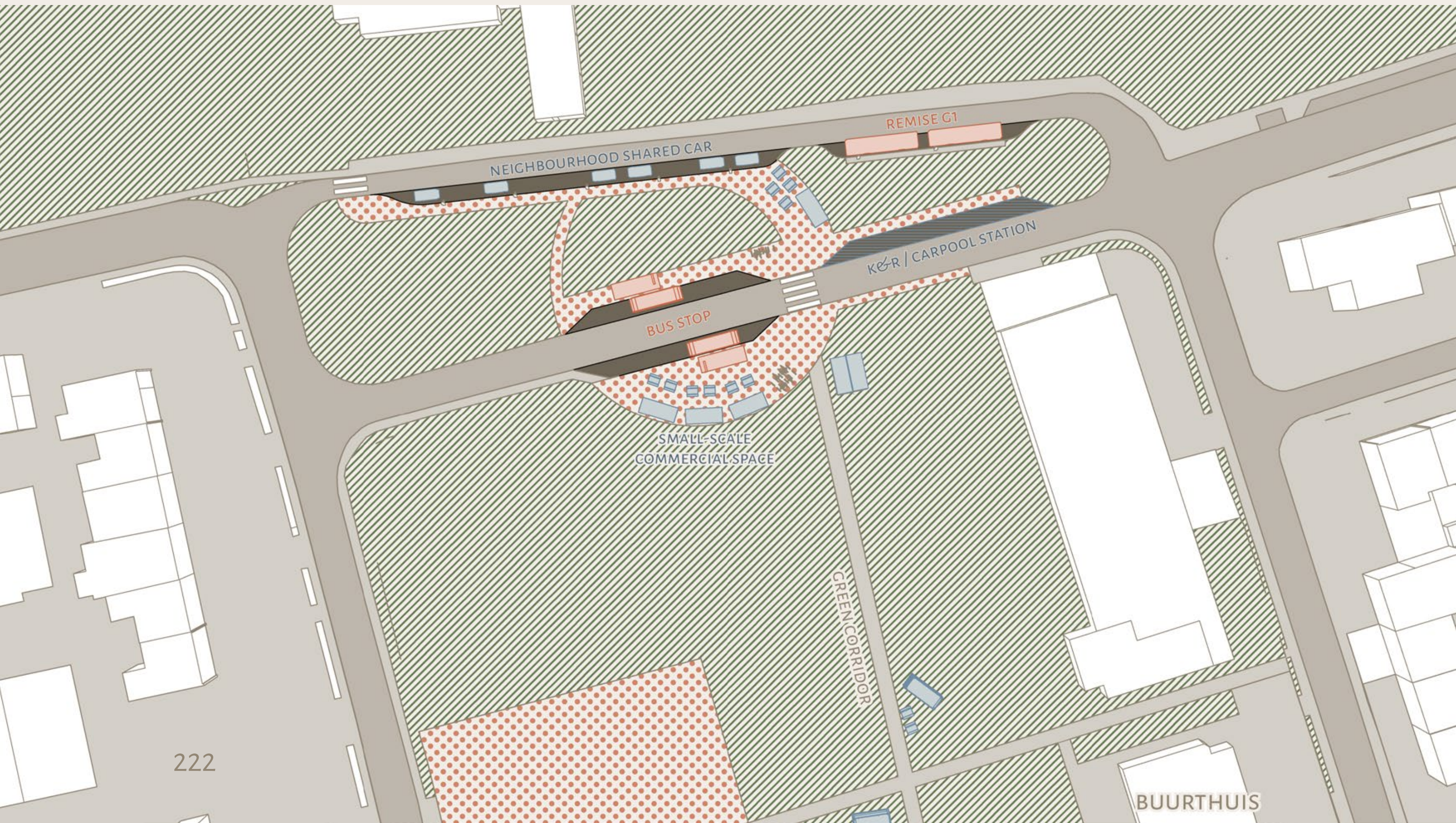


Figure 143. North end of Groene Hart after re-development



In order to make room for mobility hub in Nieuw-Sledderlo, The cul-de-sac on the north of the green peninsular could be made through, making the green peninsula an island platform for different modes. Buses and carpool vehicles may stop on the main road for faster passage, and the shared cars and remise for bus G1 that terminates in Sledderlo will be placed on the back of the island.

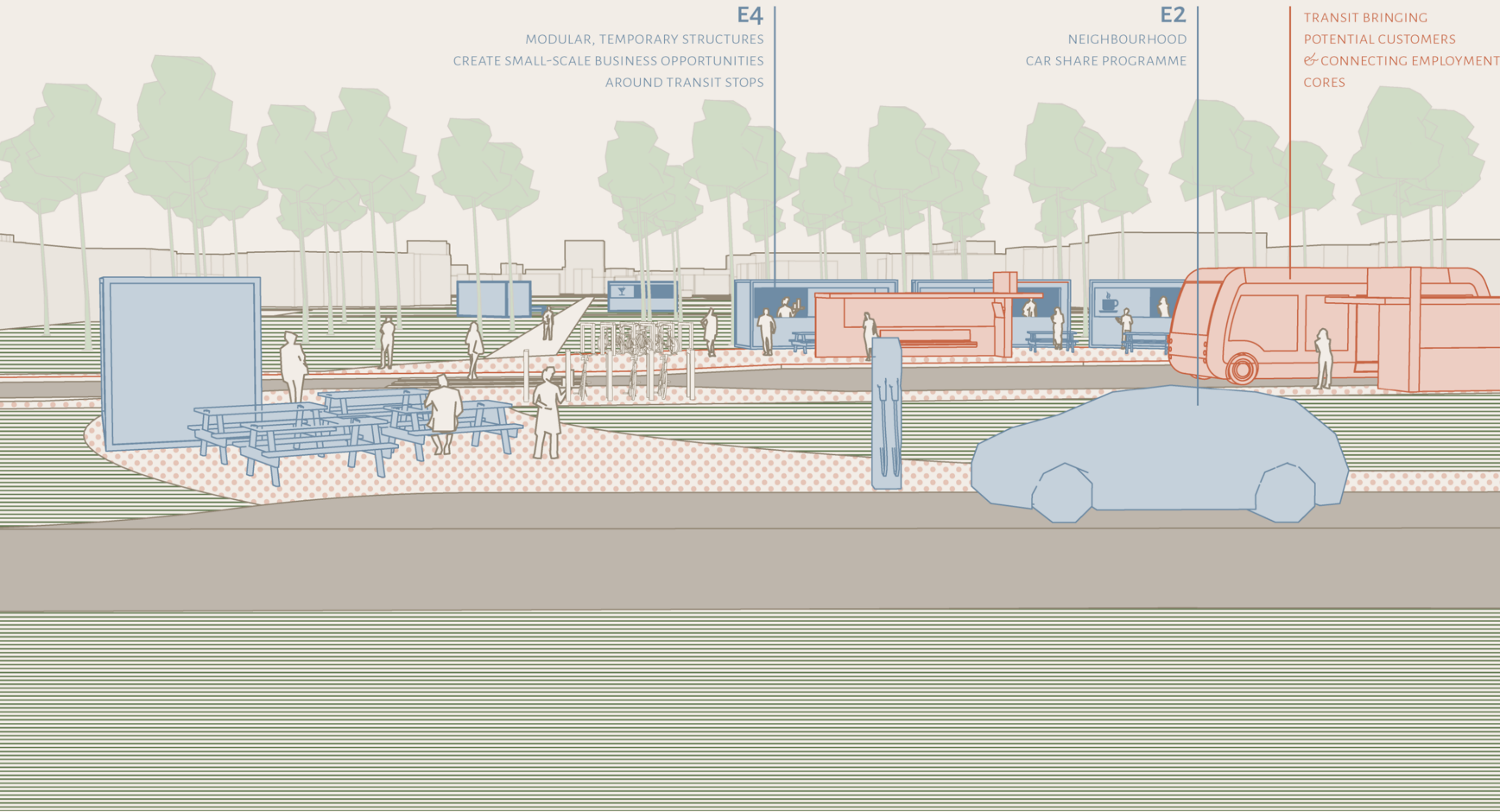


Figure 144. Applied patterns in the mobility hub

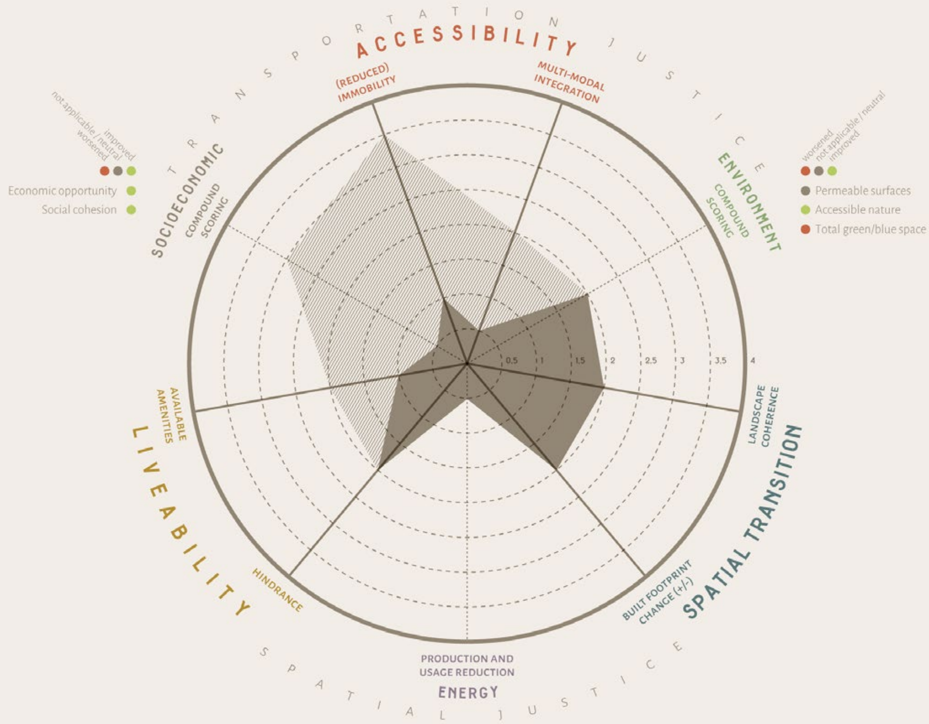
Despite being the dense population core of the area, the only shop available in Sledderlo is the Turkish supermarket. There is little to no economic opportunity available inside the neighbourhood; if one wants to open a store, one need to get permission from their landlord, the social housing corporation, and then get approved for the business from the city, and invest huge sums of money in renovating the house. Similar situation can be applied in many other social housing districts in Limburg.

As introduced with the Empower pattern E4, it can be seen as the spatial translation of the French "Zones franches urbaines" (Urban free zones) policy where small companies set up in economically deprived urban areas can get tax benefits (Bercy infos, 2023). Instead of providing tax benefits, it de-regulates and provides flexibility to the supply of spaces, consequently reducing the hurdles for local residents in opening a business.

To create burden-free economic opportunity inside the neighbourhood, and to use the newfound connectivity with Zutendaal, Hasselt, and Ford Genk as leverage, a small paved area can be added near the stop where new lines would be stopping, and modular, temporary structures can be placed for small-scale business activities, selling foods and small products in the vicinity of the transit stop. The new patrons that are made accessible to the neighbourhood could become potential customers; and depending on the type of business provided, passengers can combine it easily with their commute.

9.3.5 ASSESSMENT FRAMEWORK

Figure 145. Assesssment framework



As intended, the patterns improved accessibility, socioeconomic metrics (economic opportunities, social cohesion), and amenities access. Changes in other metrics are not significant. Therefore, in case the area's goal includes other aspects also, in such cases using other type's patterns would be recommended.

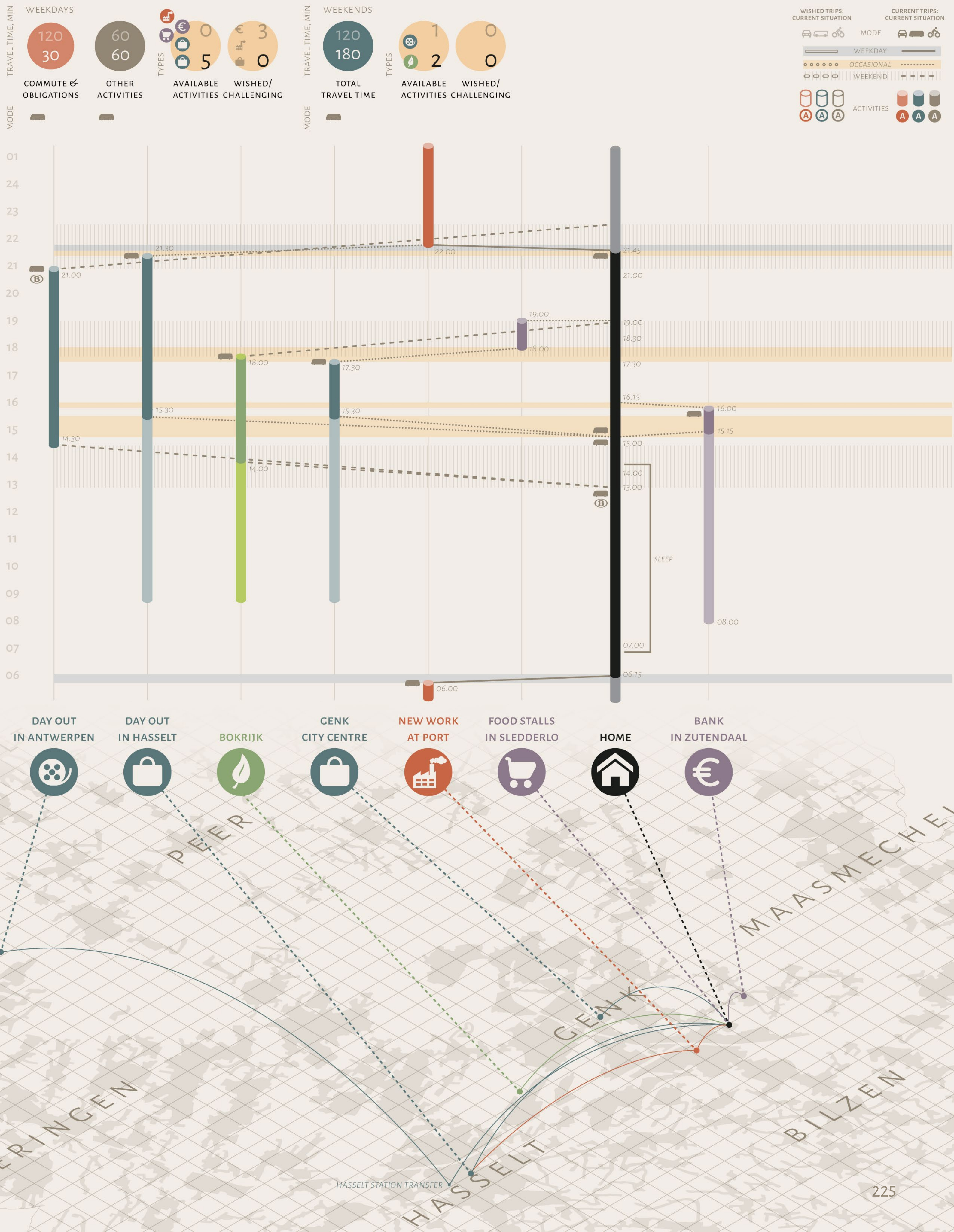
The expected effects on the problem fields are as follows:

Table 19. Design's effect on the problem fields

Spatial dispersion and spatial transition	It was not the aim of both transportation and urban design exercise.
Deindustrialisation & Innovation	The urban design with the help from transportation planning, can create opportunities for small-scale, local businesses in Sledderlo, compensating the gap left by the closure of nearby Ford Genk.
Spartacusplan & Mobility Justice	The urban design provides space for shared cars and carpool, along with creation of new activities along the line. The proposed line can connect disadvantaged areas with potential employments.

9.3.6 DAY OF LIFE: PERSONA D

Figure 146. New time-space diagram of persona D



Although he had a hard time finding a new job because of his lack of access to cars, now D can now easily take the bus to his new better job in Port of Genk, where he can easily commute on the Zutendaal – Hasselt bus line. Since his 1-hour commute is reduced to 15 minutes, he can now go to sleep at 7 instead of 8; which means that he can now wake up an hour earlier, and go to Zutendaal on a bus fairly easily within the bank and other offices' working hours. Using the new bus line, he can now also get to Hasselt station much easier, where he can take train to Antwerpen and other cities too. The new food kiosks popping up around the bus station in Sledderlo is now his favourite spot in the neighbourhood, replacing the need to travel to Oud-Sledderlo for shops other than the supermarket. His daily life is much more filled with activities now.

B. Immobility from social exclusion **C. Immobility from lacking access to cars**	Acknowledging the historic social exclusion, the public transit supply to disadvantaged neighbourhoods (where car ownership is also limited) is prioritised. The access to economic opportunities are improved both inside and outside of the neighbourhood. Combined with the urban design measures, the access to amenities is also improved, putting the neighbourhood in more favourable position in VITO Nodality and Amenities matrix, heading upper-right direction towards A.
G. Discrepancy in transit between employment opportunities and people	Along with the urban design guideline of designing working areas as a quality work-leisure destination, the transit offer to redeveloping industrial estates like Ford Genk is made much more feasible. Combined with the prioritised transit supply to disadvantaged neighbourhoods, the access to activities and opportunity is improved.

Table 20. Design's effect on the immobility types.

9.3.7 DESIGN RECOMMENDATIONS

1. Understand the context of **social exclusion and poverty** in Limburg, and actively use the urban design and accessibility as a powerful means of restroative justice.

2. While **fast, through traffic** in the neighbourhood are generally not a positive element, make sure to make exception for buses, especially if the area is the middle stop of the line

3. The design of temporary structure should not feel unorganised for the passers-by, and shall be designed to trigger positive emotion from the passers-by. Located it near green or open spaces if available, and make sure the area around the stop, including the commercial area, is easy to navigate and the structure of the space is **legible**.

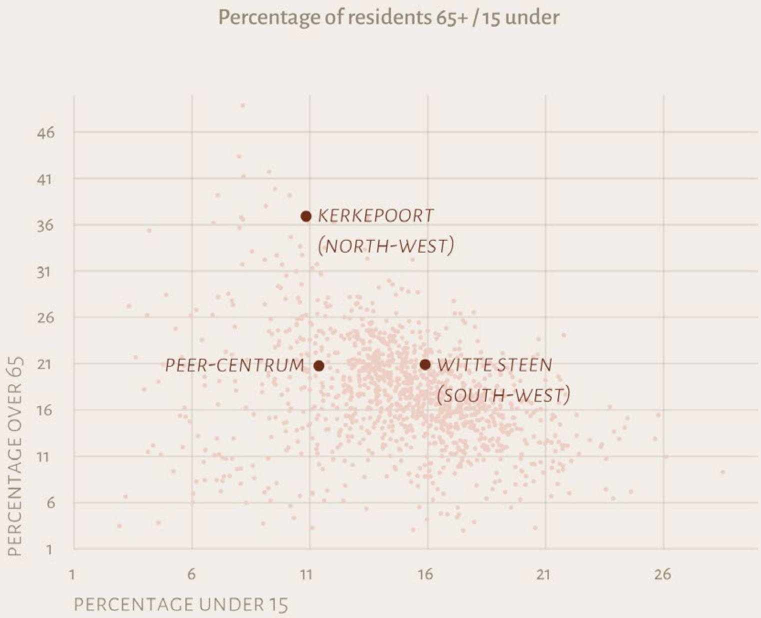
9.4 PEER

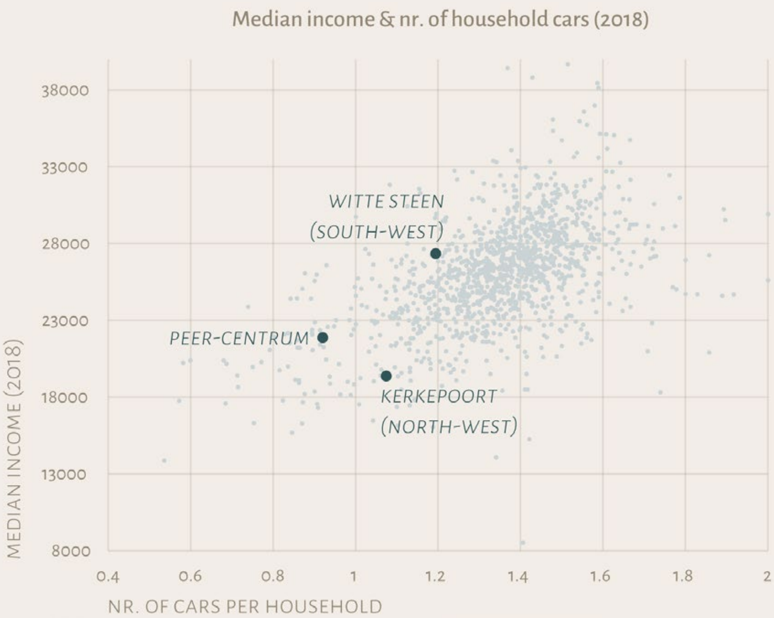
In Peer's case, urban designers can get informed about applying small-scale interventions that can strengthen the transit in town centres, and how the BRT infrastructure should further expand through.

Peer is a small but well-established city in the Northern Limburg, with plenty of shops, cultural activities, and historic centre. The city lies nearly at the entrance point of Spartacuslijn 3 for N73. Routes connecting dispersed towns north of N73 all gather in Peer, and then proceed to Hasselt. The one-way ring around Peer therefore functions as "Gateway of North Limburg".

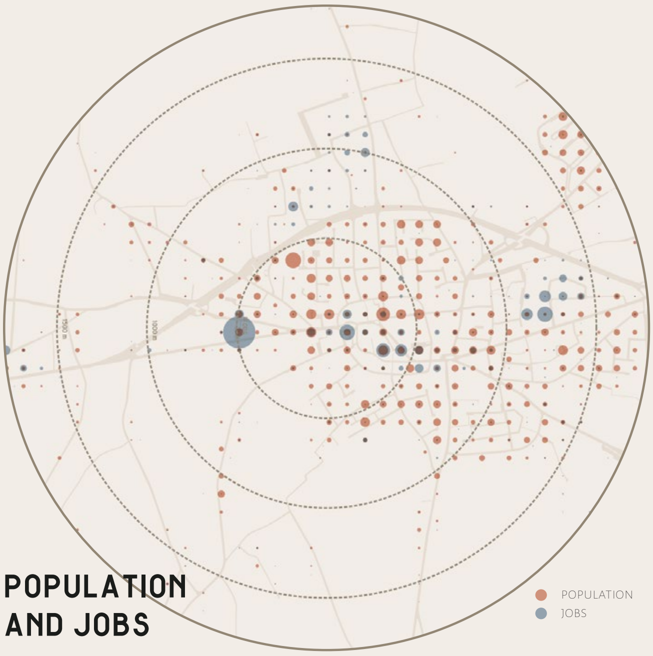
9.4.1 CONTEXT SCAN

Figure 147. Demographic analysis of Peer. Age composition (above), income and household car ownership (below), Data source: Statbel (2021)

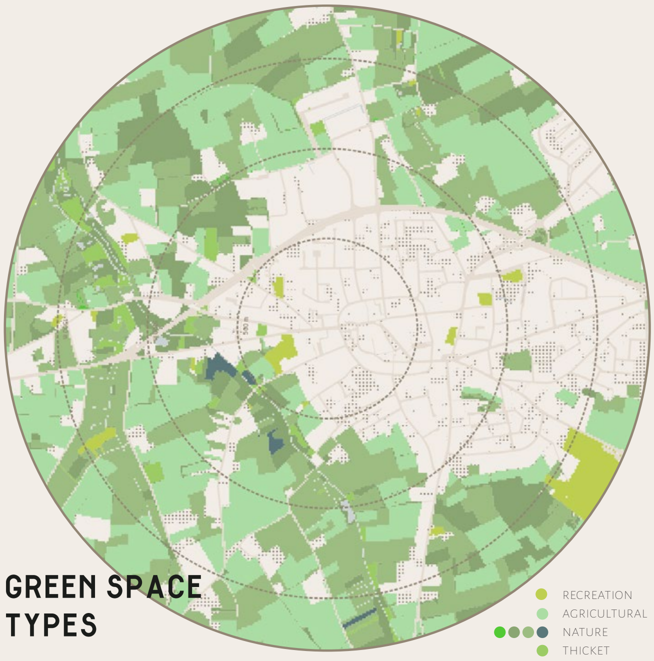




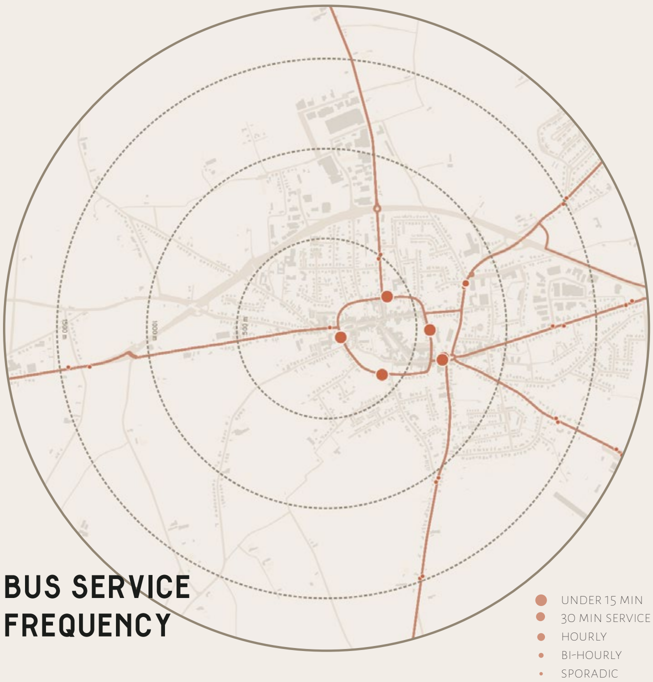
The income level of residents remain at the relatively lower end in peer, with exception of Witte Steen, a relatively less densely developed residential area in the southwest of the stop. In Peer, no necessary insight was derived from this.



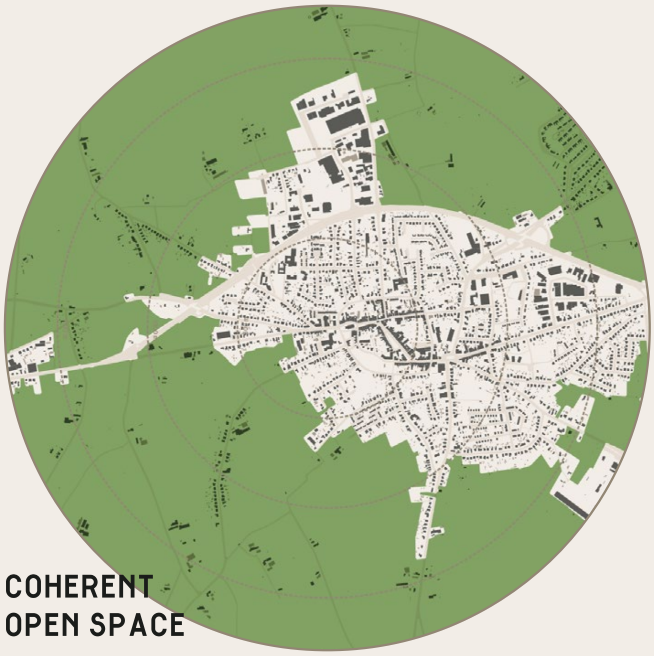
POPULATION
AND JOBS



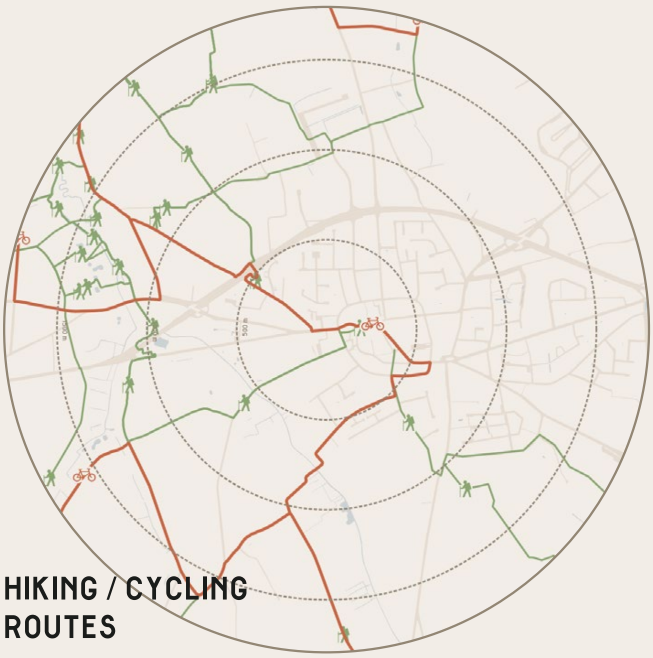
GREEN SPACE
TYPES



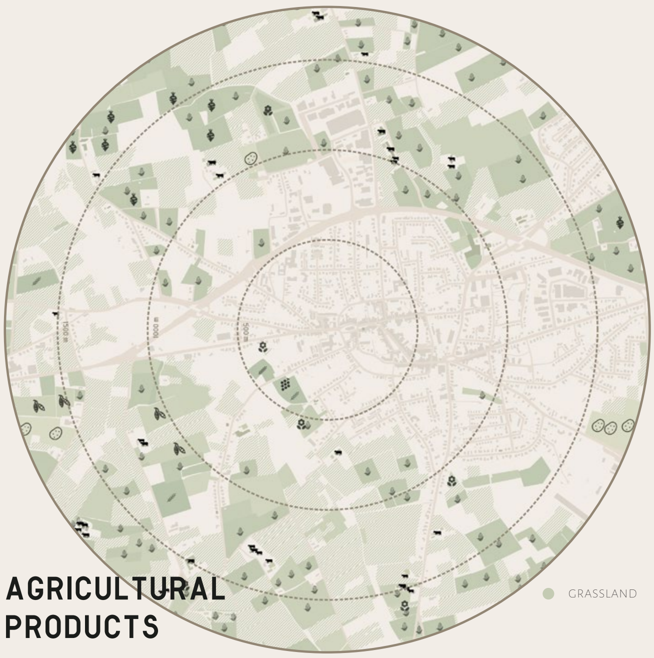
BUS SERVICE
FREQUENCY



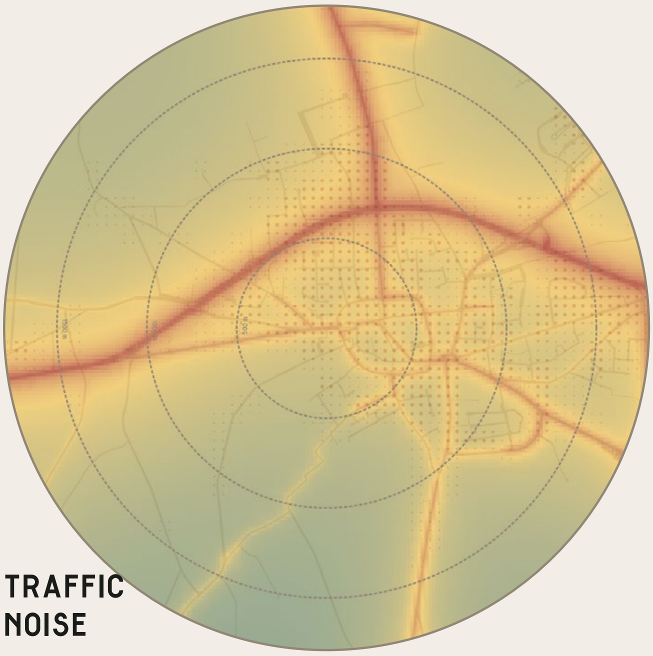
COHERENT
OPEN SPACE



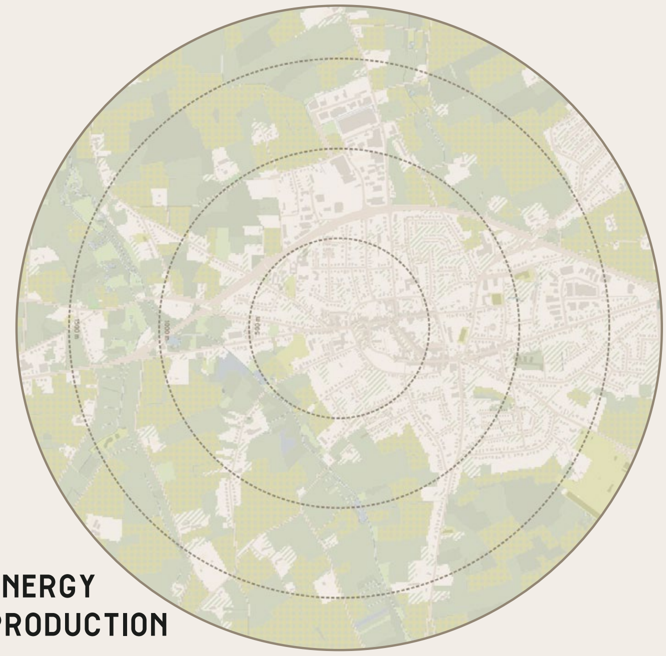
HIKING / CYCLING
ROUTES



AGRICULTURAL
PRODUCTS



TRAFFIC NOISE



ENERGY PRODUCTION

NEARBY AMENITIES

Figure 148. Quick scan of the site

9.4.2 TRANSPORT SOLUTION

Figure 149. The potential network change for Peer after Spartacuslijn 3

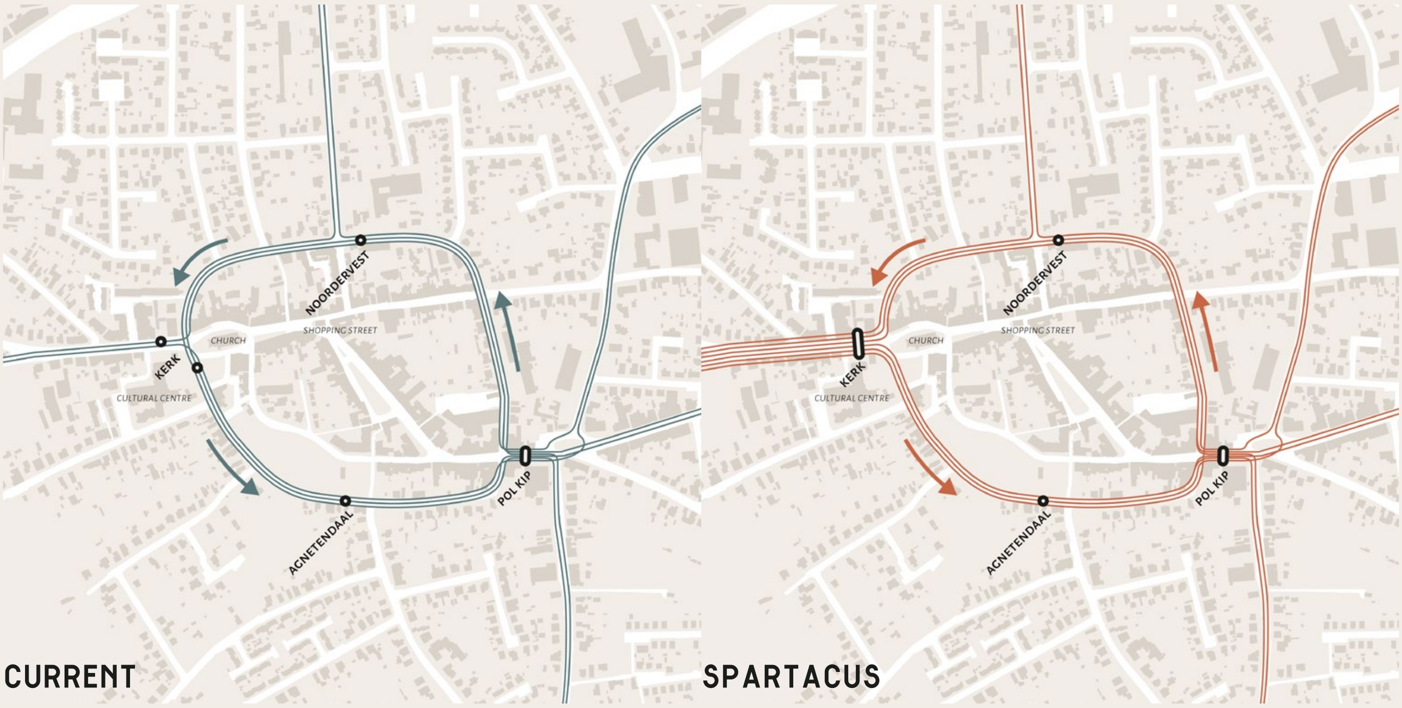


Figure 150. The network change inside Peer after Spartacuslijn 3

Currently most routes gather in Peer and head south directly from Peer instead of taking N74, however, with the completion of Spartacuslijn 3 on N74, the structure of lines around the smaller ring of Peer would change significantly. The current lines detour around the line, while the new lines would likely concentrate into the western part of the ring.

This way, despite the existing lines have relatively poor service frequency, the western point of Peer ring would have public transport capacity and frequency that is comparable with that of Spartacuslijn itself. With the newfound accessibility between Spartacuslijn 3 and Peer, new possibilities may also come along the corridor.

Therefore, for peer, no new lines will be planned; instead, it would be assumed that the existing lines' frequency will be improved after Spartacuslijn, from hourly service to 30-minute service. For the urban design exercise, the smaller scale interventions such as densification and provision of public space and amenities around the stops will be the focus.

9.4.3 APPLIED PATTERNS

From the spatial framework, Peer was listed as "Strengthen: Transit" type. Therefore the urban design exercise should focus on maximising the accessibility aspect from the assessment framework. In Peer, densification patterns related to linear densification and building on in-between spaces, and mobility patterns related to mobility hub strategy (M1: Making transit visible, M8: Multifunctional mobility hub) are applied.

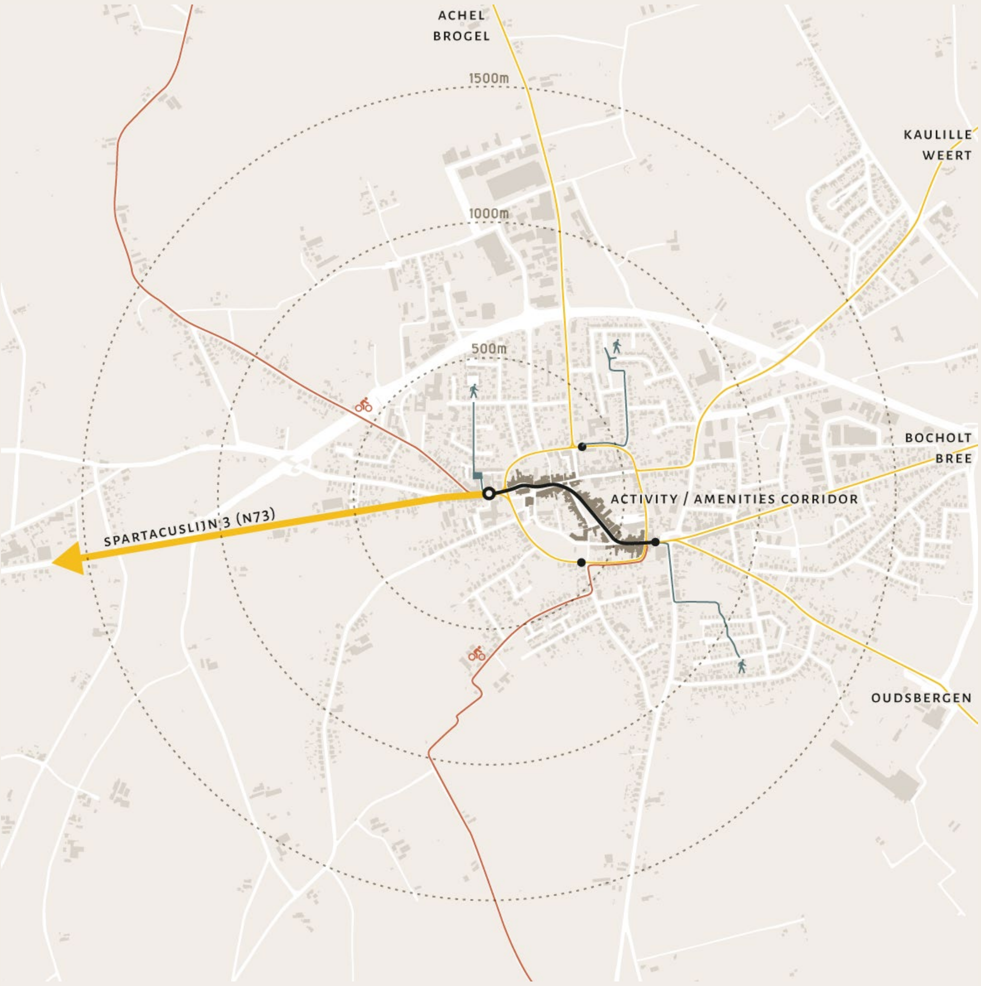


Figure 151. Circulation strategy

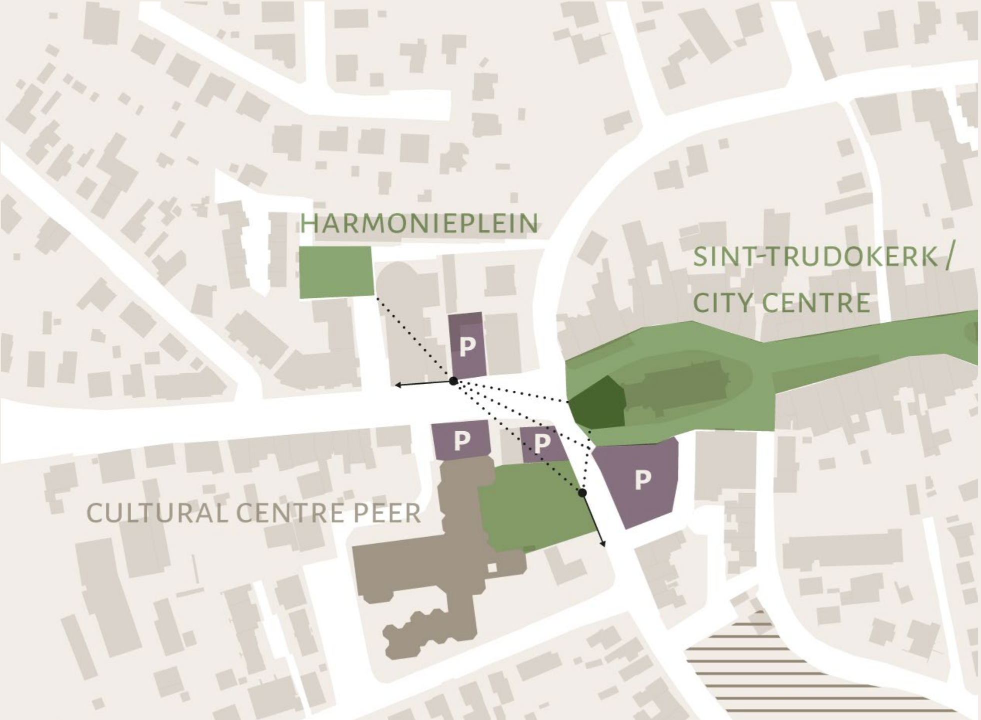
Figure 152. Applied patterns and reason for not applying certain patterns

PEER

Applicable pattern types

APPLIED		NOT APPLIED	
M1	S1	M2	NO APPARENT PERMEABILITY ISSUE
M8	S3	M3	ALREADY ONE-WAY ALONG RINGS
	S5	M4	LOCATED ON THE SHOPPING STREET
	S7	M5	NO BRT ROW YET
	S13	M6	NO GTW/GTI
		M7	NO BRT ROW OR MOTORWAY
		M9	ALREADY IMPLEMENTED
		M10	GOOD STREET CONNECTIVITY
		S2	NO DEVELOPMENT YET; CAN BE APPLIED WITH S3
		S4	NO BRT ROW OR MOTORWAY
		S6	NO SUBURBAN COMMERCIAL ACTIVITIES
		S8	NO APPARENT DISCONNECTED PATCHES NEARBY
		S9	ALREADY AGARIC MUNICIPALITY
		S10	IN-BETWEEN FOCUS; SEE BOSDEL
		S11	IN-BETWEEN FOCUS; SEE BOSDEL
		S12	NO NEIGHBOURHOOD DEVELOPMENT

Figure 153. Outdoor parking consolidation strategy



The key strategy to test in Peer is the consolidation of parking spaces surrounding the stop. They can be consolidated with a new top-up densification of Steenweg Wijchmaal 2. The remaining spaces will be turned into green spaces, except for the small parking north of Cultural Centre Peer, which will be consolidated with the Cultural Centre as regional mobility hub, as a gateway to Spartacuslijn and Northern Limburg.

The bus stops that were separated (Westbound on the main road, eastbound on the ring road) can be also consolidated to create a coherent and legible mobility hub in Peer.

9.4.4 REGIONAL MOBILITY HUB

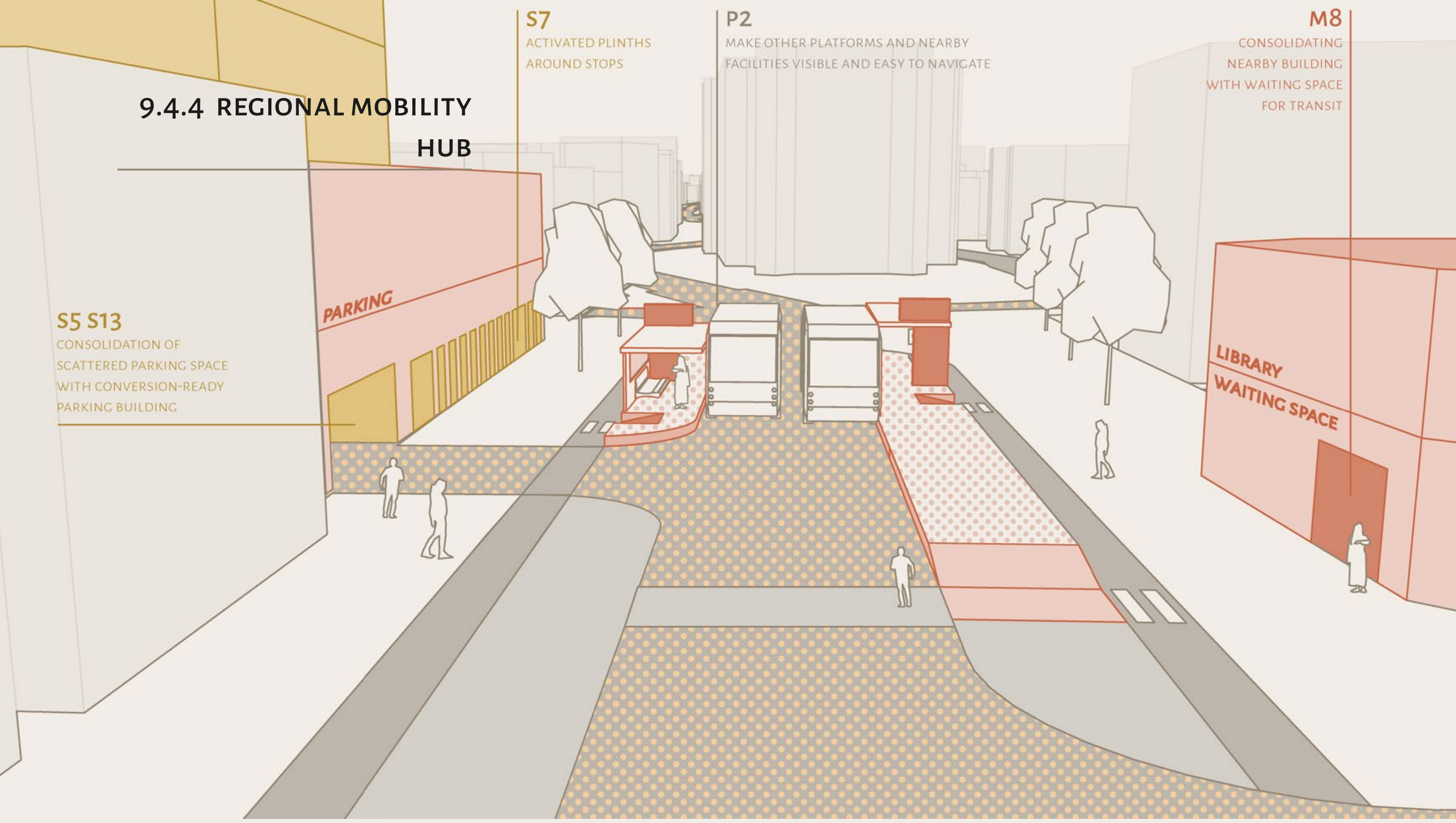
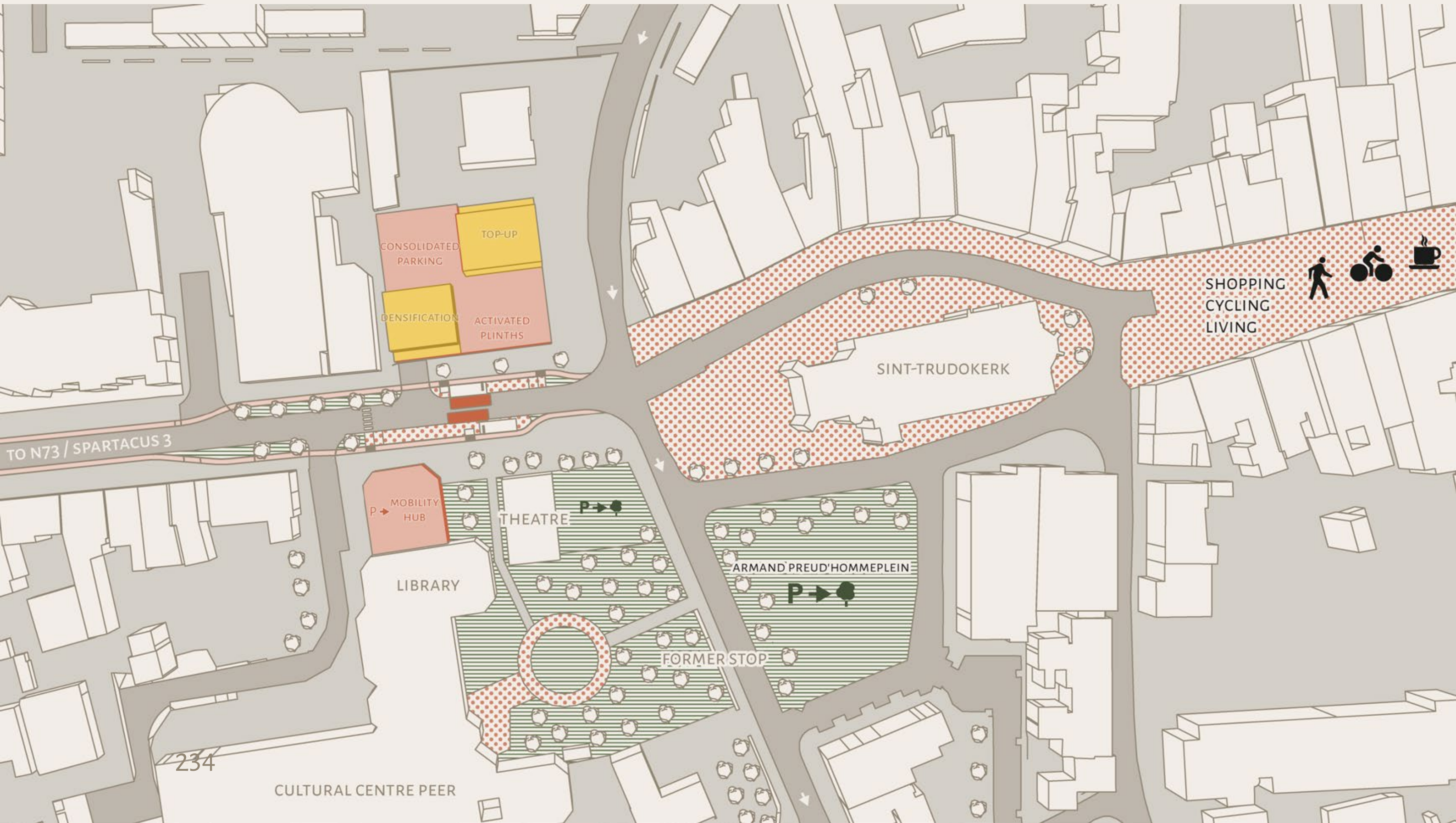


Figure 154. Applied patterns in the station area

The station is placed at the continuation of the main shopping, cycling, and tourism corridor of the city. Therefore, when N73 enters the Peer city centre and passengers get off the bus, they would instantly read where they should head to. Urban design should facilitate such placement of stops; this way, the passage of buses are not delayed, and the passengers are taken off at the point where they can easily navigate themselves.

Figure 155. Ground plan and the structure of the area after consolidation of outdoor parking



This way of scattered outdoor parking space is, unfortunately, a fairly common practice in many small cores across Limburg. In Peer, next to the bus stop, The nearby flat building can be potentially topped up and consolidated with the adjacent outdoor parking lot, which then could also consolidate other outdoor parking lots in the surroundings. Naturally, the ground floor facing the bus stop can be used for retail.

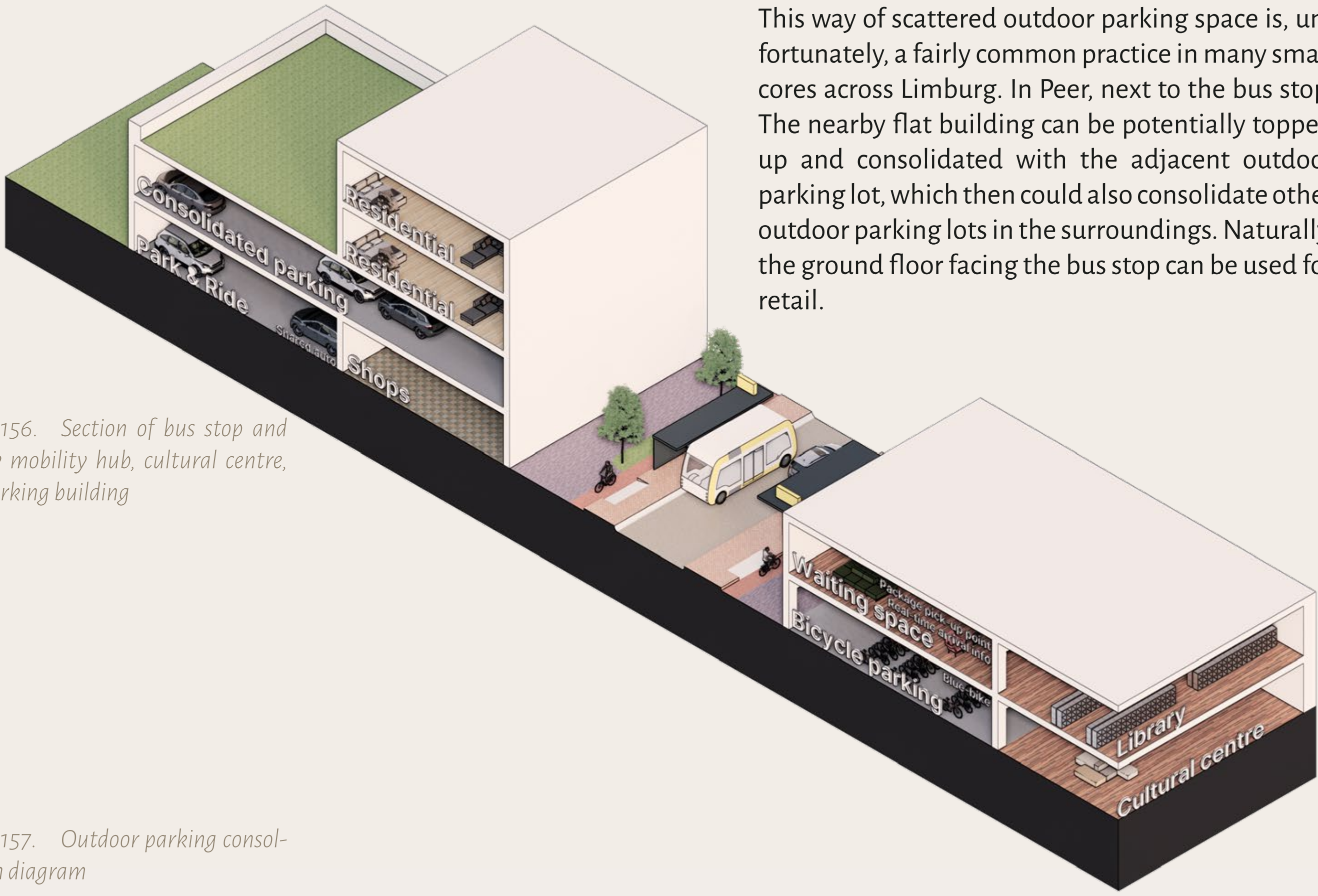
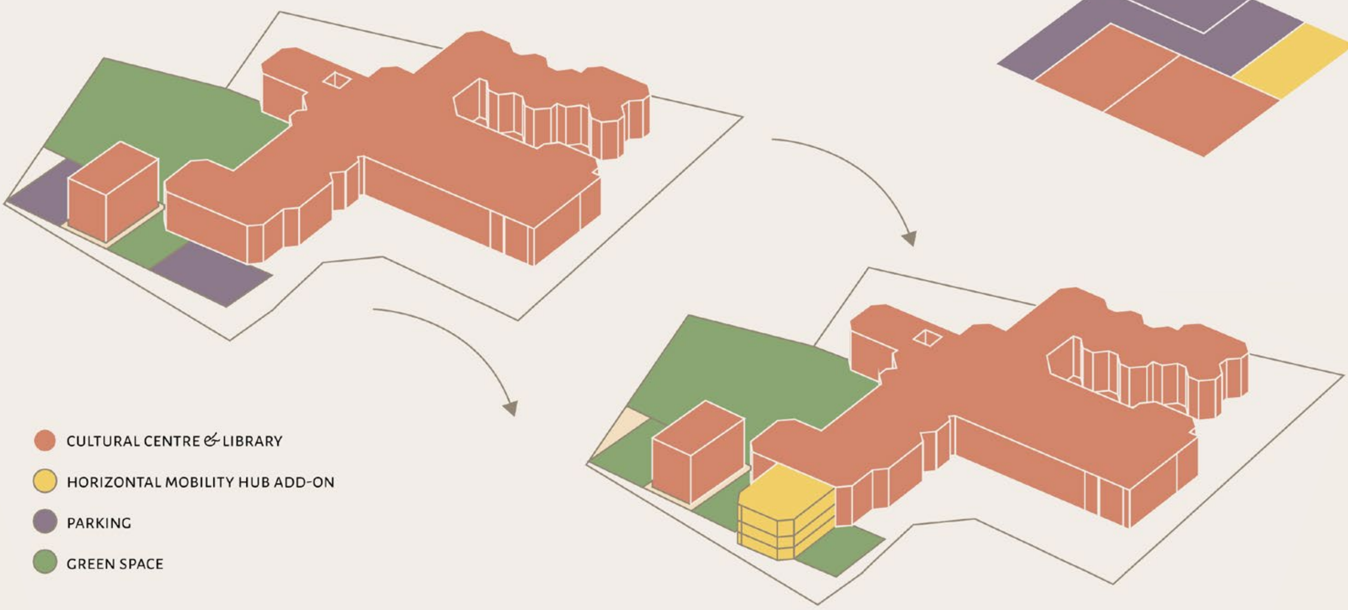


Figure 156. Section of bus stop and nearby mobility hub, cultural centre, and parking building

Figure 157. Outdoor parking consolidation diagram

Figure 158. Expansion of cultural centre towards transit



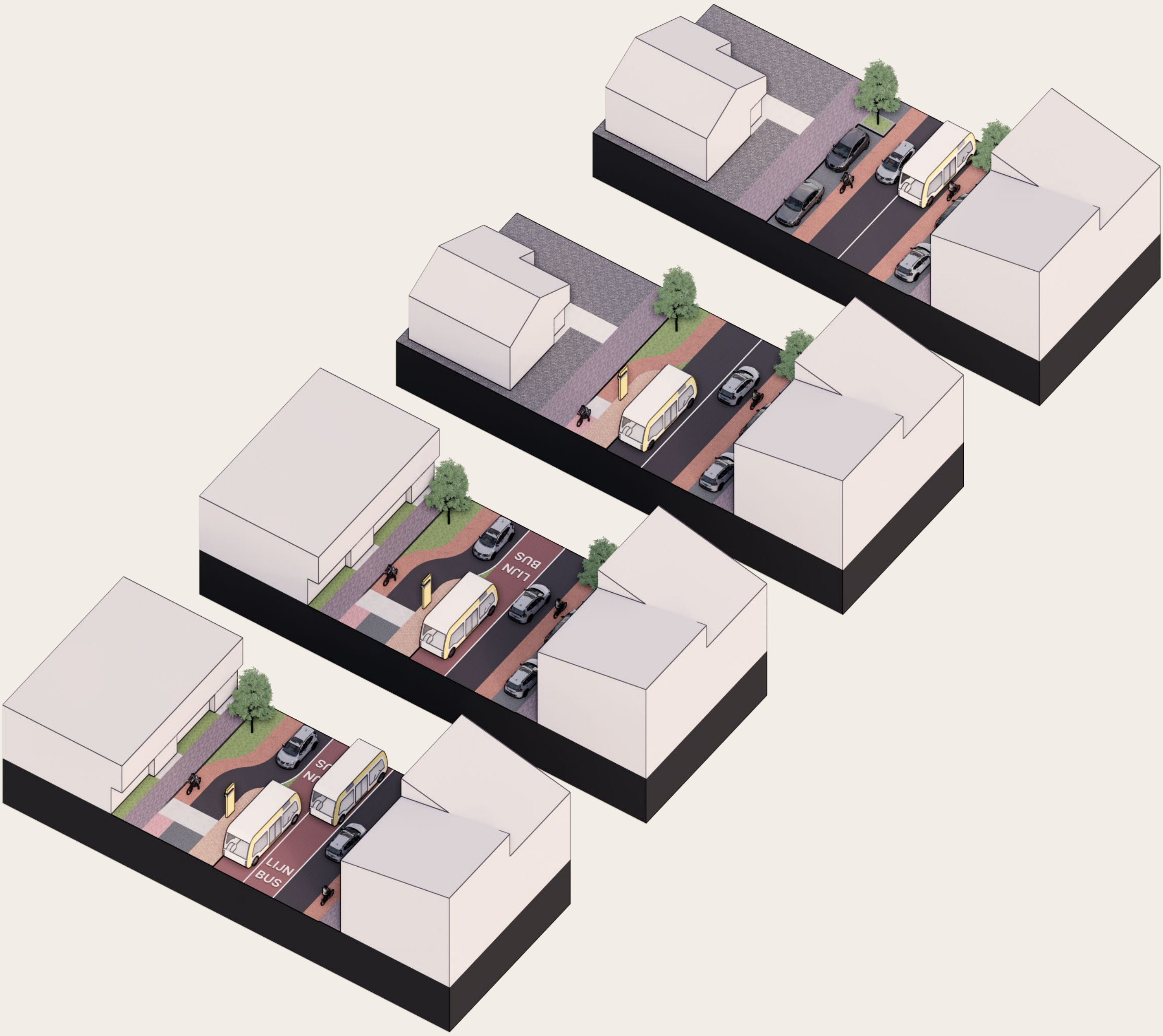


Figure 159. Process diagram of gradual expansion of BRT ROW towards Peer

The road between Spartacuslijn 3 and Peer can be gradually transformed into a proper BRT corridor with comparable standards with other Spartacuslijnen, allowing partial automation in the corridor. For this, the removal of parking lane and taking the frontage space would be essential. Therefore, an incremental approach should be used, where small bus stop would be installed to provide accessibility on the stop, replacing part of the parking space; in the long term, the surrounding buildings could be gradually densified with smaller frontage spaces, making space for BRT right-of-way to be installed.

9.4.5 ASSESSMENT FRAMEWORK

Figure 160. Assesssment framework

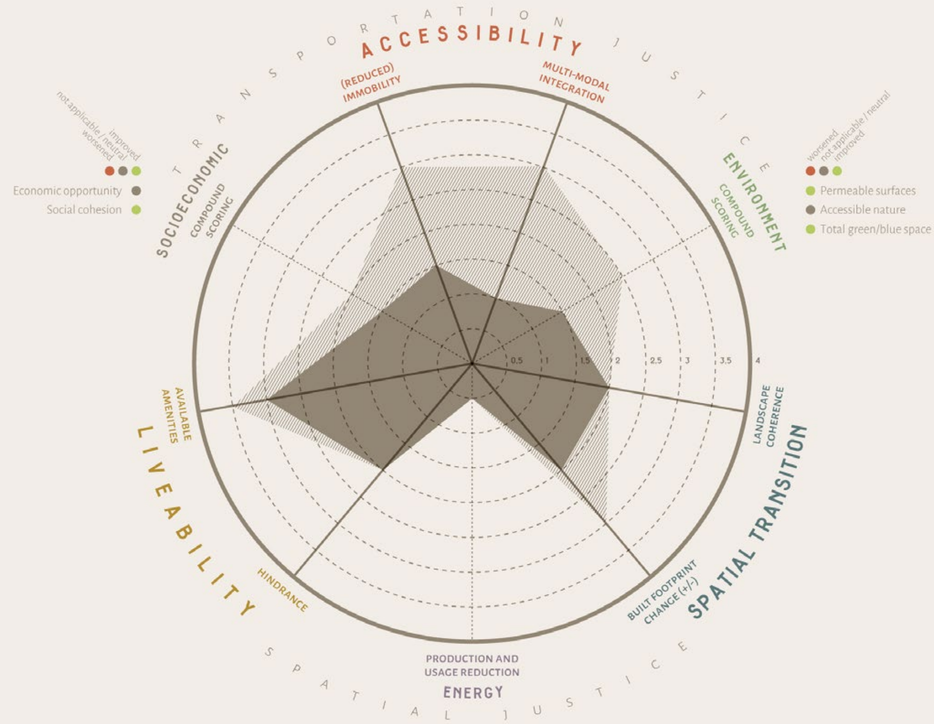


Table 21. Design's effect on the problem fields

Since improving accessibility has been the primary focus for the Strengthen: Transit types, the results are aligned with the goals. Other aspects, such as built footprints were also improved, however this was mainly due to the densification of N73 and the Flat building north of the station, which is not Mobility integration patterns. The goal of Strengthen: Transit areas remain improving accessibility first; after that is realised, then from that point the area can follow same strategy as Strengthen: Housing areas.

Spatial dispersion and spatial transition	The synergy of urban design and the transit intervention provides positive result for spatial transition by improving the densification potential and connectivity in the small towns, ultimately improving the attractiveness for development. This alleviates the burden of spatial transition from cities, and can provide more familiar and attractive alternative for countryside residents.
Deindustrialisation & Innovation	It was not the aim of both transportation and urban design exercise.
Spartacusplan & Mobility Justice	The urban design exercise offers possible expansion of Spartacuslijn ROW, which can futher improve the transportation in Limburg, and can increase the capacity to tackle immobility.

9.4.6 DAY OF LIFE: PERSONA C

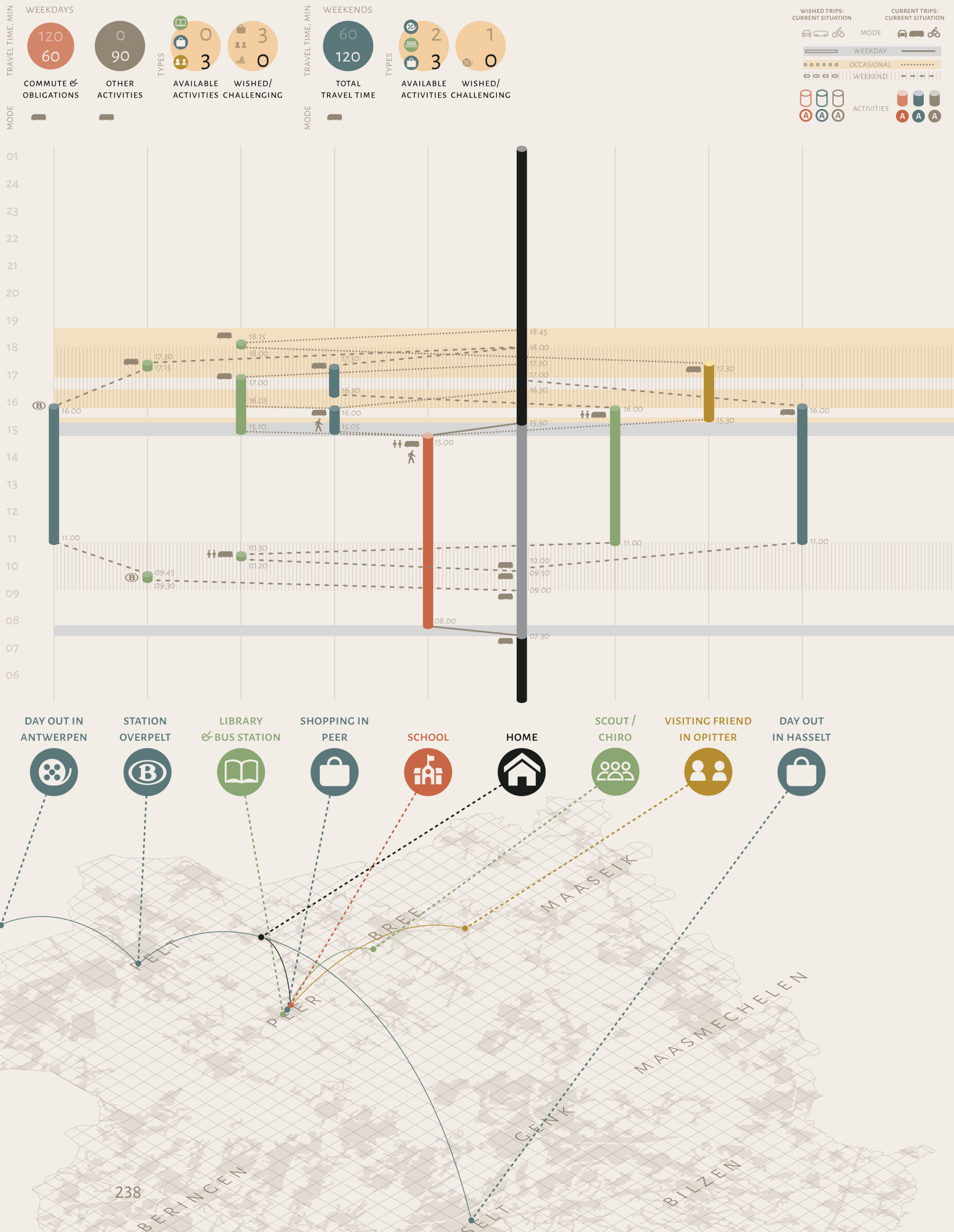


Figure 161. New time-space diagram for Persona C

The teenage persona, C, is living in Kaulille, a town north of Peer that is connected to Peer with bus line 48, which recently became part of Spartacuslijn 3. With the newly gained independence, she can now do more activities and discoveries on her own. She doesn't feel stuck at home anymore, and everyday life is now filled with activities and fun things to do.

The weekend journey to Hasselt became faster thanks to Spartacuslijn; even though she doesn't live near Spartacuslijn itself. Since all the buses that goes to Spartacuslijn have become much faster and more frequent, and they all go through Peer, she can easily visit her friends in Opitter, and go to Chiro on her own. While there was direct hourly bus between Peer and Bree, her friend and Chiro is both not inside Bree, so she had to wait more than 30 minutes just to transfer, which was way too long to try after school on her own. Now she can simply get to Peer, take the bus, and transfer to another bus to her friend and Chiro within 15 minutes. Moreover, the stop where she change to other buses in Peer is connected to the library next to it, so it is never boring to wait. After school, instead of waiting for her mum to pick her up, she can now choose what she wants to do: she can go to shops in Peer, spend time in Library, or go to her friend and come back home before dinner.

Table 22. Design's effect on the immobility types.

A. Immobility from spatial remoteness	The branching services of Spartacuslijn allowed immobile groups in dispersed cores to easily access major destinations with less time burden.
C. Immobility from lacking access to cars	
E. Immobility from polycentricity	The improved frequency and gathering of lines at or near Spartacuslijn station, along with urban design measures to create quality waiting space around stops improved travel experience for passengers connecting between non-central destinations.

9.4.7 DESIGN RECOMMENDATIONS

1. Recognise the potential of **small cores as a powerful tool for spatial transition**. Although they do not belong to any major corridor, small cores have closer ties with the surrounding dispersed settlements; for many in the countryside who would not consider moving to large, denser cities, small cores can offer familiar and attractive alternative for them, without the adverse effects of dispersion.

2. In smaller cities and towns, **placement of the stop needs to be given extra attention**. It should be located on the place that is accessible to activities and navigable for passengers, while also should be able to ensure smooth passage of the buses.

3. Design should take **future expansion of BRT ROW** into account, which needs to be weighted between the lively streets and the expansion. The understanding on the potential of each corridor is crucial. In general, if buses are already operating in high frequency (the criteria may vary between areas, but at least more than 4x per hour), or is leading to Spartacuslijn corridor from larger hinterland, then it would be good to consider it having potential for expansion.

4. Recognise the **value of accessibility in steering the spatial transition** and tackling immobility. Even if the supply does not translate to immediate passenger numbers, it would be too early to consider cutting service.

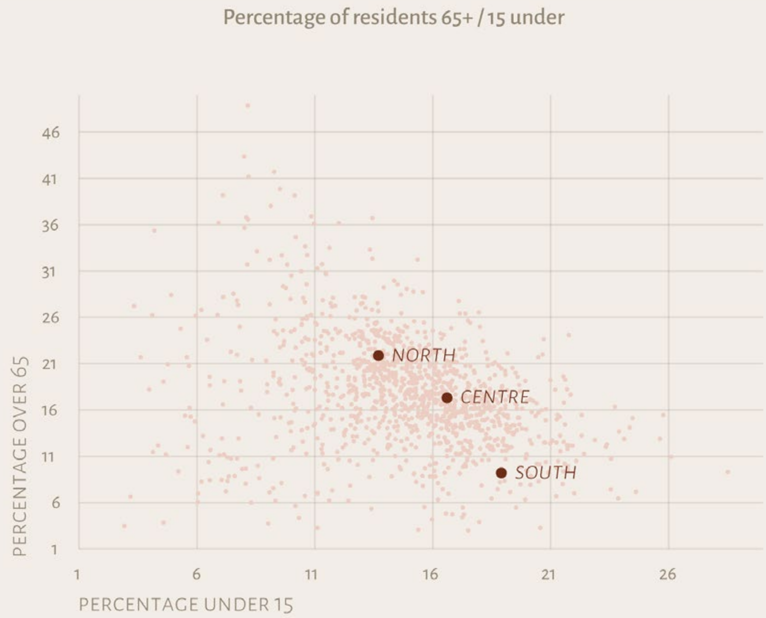
9.5 ROMERSHOVEN

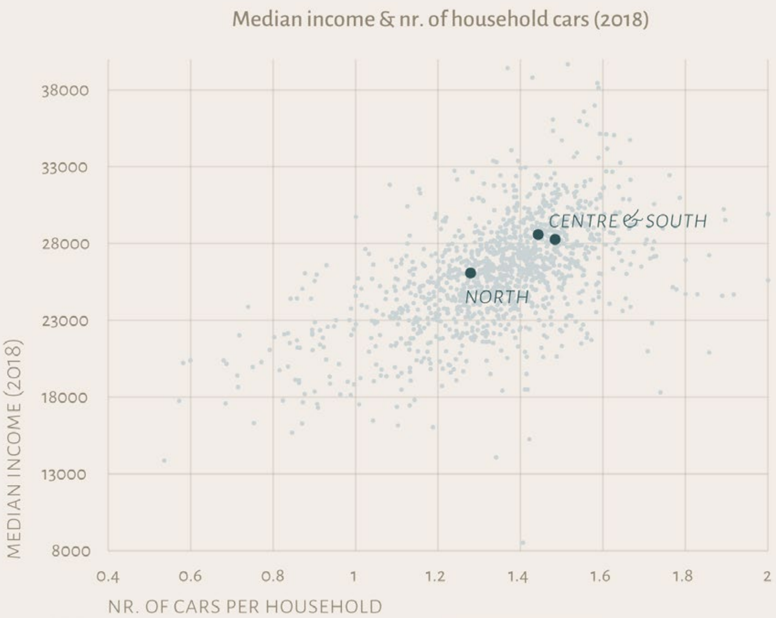
The design exercise on Romershoven is a good example for urban designers to picture how to apply “de-densification” measures in the countryside, and how the impact of spatial transition can be mitigated through it.

Romershoven is a relatively old ribbon development in the west of Hoeselt, situated on the road between Diepenbeek and Hoeselt. The area is surrounded by agricultural land, where pears are particularly common. The village sits right inside a coherent open space, fragmenting the open space.

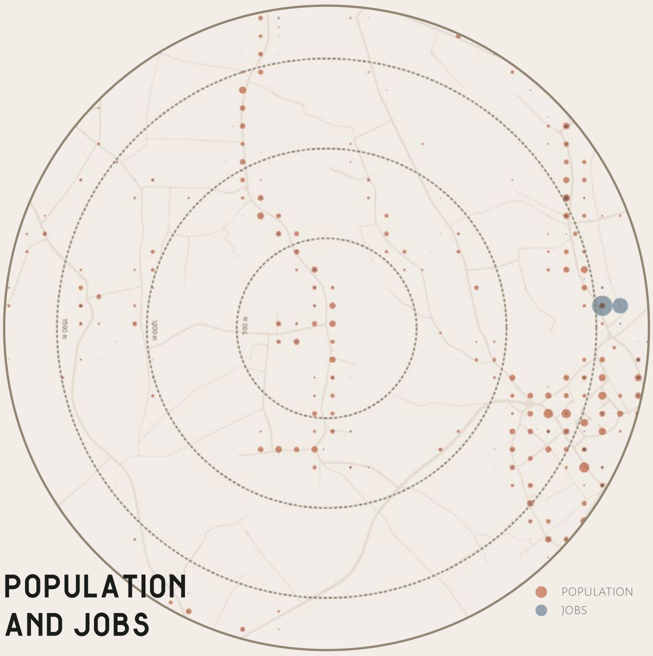
9.5.1 CONTEXT SCAN

Figure 162. Demographic analysis of Romershoven on Age composition (above), income and household car ownership (below), Data source: Statbel (2021)

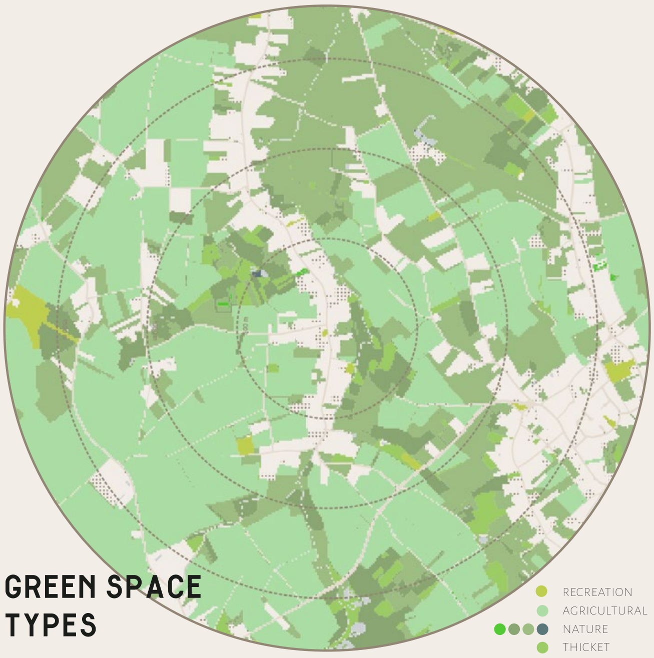




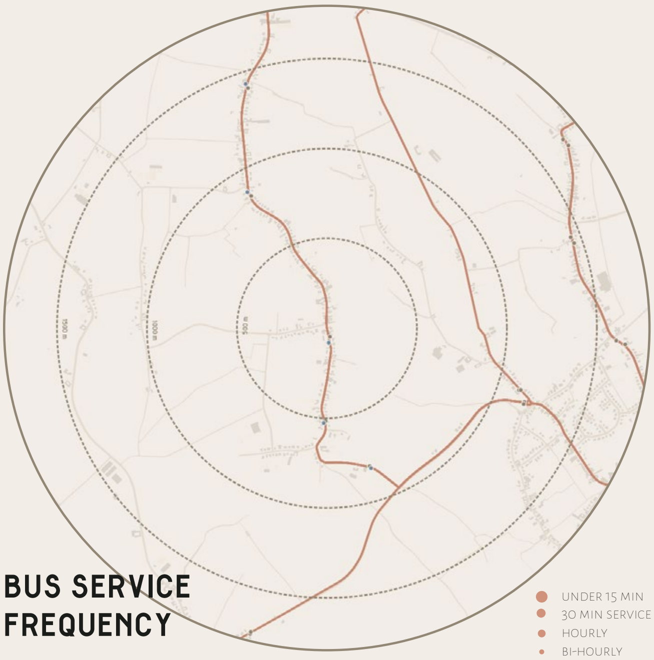
Being a dispersed settlement (ribbon development), Romershoven’s demographic composition is more or less representative of average Limburgers; the slight aging of the northern part of Romershoven is observable.



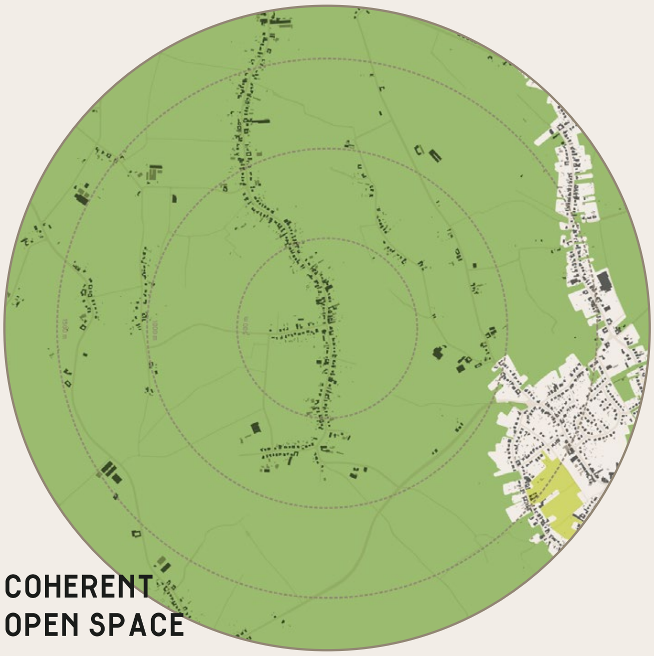
POPULATION AND JOBS



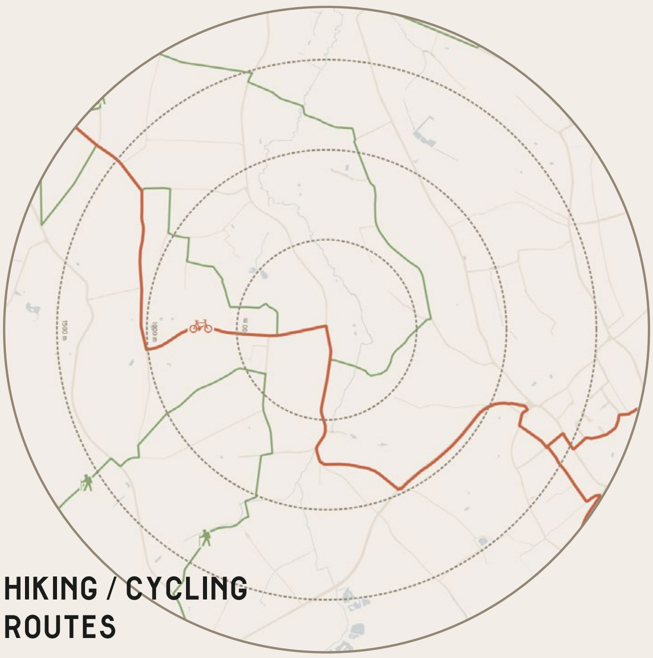
GREEN SPACE TYPES



BUS SERVICE FREQUENCY

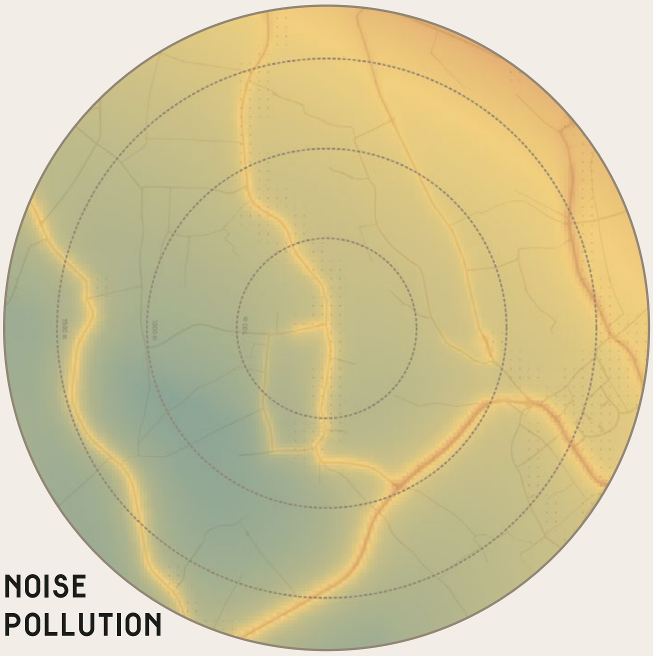


COHERENT OPEN SPACE

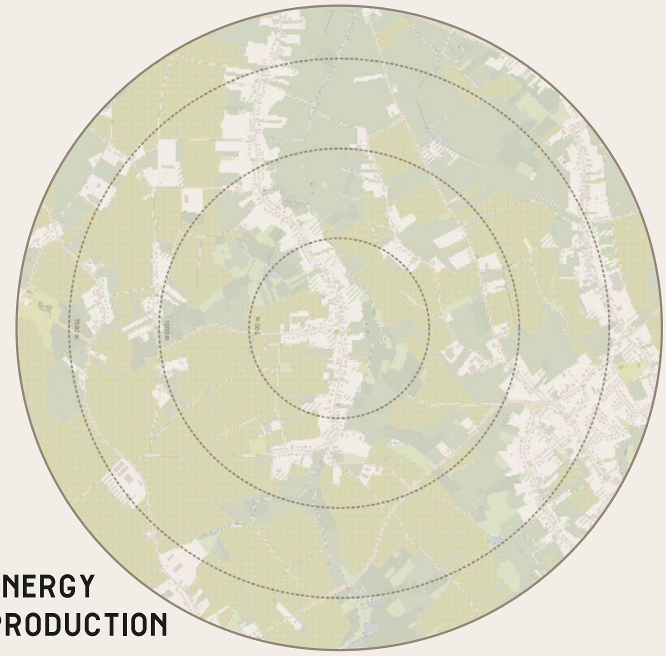


HIKING / CYCLING ROUTES

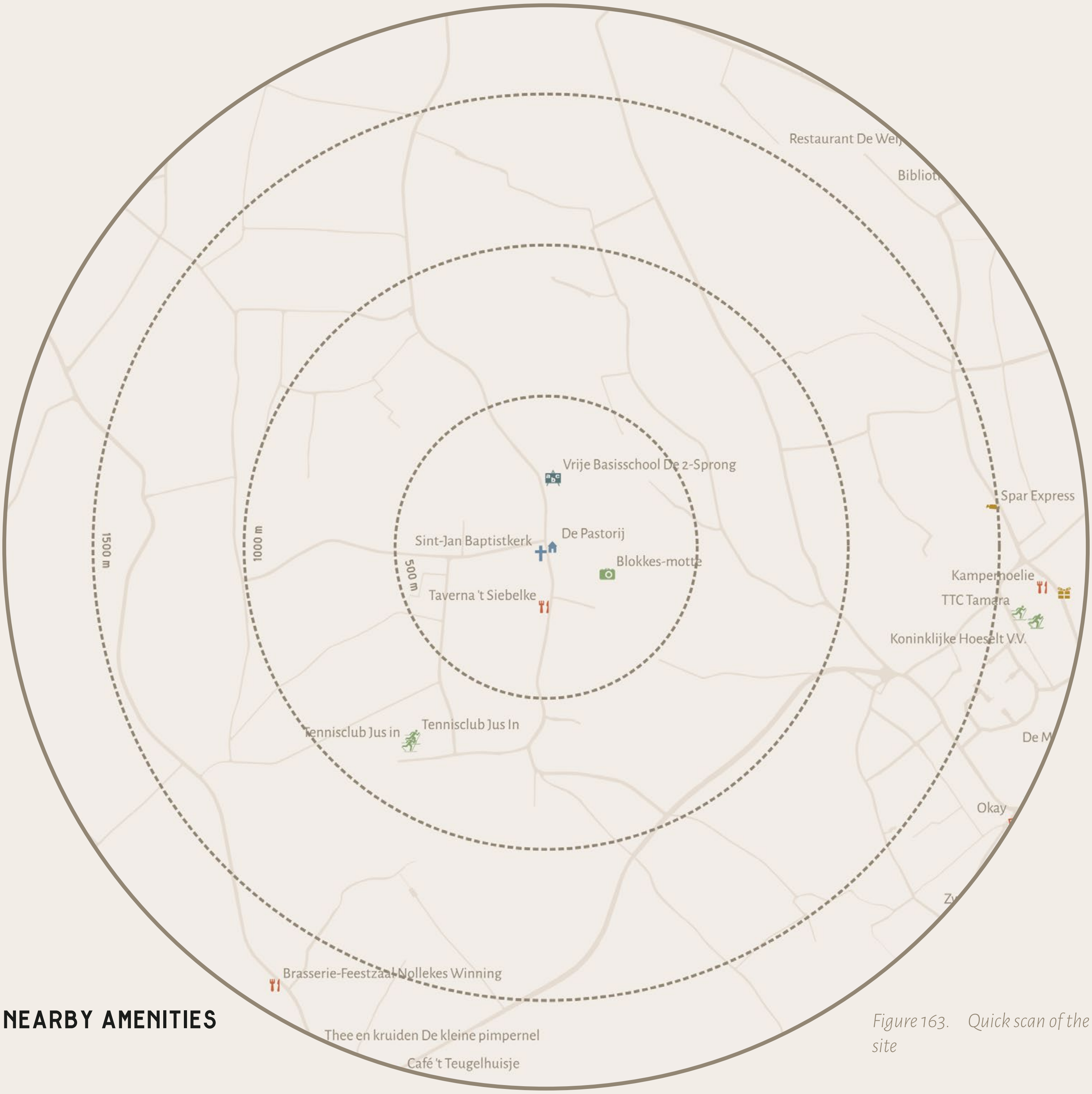
AGRICULTURAL PRODUCTS



NOISE POLLUTION



ENERGY PRODUCTION



NEARBY AMENITIES

Figure 163. Quick scan of the site

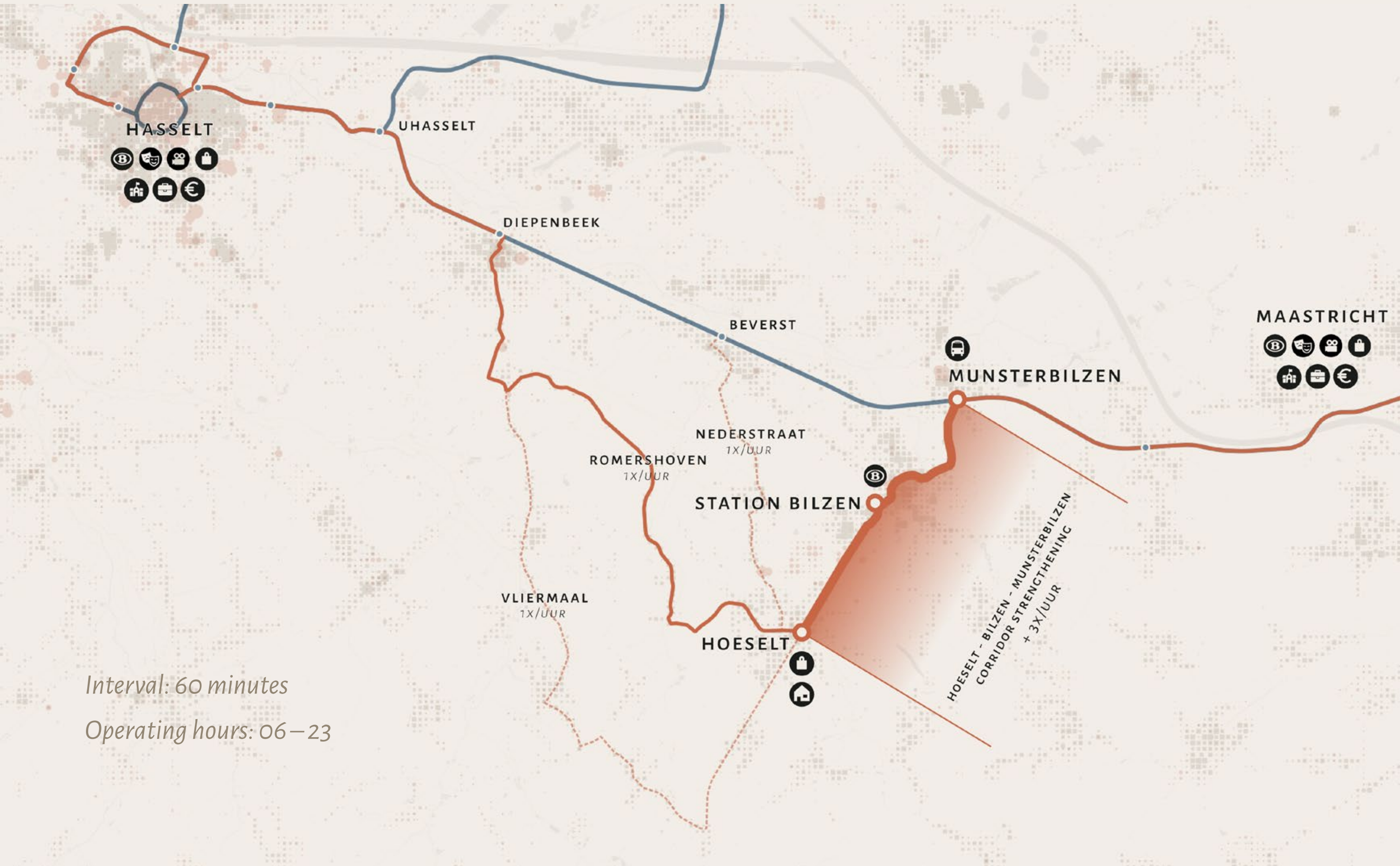


Figure 164. Routes designed for Romershoven along with other related routes for corridor strengthening

3 routes will diverge from Spartacuslijn 1 to serve dispersed neighbourhoods between Diepenbeek and Bilzen. Each route will get hourly service; these services will bundle between the busier Hoeselt – Bilzen – Munsterbilzen corridor, complementing the closure of Hoeselt's railway station in the 1980s, and connecting Spartacuslijn's Munsterbilzen station with NMBS station of Bilzen. In the long term, with the progress of land swap and spatial transition, the diverging routes will be slowly phased out, but kept bi-hourly service for minimum accessibility.

The planning of the services follow principle patterns of MP3 and MP5. From the online planning tool, the metric of current accessibility was given particular focus, and between the large cores of Hoeselt and Bilzen was given the bundling strategy.

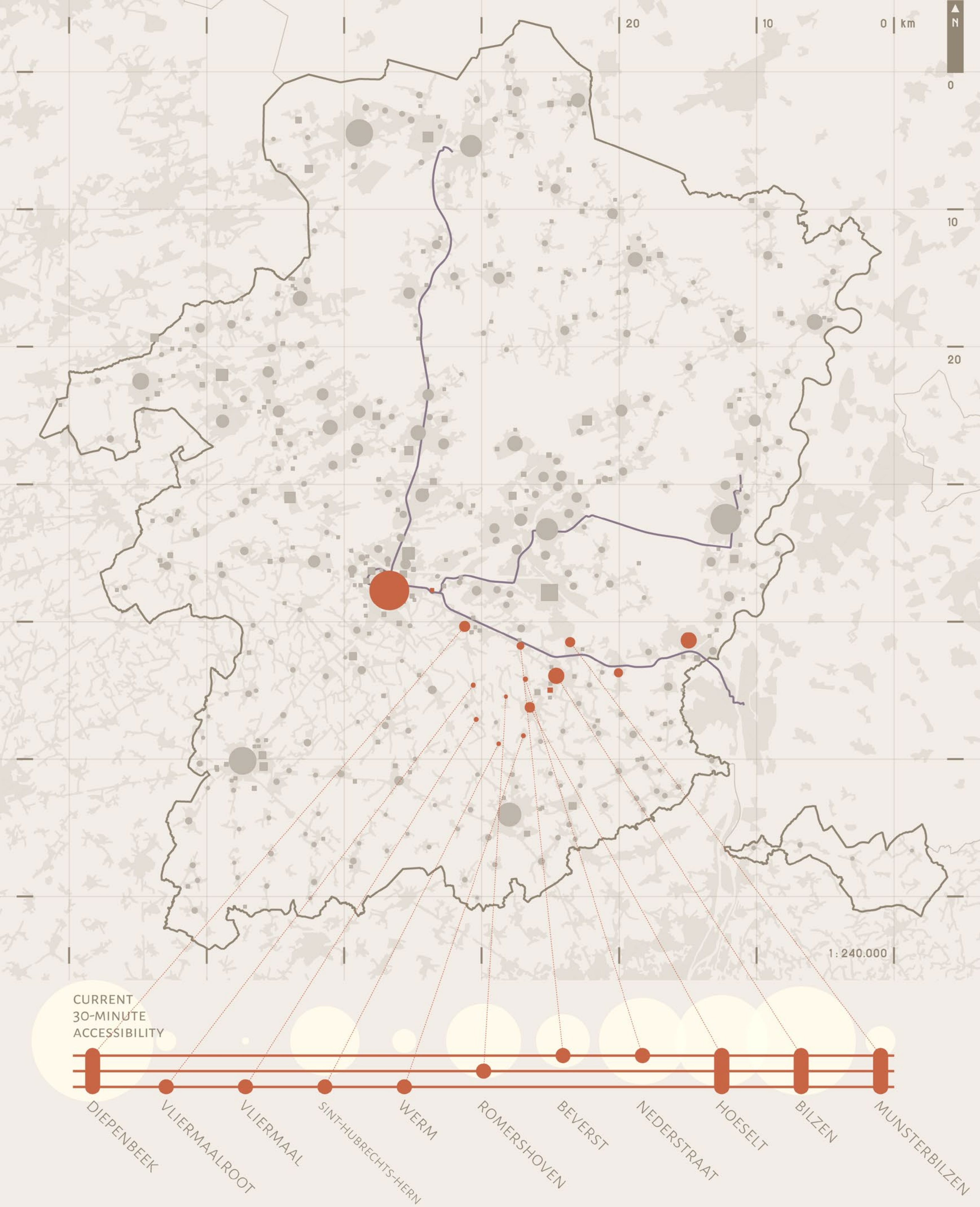


Figure 165. The 3 routes and their current accessibility retrieved from BRT service planning online tool created in chapter 8

9.5.3 APPLIED PATTERNS

In this urban design exercise, all of the transform patterns are applied, along with mobility patterns M1 (making transit visible), M4 (lively pedestrian access), M9 (traffic calming), and M10 (creating pedestrian shortcuts). As visible on Quick Scan on population, the small, parallel ribbons from Romershoven can be connected with new footpaths, connecting bus stops with parallel ribbon developments.

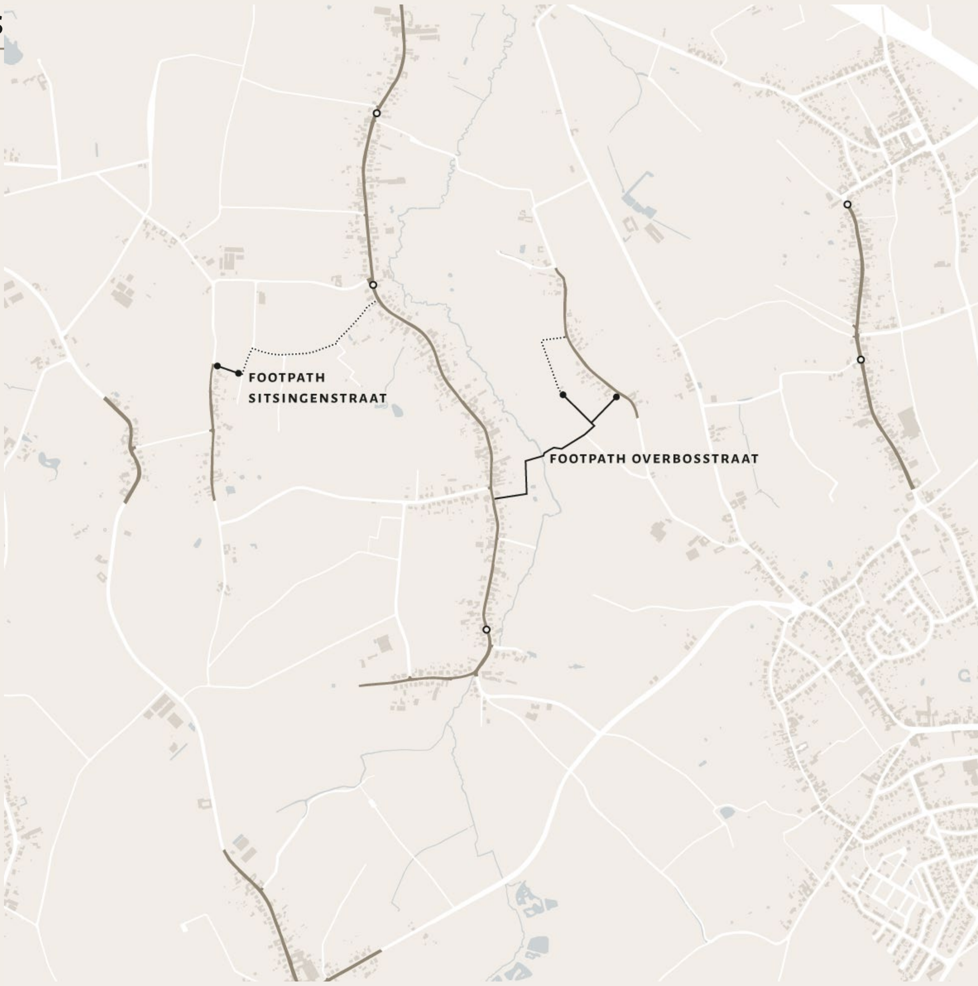


Figure 166. The parallel ribbon developments and possible connections

Figure 167. Applied pattern in Romershoven and reasons for not applying certain patterns

ROMERSHOVEN

Applicable pattern types

APPLIED		NOT APPLIED	
M1	T1	M2	NOT ENOUGH ROADS TO APPLY
M4	T2	M3	NOT ENOUGH ROADS TO APPLY
M9	T3	M5	NO BRT ROW
M10	T4	M6	NO GNW/GTI
	T5	M7	NO BRT ROW OR MOTORWAY
	T6	M8	MULTIFUNCTIONAL, BUT ONLY REPURPOSING STRUCTURES
	T7		

9.5.4 NEIGHBOURHOOD MOBILITY HUB

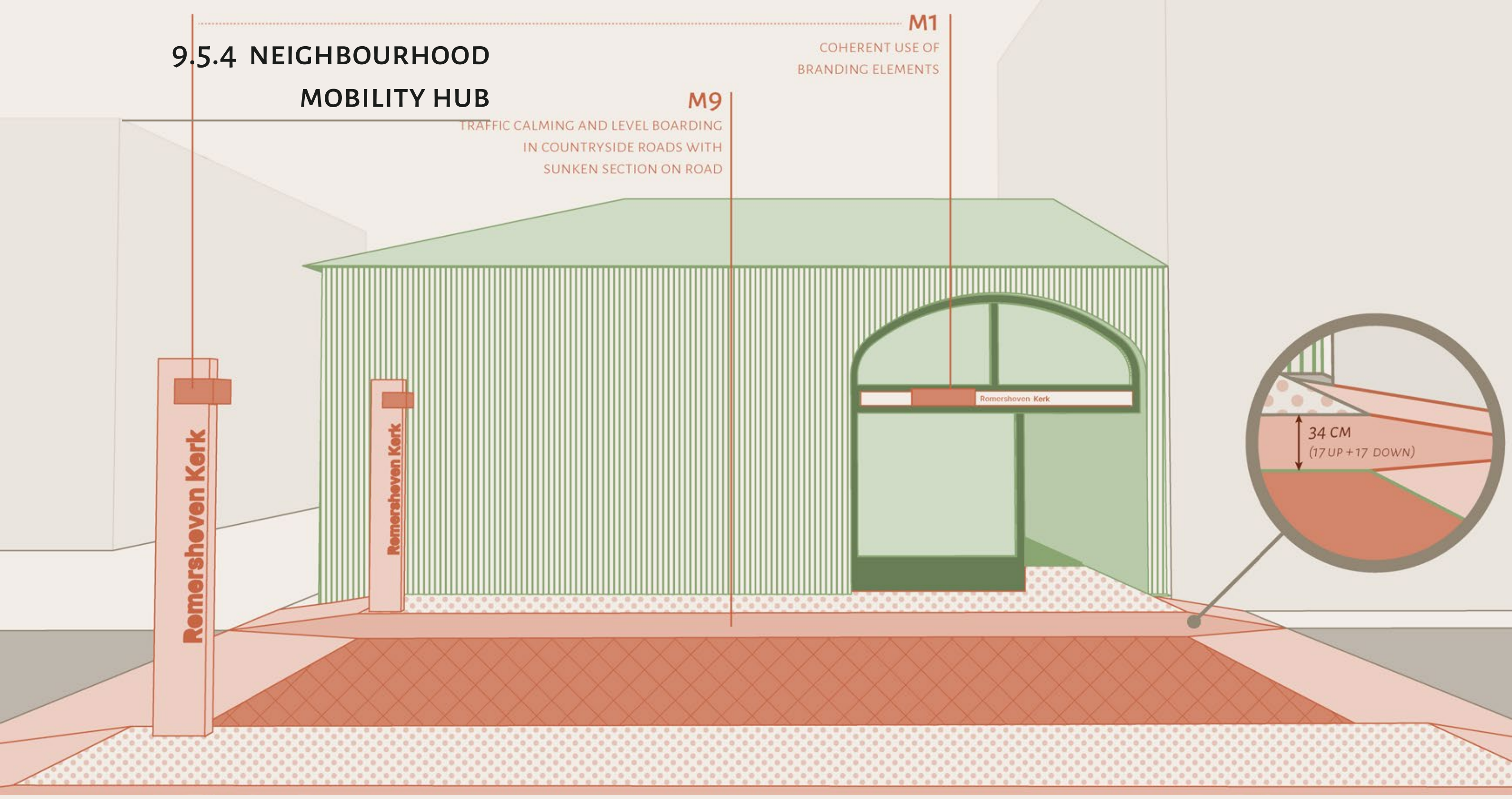


Figure 168. Street side facade of the abandoned building

Figure 169. The bus stopping at the stop

Buildings that are left behind in a result of land swap could be transformed into a small-scale neighbourhood mobility hub, which compensates for the decline in amenities in the ribbon developments by serving diverse functions in the neighbourhood. This can include a sales point for local products, library, bicycle parking, a waiting lounge, and neighbourhood energy storage with an electric bike charging point. They can even store local products; in Romershoven's case, pears (see Quick Scan) can be stored in the hub during the morning and evening peak hours, sold to local residents, and during non-peak hours they can be transported on the bus to the city. Such model can support the

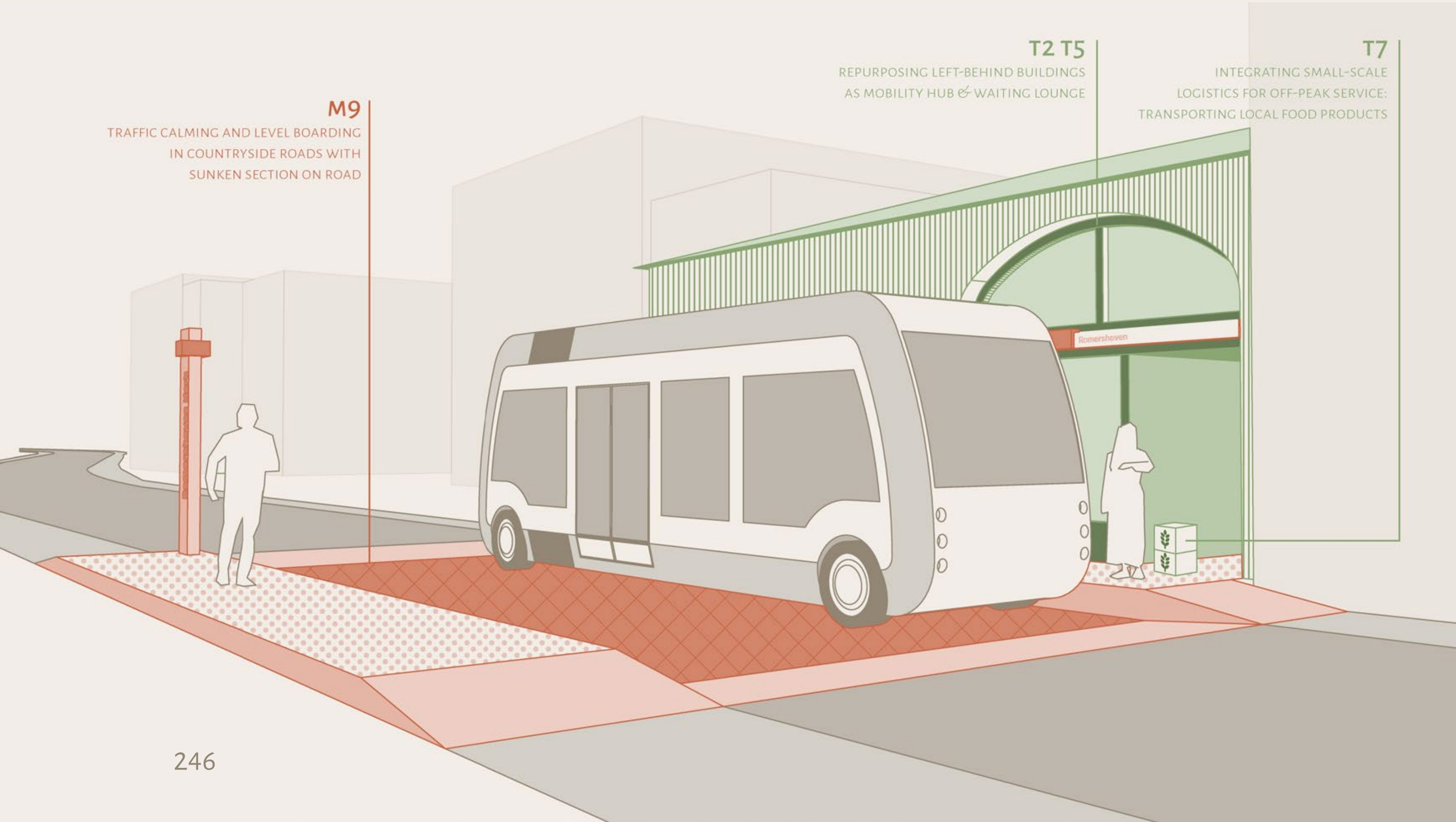


Figure 170. Interior of the building featuring real-time arrival screen and ticket vending machine

transit provision in the countryside where demands are low.

The bus stop should be moved to the place where the hub is located, along with traffic calming measures in the stop (sunken bump). The provision of ticket sales machines and real-time arrival information is therefore crucial.

Figure 171. The patterns applied inside the building

Figure 172. The patterns applied on the backyard of the building

The backyards of left-behind buildings could be sold or rented to nearby residents for a small amount of money, where they can cultivate the vacant land. This is particularly helpful for those who wish to stay in the countryside even after the neighbourhood is emptied out; just as the original ideas behind the Nebular city have intended, the hybrid of urban and agricultural lifestyle can be re-introduced for those who stay in the countryside. The area can gradually transform into its ideal form as a sparsely populated agricultural field.

9.5.5 ASSESSMENT FRAMEWORK

Figure 173. Assessment Framework

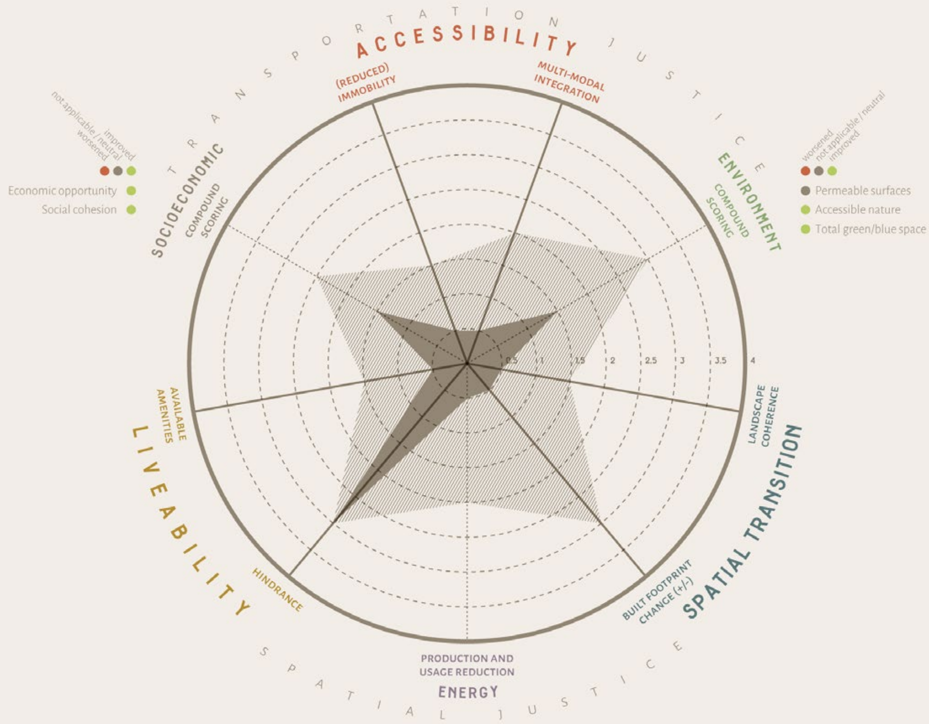


Table 23. Design's effect on the problem fields

As the patterns were primarily intended to improve spatial transition, it has been well-achieved in that regards. Moreover, through the provision of repurposed mobility hub, the amenities and multi-modal integration is also significantly improved.

Spatial dispersion and spatial transition	The urban design and the proposed line provides does not directly provide positive effects on the spatial transition, as its purpose is to remedy the impacts on the existing residents. However, the message from not leaving the residents behind and ensuring service for those in countryside regardless would provide legitimacy for the institutions in spatial transition (Rocco et al., 2021).
Deindustrialisation & Innovation	It was not the aim of both transportation and urban design exercise.
Spartacusplan & Mobility Justice	The urban design exercise sets the area's activity centred around public transportation, facilitating modal shift and improving the financial feasibility. Moreover, the significant improvements in immobility issues in the countryside is also aligned with the principles of mobility justice.

9.5.6 DAY OF LIFE: PERSONA B

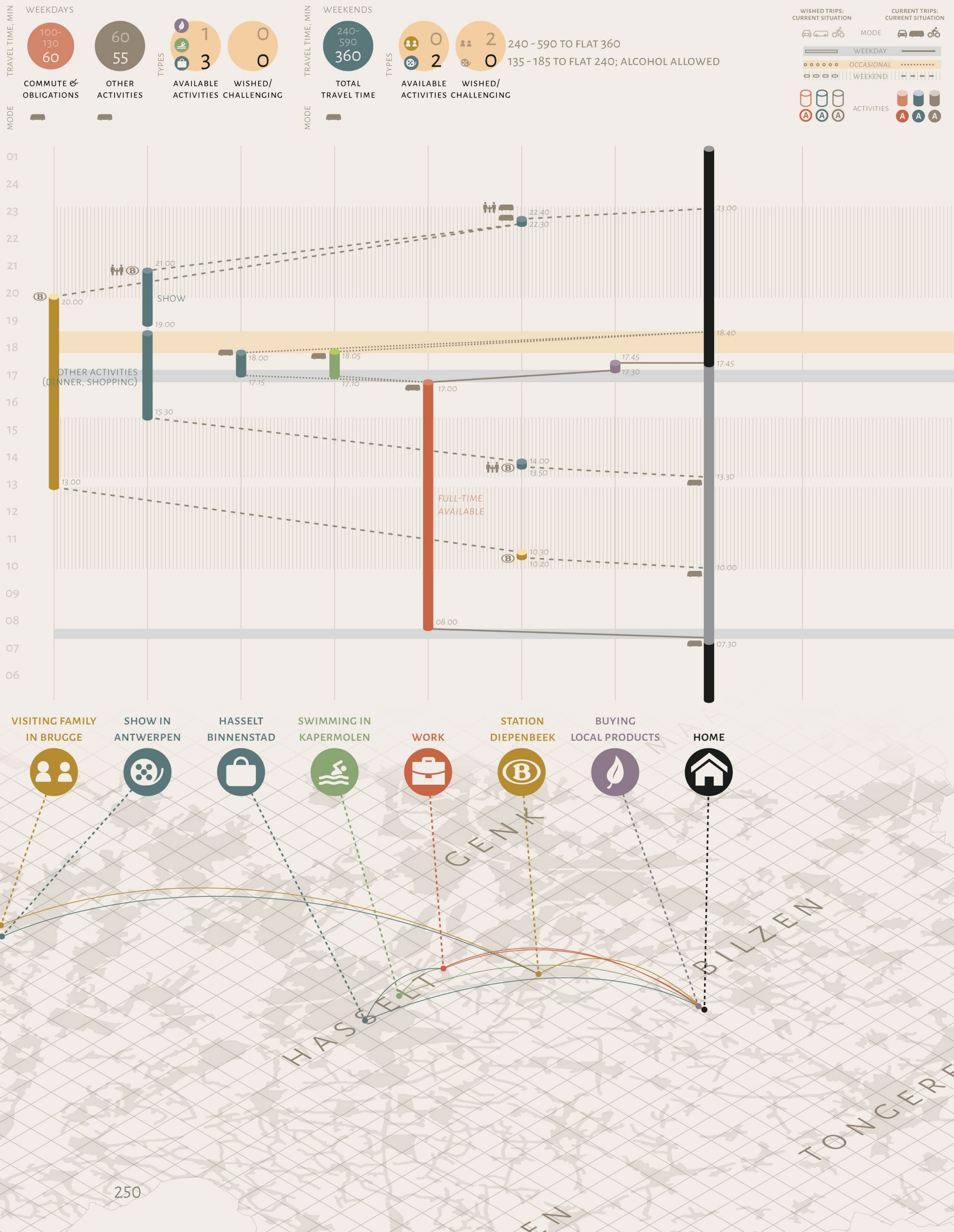


Figure 174. New time-space diagram of Persona B

Table 24. Design's effect on the immobility types

With her kid now being able to take the bus to school in Hasselt easily, she can now work full-time. With the free time she now has instead of driving kids to everywhere, she started swimming in Hasselt Kapermolen. Her occasional journey to her family and friends in Brugge is now much reliable, where previously with car a trip took somewhere between 2 to 3,5 hours, now she can simply take the bus, get to Diepenbeek station and hop on a train to Brugge in Hasselt. As the bus stop and the waiting lounge started to sell fruits and vegetables from local farmers, she enjoys her commute expecting new, fresh produce every day. Sometime during the day, she could see the fruits being transported in the bus with her too.

A. Immobility from spatial remoteness	The improved accessibility allowed the urban design measure (waiting lounge & local food) to be made available, which improved the persona's access to healthy groceries, but also attracted more passenger base into the public transportation system, sustaining the service.
F. Immobility from dependants	The improved accessibility also means her dependants can also move on their own, freeing the persona from time-consuming chauffeur tasks.

9.5.7 DESIGN RECOMMENDATIONS

1. While the previously presented Strengthen-types will work as a magnet for (voluntary) urban islands model, the "transform" strategy is using the **de-densification strategies** through patterns (T1 ~ T6) for mitigating effects of transportation. The primary aim of the design should be therefore **mitigating the issues of vacant structures, immobility, and reducing infrastructural demands.**

2. It is strongly advised to **use only existing structures**. Building new building for the sake of creating mobility hub should not happen, because by nature the intervention is temporary.

3. All material use and urban design decisions must take the **recycling of the materials** into account, as the design may have to be demolished in a few years after the implementation depending on the progress of spatial transition.

4. Connect the potential locations where the countryside residents may find attractive to move, so that the **existing social network would not be broken.** For example, people in Romershoven can be familiar with Diepenbeek or Hoeselt, as it is the place where they rely on daily activities.

N°10

OPERATIONALISING

10.1 OPERATIONAL FRAMEWORK

As the design application and testing are made, and the definitive recommendation for urban designers and transport planners are made, then the concrete pathway to realise it needs to be made. The operational framework clarifies strategies and timelines for implementing the BRT system. This does not only concern simple task division between stakeholders but also integrating residents' knowledge into the planning process of the neighbourhoods and the public transport service. This process is particularly important as it is heavily linked to procedural justice and epistemic justice (Sheller, 2018). On top of this, the project concerns multiple scale levels, from neighbourhood-level interventions to network planning that spans the whole region. Therefore, in this chapter, the strategy for engaging/persuading stakeholders and key stakeholder roles will be discussed, followed by the setup of co-creating workshops across scale levels, and finally, how the process would take place over time, and what can be expected in the future.

10.1.1 STAKEHOLDER STRATEGY

Based on the identified stakeholders and their attitudes in Chapter 5, Murray-Webster and Simon (2007)'s three-dimensional grid mapping power, interest, and attitude is used to visualise how to approach each stakeholder. Murray-Webster and Simon (2007) identify how one should approach the 8 types:

- Saviour: Active backers. They need to be kept on our side at all costs by catering to them.
- Friend: Active backers. If engaged, they can be a great help in the process.
- Saboteur: Active blockers. Has potential to block the project; needs to be engaged in order to make sure they don't block the whole project.
- Irritant: Active blockers. Needs to be engaged to "put them in the box".
- Sleeping Giant: Passive backers. Needs to be engaged to awaken them to become active backers.
- Acquaintance: Passive backers. They should be kept informed about the progress.
- Time Bomb: Passive blockers. Has the potential to block the project; they need to be understood and engaged partly to make sure they don't become saboteurs.
- Trip Wire: Passive blockers. Needs to be understood and avoided conflict with them.

In Limburg's context, the saviours are generally institutional and governmental actors, where better connectivity benefits all stakeholders. The friends are civil society and public transportation users. In this case, while the standpoint of treintrambus and the general public was not positive to trambus in general, the research assumes that the dispersed BRT plan may prove different, given the fact that the dispersed BRT tackles the (speed) issues addressed by treintrambus statement on trambus plan (Meukens, 2022).

The active blockers would be the labour unions, who justifiably fear that the automation will result in the loss of jobs, and countryside residents who would not welcome the long-term shrinkage and restrictions on paving and building activities. The environmental organisations did state against the trambus plan due to its trajectory inside nature protection areas. However, the goals on public transportation are still aligned. Van Hool, the manufacturer of trambus, may hold negative views on abandoning the trambus plan, as the manufacturer of Trambus themselves.

The federal institutions and municipalities that Spartacuslijn does not directly serve do not have high interest in the project, but will generally welcome the BRT if realised, as they do not also take the financial burden. The car users and the Netherlands (as a nation and a funding entity) are generally uninterested and negative towards the plan, not because of the dispersed BRT itself, but due to the potential financial burden (Netherlands) and potential loss of road space for cars (car users). NMBS and its infrastructural entity Infrabel share a similar position.

Germany and Wallonia are not affected by Spartacusplan and are already well-connected through the rail network. The realisation of Spartacuslijn would mean positive for them, however, they do not have much power nor interest in the plan.

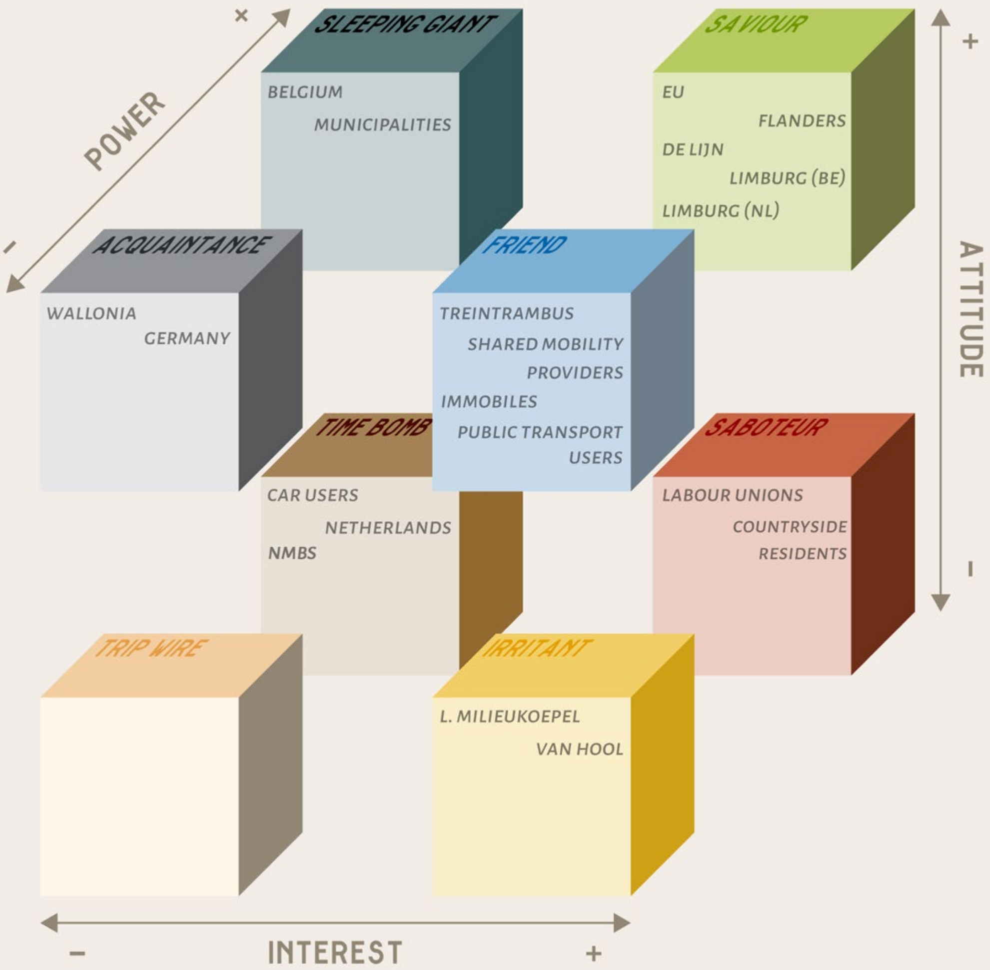


Figure 175. Current positioning of stakeholders

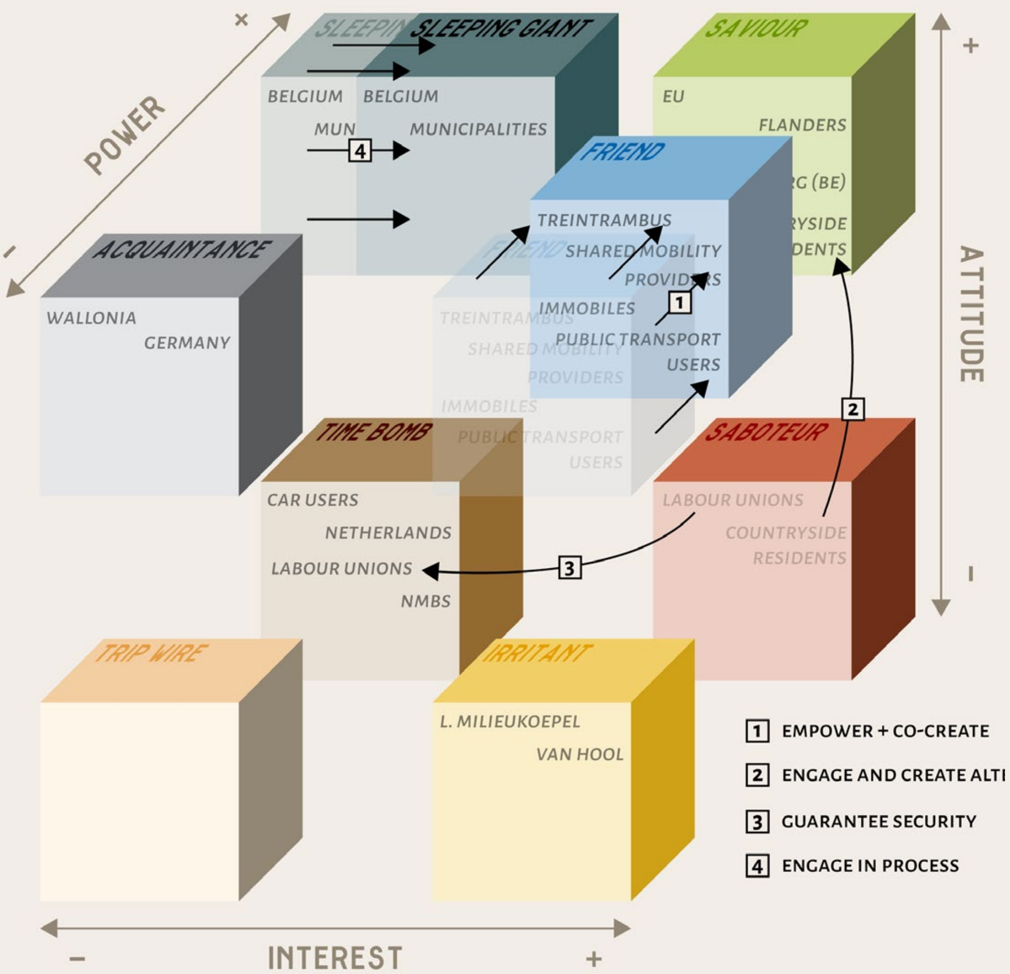


Figure 176. Proposed strategy and the movement of stakeholder positions

The stakeholders and their power, interests, and attitudes are mapped in Figure 175. The friends, saboteurs, and sleeping giants are the key categories that needs to be engaged; therefore, 4 strategies are set.

First, the "friends" of TreinTramBus (travellers group), public transit users, and especially immobile people should be actively engaged to provide them more power in decision-making. However, often public transit users and immobiles do not belong to the same group of people; moreover, clearly defining immobile people would also prove challenging. Given the principles of transportation justice, it should be concluded that the immobiles should be given more weight than existing public transit users. Also, in this context, a group that does not always have access to cars and lives in areas that are not currently well-served by current public transit network, or the service pattern does not match with their own, should be considered as "immobiles".

Second, the Labour unions can be persuaded, as the branch services outside of the corridor still require human drivers; while indeed the personnel hours remain the same as doing nothing (nulscenario) in case of scenario A, adding extra branch services can be discussed.

The people living in the countryside are ultimately the ones holding the key to the spatial transition. While their opinions may be negative towards spatial transition, partly due to stronger regulation on the hardening of their property and the gradual decline of the countryside, it is crucial to engage them in the process of design to understand their wishes and create attractive alternative developments in well-accessible, transit-oriented neighbourhoods. Moreover, the provision of public transportation should be expanded instead of further reducing it for the sake of spatial transition; this is not only in line with the principles of mobility justice, but ultimately, it will also provide legitimacy for the institutions in the spatial transition efforts, which can help the transition further (Rocco et al., 2021). The provision of services should gradually phase out following the vacating of the area.

Third, despite being the potential beneficiaries of the project, some municipalities are relatively less interested in realising Spartacusplan, especially in municipalities that Spartacuslijn does not directly serve. For these municipalities, the potential that branch services can strengthen their accessibility should be well communicated. They play a very crucial role in the core strengthening and densification efforts, therefore they need to be actively promoted to engage in the implementation of spatial interventions and potentially expand BRT right-of-way.

Additionally, NMBS (and its infrastructural entity Infrabel) require different approach. They have been criticised for years for neglecting Limburg's rail network, especially regarding reviving the disused railways like line 20 Hasselt – Maastricht (Thuwis, 2020; Van Diepen, 2021). The decision to permanently close down railway line 20 is one of the key reasons why the role of inter-city network is suddenly dumped onto regional level (Spartacusplan), which is limited to the capabilities of De Lijn (bus and tram), and it still makes it isolated from the broader national rail network . Although their position puts them into the "time bomb" category, it is necessary not to rule out the efforts to persuade NMBS and Infrabel regarding the possibility of re-opening the railways. In such case, Spartacuslijn 1 would be then replaced with railway line 20, and also Spartacuslijn 2 and 3 would perform supplementary intra-provincial transportation for the parallel rail connection.

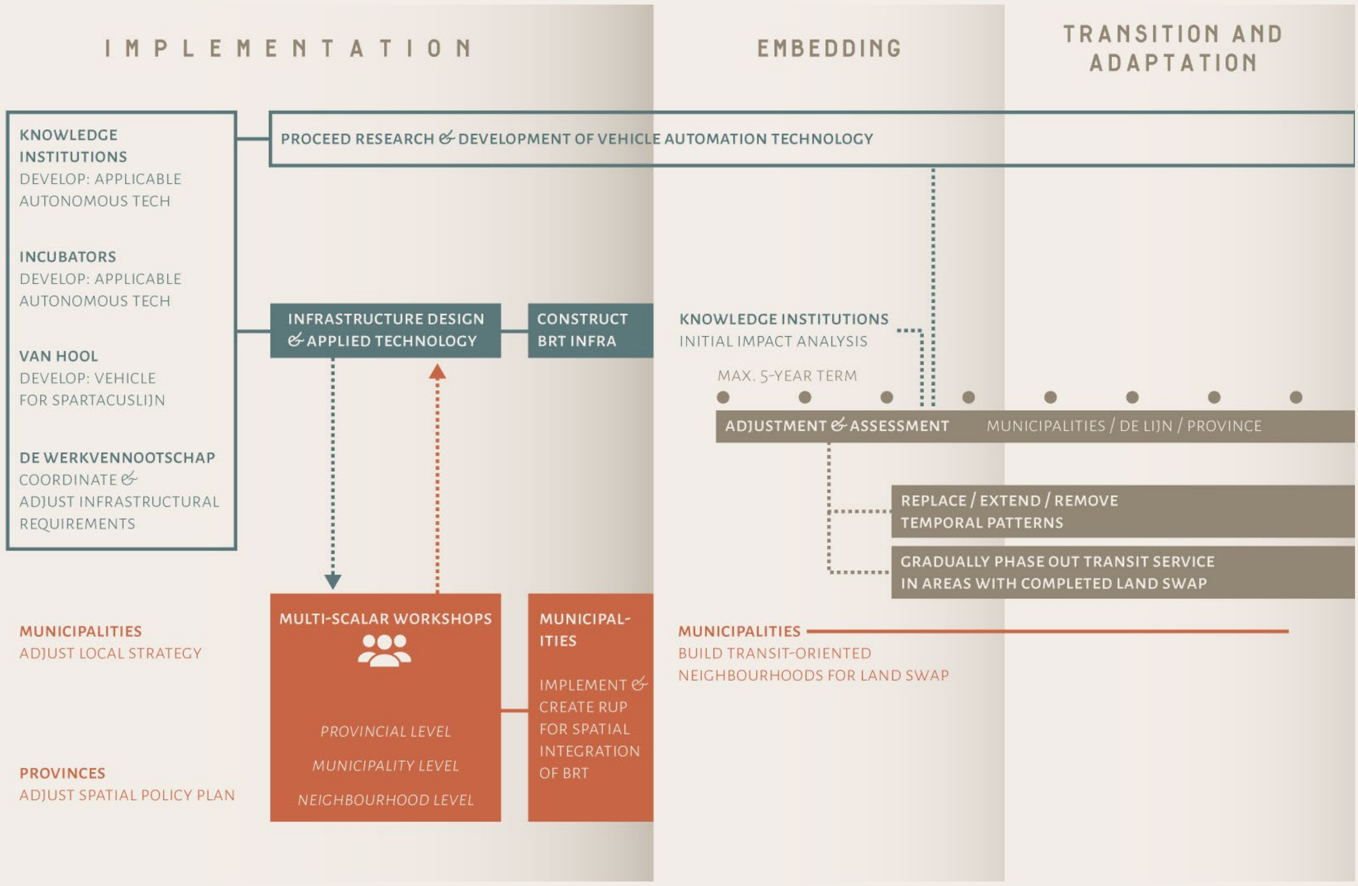
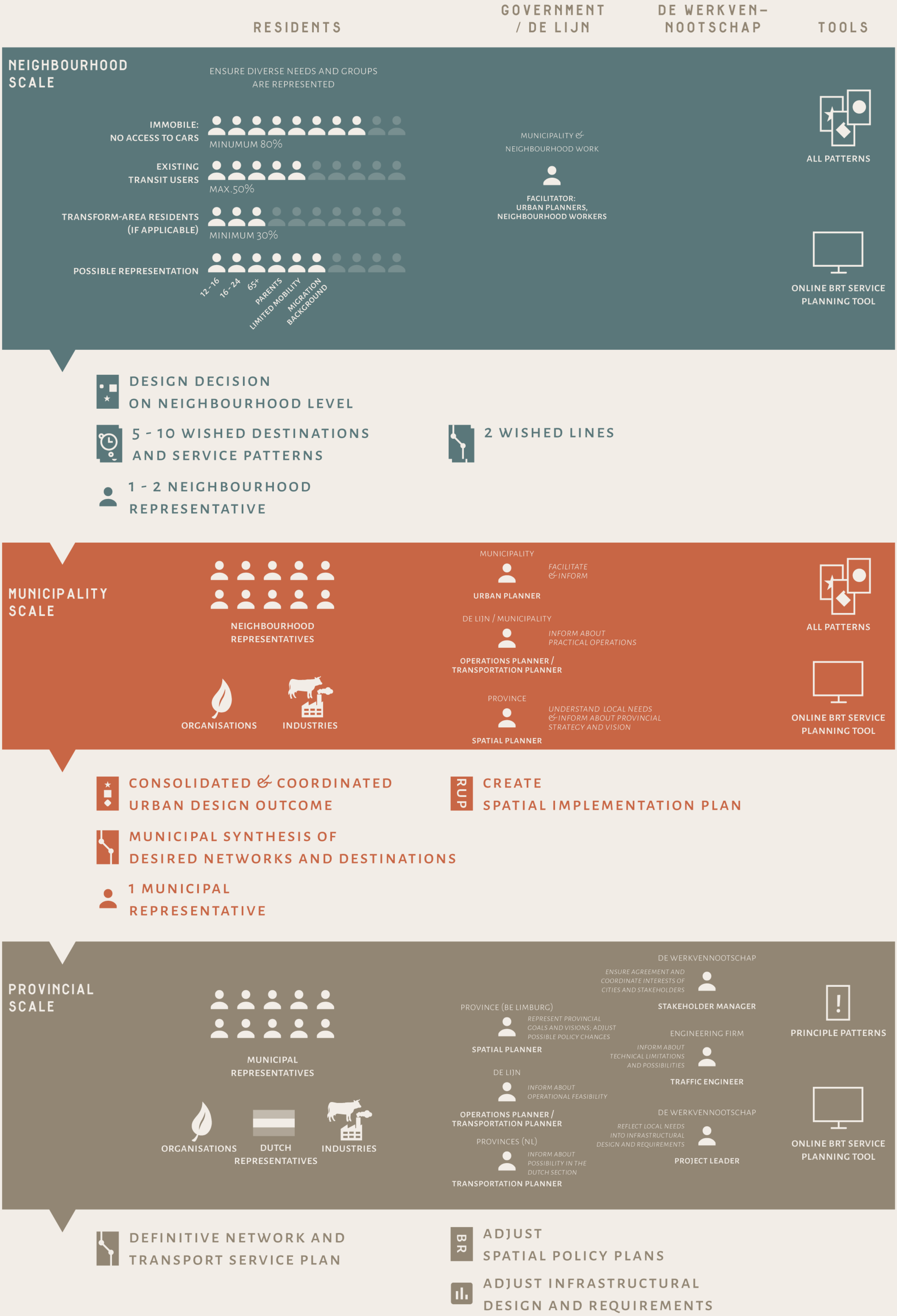


Figure 177. Stakeholder role setting

Until the implementation in 2030, the knowledge institutions, incubators, Van Hool, and De Werkvennootschap will work together to develop/apply a feasible level of vehicle automation technology for Spartacuslijn, design tailor-made vehicles, and adjust the technical specifications of the BRT right-of-way. By the time the infrastructural design and the technology that will be applied are made apparent, the multi-scalar workshops spanning the urban design of neighbourhoods and decisions to the regional network of transit services will be conducted across Limburg, which will provide feedback on the infrastructure design and potentially make adjustments to it. This is already possible in the existing operational framework of De Werkvennootschap, which specifically concerns complex infrastructure projects.

After the BRT infrastructure is realised and the branch services are all went into operation, the impact of the service in the immobility, spatial transition (land swap), and the performance metrics of the designed network would be assessed and adjusted every few years. This can be combined with the regional mobility plan of Vervoerregio Limburg. Based on the assessment, the temporal patterns applied can be decided to be replaced, extended its use, or removed; for example, a neighbourhood mobility hub in an abandoned plot in a small ribbon development can be completely replaced into a 1-euro farm when can be ended for its use and turned back into nature if the area is thinned out enough.


RESIDENTS
GOVERNMENT / DE LIJN
DE WERKVEN-NOOTSCHAP
TOOLS
NEIGHBOURHOOD SCALE
ENSURE DIVERSE NEEDS AND GROUPS ARE REPRESENTED
IMMOBILE: NO ACCESS TO CARS
MINUMUM 80%
EXISTING TRANSIT USERS
MAX.50%
TRANSFORM-AREA RESIDENTS (IF APPLICABLE)
MINIMUM 30%
POSSIBLE REPRESENTATION
12-16
16-24
65+
PARENTS
LIMITED MOBILITY
MIGRATION BACKGROUND
MUNICIPALITY & NEIGHBOURHOOD WORK
FACILITATOR: URBAN PLANNERS, NEIGHBOURHOOD WORKERS
ALL PATTERNS
ONLINE BRT SERVICE PLANNING TOOL
DESIGN DECISION ON NEIGHBOURHOOD LEVEL
5 - 10 WISHED DESTINATIONS AND SERVICE PATTERNS
2 WISHED LINES
1 - 2 NEIGHBOURHOOD REPRESENTATIVE
MUNICIPALITY SCALE
NEIGHBOURHOOD REPRESENTATIVES
ORGANISATIONS
INDUSTRIES
MUNICIPALITY
FACILITATE & INFORM
URBAN PLANNER
DE LIJN / MUNICIPALITY
INFORM ABOUT PRACTICAL OPERATIONS
OPERATIONS PLANNER / TRANSPORTATION PLANNER
PROVINCE
UNDERSTAND LOCAL NEEDS & INFORM ABOUT PROVINCIAL STRATEGY AND VISION
SPATIAL PLANNER
ALL PATTERNS
ONLINE BRT SERVICE PLANNING TOOL
CONSOLIDATED & COORDINATED URBAN DESIGN OUTCOME
RUP
CREATE SPATIAL IMPLEMENTATION PLAN
MUNICIPAL SYNTHESIS OF DESIRED NETWORKS AND DESTINATIONS
1 MUNICIPAL REPRESENTATIVE
PROVINCIAL SCALE
MUNICIPAL REPRESENTATIVES
ORGANISATIONS
DUTCH REPRESENTATIVES
INDUSTRIES
DE WERKVENNOOTSCHAP
ENSURE AGREEMENT AND COORDINATE INTERESTS OF CITIES AND STAKEHOLDERS
STAKEHOLDER MANAGER
PROVINCE (BE LIMBURG)
REPRESENT PROVINCIAL GOALS AND VISIONS; ADJUST POSSIBLE POLICY CHANGES
SPATIAL PLANNER
ENGINEERING FIRM
INFORM ABOUT TECHNICAL LIMITATIONS AND POSSIBILITIES
TRAFFIC ENGINEER
DE LIJN
INFORM ABOUT OPERATIONAL FEASIBILITY
OPERATIONS PLANNER / TRANSPORTATION PLANNER
DE WERKVENNOOTSCHAP
REFLECT LOCAL NEEDS INTO INFRASTRUCTURAL DESIGN AND REQUIREMENTS
PROJECT LEADER
PROVINCES (NL)
INFORM ABOUT POSSIBILITY IN THE DUTCH SECTION
TRANSPORTATION PLANNER
PRINCIPLE PATTERNS
ONLINE BRT SERVICE PLANNING TOOL
DEFINITIVE NETWORK AND TRANSPORT SERVICE PLAN
BR
ADJUST SPATIAL POLICY PLANS
ADJUST INFRASTRUCTURAL DESIGN AND REQUIREMENTS

10.1.2 WORKSHOP STRATEGY

Figure 178. Multi-scalar workshop strategy

The implementation of multi-scalar workshops is designed to help incorporate the needs, context, and capacities of different scale levels into a coherent process.

The workshop starts with neighbourhood-scale workshops facilitated by the municipal planner or the neighbourhood workers. The participants should be selected in order to represent and incorporate diverse desires and groups. The immobile groups are prioritised – 8 out of 10 participants should be experiencing immobility, as defined in the previous section. Existing transit users are also limited to 50% of the participants. In neighbourhoods that are classified as "Strengthen: Housing" or "Strengthen: Transit" areas, the residents from nearby countryside should be involved in the design of the infill developments and densification, with at least 30% of the participants. This ensures their desires are reflected in the urban design, resulting in an area that can attract countryside residents. In the neighbourhood-level workshops, decisions on small-scale urban design interventions are made using the patterns, along with each neighbourhood's demands on 5 – 10 wished destinations and service patterns, such as serving the sports centre or extending the service to certain hours. Based on it, two lines would be designed to show the perspective of the neighbourhood in the municipal scale workshop. They would select 1 ~ 2 representatives for the workshop on a municipal scale.

In the municipal scale workshop, the spatial intervention plans from different neighbourhoods will be incorporated into a coordinated plan that the municipality will implement in preparation for the dispersed BRT. For example, if too many neighbourhoods have opted for a certain pattern, then the issue of oversupply or conflicts will be handled in the workshop by the conversation between neighbourhood representatives. In the workshop, the civil society organisations such as neighbourhood groups, TreinTramBus or environmental organisations can participate, and the local industries will also be invited for their input. Representatives from De Lijn and Provincie Limburg will also participate in informing the participants about the practical operations and limitations of the plan and how coherent the plans are with the province's goals and visions. Through this workshop, a definitive set of the desired network of the municipality will be created, and the incorporated design decisions will be translated into the Spatial Implementation Plan of the municipality (Ruimtelijke uitvoeringsplan - RUP). A municipal representative can be chosen for the provincial workshop.

In the provincial scale workshop, representatives from De Werkvennootschap will participate in informing about the technical limitations and capabilities of autonomous BRT, and the Dutch Limburg will also be providing input for the network design and their perspective on the application. In the provincial workshop, the network ideas from the municipalities will be incorporated into a coherent network that will be implemented by the time of the commencement of service.

10.2 TIMELINES

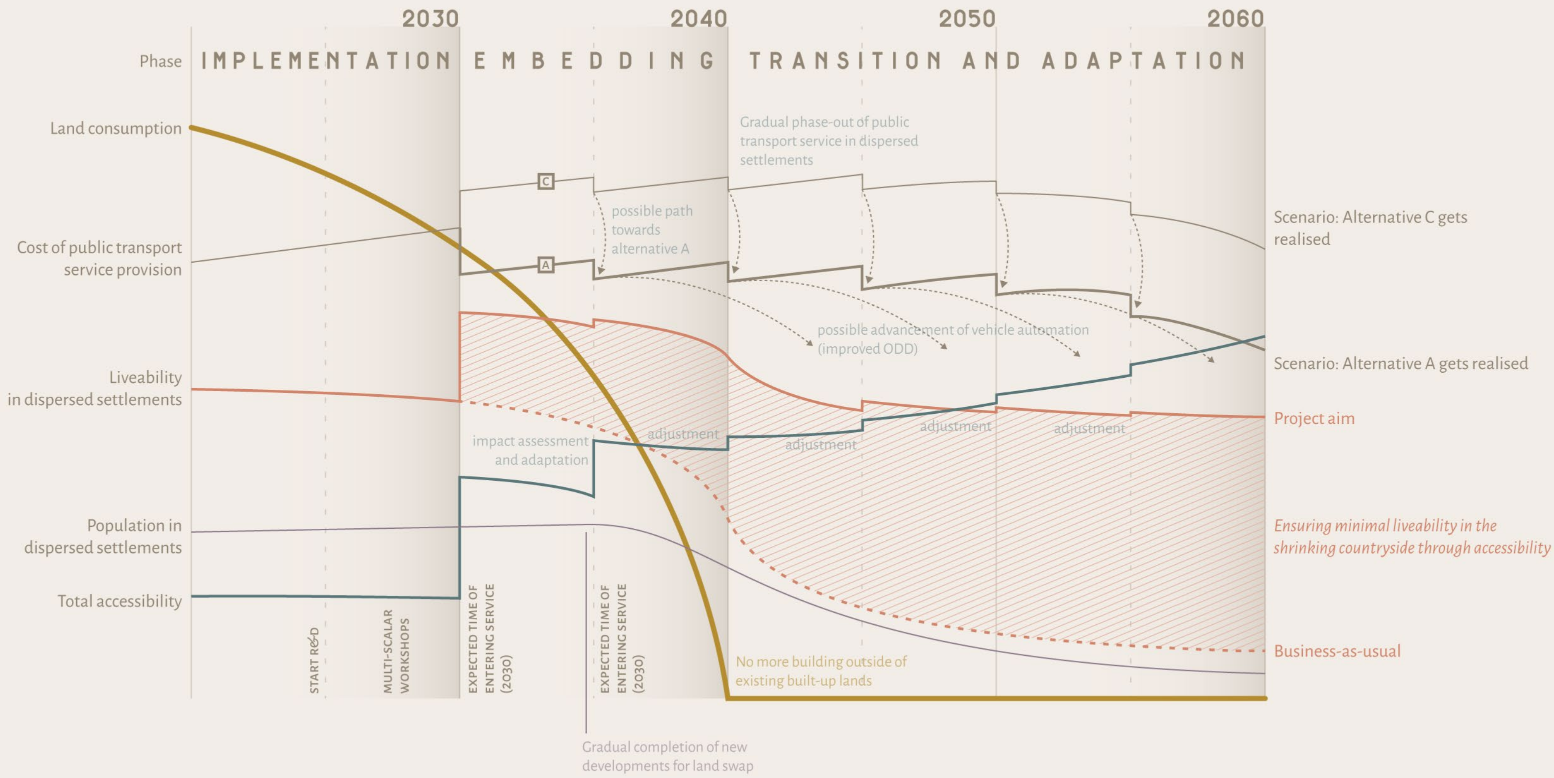


Figure 179. Spatial transition timeline until 2060 and its related metrics

The spatial transition will be facilitated by creating new developments in areas defined in the Spatial framework, such as Strengthen: Housing and Strengthen: Transit areas (after the provision of branch services), to offer alternatives to the countryside residents. In the meantime, in the countryside, the declining liveability due to the shrinking population will be compensated by the urban design measures of dedensification (Transform patterns) along with the provision of a minimum level of accessibility. Based on the personnel costs calculated in Chapter 5, if the alternative C is realised instead of A, the operating costs of public transport service will rise; but as the land swap proceeds and the ribbon development thins back into nature, the transit service in the area can be gradually pulled, resulting in the lowered operating costs in the long-term (see Chapter 6.5). The operating costs can also be lowered through the advancements in vehicle automation, increasing the ODD outside of the corridor, however, this is not something that can be guaranteed – thus, it is not sensible to rely on it, but it can be kept as a possible trajectory.

In conclusion, the application of driving automation technology can facilitate spatial transition and ensure liveability for the population in the countryside while keeping the cost of service provision stable, and gradually lowered in the long term.

N°11

CONCLUSION

The objective of the thesis was to create a strategy with both urban and transportation planning to help spatial transition efforts with the realisation of three Spartacuslijnen, with different network formations. For this, four sub-questions were formulated. The sub-questions will be answered, and then the main research question will be answered.

HOW THE "JUST" MOBILITY TRANSITION SHOULD BE, AND HOW CAN IT BE APPROACHED IN THE CONTEXT OF TRANSFORMING THE FLEMISH NEBULAR CITY?

While the core principle of transportation justice would be to distribute the benefits (accessibility) equally by focusing on those who are less served than others (Martens 2016), the just mobility transition should also consider further layers of justice. First, it should engage the diverse identities and groups of people in the process of planning, especially those who were traditionally excluded in the planning process. It should also acknowledge the marginalisation and exclusion that happened, and actively make efforts to restore the damages. Justice does not concern the aspect of transportation alone, thus, diverse aspects of justice, such as environmental, racial, gender, and climate justice, should also be taken into account.

In the context of Flemish Nebular City, the currently proposed Spartacusplan was unfortunately exclusive for those living in mainly already well-served, already high-density areas, partly owing to the difficulties providing transportation service in the unique urban fabric of Flanders. Combined with the compact city ideal posed in the Belgian countryside, the focus of investments turned further into the dense urban areas, while leaving more than a quarter of the population behind, where the youth, elderly, disabled, women, and less affluent citizens are then left immobile. While the costs of spatial dispersion are indeed immense, reflecting back to the long history of the government facilitating the spatial dispersion in Belgium, "punishing" them by depriving accessibility should not be a policy tool for spatial transition.

Instead, the aspect of justice can also play a crucial role in the spatial transition in Belgian Limburg, by legitimising the institutions involved in the spatial transition. Given that addressing the existing dispersion relies heavily on voluntary measures, the positive image from the residents can accelerate the spatial transition efforts.

WHAT KIND OF IMMOBILITY IS PRESENT IN BELGIAN LIMBURG?

The immobility in Limburg is multi-dimensional. The person's immobility can depend on one or multiple factors: spatial remoteness, social exclusion and discrimination, poverty, access to cars, national borders, poly-centricity of the area, or family composition. From the provider's perspective, service provision in remote areas away from major transportation corridors is critical.

In terms of demographic groups, the youth, women, and second-sector workers with lower socioeconomic status are especially affected by immobility in Limburg. The lack of public transportation outside of large cities often means the youth being dependent on their parents for all movements, a burden that is still disproportionately burdening women more than men. This results in the limitation of career and economic opportunities for women. The second sector (logistics and manufacturing) workers often work in shifts, which makes the limited operating hours in public transport in Limburg (07 - 20) a disproportionate obstacle for them.

WHAT WILL BE THE IDEAL FORMULA OF TRANSPORT TECHNOLOGIES AND BRT ELEMENTS THAT CAN BE APPLIED IN LIMBURG?

Based on multiple criteria (operating costs, spatial integration, environmental impacts, and accessibility), the multi-criteria analysis was conducted to understand the trade-off between infrastructural investments and flexible costs to the benefits of accessibility through potential branch services. It was concluded that the application of level 4 autonomous driving inside the BRT right-of-way with smaller vehicles was the most suited option among all, despite larger infrastructural fail-safe systems such as signalled intersections, barriers, and possible grade separation.

HOW CAN NEW PUBLIC TRANSPORT INFRASTRUCTURE BE INTEGRATED INTO DIFFERENT SPATIAL SCALE LEVELS AND TIMEFRAMES?

The infrastructure can be integrated by means of co-creation with the residents and other stakeholders. This is facilitated by the patterns created in Chapter 7. The pattern language also allows the generalised urban design measures to be adapted per local contexts and desires in each location. Along with the urban design measures, the public transportation service can also be planned similar way. For the planning of public transportation service, the online tool was created in Chapter 8 to support the co-creation process.

The design exercise has shown that the design patterns have sufficiently addressed the intended purpose. The coordinated approach by designing both public transportation services and have also generated synergetic results in the majority of aspects. The urban designers and transportation planners can follow the proposed design recommendations in Chapter 9 to further integrate the design into the neighbourhood.

As the project involves across scales, from neighbourhood scale interventions to regional network design, the project proposes three different levels of workshops for the urban design of neighbourhood interventions and planning for public transportation networks. The capacity of the public is improved through the use of pattern languages and digital tools for service planning. The neighbourhood-scale interventions and desired bus routes are decided in the neighbourhood-level workshops, which then the interventions between different neighbourhoods are coordinated, and the desired routes are made into a synthesised set of alternatives in the municipal scale workshop. It is important to involve diverse identities and groups are included in the process, of which at least 80% should be allocated to those experiencing immobility.

HOW CAN INNOVATIVE TRANSPORTATION TECHNOLOGIES HELP IMPLEMENT AN EQUITABLE AND SUSTAINABLE TRANSPORT NETWORK SUITED FOR BELGIAN LIMBURG THAT CAN CATALYSE THE SPATIAL TRANSITION?

In accordance with Wegener (2004), accessibility plays a crucial role in initiating a chain reaction of attractiveness, investment, and construction. To replicate this cycle of accessibility, attractiveness, and investment, different approaches should be implemented depending on the spatial types identified within the spatial framework. Simultaneously, efforts should be made to maintain accessibility and attractiveness at a minimum level. Given that recent policies have successfully ensured the latter, it is now possible to shift the focus towards the former.

Consequently, it is essential to facilitate the creation of well-connected and appealing development areas around less-developed locations and livable cores. Active promotion of land swaps from dispersed settlements into these areas should also be undertaken. Through design exercises and spatial categorization, specific locations have been identified as having the potential for implementing such developments. Some areas are readily available for development without requiring additional accessibility measures (Strengthen: Housing), and some have the potential to spark the accessibility-attractiveness-investment cycle if provided with improved accessibility.

This is where innovative transportation technology comes into play. While implementing a dispersed BRT network is financially unfeasible in high-income countries like Belgium, the use of driving automation can reduce the operating costs of buses within the

Spartacuslijn corridors. These corridors serve as major travel routes, merging a significant portion of travel demand. By reducing operating costs, extra financial capacity is created for De Lijn to operate branch services diverging from the Spartacuslijn corridors into dispersed settlements and cores. This enables a flexible supply of accessibility beyond the immediate surroundings of the Spartacuslijn corridor.

Meanwhile, the Belgian countryside exhibits a strong sedentarist culture. Its residents have deep attachments to the places they grew up in and predominantly prefer free-standing, single-family houses. As measures to address spatial dispersion are primarily voluntary, this demographic group holds the key to the spatial transition. Moving to dense, urban neighbourhoods is not a viable option for them.

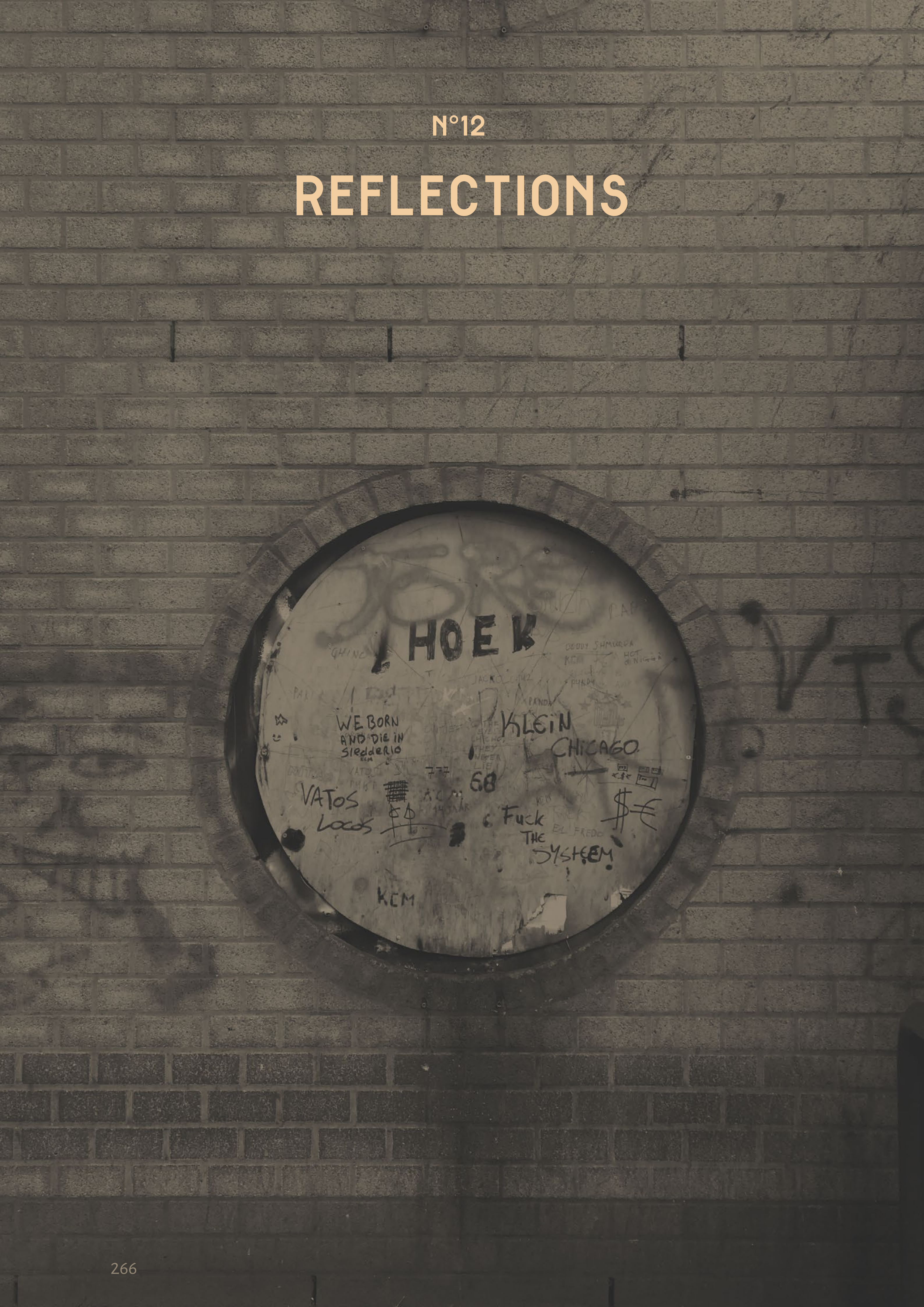
The dispersed BRT, enabled by automation, can bridge the gap between the countryside and dense urban neighbourhoods by providing services to small cores (Strengthen: Transit) in rural areas. Consequently, instead of concentrating on supplying dense urban properties, alternative developments can be created in small towns across the province, which the countryside residents are already familiar with and do not need to disconnect from their local networks. The lack of nodality in these areas can be supplemented by the branch services of Spartacuslijn, offering frequent single-seat rides from each small town to Hasselt station. These services utilize smaller vehicles and operate without drivers within the Spartacuslijn right-of-way, with human drivers only operating them for a few kilometres between the Spartacuslijn station and the dispersed towns.

This strategy can also alleviate the need to create freestanding houses to attract countryside residents to high-nodality city centres. Gradually, the ideal “urban islands” model can be achieved without resorting to unjust, forced measures of disinvestment. Urban designers can contribute to this process by preparing towns and cities for the arrival of Spartacuslijn and mitigating the negative effects of spatial transition in the countryside through de-densification measures. By avoiding a disinvestment path, it is also possible to address issues of immobility in rural areas using the same transportation service provision method, ensuring a minimum level of accessibility for all residents, albeit less frequent for Transform: Nature areas.

Overall, by approaching spatial transition through a combination of urban planning and transportation planning, and incorporating achievable levels of driving automation, a synergistic strategy for spatial transition in Belgian Limburg has been developed.

N°12

REFLECTIONS



RELATIONSHIP BETWEEN PROJECT, STUDIO AND URBANISM TRACK

Urbanism has been, and will remain, an interdisciplinary field; the (part of the) key role of urbanists is to facilitate conversation between different stakeholders and experts in different fields, and to consolidate it into a tangible form of design interventions. While during the course of the project, there were some moments in the early phase where the project's balance was slightly too weighted on the technical side, eventually, it found its balance and consolidated everything into thesis. The core of the project remains the spatial transition of Belgian Limburg – which then the transportation planning is integrated into the many approaches towards it.

The City of the Future studio was the obvious choice for me: I had a deep interest in the disciplinary relation between urbanism and civil engineering, and my topic centred around applying vehicle automation was highly aligned with the studio's topic.

RELATIONSHIP BETWEEN RESEARCH, PLANNING, AND DESIGN WITHIN THE PROJECT

The analysis of immobility, both qualitative and quantitative, forms a target group that the project should aim to prioritise. The understanding of their travel pattern, destinations, and activities helped identify not only the public transport service planning principles but also the integration through spatial integration patterns.

The project is heavily data-driven: each part of the major decision made in the project was aimed to be supported with relevant data as much as possible, where the status of spatial dispersion, liveability, demographic, and built environment is divided into hectare-level and core-level data. This provided a strong basis and framework for the design, and ultimately resulted in a different pathway through the creation of a spatial framework that categorises the potential and future interventions for the region.

The pattern language used in the project also benefited from it, as it strengthened and firmly defined what should be aimed for each category of pattern. The application of patterns has aimed to create a testing situation where all possible patterns are applied as much as possible on the one hand, but also in order to simulate the integration of public knowledge into the design through extensive context analysis and site visits.

METHODOLOGY

In the analysis phase, the analysis on immobility was originally fully quantitative: I build a macroscopic traffic model that would clarify the demand potential in each route, which then the "ideal" network could be built upon it. It was (at least I thought) the most rational and convincing approach at the time. However, in the early phase, when deepening my understanding of the two key theories of the project – Mobility Justice by Sheller (2018) and Transportation Justice by Martens (2016) – the approach that I came up with was far too utilitarian, which is the approach that is almost in direct conflict with mobility justice altogether. That approach also lacked the crucial aspect of the project, which are the recognition, understanding, and engaging the disadvantaged people and the integration of their knowledge. Therefore I added the layer of qualitative analysis on it, and put accessibility as the centrepiece of transportation planning, focusing on the actual problem of immobility and also integrating the experiences of the citizens into the technical layers.
Ultimately the choice of using the macroscopic traffic model was also pulled, as after creating the O/D matrix, it was apparent that it was far, far away from reality and unrealistic to use it in the project. That is no surprise, considering it was a very simple 4-step travel model. It would have been ideal if I had access to the existing traffic model, however, that is unfortunately limited in the master thesis level that is not funded by Flemish government. But now reflecting back on it, given the theoretical underpinnings and the aim of the research – the demand potential wouldn't have been really relevant in the end, because what matters eventually is how immobile conditions are solved, and their demands and desire to travel is addressed, not how many people would use the service regardless of the immobility, nor how profitable it would be to operate the service.

The premise part of the thesis, where I decide upon which technology would be the ideal fit for Limburg. Given the trade-off between infrastructure investments and their values, it is done using Multi-Criteria Analysis (MCA). This is ideal as the construction of busway infrastructure was already decided, so in my purpose, which is to assess the difference between automation technologies with the trade-off between additional infrastructural investments versus the benefits, the MCA was a much more suited method instead of cost-benefit analysis. This was also echoed from the mobility justice point of view, as the utilitarian cost-benefit analysis is far from the ideal method to address immobility and injustice in the process.
The most crucial criterion of the MCA was again the location-based accessibility measure with edited GTFS data based on hypothetical routes and service patterns. This is logical, as the major difference would in the end, come from the added accessibility in the dispersed countryside served by the dispersed BRT. However, since the testing requires fine-tuning the service pattern of every route and adjusting timetables for every single trip in the whole area, the timeframe and the geographic area of the testing have been greatly reduced to only 1,5 hours in the morning rush hour, affecting few key routes. Although it can still reasonably represent the effects of dispersed BRT to a certain level, it cannot represent the whole effects throughout the day, across the whole region. Since the whole graduation project has been fairly time-strapped, especially given the time spent dealing with unexpected dependency issues in the Python package (UrbanAccess) for accessibility analysis, the creation of full-scale testing data was unfortunately not possible. Given this limitation, the decision to limit the testing timeframe in my opinion has been an acceptable trade-off at MSc level.
Using hectare-level data in a tangible spatial framework with each own vision, approach, and interventions was surprisingly effective; thanks to the widely available hectare-level data in Flanders, I was able to create a good mix of detail that goes into the hectare level, while keeping general coherence in the bigger scale that allows application in the neighbourhood scale. However. The synthesising of such detailed scale of data had a risk of resulting in an incoherent set of blocks that twitches between neighbouring hectare blocks, rendering the application in neighbourhood scale useless; thankfully, by linking both rather gradient data (knooppuntwaarde) with sharper accessibility data together in the threshold, it resulted in an ideal level of detail I originally desired.
The use of pattern language was not only intended to facilitate stakeholder capacity for participation but also to standardise and generalise its use across the province: in other words, it is a means to combine neighbourhood-level interventions into the broader implementation of a regional transportation network. During the process, what actually proved useful was the combination of spatial framework types into patterns, in contrast to the usual theme-based classification. The spatial framework provided a clear pathway for which patterns to focus on, which patterns to apply, and what to achieve from this. On the other hand, allocating which patterns are applicable means that the absolute number of patterns applicable in each type are fairly limited; at the lowest Fourteen patterns for socioeconomic challenges (10 mobility patterns + 4 type-specific patterns). This may suggest that simply providing design guidelines and possible vision per type instead of creating patterns may have also been a possibility; nevertheless, I think it was the right decision to use pattern language, as it still provides room for adaptability in each neighbourhood's case whether the pattern can be applied or not – or whether the people would want it or not. Not to mention the uniform implementation of local level intervention throughout the provincial scale.

SOCIETAL RELEVANCE

The mobility transition, and in the Belgian context, the spatial transition, is undoubtedly one of the most urgent transitions ongoing in Belgium for decades. Facilitating and guiding the two ongoing transitions, and also implementing it in a 'just' direction would also be a key component of sustainability as it provides institutions legitimacy in their efforts, as Rocco (2021) noted in "A Manifesto for the Just City".
The creation of a synthesis approach using public transportation planning with its technical specifications, and innovative technologies adjusted for the spatial goals also offers great synergy in its application. Often, the application of transportation in spatial

planning has been at a surface level, as the tool for a goal: providing connectivity from A to B, based on the existing expectations and assumptions of each transportation mode. The research offers a new approach that develops a new transport mode specifically designed for the spatial configuration and challenges.

SCIENTIFIC RELEVANCE

In 2023, arguably the "cool-down" period of autonomous vehicles, the existing research, policy suggestions, and guidelines that assumed the widespread adoption of autonomous vehicles in all ODDs or on public roads are in need of re-assessment on its premise. Therefore, my research takes an alternative approach that focuses on reducing ODD and implementing creating societal values through the service configurations and addressing the spatial goals present in the region.

The project also puts the relatively recent concept of mobility justice by Mimi Sheller (2018) into spatial and transportation planning practice, of which its underpinnings are translated into patterns and principles with the urban planning method of the pattern language. The principles of patterns developed in the project, the spatial framework, and the strategy on implementation can form a basis for future design research that wishes to further utilise this in the design.

TRANSFERABILITY

Apart from the deindustrialisation context specific to Limburg, the thesis is designed to be applied in the whole Flanders and Belgian context in general; the "Nevelstad"; a quintessentially Flemish phenomenon, is what the whole design and research approach is designed to cater to. Both the pattern language and spatial framework are highly generalised, with all data available on a Flemish scale, even sharing the same theoretical underpinnings on urban fabric (De Meulder et al., 1999).

The technology choice, on the other hand, may not be completely transferable in other parts of the country, as it is specifically designed and tested for the Spartacuslijn context. However, given that Limburg suffers relatively less from ribbon developments and spatial dispersion than in the Vlaamse Ruit, there is a possibility that the suitability of semi-automated dispersed BRT could be actually higher in other regions.

Outside of Flanders, the absence of important context and goals – such as betonstop/bouwshift – means the transferability outside of Flanders would be limited. However, in such cases, the concept of applying vehicle automation technologies in enclosed infrastructure and using human drivers outside of the dedicated infrastructure may be useful for similarly dispersed regions that also seeks suitable transport mode for their region.

However, if combined with the measures to limit development in the countryside, the whole "formula" of applying the patterns proposed in the project with the proposed level of semi-autonomous BRT can be a good stop-gap for dispersed areas, where transportation solution that can assist the rather immediate mobility transition and spatial transition at once, without depriving access in dispersed areas.

ETHICAL CONSIDERATIONS

In the survey, I was very careful in collecting personal information, so I tried to collect as little information as possible: addresses were not collected and replaced with embedded ArcGIS story map with classifications of town centres, city centres, and countryside, and sensitive demographical data such as gender, migration background, and income level was not collected, and "would prefer not to answer (Zeg ik liever niet)" option was offered in the family formation question. However, further ethnographic research turned out that gender, religion, and migration origin could have played a significant role in immobility, therefore, the decision not to collect the information is rather regrettable. Moreover, the omittance of gender and migration background would eventually reduce the understanding of the immobility linked to such characteristics. These are substituted with fieldwork and street interviews in Sledderlo, but whether they can represent the whole migrants in Limburg remains a question.

Although geographically Limburg lies relatively close to Delft and I was fairly familiar with the Belgian context, being able to access there on public transportation was another challenge; therefore, the number of visits was relatively limited (7 days in total), and the other variables that have influenced the observations are not weeded out, such as the weather conditions and days of the week. Therefore the emptiness of the public space and abundance of “small encounters” in public space may have been specific to the timespan I was there.

In the fieldwork, I was also not completely fluent in Dutch at the moment (B1-B2) to conduct interviews, so the interviewees likely adjusted their level of expression when talking to me, and also possibly did not disclose actual opinions on their actual feelings regarding the public space towards me given my ethnicity.

INTERDISCIPLINARITY

Bridging disciplines, especially the technical, has always been my interest. That was the reason why I chose to graduate from the City of the Future studio in the first place. Unfortunately, the gap between urban planning and transportation engineering is bigger in the Netherlands. Compared to Belgium, where transportation’s role in addressing the challenges in the built environment is actively researched, in the Netherlands, it sometimes feels like such field between transportation and built environment has somehow completely evaporated. Each field instead grew into a separate, specialised field of its own, with the goals and aims of the fields also parting their ways.

Although the thesis takes place in Belgian Limburg, due to the interesting challenges surrounding Spartacusplan, I still wonder how my thesis would have looked like if it was taken place in the Dutch context; the spatial transition goals in the Netherlands involving the unique landscape of Dutch deltas, the Port of Rotterdam, and its (sinking) peat landscape would have provided interesting and completely different challenges.

Working between urban design, spatial planning, and transportation planning, I believe integrating all the different perspectives and inputs into a tangible output has been a great opportunity to develop my skills in synthesising different fields, and eventually finding my niche in the broader field. And I believe that is ultimately what urbanists are supposed to be: a bridge connecting fields, and a blender that can make good smoothies out of apples and oranges.

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APPENDIX

JR WEST MI-NNA, JAPAN

MI-NNA (Mobility Innovation - Next Networked Action; backronym of the Japanese word みんな, meaning "everyone") is a project by West Japan Railway Company (JR West) and the Japanese telecommunication company SoftBank. The project aims to realise autonomous platooning autonomous BRT in relation to the regional development goals and the personnel shortages due to ageing population (森山, 2021). The project will allow door-to-door connectivity outside of the main corridors by using smaller vehicles that can join the platoon inside the BRT corridor, while also significantly reducing personnel costs by only having drivers in the first vehicle of the platoon (Ibid.). They plan to reduce technical obstacles by limiting its automation ODD to controlled environment, which is the dedicated BRT busway (SoftBank, 2020; 坂本, 2022). The project started in April 2020, and has built a testing track which is put to use since October 2021. The project timeline expects it to be finalised in mid-2020s.

Figure 180. Test ride of MI-NNA, 坂本貴史, https://response.jp/article/2022/11/21/364371.html

The project uses 3 different vehicle sizes, all retrofitted from existing vehicles. The small vehicle uses 6-metre Hino Poncho, the medium and articulated vehicles also uses off-the-shelf 11 and 18 metre buses (坂本, 2022; 森山, 2021). The testing track located in Yasu city, Shiga Prefecture, features markers for checking the location in severe weather conditions. The vehicles can follow each other with 10 to 20 metre distance, and can stop in 1 ~ 3 metre from each other (直樹, 2022).

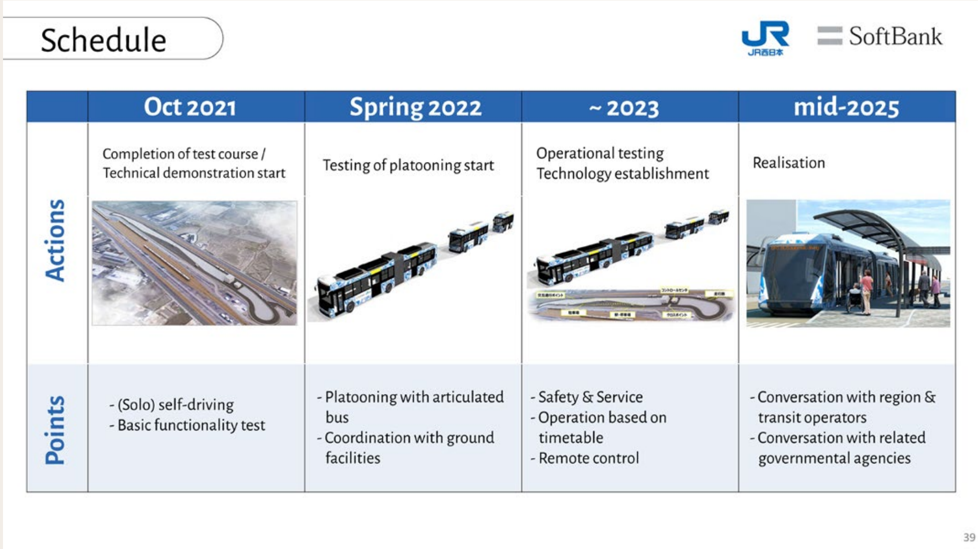

Figure 181. Roadmap of MI-NNA project, translated from Japanes. Soucre: SoftBank

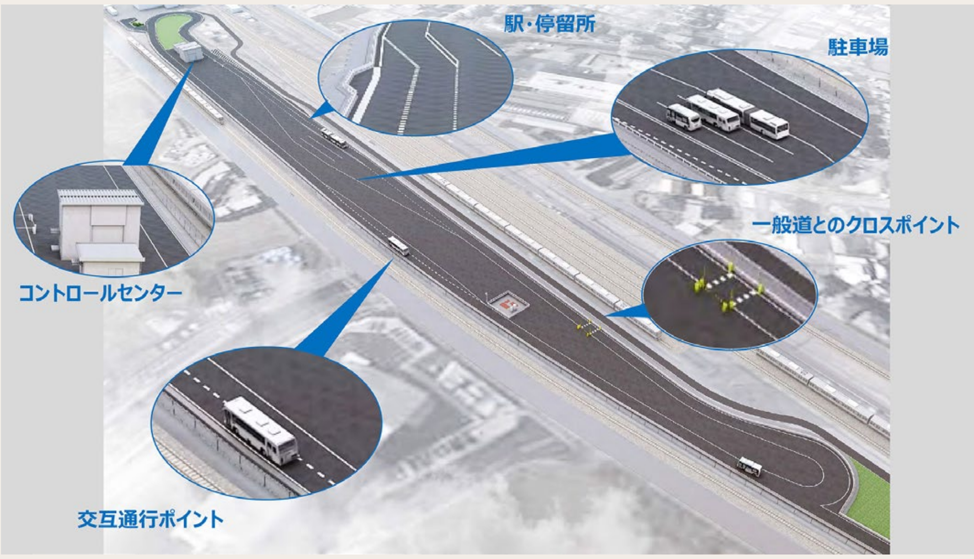

Figure 182. Specification of the testing track, from the top right to clockwise – statios; depot; crossing with road; single-track crossing point; control centre, 森山 (2021)

The 1,1 kilometre-long testing track built for testing features elements such as control centre, stops, level crossing with existing roads, crossing on single-track sections, and depot. When realised, the project will replace less used railways by replacing tracks with busways; but JR West says that it is not limited to railways, and can be applied everywhere regardless of the existing context (直樹, 2022). In line with the timeline, as of 2023, it is decided to apply the technology in Higashi-Hiroshima's BRT project, where dedicated bus infrastructure will be built on the existing 4-lane boulevard between Saijo Station and Hiroshima University (日川, 2022).

CAVFORTH, UK

CAVForth is a pilot project that had its first passenger service in January 2023. It provides level 4 autonomous bus service between Fife and Edinburgh on the speed of 50 mph (80 km/h) (CAVForth, n.d.; Crow, 2023; Russell, 2022). The ODD is limited to pre-selected route, where the "digital twin" of the route and surroundings have been created to test the possible scenarios. It uses an off-the-shelf Alexander Dennis Enviro 200 with length of 11 metres. CAVForth retrofitted the bus with sensors including radars, LIDARs, and cameras. The current ODD includes motorways, A-roads, minor roads, bus lanes, roundabouts, junctions and traffic lights (CAVForth, n.d.).

Figure 183. CAVForth vehicle, CAVForth (2021) https://www.cavforth.com/first-glimpse-of-uks-first-av-level-4-full-sized-autonomous-bus-service/

As of 2023, it is currently in revenue service, operating in a pre-determined mixed traffic environment by local bus operator Stagecoach, with onboard "safety driver" monitoring technology and "bus captains" to inform and re-assure passengers (Crow, 2023; Halford, 2023). The service is designated as route AB1, and officially launched on 11 May. This makes AB1 the first registered bus service in the world that uses a full-sized autonomous bus (Halford, 2023). The route consists of motorways and several roundabouts, however, the route mainly consists of segregated rural roads with minimal foot traffic, thus its applicability in truly urban environments are yet unknown.

HITACHI BRT, JAPAN

Figure 184. Crossing with existing roads equipped with barriers, Michinori Holdings (2021)

Hitachi BRT is a single-track busway built upon a rural railway line in Hitachi City, Ibaraki Prefecture, Japan. Hitach BRT's autonomous vehicle project (2018) came years after the opening of the BRT, with parts of the section running on mixed traffic. This required the ODD to expand to non-dedicated roads; but unlike CAVForth, Hitachi BRT supplements the BRT in mixed traffic by installing roadside sensors. Every intersection with BRT is equipped with barriers, but unlike MI-NNA, the barriers are installed facing the ROW instead of the road. Most of the crossings with existing roads are also not signalled.

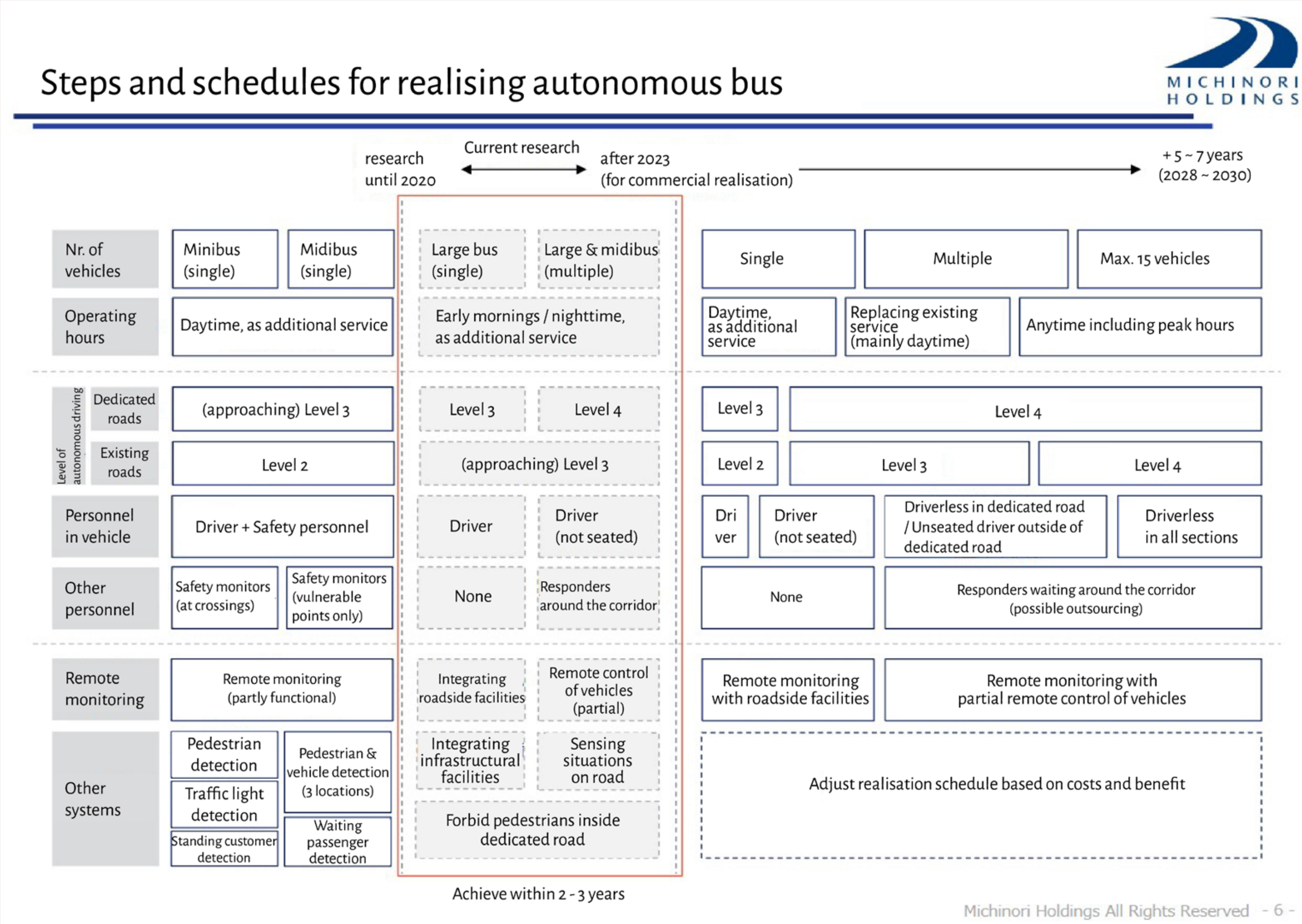

Figure 185. Roadmap of Hitachi BRT's implementation (translated from Japanese), Michinori Holdings (2021)

As of 2023, Hitachi BRT's autonomous bus service is undergoing free passenger service with pre-booked passengers. It is expected to realise full level 4 operation on all sections, including mixed traffic sections until 2030. The roadmap includes responders to be added along the corridor.

SEJONG BRT, SOUTH KOREA

Sejong BRT is a case where infrastructure is entirely designed along with the city's development, in this case, a new administrative capital (i.e. Den Haag, Bonn) of 500.000 residents. However, the introduction of autonomous buses was not considered in the design itself, as the plan came before the introduction of autonomous vehicles (배 et al., 2008). Nevertheless, due to this origin, the infrastructure level is fairly high, with maximum scores on dedicated busways and busway alignment on ITDP BRT Standards (ITDP, 2023). It consists of a motorway section with a max speed of 80 km/h, and the rest consists of a dedicated ROW in a 4-lane urban boulevard with a max speed of 50 km/h. The ROW is completely dedicated for BRT, with physical barriers for horizontal separation, and dedicated underpasses and overpasses where major intersections with crossing traffic exceed 1.000 per hour. All intersections with the ROW is signalled.

The system is currently on revenue service with level 3 operation since 2023 (최, 2022), of which drivers are still present on the vehicle. When the bus enters mixed traffic around the end of the line, human drivers take over the driving tasks.

The characteristics of the reference cases are listed back in the main text, on Table 5.