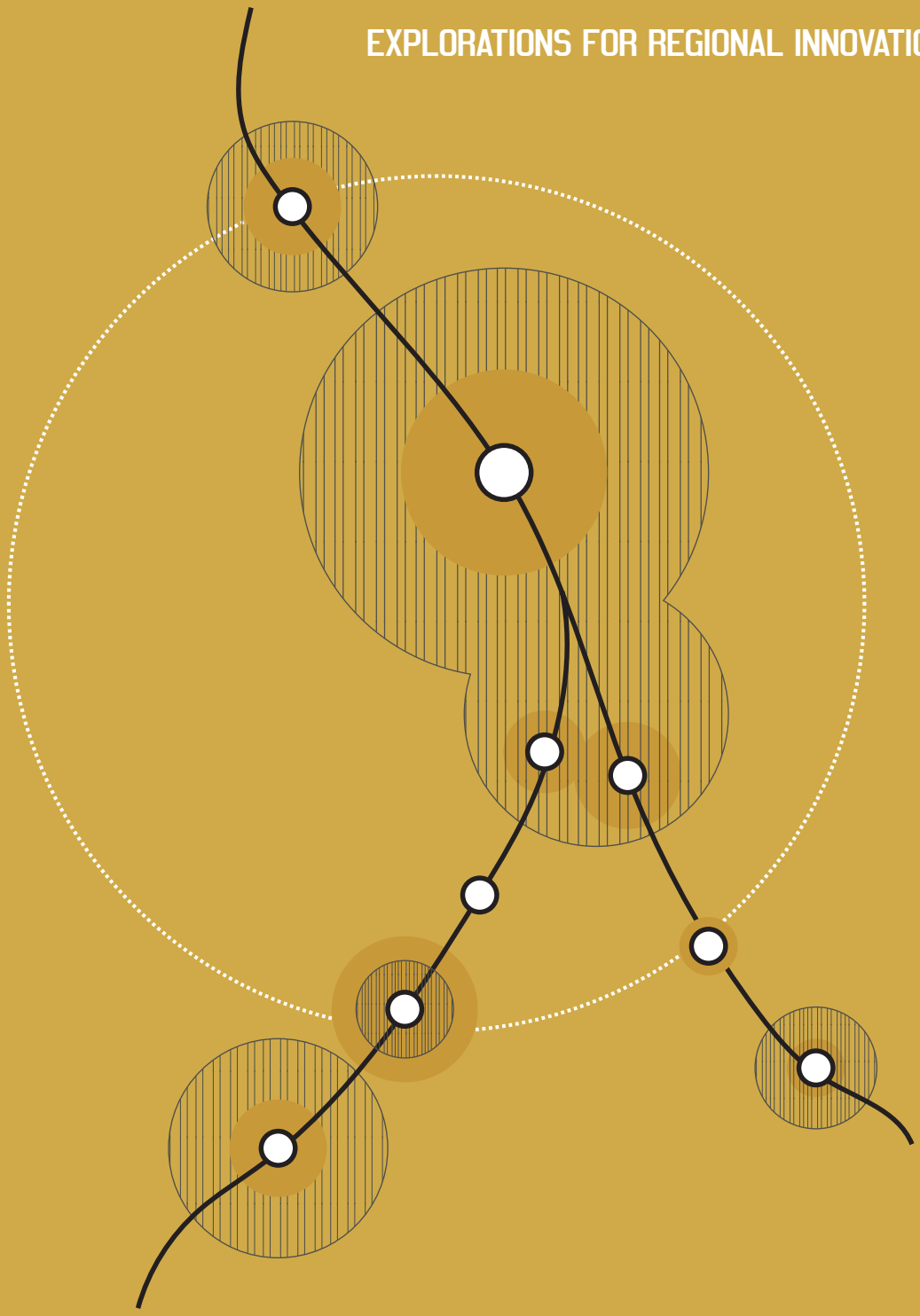
REDEFINING RESOURCE MANAGEMENT IN A FAST GROWING URBAN SETTING

EXPLORATIONS FOR REGIONAL INNOVATION IN LUXEMBOURG



Colophon

Title:
Redefining resource management in a fast growing urban setting
- Explorations for regional innovation in Luxembourg -

Graduation thesis

MSc Architecture, Urbanism and Building Sciences
Urbanism track

Vera Nimax

4631803

Keywords:
regional strategy, resource efficiency, spatial justice, transit-oriented development

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* all visual representations have been created by the author unless stated otherwise

Abstract

Despite its small size Luxembourg has made a name for itself, even on a global level. This has to do with the importance of its financial centre, and, above all, with the country's morally questionable tax principles. Which makes Luxembourg hit the headlines regularly.
Renowned for its growing economy, stable political situation and a general high standard of living, to many Luxembourg might seem to be the ideal country. This is also reflected by Luxembourg's continuous and rapid population growth, caused almost exclusively by immigration. In addition, massive commuter flows, and the related rising resource consumption cause major problems in the national territory (e.g. traffic jams, air pollution, excessive resource consumption). Due to these challenging conditions and the specific geography, Luxembourg constitutes an exceptional case study.

In search of innovative solutions, this design and research project shows the possibilities for resource efficient planning by exploring the concept of transit-oriented development.
With my thesis, I aim to analyse how resource efficiency can be achieved on a regional scale through important changes in current spatial development strategies. And thus, turn Luxembourg into 'smart Luxembourg', a productive economic space, an ecologically sustainable society and a role model in resource management for other European countries. In particular, Luxembourg's spatial configuration and its population adaptability can be advantageous in the process of becoming a laboratory for regional innovation.

Acknowledgements

To my mentors
Huge thanks to my mentors Dominic and Alex!
I would like to thank you for your constant support over the past year, for encouraging and inspiring me, and above all for your patience. It was, without doubt, a challenging year.

To my fellow students and friends in Delft
Thank you all for a great time, for your support, for your help, for your friendship.

To my interviewees
I would also like to thank the experts who were involved in my interviews. Thank you for sharing your knowledge with me and helping me to gain a better understanding of the ongoing challenges.

Un meng Elteren a meng Geschwëster
Merci Mama, Papa, Ralph a Julie! Ech sinn iech immens dankbar dass dir mir dat alles erméiglecht hutt, hannert mir stoungt a mech ëmmer an allem ënnerstëtzt hutt.

Un mäin Frënd
Villmools Merci Philippe fir deng léif Ënnerstëtzung iwwert déi lescht Méint, dass du ëmmer een oppent Ouer fir mech has an ech dech ëmmer em Rot froe konnt.

Un meng gutt Frënn a Frëndinnen
Merci dass dir déi lescht Jore mat mir matgeféiwert hutt, fir äert Daumen drécken an är immens Ënnerstëtzung trotz Distanz.

Ech widmen meng Thees menger léiwer Bomi.
Merci, dass du ëmmer un mech gegleeft hues!

Vocabulary used

Transit-oriented development
Transit Oriented Development is the exciting fast growing trend in creating vibrant, livable, sustainable communities. Also known as TOD, it's the creation of compact, walkable, pedestrian-oriented, mixed-use communities centered around high quality train systems.
(Definition from http://www.tod.org)

Resource efficiency
Resource efficiency means using the Earth's limited resources in a sustainable manner while minimising impacts on the environment. It allows us to create more with less and to deliver greater value with less input.
(Definition from http://ec.europa.eu/environment/resource_efficiency/index_en.htm)

Spatial justice
Spatial (in)justice refers to the spatial and geographical aspects of justice and injustice. This involves for example the fair and equitable distribution in space of socially valued resources and the opportunities to use them.
(Definition from Soja, E.W. (2009). The city and spatial justice.)

Circular economy
In a circular economy, the value of products and materials is maintained for as long as possible. A circular economy encourages sustainability and competitiveness in the long term. It can also help to preserve resources, including some which are increasingly scarce.
(Definition from https://ec.europa.eu/growth/industry/sustainability/circular-economy_en)

Catchment zone/Transit zone
In general, a catchment area for public transport can be defined as the vicinity of a stop or station of a public transport line. In this thesis, this term refers to the 800 meter radius around a train station.

Level of urbanity
Within this thesis, the level of urbanity is determined by the chart from http://www.andrewwrightassociates.com/docs/content.php?id=4:0:42 adapted to the Luxembourgish context. The chart gives indications about existing and missing functions and shows opportunities for increasing urbanity within the respective area.

CONTENT

1

Problem definition

The following chapter provides a detailed introduction to the challenges that Luxembourg is currently facing, explains the location of interest as well as the country's position in the global economic network, and lays out the problem field in its entire complexity.

Currently, still limited by numerous out-dated regulations and systems, new environmental, economic, social and political developments have challenged these urban systems, forcing Europe to rethink strategies and policies for the future. And with its new strategy focused on driving the third industrial revolution, Europe is reinforcing its commitment to becoming a smart, sustainable and inclusive economy. (Singh, 2016)

The main driving force behind these developments is the economy. The entropic bill for the first and second industrial revolution has arrived; resource shortage and environmental pollution are the sad result of the open and linear oriented global economy. But also, the social behaviour plays an important role in the on-going trends. In particular, housing preferences, commuting behaviour, and the related energy consumption have serious side effects, threatening the environment.

The evidence for climate change is compelling, the term sustainability is currently extremely fashionable and on everyone's lips, and day-to-day you will inevitably be confronted with the concepts of circular and shared economy. Although, the majority seems to try to find equitable and innovative solutions for the on-going crisis, what is demanded now is a fast and thought-out action plan. To attain progress as quickly and as reliably as possible, a restructuring of the governmental strategy has to be implemented. A change in the economic model implies a change in the way development takes place, because every development is driven by an economic factor.

In 2016, the American economist Jeremy Rifkin has presented a roadmap for the "Third Industrial Revolution" for Luxembourg.

The Grand-Duchy of Luxembourg is located in the western part of the Eurpoean territory.

Image from http://tripmeter.me/europe-map-outline.html/free-printable-maps-of-europe-with-map-outline

The Grand-Duchy of Luxembourg, Wallonia (Belgium), Lorraine (France), Rhineland-Palatinate and Saarland (Germany) form together the Greater Region.

Own drawing

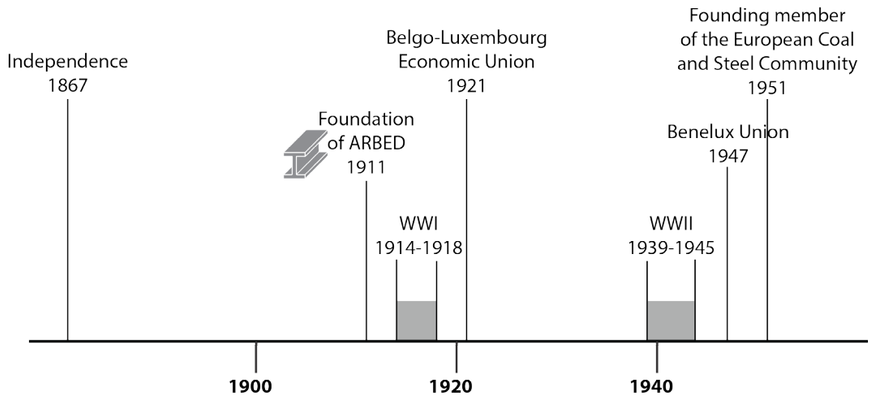
Location of interest

The Grand Duchy of Luxembourg, located in the centre of Europe.

Well known as one of Europe's main financial centres, Luxembourg's current socio-economic model is driven by extensive growth. At the moment still blessed with a formidable economic climate and resilience in public finances, the national economy is strongly affected by uncertainty within the global economic outlook. But Luxembourg is known as a country that constantly rein-vents itself to adapt to the future outlook.
The success of the financial centre is founded on the social and political stability of the Grand Duchy and on a modern legal and regulatory framework that is continuously updated.

But Luxembourg was not always that powerful in the financial sector, on century ago, Luxembourg was proud of the presence of a powerful steel industry that had its golden years in the mid-20th century. The early days of industry in Luxembourg, dating back to the middle of the 19th century, were dominated by steel production. Luxembourg owes its wealth largely to the discovery of iron ore in the south at the end of the 19th century, which gave rise to a powerful steel industry. However, following the steel crisis of the 1970s, the iron and steel industry was no longer the driving force of the Luxembourg economy.
Another important element of Luxembourg's economic success story is its particular territorial configuration and its membership of the European Union (founding member), which allows Luxembourg to maintain important economic and social relations with their neighbouring countries. This largely benefits the country. One example would be, attracting qualified foreign labour force, as it is not available in sufficient quantities within the country. The strategic location in the centre of Europe and the moderate size of the Grand Duchy form the optimal basis for cross-border commuting on a daily basis. Another example is the establishment of several European institutions within Luxembourg.

Between 2011 and 2015 Luxembourg's population has grown by 9,88%. For comparison: The population of the metropolis of London has only increased by 5,73% in the same time period.



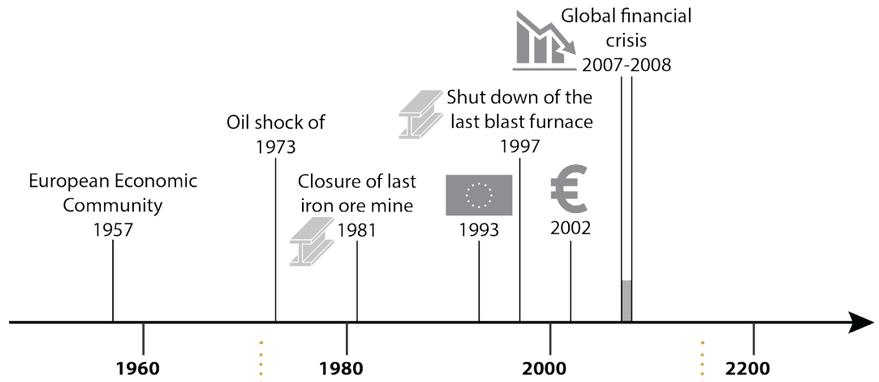
Historical development

After Luxembourg gained independence in 1867, the national steel industry quickly developed and helped the country to achieve wealth and power.
During the heyday of the steel industry, the Luxembourgish mining areas, which were mainly located in the south of the country, operated in close cooperation with the steel industries of Belgium, France and Germany. All together contributed greatly to the wealth of the Greater Region.

But since the decline of the steel industry in the 1970s, the economic structure of the Greater Region has changed significantly. Today, Luxembourg City is the most important economic centre of the region and generates the highest revenues in the Greater Region. Even though, the many cross-border workers from Belgium, France and Germany benefit from this in the form of higher salaries, their home countries do not see any economic advantages.

Luxembourg's territorial loss over time.

Image from http://www.luxembourg.public.lu/pictures/photos/cartes-du-luxembourg/09-cartes-historiques/carte-demembrement-FR.png



Historical events that shaped the development of Luxembourg.

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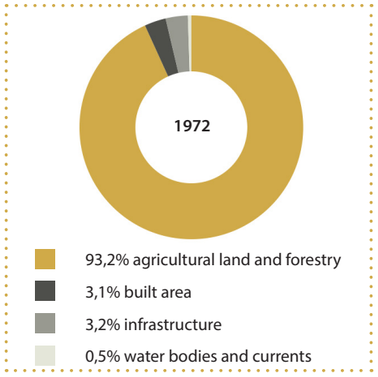

Land use in Luxembourg in 1972 (in %).
Until then Luxembourg was still a leading steel supplier.

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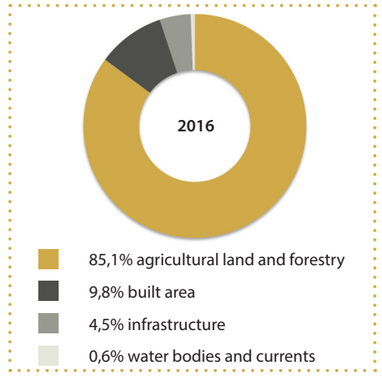


Land use in Luxembourg in 2016 (in %).
Becoming a global financial centre had a considerable impact on the land use.

Own drawing

Luxembourg was ranked 14th most powerful financial centre in the world and 3rd most powerful in the European Union in 2017.

Luxembourg also holds the 2nd largest investment fund centre in the world, after the US.

In the global context

At a global level, Luxembourg is unknown to many. It should, however, not be. Despite its size, the Grand Duchy is ranked 14th most powerful financial centre in the world (business insider, 2017) and the second largest investment fund centre in the world after the United States. (luxembourgforfinance.com) The country enjoys exemplary economic, social and fiscal stability, making it one of the rare countries in the world with an AAA rating (e.g. exceptional degree of creditworthiness) from every major ratings agency.

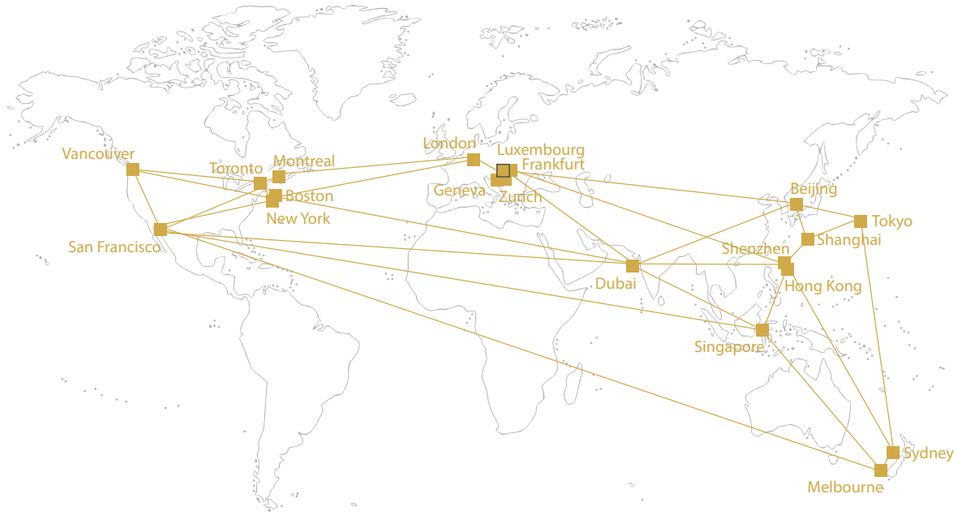
With an investment fund distribution market covering over 70 countries worldwide, the Grand Duchy also plays a crucial role by attracting international investors to Europe. (Luxembourg.public.lu)

Before becoming a global financial centre, Luxembourg was a leading supplier of steel. The previous leading position in the steel industry is today characterised by the headquarter location of several world leaders within the Grand Duchy: ArcelorMittal, leader in the worldwide steel production; Aperam, world leader in the stainless steel production; and Paul Wurth, one of the world leaders in the design and implementation of mechanical equipment and systems and methods for blast furnaces. (Luxembourg.public.lu)

In the European context

Nestled between France, Belgium and Germany, Luxembourg has been involved in the great European developments. Having been one of the founding members of Benelux in 1944, of the UN in 1945, of NATO in 1948 and of the Council of Europe in 1948, Luxembourg became one of the six founding members of the European Coal and Steel Community (ECSC), which would itself evolve to become the European Union we know today. Today, along with Brussels and Strasbourg, Luxembourg City is still one of the EU's capitals: it is home to services of the European Commission and European Parliament, while the European Court of Justice, the European Court of Auditors, and the European Investment Bank, among others, have their headquarters there. Furthermore, the Luxembourgish politician and former Prime Minister Jean-Claude Juncker is the President of the European Commission since 2014.

On the economic level, Luxembourg is the premier captive reinsurance market in the European Union and the premier private banking centre in the Eurozone and is currently ranked the 4th most powerful financial centre in Europe. (business insider, 2017)



Luxembourg's position in the global financial network

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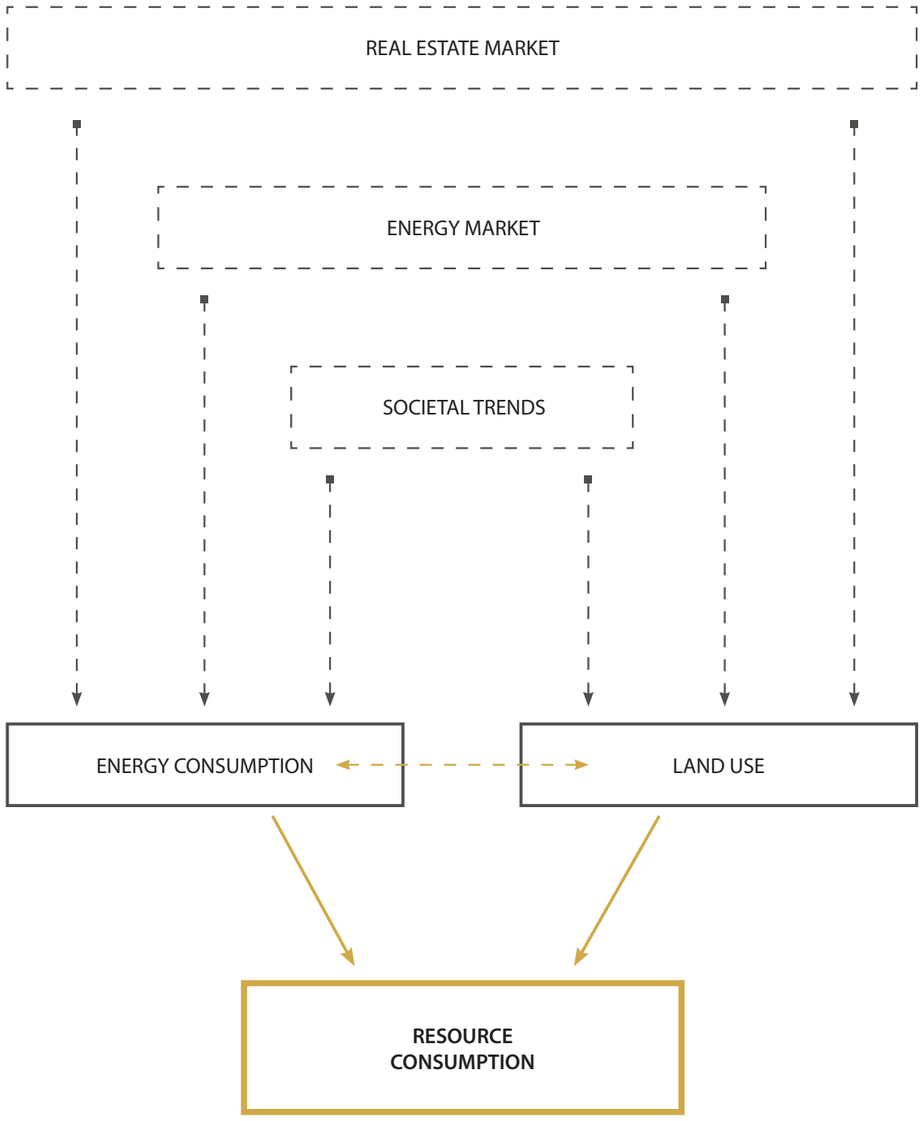


Problem field

The main challenges that the Grand Duchy of Luxembourg has to face at the moment can be clustered in two main problem fields: energy consumption and land use. Both are closely interlinked and set a challenging task for the decision makers. The economic development and the related trends in Luxembourg can be identified as the source of the problem. However, the problem is much more complex and multidimensional and will be explained in the following sections.

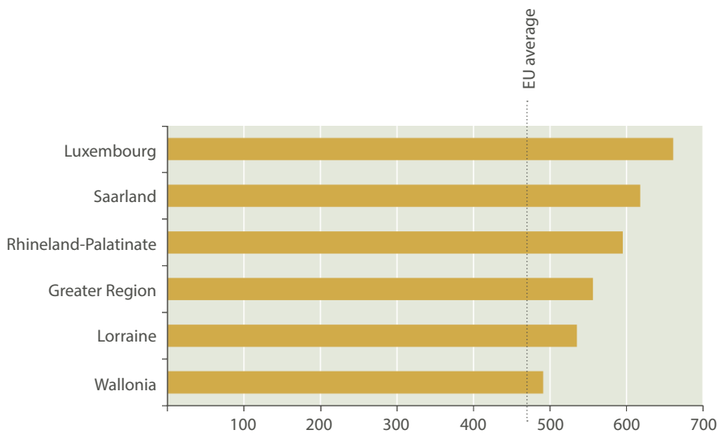
Energy consumption:
-Automobile dependency, Energy consumption of the transport sector-

The end of the 19th century was characterised by the invention of the car, one of the most revolutionary inventions of all time. Designed to facilitate everyday travels as well as to travel long distances, the car quickly became a symbol of independence and freedom.
Still nowadays the automobile is widely perceived as a status symbol, and car lovers and enthusiasts enjoy showcasing their cars. However, today, the automobile industry is repeatedly making negative headlines, and its downside unfolds more and more. The cars become a necessity rather than a luxury. "It is well known that automobiles are primary contributors to air, noise and water pollution, and major consumer of non-renewable resources." (Litman, 2002, p.14)
In particular the exhaust gases cause worries, as they pose a real risk to public health and to nature. But not only the CO_2 emissions are worrying, the fuel and its extraction spark vehement discussions for decades now. In order to reduce CO_2 emissions and protect the natural resources, everything possible was done to find an alternative solution. In the future, the automobile will be running on electricity. This concept seems to be accepted by the majority of the population and it has already been partly implemented. But although, this concept can be based on renewable energies, and thereby preserve the stock of fossil fuels, it does not prevent side effects such as congestion, accident damages and a variety of environmental impacts caused by huge infrastructure networks.

"Automobile dependency is

The low petrol price and the suburbs as a preferred place of residence promote automobile dependency. The large majority of the working population commutes to work by car, causing enormous traffic flows everyday.

Image from https://blobsvc.wort.lu/picture/2c7e49da86e9467a117968938aaa474e/860/484/wortv3/9d3dc803964ffec0a11fa7466d41e6c15e8f80a9



The car density in Luxembourg does not only largely exceed the EU average, it is also the highest within the Greater Region.
(car density in cars/1000 habitants)

Image from http://www.grande-region.lu/portal//images/publications/documents/statistiques-en-bref-2016-version-web.pdf

defined as high levels of per capita automobile travel, automobile oriented land use patterns, and reduced alternatives. This automobile dependency causes both benefits and costs. Most benefits are direct and internal to users while many costs are indirect, external, and cumulative." (Litman, 2002)

This means that the high percentage of car ownership, as it can also be observed in Luxembourg, increases the need for paved roads and highways, which in return causes spatial and environmental fragmentation. At first glance, it appears that the private car is the most convenient mean of transport, especially when energy prices are low. However, the costs and side effects of automobile dependency are devastating, even though they might not be immediately perceptible.
Looking at the maintenance costs, car ownership is actually not that favourable in the long run. The environmental costs, often less obvious at first sight, are very alarming and the damages are mostly
irreversible.

The on-going debates about automobile dependency do not aim for a general car ban, but simply suggest that the population should benefit from a better offer of public transportation services, through a shift towards a multi-modal community with good transit services, and reduce their number of travels where appropriate. Even though this sounds very promising, the implementation highly depends on the peoples´ place of residence.

Regarding vehicle expenses, studies have revealed that automobile dependency significantly increased consumers' total transportation costs, mainly due to ownership and use. As a result, transportation costs represent a larger portion of household expenses. In this context, one of the
most alarming examples is North America. Despite relatively low prices for vehicles and fuel, North American households expend far larger portions of their budget on automobiles than in most other parts of the world.
However, big differences in behavioural patterns can be observed across the country. The Northeast region, for example, spends much less on transport

Luxembourg has the second highest number of cars per capita in the European Union, after Malta.

than other regions, this seems to be linked to these cities more balanced transport systems that allow lower rates of automobile ownership.

Looking at the European trends, one country clearly stands out: Luxembourg. Unfortunately, it doesn´t stand out in a positive way. Like in the US, in Luxembourg, a high level of automobile dependency can be observed. The Grand Duchy of Luxembourg does not only have the highest number of vehicles per capita, but the transportation sector is also the major energy consumer.
The reason behind this is certainly a different one than in North America. In North America the population tends to flee from the city centres to the suburbs, as the cities are often considered to be an unsafe environment, whereas housing prices and housing preferences (e.g. detached single-family house with private garden) are the main drivers behind this phenomenon in Luxembourg.
Relatively low taxes on vehicles and above all on fuel have been promoting this trend for decades, and had a direct impact on the urban structure of the country.

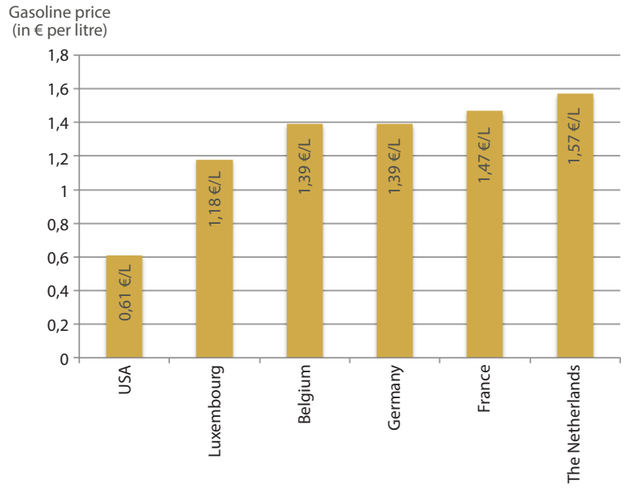
Excessive car use heavily influences the quality of life on a daily basis. High-speed traffic for example creates barriers to walking and cycling, constituting insurmountable obstacles. "Traffic congestion is consistently cited as the most frustrating aspect of daily life. But where pedestrians, bicycles and transportation are rarely an option, everyone is forced to drive." (Duany et al., 2000, p.22) Despite high investments in the public transport network, the attempt towards sustainable transport development makes slow progress.

Another important factor is the increased risk of traffic crash injuries and deaths that car dependency involves. Just like the rise of personal stress caused by the increased amount of driving under congested conditions. This specific lifestyle also has side effects on the health condition, increasing the cardiovascular risk.

Concerning the issue of land use impacts, automobile dependency performs poorly. "Car dependency increases the amount of land paved for roads and parking which has economic, social and environmental costs. (Litman, 2002, p.15) Furthermore, the reliance on cars tends to result in

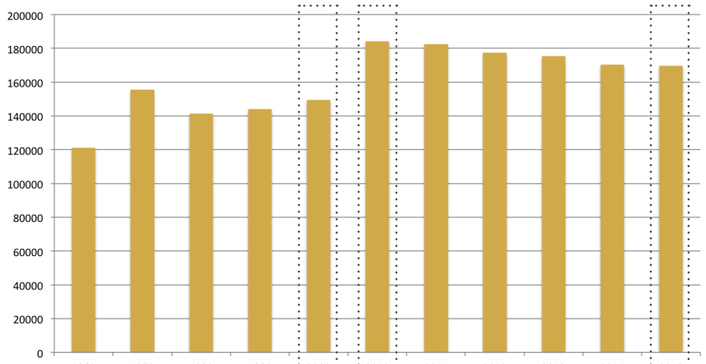
Luxembourg's extremely high energy consumption can be explained by the considerably low petrol price, stimulating automobile dependency and fuel tourism.

Image from https://luxtimes.lu/archives/7251-luxembourg-petrol-prices-rise



This comparison of gasoline prices shows the great differences between the neighbouring countries. (Prices from 1 January 2018)
The high level of automobile dependency in Luxembourg is actively stimulated by the low petrol price. This does not only benefit the national residents, but also the numerous cross-border workers from Belgium, France and Germany. On the spatial level, due to low commuting prices, the Luxembourgish territory is characterised by a high level of sprawl. The situation is similar in the USA, where low gasoline prices have also led to a high level of sprawl and encourage long commuting distances.

Information retrieved from http://www.globalpetrolprices.com/gasoline_prices/ Own drawing



This graph shows the average annual energy consumption of Luxembourg (in Tj). Looking at energy consumption patterns between 2000 and 2015, it can be noticed that after a significant increase of energy use in the transport sector between 2000 and 2010, the energy consumption has declined since 2010.
Despite this positive tendency, the annual energy consumption is still too high and needs to be addressed.

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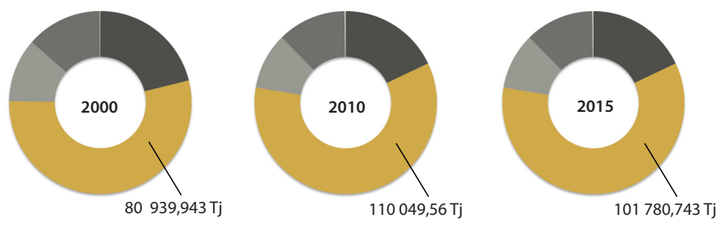
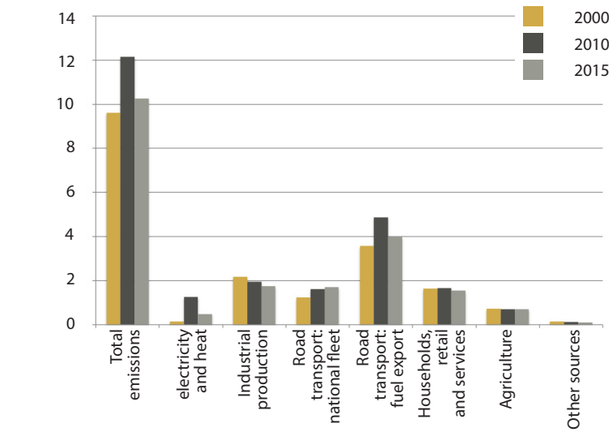


Looking at energy consumption patterns between 2000 and 2015, It can be clearly seen that the transport sector is the most intensive energy user. It can be noticed that after a significant increase of energy use in the transport sector between 2000 and 2010, the energy consumption has declined since 2010.
This is closely linked to the ongoing car ownership trends. Since 2010 the car per capita indicator remained more or less stable, and in 2014 a decline in car ownership could even be recorded.

Information from http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12772&IF_Language=fra&MainTheme=1&-FldrName=4&RFPath=51 Own drawing

CO2 emissions
(in mio tons)



The high level of automobile dependency also explains the fact that road transport is the main source for greenhouse emissions in Luxembourg. However, a decrease has been noticed since 2010 (in million tons of CO2, excluding LULUCF).

Information from http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12724&IF_Language=fra&MainTheme=1&-FldrName=3&RFPath=63 Own drawing

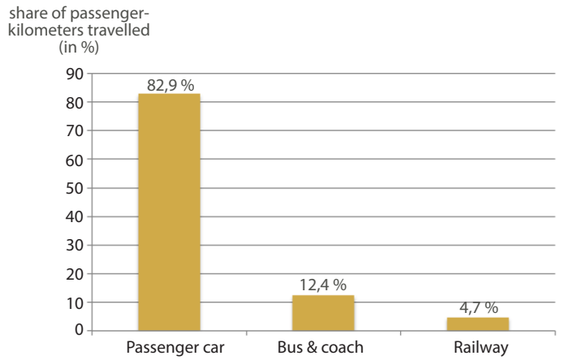
lower density, urban periphery development (e.g. urban sprawl), which also imposes a number of economic, social and environmental costs. Sprawl in turn increases the amount of land used per capita for roads, parking, buildings and reduces the land left for agricultural and wildlife habitat." (Litman, 2002, p.15) This situation, which almost seems to be a banal routine to some motorists, actually has a huge impact on the urban structure, quality of life, and the nature itself. "Not to forget the negative impact that automobile dependency causes on the social level, contributing to the loss of sense of community through encouraging social and economic stratification, in which people spend an increasing portion of their lives in private and semi-private environments. Although this may appear attractive, it contradicts the development of a true, diverse and complex community." (Litman, 2002, p.17)

<u>Land use</u>:
-Economic concentration, Sprawl-

Without doubt, Luxembourg will continue to grow. The question however is, which model of urban growth the government will opt for. Now, the standard Luxembourgish pattern of growth is sprawl. Unlike the traditional neighbourhood model, which evolved organically as a response to human needs, and which could be observed during the steel industry in the south of the country, sprawl is largely predictable and artificial.
Sprawl is considered to be an unhealthy and self-destructive growth by many scholars. (Brueckner, 2000; Breheny, 1997; Holden, Norland, 2005) They argue that due to its low density and its high consumption of land, sprawl causes insurmountable traffic problems, environmental damages and consumes large investments.
According to Duany et al. (2000) "Sprawl consists of five very homogeneous components:
1. Housing subdivisions – exclusively res- idential
2. Shopping centres – exclusively for shopping
3. Office parks – exclusively for working
4. Civic institutions – public buildings
5. Roadways – the huge amount of pave- ment necessary to connect the other four disassociated components"
(Duany et al., 2000, p. 6)

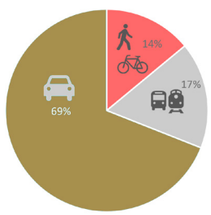
Luxembourg's landscape is characterised by sprawl.

Image from http://l7.alamy.com/zooms/9cf838e92afc46a98e27f156758b5ba0/aerial-view-of-the-kirchberg-city-luxembourg-h198p1.jpg



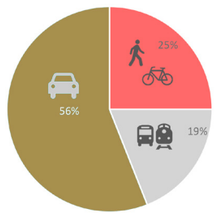
This graph, showing the distribution of passenger-kilometres travelled by land in Luxembourg in 2015 by mode of transport, confirms the dominance of the passenger car as a means of transportation.

Information retrieved from https://www.statista.com/statistics/449418/luxembourg-modal-split-of-passenger-transport-on-land/ Own drawing



Modal split in Luxembourg in 2017. According to a study carried out by the Luxembourgish government, 69% of all travels are made by passenger car. The whole study can be found in the appendix.

Image from http://www.developpement-durable-infrastructures.public.lu/fr/actualites/articles/2017/12/07-EnqueteMobilite/EnqueteMobilite-Presse-v2.pdf



Objective MODU (2012) set for 2020. The government targets to decrease the automobile dependency by 13% until 2020. And enhance the use of public transportation and slow mobility. The whole study can be found in the appendix.

Image from http://www.developpement-durable-infrastructures.public.lu/fr/actualites/articles/2017/12/07-EnqueteMobilite/EnqueteMobilite-Presse-v2.pdf

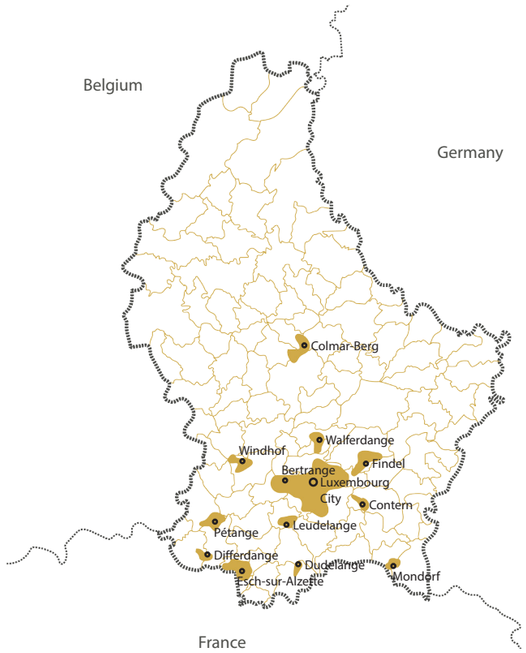
In his very interesting paper on Urban sprawl: diagnosis and remedies (2000), "Jan K. Brueckner argues that urban spatial expansion results mainly from three powerful forces: a growing population, rising incomes and falling commuting costs." (Brueckner, 2000, p.160)

This holds also true in the case of Luxembourg. Current trends show that low energy prices, especially on gasoline, does encourage sprawl as they result in low commuting costs. And on a cross-border level, the low prices promote fuel tourism. Furthermore, Luxembourg is characterised by an excessive socioeconomic growth since decades. It's good economic performance is attracting thousands of migrants every year and additionally thousands of cross-border commuters every day.

"Today the cross-border workforce is essential to the Luxembourg economy. It currently represents 43% of total employment in Luxembourg and concerns some 170,000 cross-border commuters, mostly coming from Belgium, France and Germany." (http://www.luxembourg.public.lu/en/actualites/2017/05/16-frontaliers/index.html, 2017)

"Through history, the nature and availability of energy resources have influenced the distribution of human activities and the form of the built environment. During the 20th century, falling energy prices have permitted increasing physical separation of activities and the outward spread of urban areas at decreasing densities." (Owens, 2011)

So in the specific case of Luxembourg these two indicators can indeed be considered as the main sources of sprawl. However, regarding rising incomes, even though incomes are relatively high in general and did rise in the last decades, housing prices have been skyrocketing since the beginning of the extreme population growth in the 1960s. The general living costs are as well extremely high compared to other western European countries. Therefore, in this specific case, rising incomes are not a source of sprawl, it is rather the unaffordable housing prices and the very limited housing offer in Luxembourg City that contributes to the phenomenon of sprawl. At the same time the population's housing preferences play a crucial role in choosing a



A strong economic concentration in and around Luxembourg City can be observed. Due to the massive interest in Luxembourg City, the municipality had to take necessary measures. After introducing stricter rules, some major companies decided to relocate their headquarter in nearby industrial zones and activity zones, where land developing guidelines are practically non-existent. Especially for private parking facilities. Very often, these locations are badly or not at all connected to the public transport, and only accessible by car.

Data from Kussbus company.
Own drawing

place of residence. A key element of the Luxembourgish lifestyle is the single-family unit with a large amount of living space and a private garden, preferably, at an affordable price.

As housing prices keep rising on Luxembourgish territory, many Luxembourgers have chosen to change their place of residence to the other side of the border. Most of them have opted for Germany as their new place of residence. Instead of renouncing to the dream of a single-family house with garden, they accepted voluntarily to cross-border commuting. This led to a crossborder sprawl, which in return led to an increase in housing prices in the border area of the neighbouring countries.

"An adequate response to such price escalation would be that consumers would reduce their consumption of housing space. Therefore, an attack on urban sprawl would lead ultimately to denser cities containing smaller dwellings." (Brueckner, 2000, p.161)

Another valid point is that "excessive urban expansion also means overly long commutes, which generate traffic congestion while contributing to air pollution. This outspread also has a negative

A detached one-family house with a private garden, preferably in a suburban environment, is still largely conceived as the 'Luxembourgish dream'.

Image from google street view

Most large-scale developments are still located around Luxembourg City, neglecting the potential of other Luxembourgish cities and actively contributing to spatial injustice. The pictured development is located in the district Gasperich.

Image from https://blobsvc.wort.lu/picture/b971b3fc-768070d256a6203b5daeedf4/396/297/wortv3/447ffc2e44993db0e6e1ec8bd-0d0325ad3e20234

Besides the trends of automobile dependency and sprawl, which have already been described in detail in the previous sections, there are also other elements that contribute to an increased resource consumption. Large-scale monofunctional developments, as it can be observed in the Kirchberg district of Luxembourg City, represent unsustainable trends and do not benefit the urban structure. And although more recent large-scale development projects have been planned with a focus on mix of uses, most of them are located around Luxembourg City, neglecting the potential of other localities.

Image from http://www.athenecapital.eu/wp-content/uploads/2016/09/novotel-kirchberg-luxembourg.jpg

	1970	1980	1990	2000	2010	2014	2015
Total population	339 800	364 850	379 300	433 600	502 066	549 680	562 958
Total registered private vehicles *	73 640	130 400	186 738	293 446	372 623	389 000	400 102
Car ownership	220 cars per 1000 people	360 cars per 1000 people	490 cars per 1000 people	680 cars per 1000 people	740 cars per 1000 people	710 cars per 1000 people	710 cars per 1000 people
Car ownership trends		+ 140 cars per 1000 people compared to 1970	+ 130 cars per 1000 people compared to 1980	+ 190 cars per 1000 people compared to 1990	+ 60 cars per 1000 people compared to 2000	- 40 cars per 1000 people compared to 2013	/ per 1000 people compared to 2014

*includes all different types of private vehicles, two and four wheeled.

This table, representing the car ownerships trends in the Grand-Duchy, shows a slight trend towards decrease. However, car density in Luxembourg remains a pressing problem.

Information from https://data.public.lu/en/datasets/types-de-vehicules-par-localite/ Own drawing

Especially the construction waste disposal causes great concern. All national landfill sites are already overloaded, having caused several landslides in the past years.

Image from https://www.wort.lu/de/lokales/erdrutsch-in-esch-luftaufnahmen-zeigen-ganzes-ausmass-5322eee3e4b077ddb0e64d70

The high percentage of sealed surface, caused by sprawl and low density trends, has increased the risk for flood considerably.

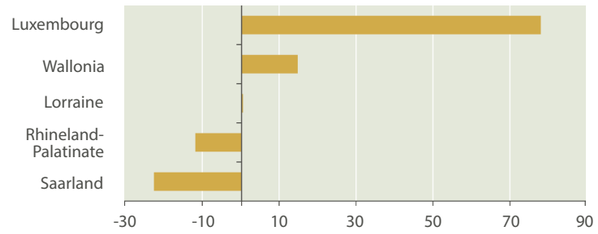
Image from https://luxtimes.lu/archives/4644-flooding-and-greening-up-luxembourg-s-transport-sector

impact on social health, as low-density development may reduce social interaction weakening the bonds that underpin a healthy society." (Brueckner, 2000, p.160)

So, although the majority of the population in Luxembourg has settled down in the sprawling area, the economic activities and public institutions are concentrated in Luxembourg City. This spatial imbalance is also reflected in the high level of automobile dependency and contributes to spatial injustice. The spatial distribution of everyday activities of urban functioning is a primary source of inequality and injustice. Luxembourg's spatial structure does not encourage a fair and equitable distribution in space of socially valued resources and the opportunities to use them. This does not only result in spatial injustice, but also in social and environmental injustice, which are increasingly seen as interlinked.

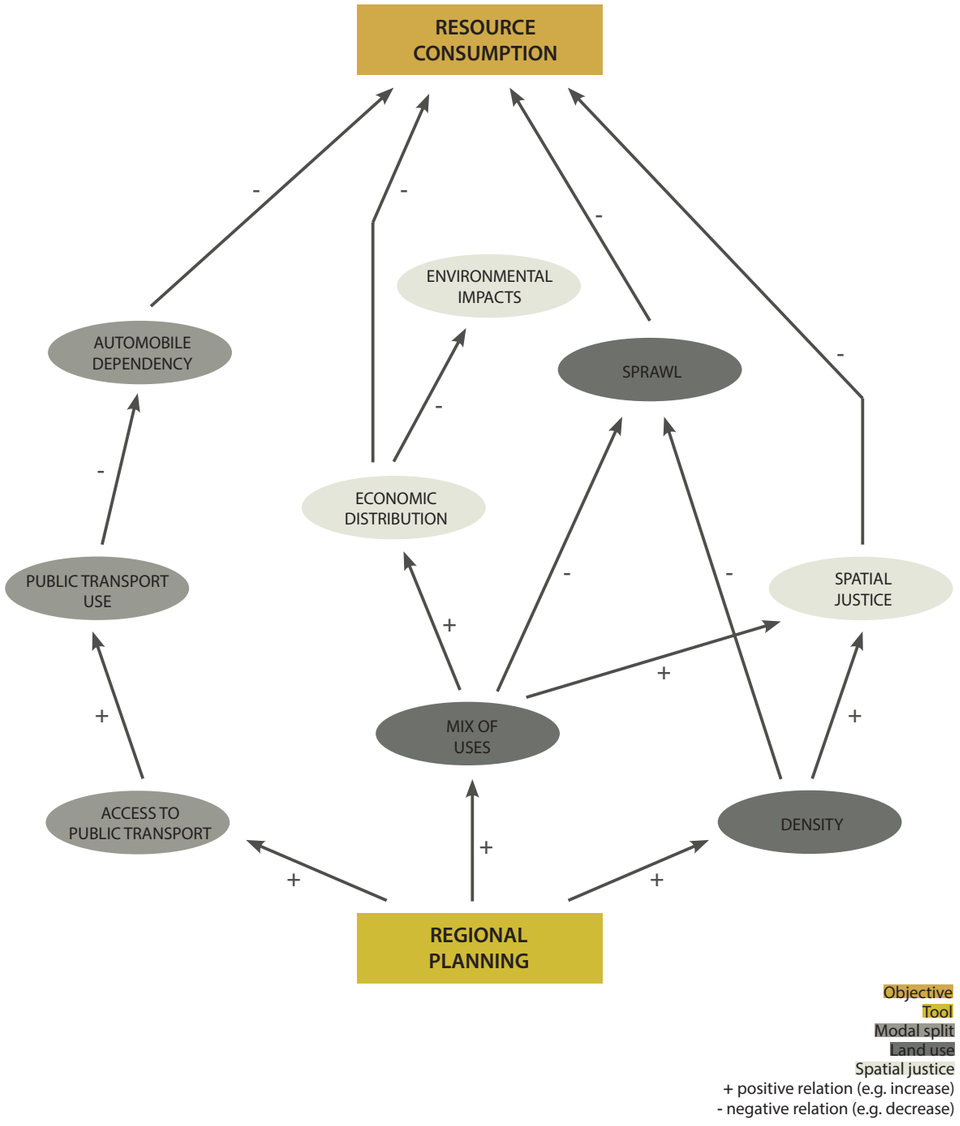
Whereas social injustice names the unequal opportunities of different social groups, environmental injustice refers to the unfairness that the environment experiences due to human actions as well as the unequal.

The role of space in dealing with injustice is a very present topic. According to Marcuse (2009) "there are 2 cardinal forms of spatial injustice: the involuntary confinement of any group to a limited space (e.g. segregation) and the allocation of resources unequally over space. He also argues that social injustices always have a spatial aspect, and social injustices cannot be addressed without also addressing their spatial aspect." (Marcuse, 2009)



According to the forecast population development within the Greater Region, Luxembourg will face a continuous and rapid growth, nearly doubling its population until 2050. At the same time, most of the other members of the region will see a decrease in population. Therefore, the pression, especially on the economic level, will become even more devastating.

Image from http://www.grande-region.lu/portal//images/publications/documents/statistiques-en-bref-2016-version-web.pdf



Problem statement

Analysing trends, current and past urban processes and governmental approaches provided a great understanding of the different urban systems and its interrelation. However, these processes are of great complexity and require an in-depth research in order to be able to develop an innovative solution.
In particular, the high consumption of energy of the transport sector is alarming. Especially because Luxembourg's potential for energy production is very limited and therefore is highly dependent on its neighbouring countries as energy source. Besides this, and as mentioned earlier on, sprawl also causes several problems on the social and environmental level and therefore needs to be addressed.

Luxembourg finds itself with challenges and opportunities, in which inaction is not an option. The limitations of the present development policies and strategies are becoming increasingly observable since all the national sector plans have been rejected by the municipalities, which benefit from a high level of autonomy. Therefore it is important that the new regional strategy emphasises the municipal advantages and advocates the interests of the local population.

Notorious for its highly ranked and international competitive economic model, the Grand Duchy seems to be still a very popular destination for immigrants and cross-border workers. This is also reflected in the rapid population growth that Luxembourg is meeting at the moment. In order to be able to maintain for example its generous welfare provisions, Luxembourg's GDP has to grow annually. This also explains the country's strategy of promoting socio-economic growth. Therefore qualified foreign labour force is attracted, as it is not available in sufficient quantities within the country. In this context, Luxembourg largely benefits from its territorial configuration, its membership of the European Union and the treaty of Schengen, allowing the free flow of people and goods cross-border wise.

To sum up, Luxembourg suffers of 3 main problems:

•Energy consumption
The energy management, and

The implementation of the national sector plans (2013) was put on hold due to the large discontent of the municipal councils. Since then, the national and municipal authorities are working together on designing new plans.

more precisely the energy consumption pattern, causes concern. Due to the high level of automobile dependency, the transport sector secures first place in energy consumption since decades now. Several factors can be held responsible for this trend. First steps towards energy efficiency have been taken, especially on the municipal level various measures have been introduced.

• Sprawl

Housing preferences play a crucial role in that regard. The ownership of a single-family house with a private garden in a more or less rural environment is conceived as the Luxembourgish dream. This housing trend is, however, not entirely voluntary. Skyrocketing housing prices and a limited housing offer, especially in Luxembourg City, have expelled the inhabitants from the city and played their part in the process of sprawl. Furthermore, in the case of Luxembourg, the real estate market and municipalities oftentimes play a more powerful role in land development processes than the government.

Sprawl, in return, encouraged automobile dependency and increases land use. As the public transport offer has been very limited for decades, the use of private cars quickly became a habit. And even today, after several attempts to improve the public transportation system, automobile dependency retains the upper hand.

• Low energy prices

Another factor, which encourages sprawl, and at the same time automobile dependency, is the low energy price. Luxembourg is known for extremely low gasoline prices compared to other European countries. This does not only lead to sprawl on the national territory, it also attracts fuel tourism and comes in handy for the cross-border commuting. The close relation between low energy prices and urban sprawl has also been discussed in several scientific papers.

Luxembourg's spatial structure, characterised by sprawl on one hand and a strong economic concentration in Luxembourg City on the other hand, led to severe conflicts. Everyday, cars flock in huge numbers to Luxembourg City, creating problems in the form of congestion, noise emissions. Not to forget the incredible amount of energy that is consumed on daily basis. Even though the switch towards electric cars, thus a change of the energy source, might reduce some of these side effects, it would bring no improvement in terms of the energy and land consumption.

It can reasonably be concluded that the case of Luxembourg supports the statement that the relationship between energy and land use is important at all scales, from the local to the regional. Even though multiple measures to enhance energy efficiency on the local scale have been taken in the last years, the regional scale is still lacking a thought out strategy that tackles the issues at source. Therefore, it is of utmost importance to develop a regional strategy that improves the energy and land use management, and thereby enhances resource efficiency. As the transport sector represents the major energy consumer in the national territory, which has to do with the spatial structure of the country, the strategy has to cover 3 important elements: resource management, urban form and mobility solutions.

2 Research

This chapter outlines the research questions that determine the focus of the thesis, as well as the relevant theoretical framework and methods that are required to carry the study forward.

Main research question

How can transit-oriented development practices be integrated in regional planning to enhance resource efficiency and spatial justice in the context of Luxembourg?

Sub- research questions

What are the main trends and driving forces that may influence development strategies in Luxembourg?

What are the present locational policies and strategies for new developments?

What are the values and spatial conditions of spatial justice?

How do the principles of resource efficiency correspond to the concept of circular economy in the built environment?

How can transit-oriented development be defined and what could be possible beneficial results for Luxembourg?

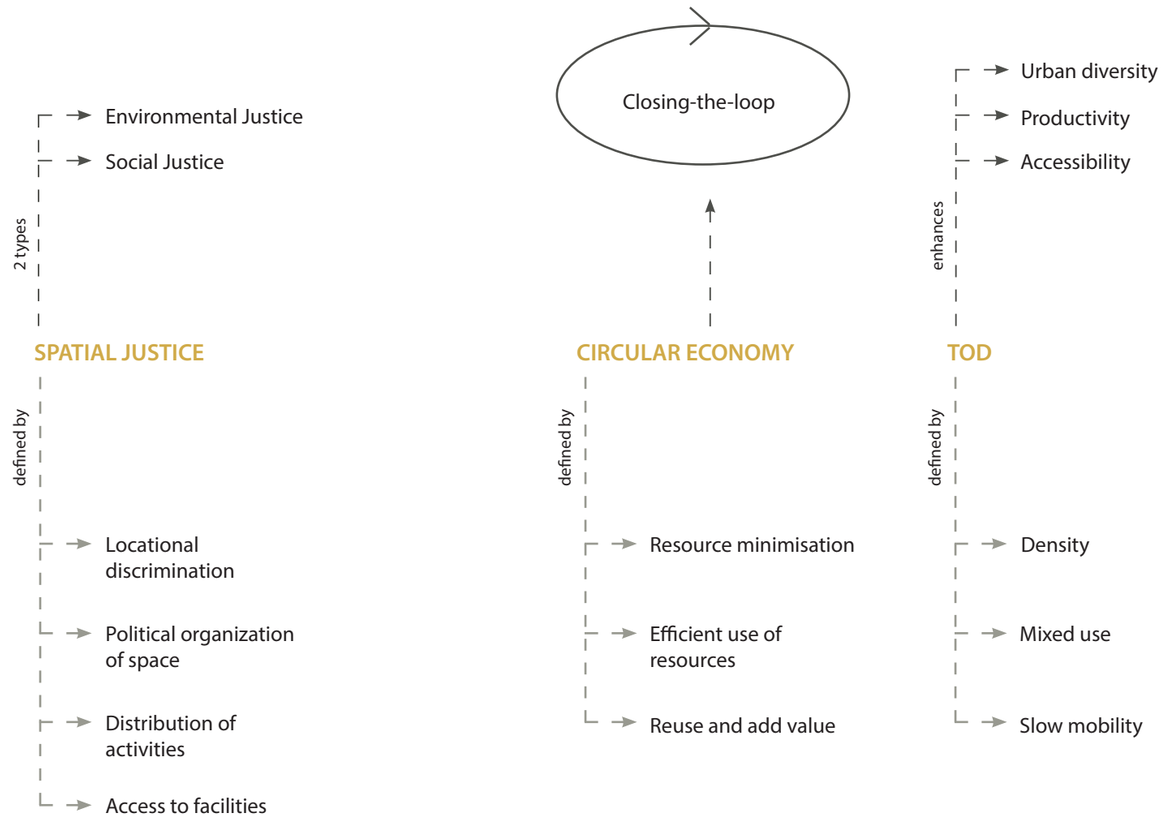
How can transit-oriented development contribute to resource-efficient planning and spatial justice within a circular framework?

Theoretical framework

An in-depth literature review is necessary to describe theories that helped me understand the complexity of the spatial structure of the Grand Duchy, and define how I could evaluate and redefine the relationship between the urban processes and the growth dynamics in the territory.

This section of the report seeks to describe the theoretical framework for my understanding of:

a) brief overview of definitions on spatial justice, resource efficiency and circular economy as related to the spatial context
b) the current urban processes which put spatial justice in a vulnerable situation, and the importance and need for spatial justice
c) the current trends in resource consumption and the importance of an efficient resource management strategy through scales
d) circular economy as an opportunity for positive impacts through scales
e) the potentials and limits of transit-oriented development



These diagrams show my understanding of the respective theories, gained through literature research. Furthermore, the aspects that are of great importance within this thesis are highlighted.

Own drawings

Literature:
Soja, E.W. (2009). ***The city and spatial justice.*** **Marcuse, P. (2009).** ***From critical urban theory to the right to the city.***

Spatial (in)justice

There is an on-going discussion on the theory of spatial justice. This theory raises at least two questions: 1) what is spatial justice, and more generally, what is its relation to social and environmental justice? And 2) what remedies are there for spatial and social injustices that we would wish planning to adopt? (Marcuse, 2009)

The specific term 'spatial justice' has not been commonly used until very recently, describing the search for justice and democracy in contemporary societies. And according to Edward Soja "it is crucial in theory and in practice to emphasize explicitly the spatiality of justice and injustice, not just in the city but at all geographical scales, from the local to the global. Furthermore, he states that thinking spatially about justice can uncover significant new insights. Critical spatial thinking today hinges around 3 principles:

- The ontological spatiality of being (human being as a spatial, social and temporal entity)
- The social production of spatiality (space as a social product)
- The socio-spatial dialectic (The spatial shapes the social and vice versa)" (Soja, 2009)

The geographies we live in can have negative as well as positive consequences on practically everything. Therefore, spatial (in) justice refers to the spatial and geographical aspects of justice and injustice. This involves for example the fair and equitable distribution in space of socially valued resources and the opportunities to use them. But spatial (in)justice can be seen as both outcome and process: as geographies that are in themselves (un)just and as processes that produce these outcomes.

In this context, locational discrimination is fundamental in the production of spatial injustice and the creation of spatial structures of privilege and advantage. For example, the lack of everyday activities of urban functioning is a primary source of inequality and injustice.

Therefore, seeking to increase justice or to decrease injustice is a fundamental objective. However, we must be aware that perfectly even development, complete socio-spatial equality, pure distributional justice, as well as universal human rights are never achievable. Every geography in which we live has some degree of injustice, making the selection of sites of intervention a crucial decision. (Soja, 2009)

Regarding spatial justice, there are 2 other important aspects: social justice and environmental justice. All 3 notions of justice are closely interlinked and involve equity issues at a range of scales, from the local to the global.

While spatial injustice refers particularly to the unequal allocation of functions and socially valued resources over space, environmental injustice on the contrary relates to 2 main elements: the injustice done to the environment (e.g. environmental degradation) by dominant market-driven processes and the inequitable access to the environment by the population. Thus, environmental injustice can be noticed from two different point of views.

Social injustice manifests itself for example in terms of segregation (e.g. the involuntary confinement of any group to a limited space) and the exposure to nuisance (e.g. pollution, noise).

However, both, social and environmental injustice, have a spatial aspect and cannot be addresses without also addressing their spatial aspect.

"To achieve justice, a change in the broader systems that shape human behaviour is needed." (Haughton, 1999) Not only a change in human behaviour is necessary, "but also in economic structures as capitalism necessarily continuously reproduces inequality." (Fainstein, 2009)

Marcuse also agrees on this idea as he stated in 2009 "that any attempt to achieve a Just City within the bounds of capitalism is doomed to failure." (Marcuse, 2009)

Literature:
Andersen, M.S. (2006). ***An introductory note on the environmental economics of the circular economy.***
Sauvé, S., Bernard, S., Sloan, P. (2015). ***Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research.***

Circular economy

Ghisellini et al. (2016) define circular economy as following: "In the last few years Circular Economy (CE) is receiving increasing attention worldwide as a way to overcome the current production and consumption model based on continuous growth and increasing resource throughput. By promoting the adoption of closing-the-loop production patterns within an economic system CE aims to increase the efficiency of resource use, with special focus on urban and industrial waste, to achieve a better balance and harmony between economy, environment and society.
In the European Union, circular economy is promoted as a tool to design bottom-up environmental and waste management policies. The ultimate goal of promoting CE is the decoupling of environmental pressure from economic growth." (Ghisellini et al., 2016)

Generally spoken, the concept of circular economy – currently widely promoted all over the world – can be understood as promoting resource minimisation and a more efficient use of them. Therefore, circular economy is directly linked to environmental sciences and sustainable development, as all of them are addressing environmental problems.

Our growth and prosperity is currently based on fossil fuels and finite land resources. The benefit of generating growth and the associated pollution is mainly private while all shares the social and environmental cost.
Circular economy refers to a model of production and consumption that is fundamentally different from the 'linear economy' model that has dominated society. The linear economy is based on a simple, linear process: extract, produce, consume, trash. And is characterised by the primacy it gives to economic objectives with little regard for ecological and social concerns.
"In contrast to the linear economy, circular economy aims to decouple prosperity from resource consumption and be independent from virgin resources and thus ensure closed loops. In these loops, integrated combinations of industrial activities act synergistically to feed and be fed by one another. In such eco-industrial settings, resource supply and waste assimilation are optimised to promote the resiliency of resources. As a result, the circular economy approach is mainly defined at the micro-level: a bottom-up approach.
Circular economy comes with a set of tools that may be used for sustainable purposes, acknowledges the need for a favourable economic context, but the social objective is usually absent." (Andersen, 2006)

Nevertheless, the complexity and novelty of the circular economy model raises a number of practical challenges. One of the challenges that circular economy faces is that it is usually more expensive to manufacture a durable long lasting good than an equivalent quick and disposable version. There is also a need to re-orient consumer thinking towards assessing alternative products in terms of functionality, which dissociates the product from the utility it provides. Mainly in relation to the shared economy model as sharing services is another way to increase the efficient use of available resources and equipment. Last but not least, using raw materials that emit fewer atmospheric pollutants during the manufacturing of a product could lead to a more complicated recycling or reuse at the end-of-use. (Sauvé, Bernard, Sloan, 2015)

As circular economy is largely perceived as a bottom-up approach in the European context, most of the proposed circular projects are carried out on the local scale. However, the larger scales (e.g. regional and national scale) do play an important role in circularity. Especially regarding the networks of flows. In this context, the sharing economy, which is a basic element of the concept of circular economy, could be of great importance to achieve positive impacts on the regional and even on the national level. The sharing economy pursues the following objectives: reducing resource consumption and increasing the efficient use of land and the built environment. In this approach, the focus is on the human being, its health and wellbeing.

Literature:
Holmes, et al. (2008). ***Transit oriented development.***
Bertolini, et al. (2012). ***Station Area projects in Europe and Beyond: Towards Transit Oriented Development.***
Bishop, Z. (2015). Transit-oriented development: Benefits and Studies.

Transit-oriented development

The issue of automobile dependency and the related energy consumption has become public knowledge. As the United States of America play the role of the biggest culprit in this regard, numerous studies have already addressed this issue in the context of North America. As a result, several approaches have been developed in order to move away from automobile dependency, Transit-oriented development is probably one of the most known methods. But this is by no means a purely American phenomenon. Around the world experts and nation leaders are working against automobile dependency and its damaging effect, turning transit-oriented development into a global topic.

"Transit-oriented development (TOD) is generally defined as a mixed-use residential or commercial area that intends to maximize access to public transportation. Such neighbourhoods often consist of a centre with a public transit station, surrounded by high-density development with gradually lower-density development spreading outward from the centre." (Holmes, van Hemert, 2008)
In conclusion, it can be said that TOD is a development pattern that is focused on its proximity and reliance on high-frequency transit. However, geographic proximity alone does not make development transit oriented.
"In general, a number of distinct factors can be seen as driving forces in transit-oriented development projects. These encompass technological innovation, institutional innovation, public policies and discourses, and more autonomous developments." (Bertolini, Curtis, Renne, 2012, p. 32)

In his work Transit-oriented development: Benefits and Studies, Zane Bishop (2015) promoted TOD as "an approach with many benefits, for transit users, developers, municipalities, cyclists, pedestrians, and non-participants, such as drivers or visitors. He justified this by saying that reduced dependence on automobiles makes streets safer, reduces pollution, and promotes healthy cities. All this without adding to sprawl." (Bishop, 2015)

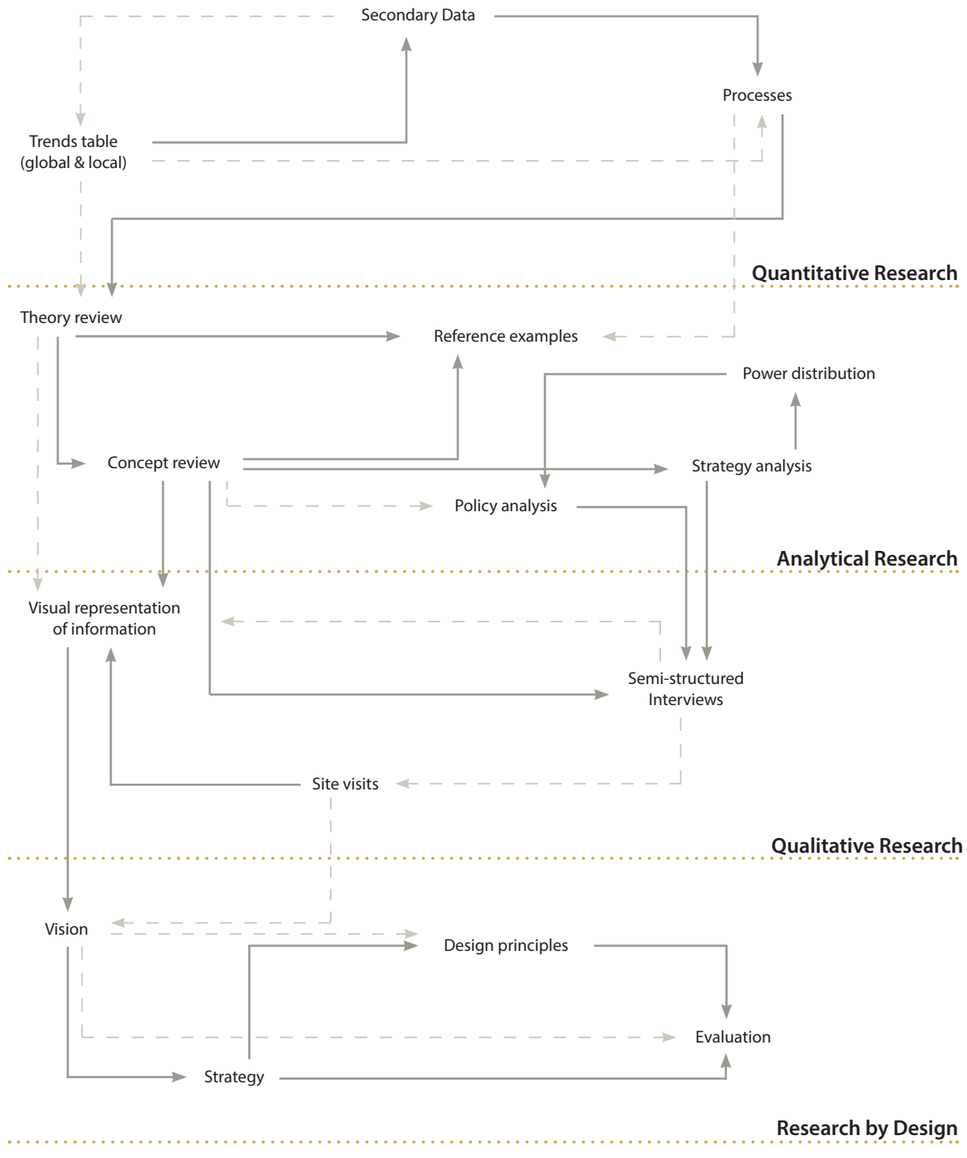
The support for transit-oriented development fits in with the general concept of sustainability. But at the same time it offers solutions for social injustice, as "TOD enables the young, elderly, poor, and disabled to access services where services are clustered together and served by efficient public transport. Furthermore, it created activity and vibrancy in community life by having more people living closer together, who are walking, cycling, catching public transport and generally interacting with each other much more than if they lived further apart." (Bishop, 2015)
"Several demographic shifts, such as increased percentage of elderly population, increased number of non-family households and increased immigration, all contribute to the demand for denser communities with increased access to public transit. Therefore, varied housing options for diverse economic demands are an essential component to successful TOD. Generally, TOD areas are both more economically and racially diverse than traditional housing options." (Holmes, van Hemert, 2008)

The safety factor plays a decisive role in determining how successful a transit-oriented development's implementation is. "In order to carefully integrate transit into a community, citizens must feel comfortable and safe in their neighbourhoods. In addition, transit authorities must ensure transit service is safe and unobtrusive." (Holmes, van Hemert, 2008)

In order to have more sustainable, social and economically efficient cities, national authorities as well as municipalities have a role to play.

Methods

Different methods have been applied during the process. They are not only of different nature but also require different tools.
The following pages will explain in detail which methods have been applied within the framework of this thesis and in how far each method has contributed to the end result.



Analytical Research

- Literature review

In order to be able to show an in-depth grasp of the subject, a profound literature review is of utmost importance. For this, books, journal articles, presentations, scientific papers or any other relevant document can be used for referencing.
This also points out studies that have already been concluded on the research topic and could even provide answers and thus facilitate the process significantly.

- Actors analysis

The actor analysis provides a better understanding of the complexity of the involved stakeholders. Not only the hierarchical structure has to be clarified, also an overview of the interests of each actor has to be made in order to be able to consider them in future steps.

- Policy analysis

Within the policy analysis all levels have to be taken into account: European, national, regional, communal. The analysis of existing directives is also necessary to point out eventual missing elements and guidelines. Always with the aim of facilitating and boosting the existing legal framework.

Quantitative Research

- Data research

It goes without saying that each problem statement has to be underlined with data and statistics in order to convince the audience. Additionally, data is most likely going to reveal the origin of the problem and gives clear indication about possibilities for improvement.

- Trends table

Ongoing trends do not only predict future developments, they also give indications about potentially occurring events causing new problems. To take these possible new challenges into account it is of a great advantage to set up an adaptive trends table from the very beginning.

Qualitative Research

- Mapping

For a better understanding of the complexity and the correlation of the topic mapping is a great tool as it translates the theory into space. As urban planners we have a great interest in spatial relations and therefore need to understand these relations on all levels and from all different perspectives.

- Interviews

Conducting interviews with involved actors or the civilian population is always a good opportunity to get a better insight into the topic and location from directly involved entities. However, attention should be paid that the questions are well formulated and do not lead to desired answers.

- Site visits

Of course it is important to get a picture of local conditions to understand the bigger picture. Although maps, literature review and new virtual technologies give you a very good overall impression of the local circumstances, the local approach offers a whole new experience and provides new impressions, often differently than expected.

Research by Design

- Vision

Regional planning aspires to deliver a completely new picture of what a specific location could look like in the future. A vision is an ambitious image that should set an utopian objective to grab attention.

- Strategy

A strategy is understood as a plan of action designed to achieve a long-term or overall aim; a vision or desired outcome.

- Design principles

Design principles are concepts used to translate fundamental ideas into form. They are utilised to shape the urban form and can be applied on all different levels. Furthermore, it is a useful tool in the process of working towards the goal/vision.

- Evaluation

Regional planning is a continuous process that has to be evaluated and revised constantly in order to achieve an optimum result. Evaluating does not only help to determine the quality of a product, in certain cases it can also reveal potential for improvement.

3 Conditions

The following chapter emphasises the specific geography that characterises the location of interest and identifies its spatial conditions. Furthermore, taking a look at growth trends and current approaches confirms the need for action.

Specific geography

The specificity of the Grand-Duchy of Luxembourg is the country's specific geography. These exceptional spatial conditions encourage large cross-border flows and a close cooperation with the surrounding region. This contributes actively to the economic success of Luxembourg.

Due to the close proximity and the higher salaries, many employees are willing to accept to cross-border commute to Luxembourg everyday. Besides work there are other reasons to cross the border. Selling prices for alcohol, cigarettes, coffee and petrol are for example significantly lower in Luxembourg than in its neighbouring countries.

Because of the country's large cross-border interaction, its geographic location, and its global networking, Luxembourg represents a very unique and interesting case study, with great potential to become a pioneer for regional innovation.

Distance to the Luxembourgish border.

Own drawing

Territorial and border dimensions

Own drawing

Population:
590 667 residents (1 January 2017)

Geographic coordinates:
latitude 49° 37' N
longitude 6° 08' E

Neighbouring countries:
Belgium
France
Germany

Surface:
2 586 km²

Average population density:
228,4 habitants/km² (1 January 2017)

Border length:
356 km

Altitudes:
maximum (Wilwerdange): 560 m
minimum (Wasserbillig): 130 m
Luxembourg City: 300 m

Area covered by water:
0,6% of the national territory

Area covered by woods:
34% of the national territory

Information retrieved from http://www.luxembourg.public.lu/en/le-grand-duche-se-presente/luxembourg-tour-horizon/geographie-et-climat/index.html

Luxembourg's spatial configuration initiated and facilitated the cross-border interaction. Today, nearly half of Luxembourg's workforce are cross-border commuters.

Image from http://www.grande-region.lu/portal//images/publications/documents/statistiques-en-bref-2016-version-web.pdf

Cross-border integration

Taking account of Luxembourg's specific territorial configuration, its strategic location in the centre of Europe and its strong relations with the neighbouring countries, one element plays an important role in the country's existence: cross-border integration. Especially in the case of small sized countries, cross-border integration plays a central role in ensuring the economic success of a nation. To be able to write a review paper about cross-border integration in the European territory, I looked into different elements related to the topic: the meaning of spatial integration, current approaches, its limitations, and the specific case of Luxembourg.

Theory paper - Abstract

Over the last years, the interest to define a general framework for spatial planning within the European territory has significantly increased, creating a vertical exchange of ideas and concepts between the EU and the national institutions (Dühr, Stead, Zonneveld, 2007, p. 291). Within the context of cross-border integration, the EU pursues two key objectives: regional harmonisation and de-bordering process.
Several scholars have since the 1990s contributed to the research on adequate integration strategies and highlighted the importance of spatial integration. The concept of spatial integration is generally used to refer to the interactions between different territories, whether these relations are international, interregional, intra-metropolitan or between cities.
This review paper intends to reveal the limits of planning approaches targeting spatial integration and uncover missing evaluation criteria in existing strategies. This is done by referring to formulated strategies, which serve to facilitate cross-border planning in the European context. This research will offer a suggestion for a revised strategy and evaluation procedure to enable a more efficient process towards spatial integration in the cross-border context.

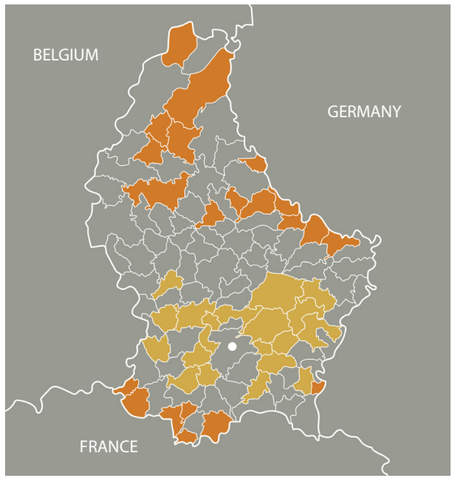
key words:
spatial integration, territorial cohesion, cross-border planning

The entire theory paper entitled *Cross-border integration in the European territory -A review of current approaches-* is included in the appendices (p. 162-173)

Spatial conditions

Across the territory of the Grand-Duchy, a great difference in spatial conditions can be noticed.
Luxembourg is divided into two different geographic areas:
Oesling (north) and Guttland (south)
In general terms it can be stated that the north is largely used as agricultural land, whereas the south is characterised by an urban structure.
This functional difference can also be observed in the following characteristics.

Welfare indicator

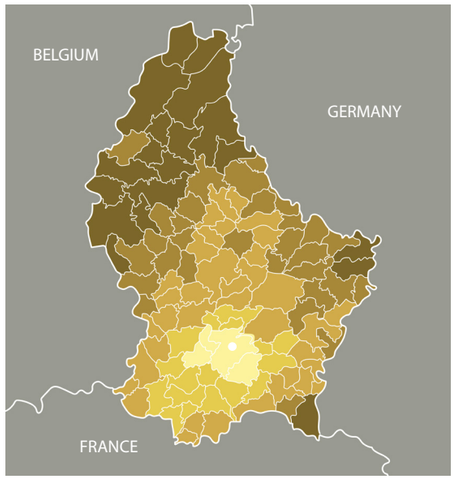


lowest socio-economic index
highest socio-economic index

Spatial distribution of the highest and lowest ranked municipalities regarding socio-economic factors in 2017.
This includes household income, unemployment rate and generated revenues through economic activities.

Figure from http://www.chd.lu/wps/PA_RoleDesAffaires/FTSByteServ-ingServletImpl?path=/export/exped/sexpdata/Mag/0007/077/14777.pdf

Average travel distance home-work

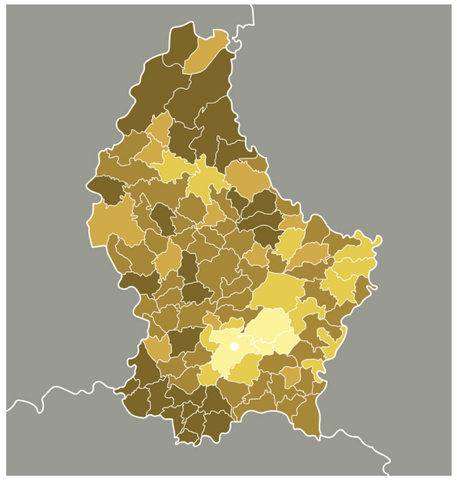


4,92-10 km
10-15 km
15-20 km
20-25 km
25-36,40 km

This map shows the average travel distance between home and work.
The economic concentration also has an impact on the commuting time, which is especially high in the north of the country.

Figure from http://www.chd.lu/wps/PA_RoleDesAffaires/FTSByteServ-ingServletImpl?path=/export/exped/sexpdata/Mag/0007/077/14777.pdf

Communal commercial tax

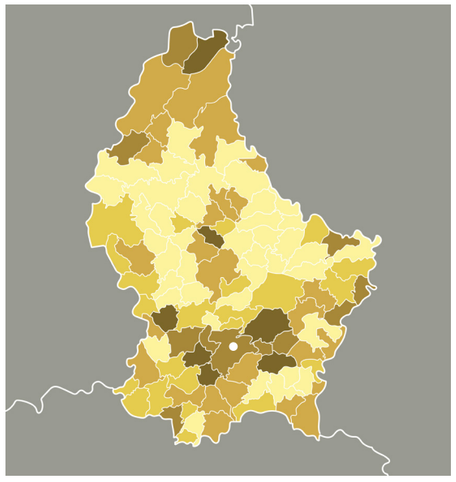


225 %
226-260 %
261-285 %
286-320 %
321-400 %

The economic concentration in and around Luxembourg City can be explained by the communal commercial tax. As these municipalities raise the lowest multiplicator of the national commercial tax.

Figure from http://www.chd.lu/wps/PA_RoleDesAffaires/FTSByteServingServletImpl?path=/export/exped/sexpdata/Mag/0007/077/14777.pdf

Ratio between jobs and residents

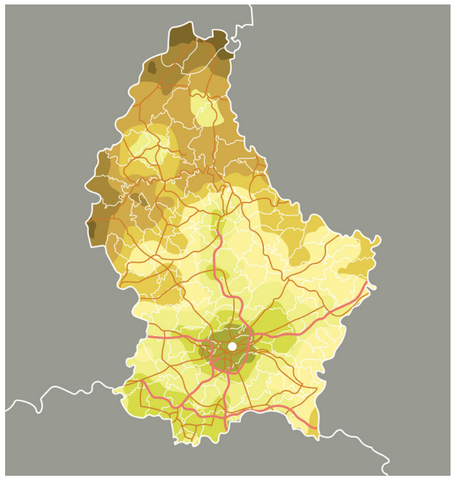


0,1-0,2
0,3-0,4
0,5-0,8
0,9-1,4
1,5-3,1

This map shows the ratio between the number of jobs and the number of residents per municipality in 2017. A strong economic concentration can be observed in and around the capital.

Figure from http://www.chd.lu/wps/PA_RoleDesAffaires/FTSByteServingServletImpl?path=/export/exped/sexpdata/Mag/0007/077/14777.pdf

General accessibility

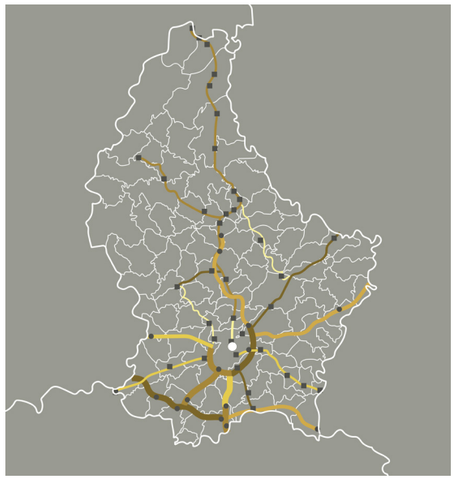


13-30 minutes
31-45 minutes
46-60 minutes
61-75 minutes
76-90 minutes
91-110 minutes
111-130 minutes
131-160 minutes

This map shows the general accessibility to a selection of functions and services by car. It can be clearly seen that the north has a lower accessibility than the rest of the country.

Figure from http://www.chd.lu/wps/PA_RoleDesAffaires/FTSByteServingServletImpl?path=/export/exped/sexpdata/Mag/0007/077/14777.pdf

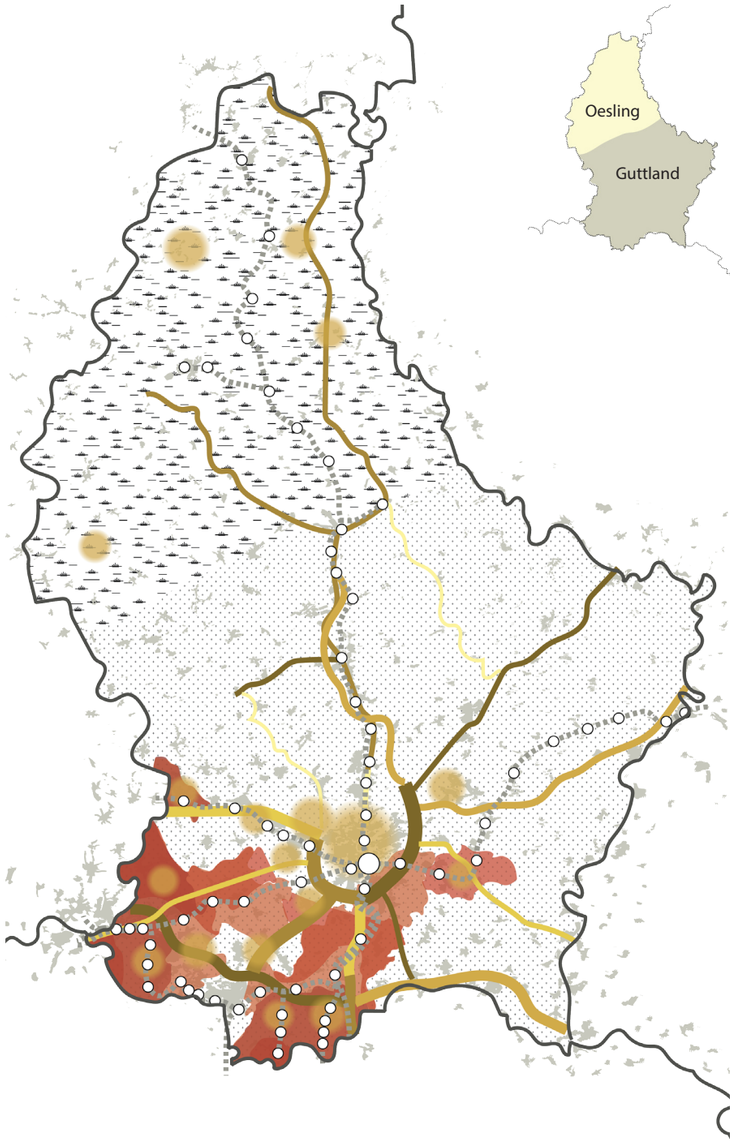
Traffic development



meter on highway
meter on national road
daily road flow of 10000
daily road flow of 50000
daily road flow of 100000
-0 %
0-1,5 %
1,5-3 %
3-4,5 %
+4,5 %

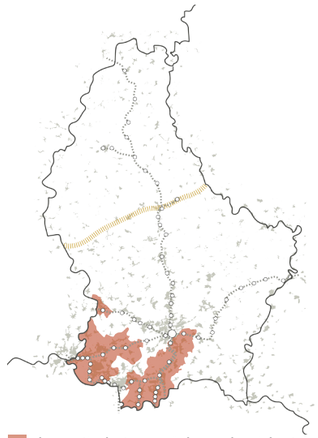
Luxembourg has experienced a strong increase in traffic over the past years, particularly in the south of the country.

Figure from http://www.chd.lu/wps/PA_RoleDesAffaires/FTSByteServingServletImpl?path=/export/exped/sexpdata/Mag/0007/077/14777.pdf



Most of the spatial conditions are closely linked to the country's division into 2 regions: Oesling and Guttland. The previous maps have presented the north region as the more vulnerable region. However, the low level of accessibility can be explained by the fact that the north is mostly used for accessibility can be explained by the fact that the north is mostly used for agriculture. And thus contributes to ensure the country's food supply at least partly. To preserve the agricultural functions and the natural resources in the north, it is logical to help the north by developing the south.

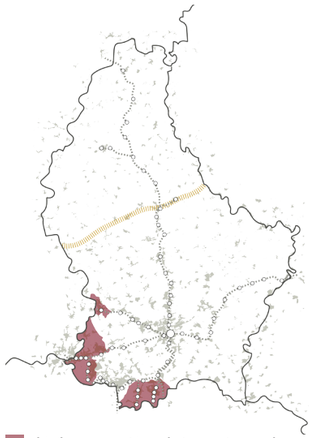
Own drawing



low ratio between jobs and residents

This map highlights the municipalities with the lowest ratio between jobs and residents within the south region, with train connections. Even though these municipalities are well connected by railway, the economic activity is still very low.

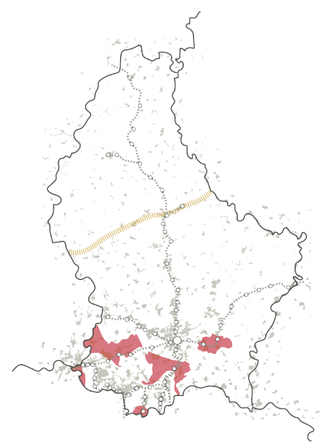
Own drawing



high commuting distance to work

Due to the low ratio, the majority of the residents still need to commute long distances to work. This can also be explained by the economic concentration (e.g. job concentration) in Luxembourg City.

Own drawing



low general accessibility

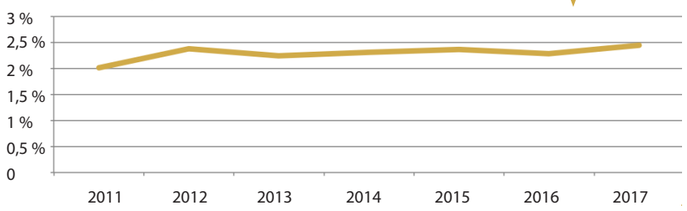
Besides the low accessibility to job opportunities, a large part of the municipalities located along the railways are also characterised by a low accessibility to daily functions.

Own drawing

Luxembourg's population growth between 1991 and 2016.

Image from Ministry of sustainable development and infrastructure - Luxembourg

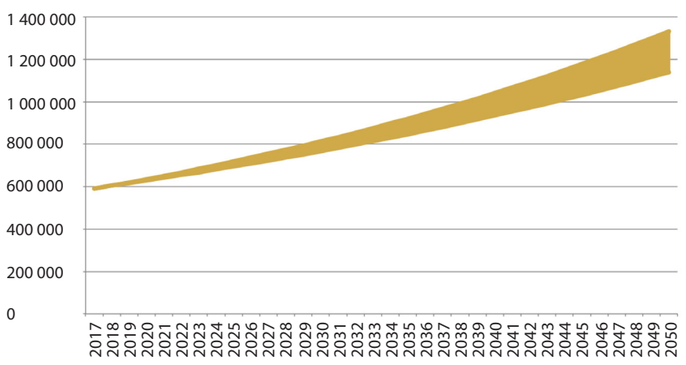
Annual population growth in %



The annual population growth remained relatively stable fluctuating between 2 and 2,5% in the past years.

Data from hhttp://www.statistiques.public.lu/stat/ReportFolders/ReportFolder.aspx?IF_Language=fra&MainTheme=2&FldrName=1

Projected population growth



Current studies show that Luxembourg is faceing a strong population growth. Although this is not a new phenomenon, the annual growth rate has considerably increased over the last few years. Between 2011 and 2017, Luxembourg has faced an average annual population growth of 2,32%. This graph shows the expected population growth, if continuing in the same rhythm. (e.g. with an annual population growth between 2 and 2,5%)

Own drawing

Forecast

The particularly high housing prices can be explained by the very limited housing offer. In 2017, the media made the lack of housing a subject of discussion (https://luxtimes.lu/archives/2764-luxembourg-needs-8-000-new-homes-per-year). According to studies, Luxembourg would need to provide 8000 new homes each year in order to be able to accommodate the continuous growing population. However, this is not in line with reality.
In the period between 2004 and 2010, 10111 new homes have been built, this corresponds to about 1700 homes per year.

Theoretically, 2719 hectare of construction land intended for housing is still available in Luxembourg. Whereof 92% is privately owned. Currently, the average residential density is 32,2 housing units per hectare. (74,9 for land with apartment buildings built on and 17,8 for land with single-family houses built on)
If this average net density will be maintained for future housing development areas, Luxembourg will only be able to provide 87551 new housing units. Which is largely insufficient to accommodate future generations.


LUXEMBOURG TIMES

HOME ECONOMICS LUXEMBOURG COMMUNITY EUROPEAN UNION WORLD CULTURE & LIFE

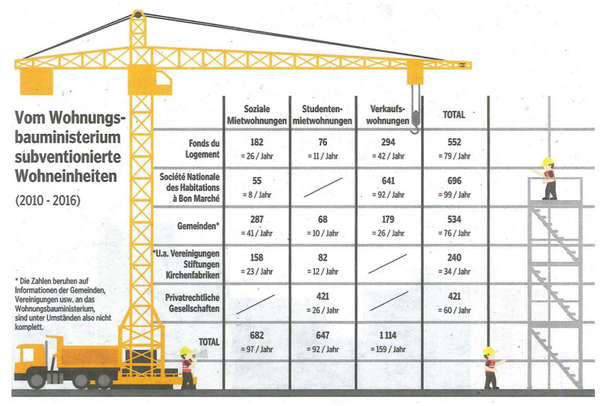
LUXEMBOURG

Luxembourg needs 8,000 new homes per year

Luxembourg needs between 7,500 and 8,000 new homes annually to solve the problems the country faces in the housing market, according to the Housing Observatory.

Image from https://luxtimes.lu/archives/2764-luxembourg-needs-8-000-new-homes-per-year

There is a large discrepancy between the housing offer and demand.
In the period between 2004 and 2010, a total of 10111 new homes has been built, this corresponds to about 1700 homes per year. Which is far below expectations and also explains rising housing prices.


Vom Wohnungsbauministerium subventionierte Wohneinheiten
(2010 - 2016)

	Soziale Mietwohnungen	Studenten-mietwohnungen	Verkaufs-wohnungen	TOTAL
Fonds du Logement	182 = 26 / Jahr	76 = 11 / Jahr	294 = 42 / Jahr	552 = 79 / Jahr
Société Nationale des Habitations à Bon Marché	55 = 8 / Jahr		641 = 92 / Jahr	696 = 99 / Jahr
Gemeinden*	287 = 41 / Jahr	68 = 10 / Jahr	179 = 26 / Jahr	534 = 76 / Jahr
*i.a. Vereinigungen Stiftungen Kirchenfabriken	158 = 23 / Jahr	82 = 12 / Jahr		240 = 34 / Jahr
Privatrechtliche Gesellschaften		421 = 26 / Jahr		421 = 60 / Jahr
TOTAL	682 = 97 / Jahr	647 = 92 / Jahr	1 114 = 159 / Jahr	

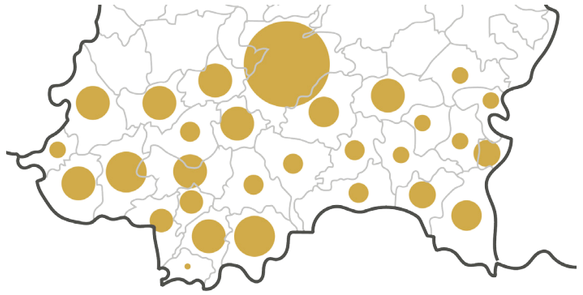
* Die Zahlen beruhen auf Informationen der Gemeinden, Vereinigungen usw. an das Wohnungsbauministerium, sind unter Umständen also nicht komplett.

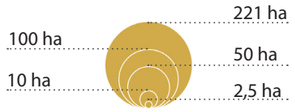
This illustration, showing the social housing offer between 2010 and 2016, underlines the gravity of the current situation.

Newspaper article from Luxemburger Wort, published on 12.04.2018

In Luxembourg a total of 2719 hectare of construction land intended for housing is still available at the moment.

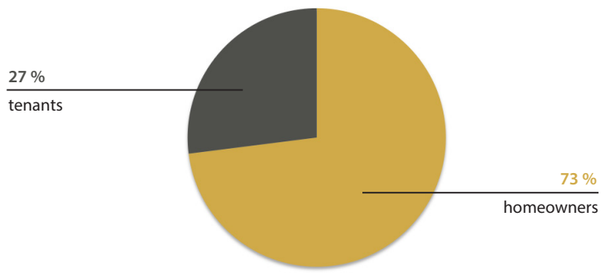
Data from http://observatoire.liser.lu/index.cfm?pageKw=potentiel_foncier_habitat





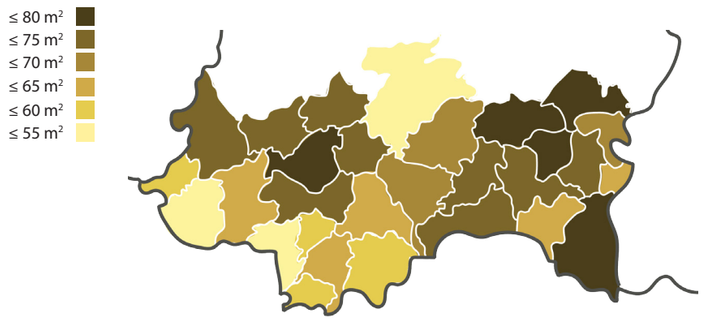
This map shows the amount of available land for housing per municipality in the south of Luxembourg for the year 2011.

Data from http://observatoire.liser.lu/index.cfm?pageKw=potentiel_foncier_habitat
Own drawing



Statistics show that there is a strong tendency for home ownership. This makes the development process even more difficult.

Data from http://www.statistiques.public.lu/fr/population-emploi/rp2011/maisons/index.html
Own drawing

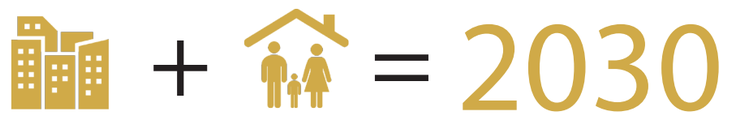


This map shows the average living space per capita per municipality in the south of Luxembourg of the year 2011. Homeownership trends also explain the generally high average living space per capita.

Data from http://www.statistiques.public.lu/stat/tableviewer/document.aspx?ReportId=8771
Own drawing

With the current housing density and household trends, and the available construction land for housing, sufficient housing offer can only be ensured until 2030.

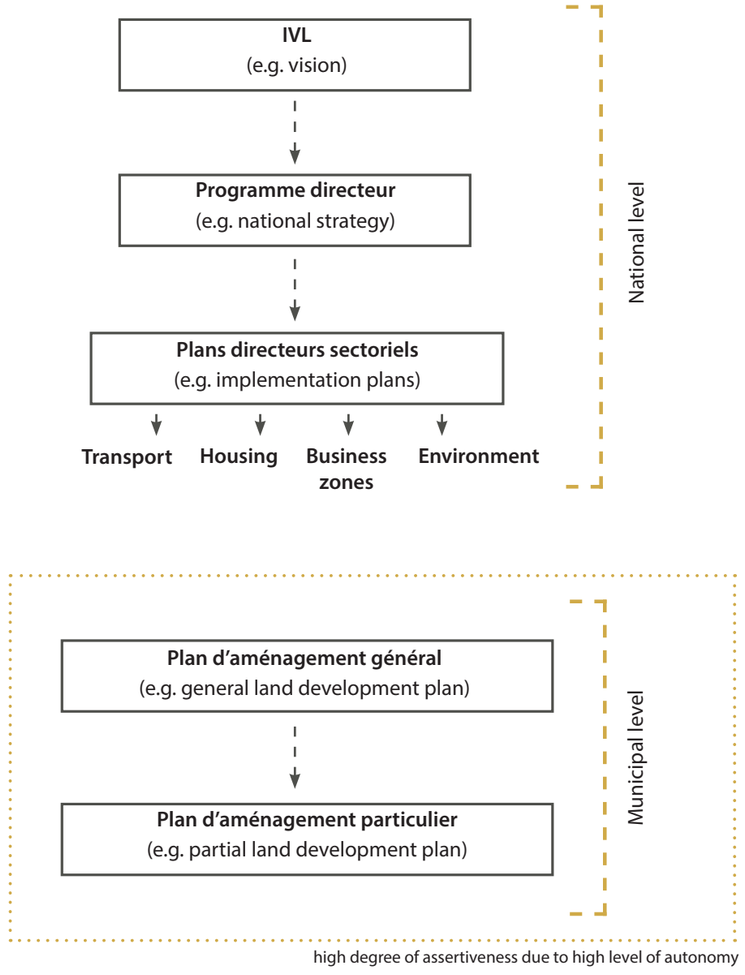
Data from http://observatoire.liser.lu/index.cfm?pageKw=potentiel_foncier_habitat
Own drawing



Average housing density:
32,2 housing units per hectare

Average household type:
2,41 people per household

The discrepancy between the housing offer and demand, as well as the housing preferences, have largely contributed to the high degree of sprawl that characterises Luxembourg nowadays. Which also explains the increase in resource consumption. Current trends and a look into the future make you realise the extent of the problem. Luxembourg finds itself in a situation of challenges and opportunities, in which inaction is not an option.



This graphic shows the existing planning hierarchy in Luxembourg. Due to their high level of autonomy, the municipalities are the real decision-makers. And thereby the municipal level has a high degree of assertiveness.

Own drawing

Current approach

The national vision IVL, presented in the year 2004, was a purely governmental initiative and not discussed with the municipal authorities. One must understand that in Luxembourg, the municipal authorities have a high level of autonomy and have the legislative possibility to oppose national strategies. Unfortunately, it is still lacking assertiveness and binding planning guidelines on the national level. For this reason, after the publication of this national vision in 2004, and the national sector plans in 2013, municipal authorities have voted against it, and since then talks are being held with municipal authorities in order to develop a new national vision and cohesive development plans.

But, as it can be seen in the vision map, the national authorities support the idea of a decentralisation and a transit-oriented development. Resulting, if carried out according to plan, in a higher level of spatial justice.

This is however contradictory with the goernmental evaluation process to define new development areas. Accessibility and the necessary infrastructure are not taken into account during the evaluation. Future development areas are identified based on a set of existing functions, however, the amount of functions is not relevant.

Implementing this approach will lead to an increase in automobile dependency, as the importance of public transportation and accessibility are are not recognised in the current approach.

The weaknesses of the current approach have also been specified by my interviewees, all experts from both private and public sector. Details about the semi-structured interviews can be found in the appendices (p. 157-161)

Public sector

THE GOVERNMENT OF THE GRAND DUCHY OF LUXEMBOURG
Ministry of Sustainable Development and Infrastructure

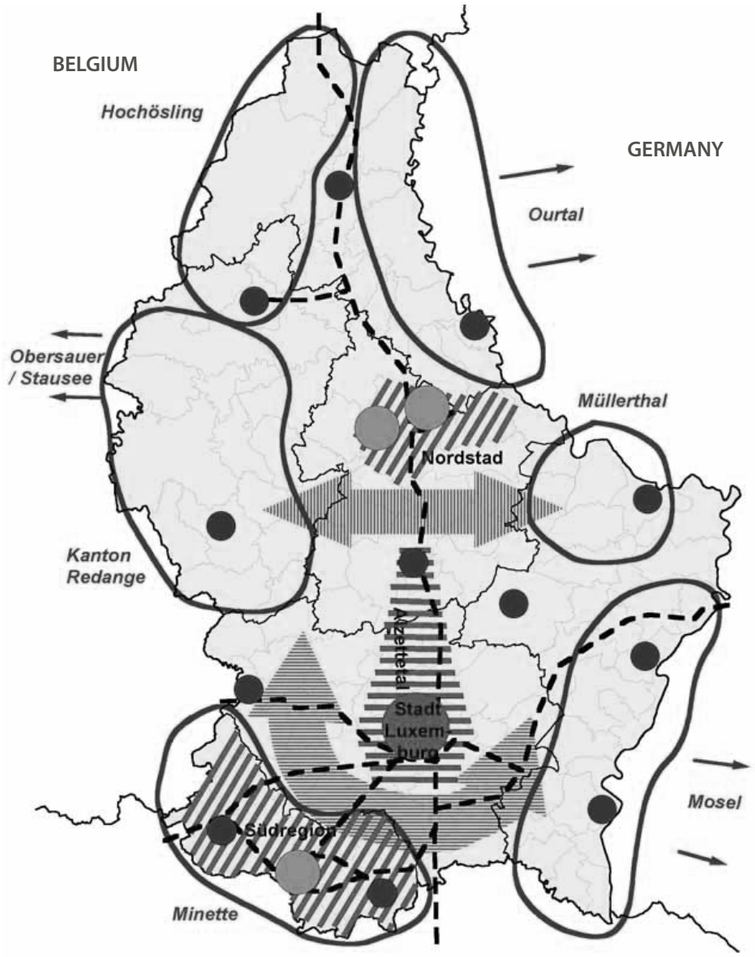
facilitate URBANISME ENVIRONNEMENT

uni.lu UNIVERSITÉ DU LUXEMBOURG

Private sector

myenergy Luxembourg

PRO group



The national vision and national development plans have been met with great skepticism and rejection. A more detailed version of the proposed concept can be found in the appendices, as well as the mentioned sector plans. (p. 177-187)

Image from http://docplayer.org/docs-images/56/38865341/images/82-0.jpg

Type d'équipement	Présence / absence							
	Commerces	Boevange	Brouch	Buschdorf	Grevenknapp	Openthalt	Bill	Finsterthal	Source / remarques
1	Boulangers	0	1	0	0	0	0	0	GWS17
2	Supermarchés inférieurs à 500 m² et/ou magasins d'alimentation générale	0	0	0	0	0	0	0	GWS17
3	Stations-services	0	0	0	0	0	0	0	GWS17
4	Magasins de vêtements et de chaussures	0	0	0	0	0	0	0	GWS17
5	Supermarchés (supérieurs à 500 m²)	0	0	0	0	0	0	0	GWS17
6	Grandes surfaces spécialisées	0	0	0	0	0	0	0	GWS17
7	Commerces spécialisés	0	0	0	0	0	0	0	GWS17
8	Garagistes	0	0	0	0	0	0	0	GWS17
	Coiffeurs	0	1	0	0	0	0	0	GWS17
	Boucheries	0	0	0	0	0	0	0	GWS17
	Services	Boevange	Brouch	Buschdorf	Grevenknapp	Openthalt	Bill	Finsterthal	Source / remarques
9	Services à la personne, banques, assurances	1	1	1	1	0	0	0	GWS17
10	Distributeurs automatiques de billets	0	0	0	0	0	0	0	Sites internet banques
11	Bureaux de poste	0	0	0	0	0	0	0	GWS17
12	Notaires	0	0	0	0	0	0	0	GWS17
	Services publiques	Boevange	Brouch	Buschdorf	Grevenknapp	Openthalt	Bill	Finsterthal	Source / remarques
13	Mairie	1	0	0	0	0	0	0	site internet commune
14	Commissariat de proximité	0	0	0	0	0	0	0	
15	Offices sociaux	0	0	0	0	0	0	0	
16	Agences de la Caisse nationale de santé	0	0	0	0	0	0	0	
17	Agences pour l'emploi	0	0	0	0	0	0	0	
18	Centres de secours	0	0	0	0	0	0	0	
	Education	Boevange	Brouch	Buschdorf	Grevenknapp	Openthalt	Bill	Finsterthal	Source / remarques
19	Ecoles fondamentales (publiques, privées, européennes et internationales)	1	1	1	0	0	0	0	Buschd. C2; Boev. C3; Brouch C4. C1 in den 3 Ortschaften. Source: Site internet commune
20	Lycées (publics, privés, européens et internationaux)	0	0	0	0	0	0	0	
21	Facultés	0	0	0	0	0	0	0	
	Social	Boevange	Brouch	Buschdorf	Grevenknapp	Openthalt	Bill	Finsterthal	Source / remarques
22	Crèches	0	1	0	0	0	0	0	GWS17
23	Maisons relais	0	0	1	0	0	0	0	Site internet commune
	CIPA (Centres intégrés pour personnes âgées)	0	0	0	0	0	0	0	
	Maisons de jeunes	0	0	0	0	0	0	0	
	Santé et domaine paramédical	Boevange	Brouch	Buschdorf	Grevenknapp	Openthalt	Bill	Finsterthal	Source / remarques
24	Médecins généralistes	0	0	0	0	0	0	0	
25	Dentistes	0	0	0	0	0	0	0	
26	Kinésithérapeutes	0	1	0	0	0	0	0	
27	Laboratoires de prise de sang	0	0	0	0	0	0	0	
28	Pharmacies	0	0	0	0	0	0	0	
29	Vétérinaires	0	0	0	0	0	0	0	
30	Médecins spécialistes	0	0	0	0	0	0	0	
31	Maisons médicales	0	0	0	0	0	0	0	
32	Hôpitaux	0	0	0	0	0	0	0	
	Restaurants, cafés	Boevange	Brouch	Buschdorf	Grevenknapp	Openthalt	Bill	Finsterthal	Source / remarques
33	Cafés, bars	1	1	0	0	0	0	0	GWS17
34	Restaurants	0	1	0	0	0	0	0	GWS17
	Culture, sport et loisirs	Boevange	Brouch	Buschdorf	Grevenknapp	Openthalt	Bill	Finsterthal	Source / remarques
35	Centres sportifs	1	0	0	0	0	0	0	Centre sportif & culturel Site internet commune
36	Piscines	0	0	0	0	0	0	0	
37	Musées, galeries d'art	0	0	0	0	0	0	0	
38	Bibliothèques	0	0	0	0	0	0	0	
39	Théâtres, salles de spectacle	0	0	0	0	0	0	0	
40	Cinémas	0	0	0	0	0	0	0	
Total		5	8	3	1	0	0	0	coiffeurs auch mitgezählt

This document shows the evaluation form to define new development areas. Decisive in this process are existing functions. Accessibility or the necessary infrastructure that enhances accessibility are not taken into account.

Document from http://amenagement-territoire.public.lu/content/dam/amenagement_territoire/fr/actualites/2018/debat-de-consultation-at-chambre-deputes-2018-vf-signe.pdf

Final product

With my research and design project I am aiming to lay the foundation for future developments. In this regard, the final product will have a strong focus on research and the adequate evaluation criteria to define new development areas.

Therefore, the final product intends to be a regional strategy that includes a specific methodology to evaluate existing transit zones and provide a concept and a set of design principles that can be implemented.

It is important that the final product considers all aspects that are relevant for a successful implementation of the concept of transit-oriented development and thus provides clear guidelines for future developments.

Desired outcome

The previous paragraphs have explained the identified ongoing trends in Luxembourg and the border region, analysed in detail the problem causing developments and structures, their origin and all their manifestations. I believe that due to the complexity and the interdependence of the current challenges, regional planning plays the leading role in the process of finding adequate solutions. Therefore a regional strategy that enhances transit-development with the overall objective of resource efficiency and circular economy would be a preferable outcome of my graduation thesis. Therefore, the interrelation between new developments and transportation systems plays a central role in my graduation project. My proposed strategy intends to support the step towards resource-efficient planning. And at the same time, enhance the productivity of the whole region by widening the opportunities for economic activities in secondary cities in the territory of Luxembourg.

Already documented in theory, the method of transit-oriented development and its added values now need to be translated into space. And by this help Luxembourg to a circular management of resources. Furthermore I hope to develop interscalar design principles that aim for resource efficiency and will lead the region's future development towards circularity.

To obtain optimum results, the complex cross-border context has to be borne in mind. However, even though the high amount of cross-border workers is often held responsible for most of the current negative trends in Luxembourg, this is most often only a convenient excuse. Because even if excluding the cross-border aspect from the current trends, Luxembourg is characterised by a fatal development that clearly indicates that the automobile dependency and the land use patterns on the national level have high negative impacts.
Having recognised the importance of the Greater Region and being aware of the cross-border aspect, I consciously chose to develop a regional strategy within the boundaries of the Luxembourgish territory without neglecting the transboundary network.

4

Strategy

This chapter explains the developed strategy and proposed design. The following pages outline the principles and design elements, illustrate reference projects, explain the findings of the case study and demonstrates the implementation of the proposal.

General principles

These guiding principles combine the ideas of spatial justice, circular economy and transit-oriented development.

When applied properly, these principles create a diverse, pleasantly dense, and just environment where the quality of the built environment is the absolute priority.

Accessibility by public transportation

Improving the collective mobility system and making it more efficient, makes it more attractive for the users.

Density

A high density creates bustling environments and reduces land consumption considerably. Furthermore, dense environments consume less energy.

Mixed use

Mixed use helps creating an environment with a high level of urbanity. Providing functions of the everyday need, and combining working and living imply a reduction of commuting.

Soft mobility

To encourage soft mobility, suitable infrastructure for cycling and walking is of utmost importance. Surface quality, lighting, accessibility to disabled people, cleanliness and maintenance are important criteria.

Different house types

A resource-efficient and just environment should provide housing units for all types of households, all age and professional groups. Allowing to live in the same neighbourhood for a lifetime.

Car free zones

Off-centre collective car parks, with the possibility for repurposing, increase the attractiveness of slow mobility, and cut the individual living space significantly.

Car and bike sharing

Vehicle sharing leads to a decrease in the amount of cars per capita and reduces the budgetary costs since you only pay when using.

Compact living space

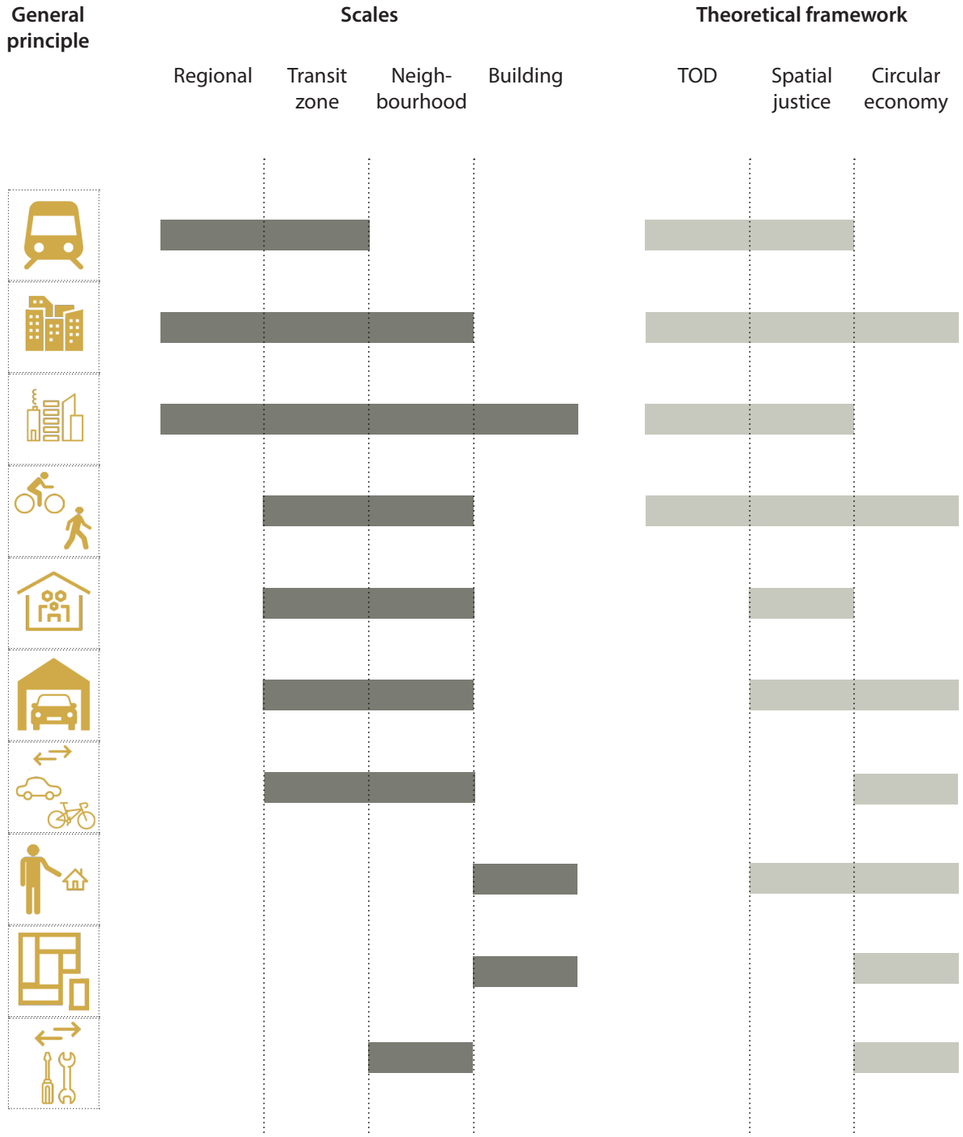
Another important aspect of resource efficiency is compact living space. The reduction of the living space per capita leads to an overall reduction of land use for housing.

Modular building construction

A modular construction reduces costs for production and thus cuts housing prices. Furthermore, it allows the deconstruction and reuse of its piece parts and thereby contribute to a circular building stock.

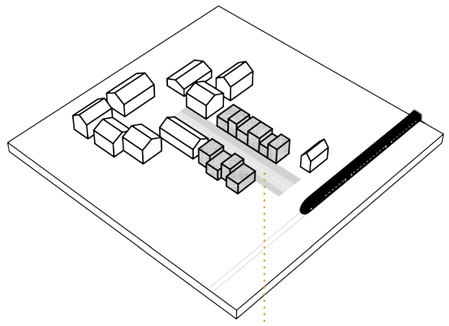
Commodities sharing

Sharing commodities is another measure to reduce the living space per capita, as storage space accounts for a major part of the living space. Furthermore, it implies a reduction of the budgetary costs because costs are split.



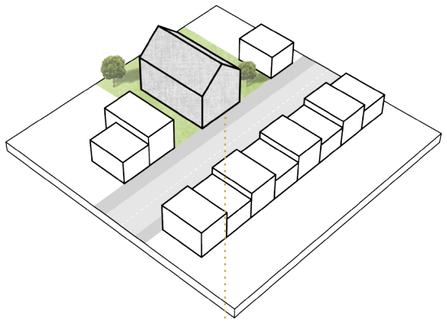
Design elements

The following design elements have a more general purpose: they intend to enhance the level of urbanity and to increase liveability within the transit zone



Urban core connection

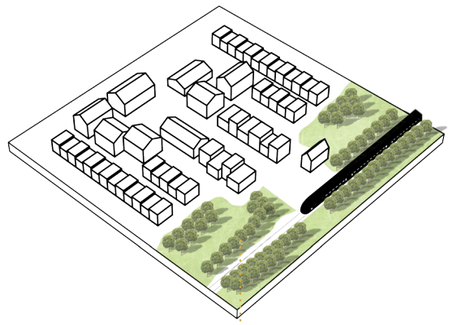
In case the catchment zone in question contains already an urban core, characterised by the settlement of different functions that contribute to urbanity, the connection between the station and this urban core should be strengthened.



Integration of worth preserving elements

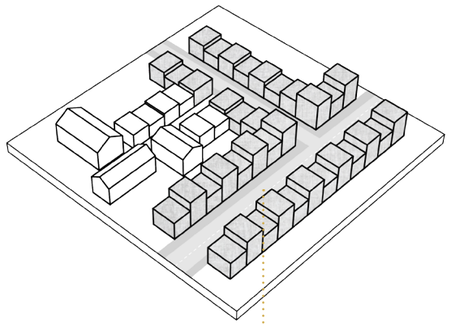
Elements which have shaped the respective built environment and have contributed to improve the urban quality in the past, should be integrated in the new development. The form of these elements can vary. They can be built structures, such as buildings or streets, natural elements, as for example forests or green verges, or specific functions, such as agricultural land, a farm or a former industrial site.

These elements have built the identity of the location in the past and shall continue to do so in the future.

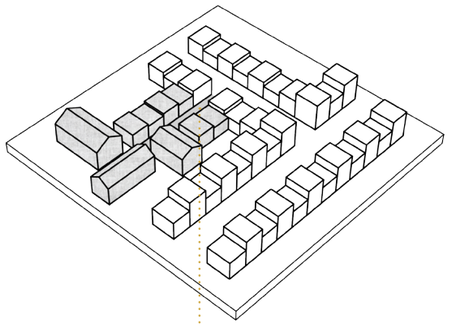


Green buffer

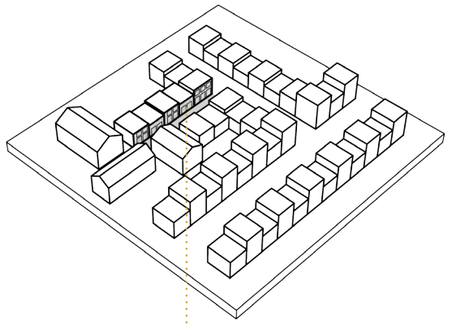
Greenery is a very important design element within this concept. It does not only, same as public parks, improves the microclimate, but serves above all as noise protection. Furthermore, green buffer zones have a filter effect for air pollutants.



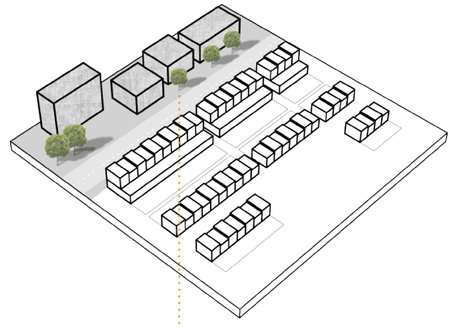
Hierarchy of streets by traffic capacity
Within the hierarchy of streets, a distinction is made between arterial roads, sub-arterial roads, distributor roads and access streets. The affiliation of each street is determined by its traffic capacity. And the hierarchy defines the road users of each street, and thus the road width.
Furthermore, the spatial influence of the street hierarchy by traffic capacity is so significant that it can even be recognised in the aerial view of the respective location.



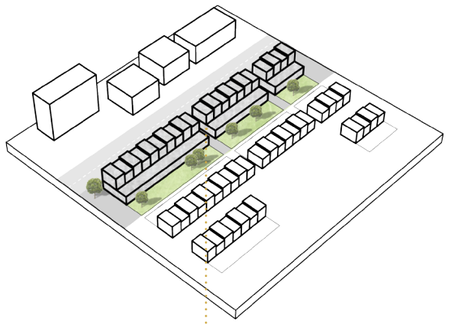
Hierarchy of streets by importance for the characteristic of urbanity
Unlike the previous principle, the hierarchy of streets by importance for the characteristic of urbanity does not necessarily have an impact on the width of the road.
But rather the urban quality of the streets, mostly defined by the functions located along them, the attractiveness and the walkability of the streets.



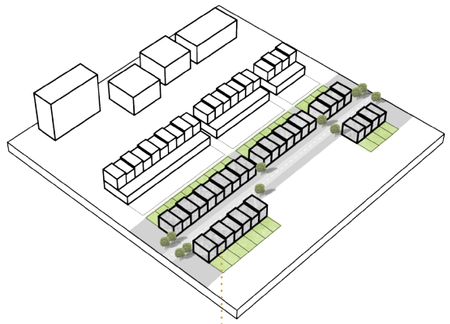
Key edges in the urban space
Based on the previous principle, the key edges are located along the streets that are important for the characteristic of urbanity. They basically highlight the streets that create urbanity, these are usually streets with less traffic volume, pedestrian friendly and invite you to linger.
Therefore, these edges are also characterised by a high level of mixed use and density, accommodate several special functions, and are connected with public spaces.



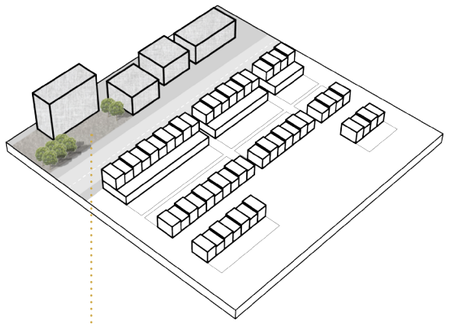
Special use plot
Special use plots stand not only out because of their dimensions, they are also the major element in the urban core. Often designed together with an urban square, the special use building should stand out from the surrounding buildings and attract people.



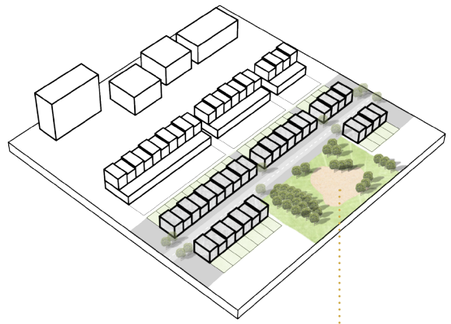
Mixed use plot
Mixed use plots contribute to a higher level of urbanity and increase liveability. At the same time, they constitute the transition between the residential and special use.
Furthermore, the mixed use plot can be used to highlight important spatial connections.



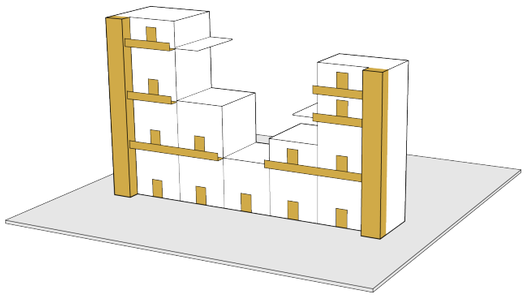
Residential plot
Monofunctional plots, which only accommodate housing, should be located at the limits of the transit zone.



Public urban square
Public squares are located in direct relation to special use plots and have a high characteristic of urbanity. As they define urban space, public squares should be located in the centre of the urban core.

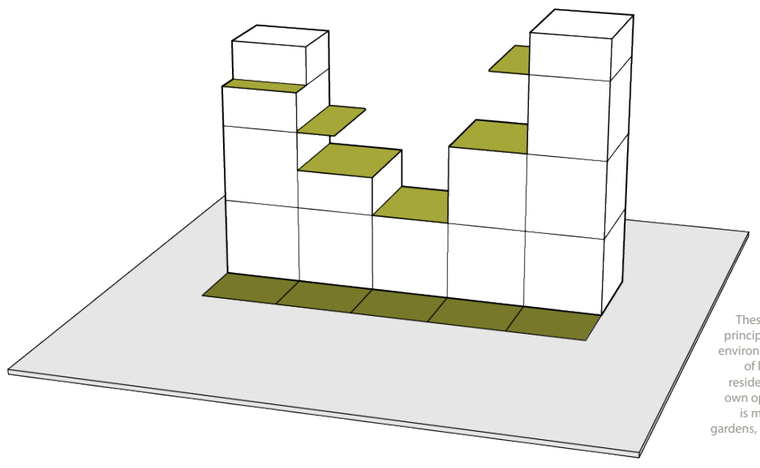


Public green space
Public green spaces are an important component of the urban structure. They primarily serve for local recreation. Besides the benefit of recreation, green spaces provide habitats for flora and fauna and have a cooling effect on the microclimate. Furthermore, they can serve as compensation areas for climatic adaptation processes.
In the proposed concept it is retained, that each transit zone should have at least one public park, designed or semi-designed. And it should be located off the core centre, preferably close to a residential plot.



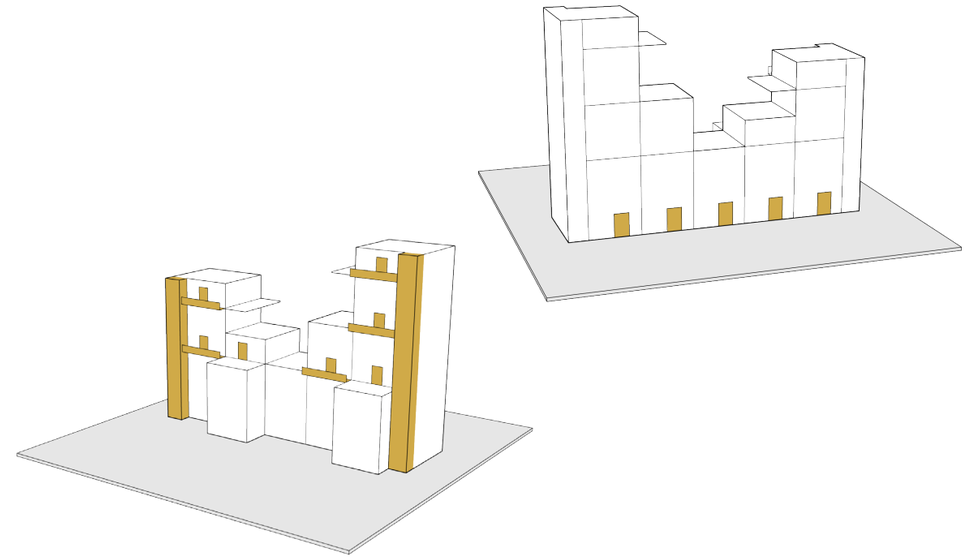
'Every housing unit with an open space and a private entrance'

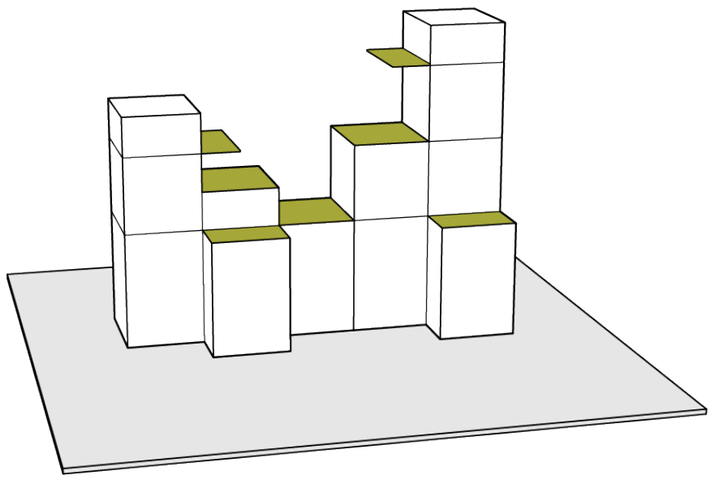
Besides the design elements on the transit zone scale, design elements have been developed on the building scale. They intend to connect and satisfy the requirements of the theoretical framework and the housing preferences of the population.
True to the motto 'every housing unit with an open space and a private entrance' the design elements meet the standard of Luxembourg's population, without having to sacrifice a high housing density. And thus reduce resource consumption.



These illustrations show how the design principles can be implemented to the built environment and still provide a high quality of living. These two illustrations show a residential plot, each housing unit with its own open space and private entrance. This is made possible by groundfloor private gardens, elevated open spaces, and pergolas.

Own drawing





These illustrations show a mixed use plot. Special characteristics of this typology are the higher ceiling and building depth in the lower floors. Furthermore, to improve the quality of housing, the economic and gastronomic activities are facing the street, whereas the housing units are accessible on the back.

Own drawing

Reference projects

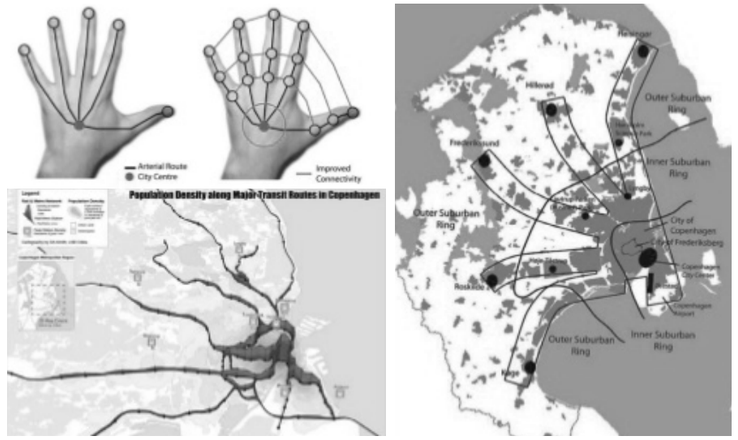
The following projects have been of great inspiration along the process of developing my thesis. Above all because of their positive contribution to transit-oriented development, spatial justice and circular economy.

The planning and design concept 'transit-oriented development' consists in promoting urban development that is compact, mixed use, promotes slow mobility and is highly accessible by public transportation.
The concept of TOD enhances access to job opportunities and services for residents at all income levels. Furthermore, the diversity in housing types allows the residents to spend their whole lives in the same neighbourhood even if changes in the household occur.

Transit-oriented development typically translates into higher productivity and a smaller carbon footprint, resulting in a better resource management.
TOD has been successfully applied at a city scale in cities around the world, including Stockholm, Copenhagen, Hong Kong, Tokyo, Singapore and Portland.

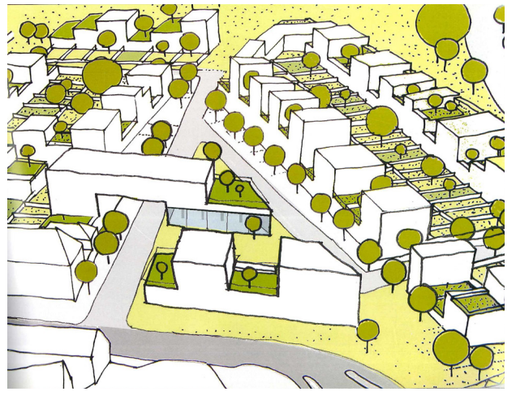
All of these cases had to deal with similar issues than Luxembourg is at the moment; strong population growth, rapid urbanisation and sprawl. Therefore, TOD seems to be also the innovative solution, Luxembourg is looking for to successfully face its issues.

An important component of the concept of transit-oriented development is density.
Unfortunately, housing density is often associated with high-rise buildings, anonymity and a low quality of life. The following reference examples show that this is a huge misunderstanding. And dense housing projects by all means can be comfortable without neglecting the advantages of a single-family unit: a private outddor space.



This visual representation explains the transit-oriented development based strategy that has been applied in Copenhagen.

Image from https://www.slideshare.net/WorldResources/holger-norway-19nov2014

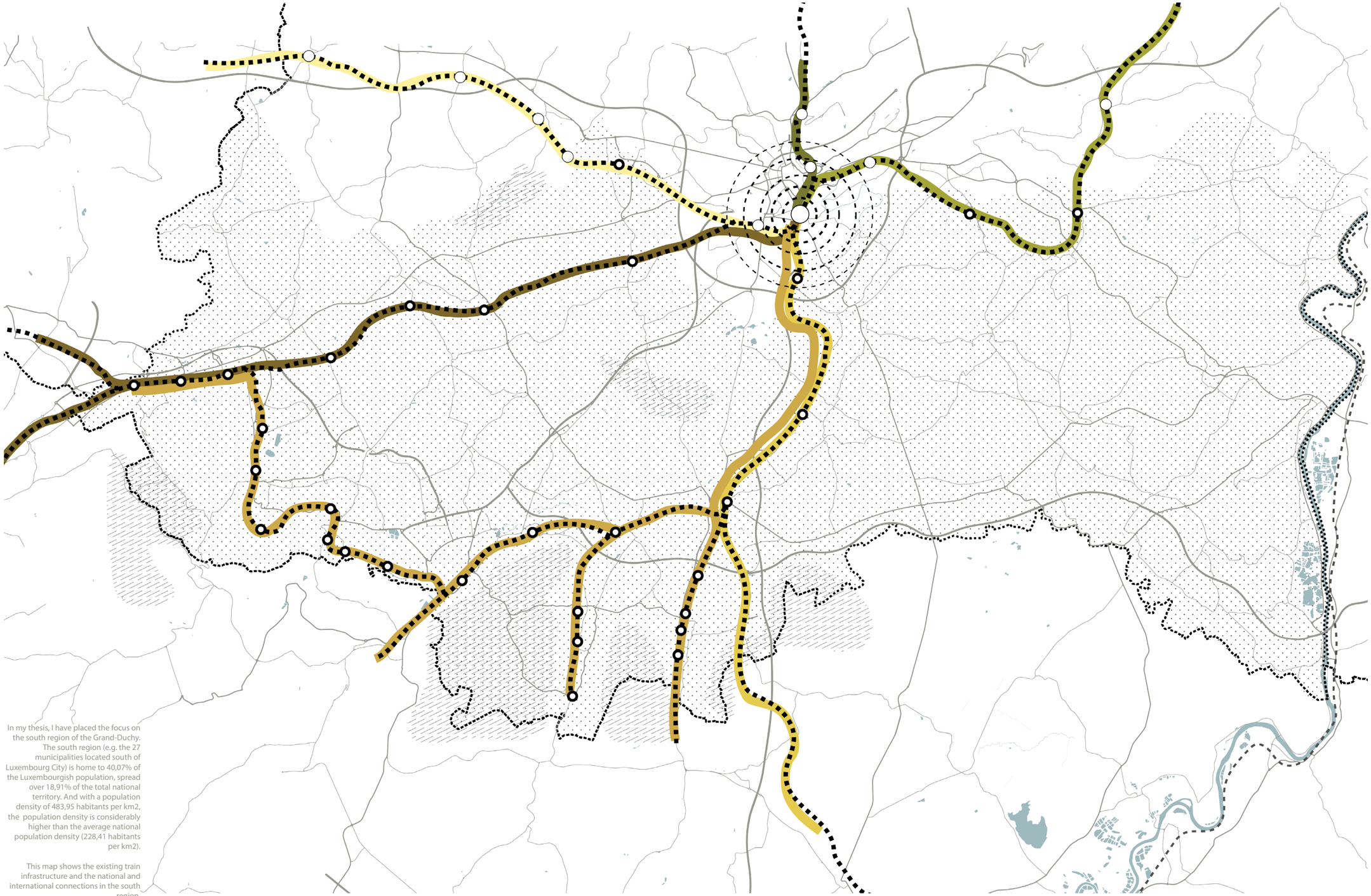


57 housing units / hectare
The housing development project 'Bloemenbuurt-Zuid' in Eindhoven by FÜNDC has been an important reference project in my thesis.

Illustration from Aurora Fernandez Per and Javier Arpa (2007). a+t density series: Density projects.

120 housing units / hectare
The mountain dwellings project in Copenhagen by PLOT (=BIG+JS) has been a reference for combining parking and living in a resource efficient framework.

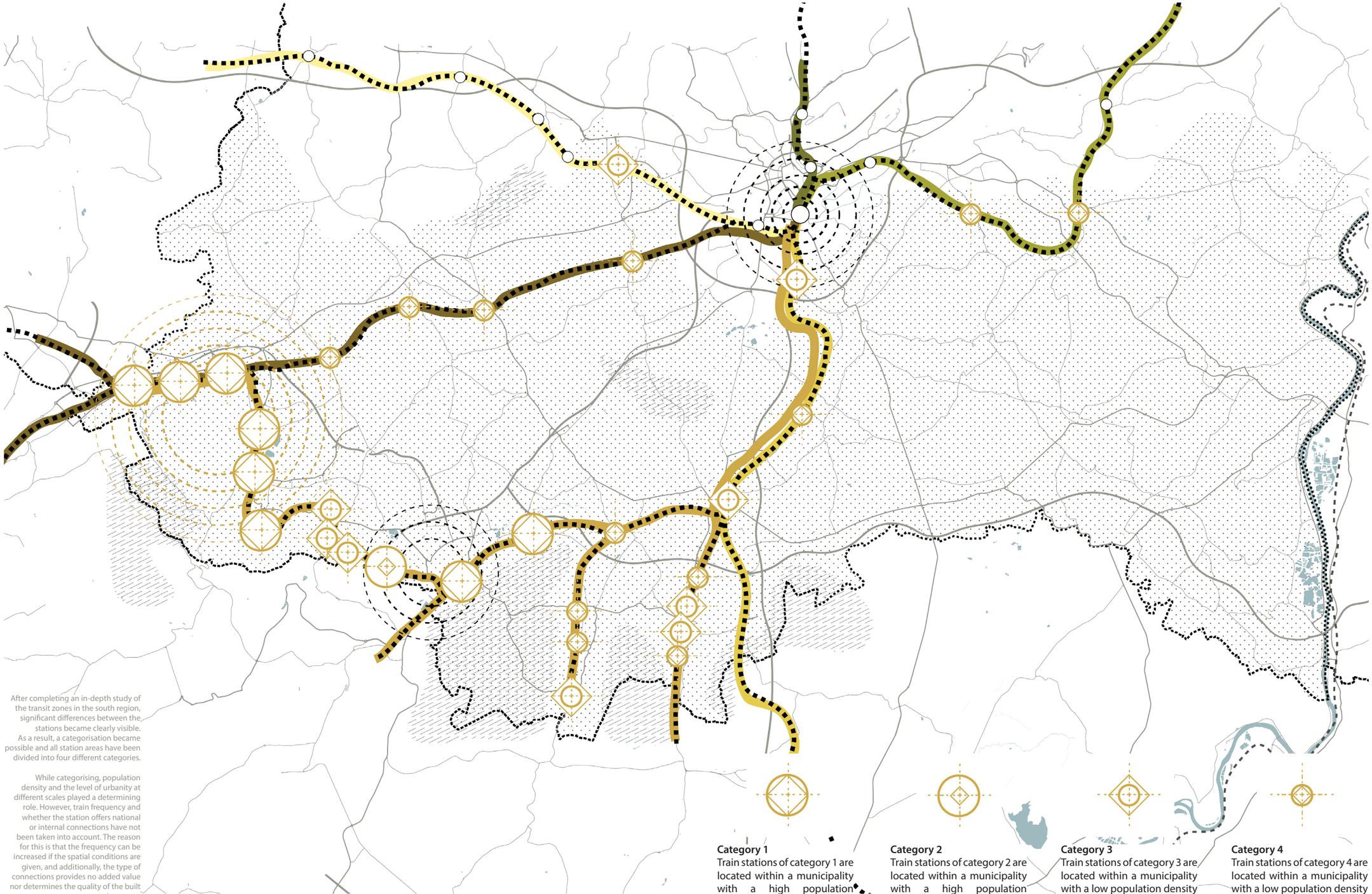
Illustration from Aurora Fernandez Per and Javier Arpa (2007). a+t density series: Density projects.



In my thesis, I have placed the focus on the south region of the Grand-Duchy. The south region (e.g. the 27 municipalities located south of Luxembourg City) is home to 40,07% of the Luxembourgish population, spread over 18,91% of the total national territory. And with a population density of 483,95 habitants per km2, the population density is considerably higher than the average national population density (228,41 habitants per km2).

This map shows the existing train infrastructure and the national and international connections in the south region.

Own drawing



After completing an in-depth study of the transit zones in the south region, significant differences between the stations became clearly visible. As a result, a categorisation became possible and all station areas have been divided into four different categories.

While categorising, population density and the level of urbanity at different scales played a determining role. However, train frequency and whether the station offers national or internal connections have not been taken into account. The reason for this is that the frequency can be increased if the spatial conditions are given, and additionally, the type of connections provides no added value nor determines the quality of the built environment.

Own drawing

Category 1
Train stations of category 1 are located within a municipality with a high population density and are characterised by a high level of urbanity.

Category 2
Train stations of category 2 are located within a municipality with a high population density and are characterised by a low level of urbanity.

Category 3
Train stations of category 3 are located within a municipality with a low population density and are characterised by a high level of urbanity.

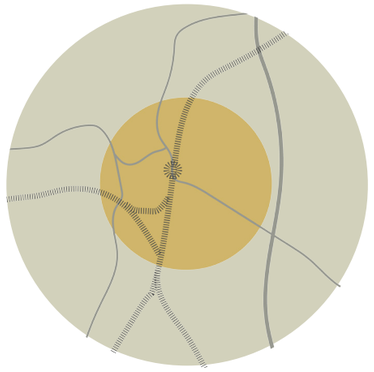
Category 4
Train stations of category 4 are located within a municipality with a low population density and are characterised by a low level of urbanity.

Case study example

To develop a better understanding of the functioning of the south region and the importance as well as the potential of the station areas, I carried out an in-depth analysis of the region.
Throughout this analysis several aspects have been evaluated. As a first step, the accessibility and density of all municipalities located in the south region have been assessed. Next, all train stations and their catchment area have been analysed according to a number of criteria.

This detailed case study made it possible to define a categorisation of train stations that allows location-based approach.

The following pages show the example of the municipality of Bettembourg and the train station Bettembourg Gare. The complete study with all the examples can be found in the case study booklet.



This illustration shows a schematic representation of the relation between the built environment of Bettembourg and its infrastructure network.

Own drawing

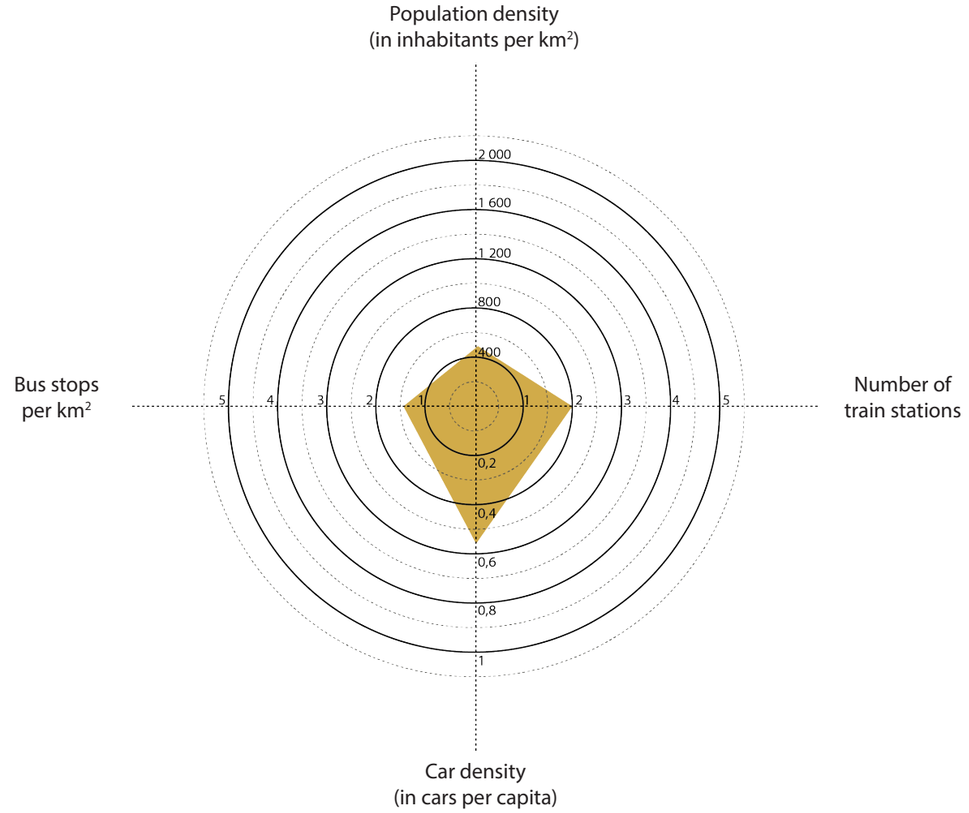
Municipality of Bettembourg

Consisting of the following localities: Abweiler, Bettembourg, Fennange, Huncherange, Noertzange

_Surface	21,94 km²
_Population	10 736
_Population density	489,33
_Number of passenger cars*	6 013
_Cars per capita	0,56
_Number of train stations	2
_Number of bus stops	29
_Bus stops per km²	1,32

* The number of passenger cars includes all private cars owned by a natural person. Excluding leasing cars.

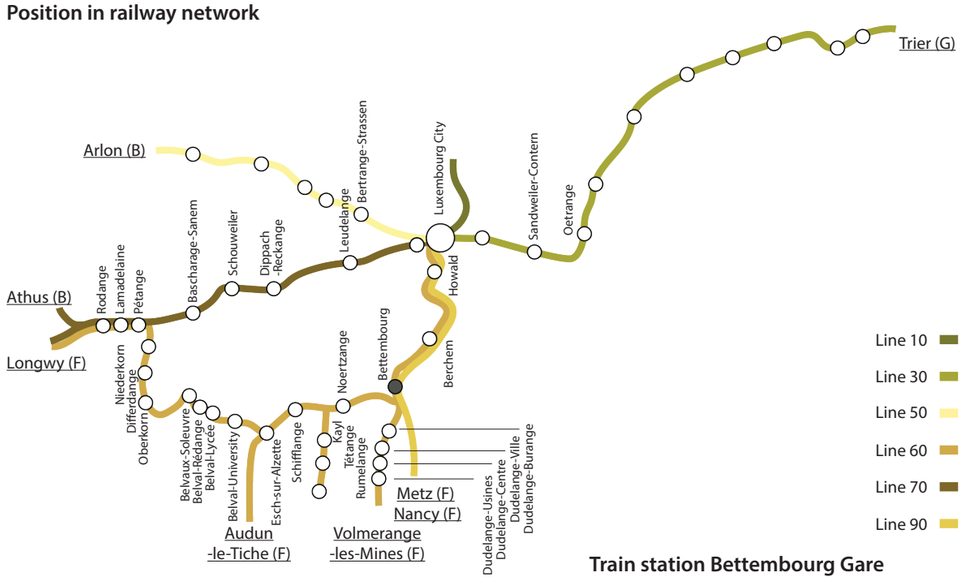
Data from year 2017. Information retrieved from http://www.Wblic.lu



The chart shows the relation between the population density and the accessibility of the respective municipality.
From this, it becomes clear which conditions need improvement.

Own drawing

Position in railway network



Line 10
Line 30
Line 50
Line 60
Line 70
Line 90

Train station Bettembourg Gare

_Train station typology

(Transit station offering international connections. With very high frequency.)

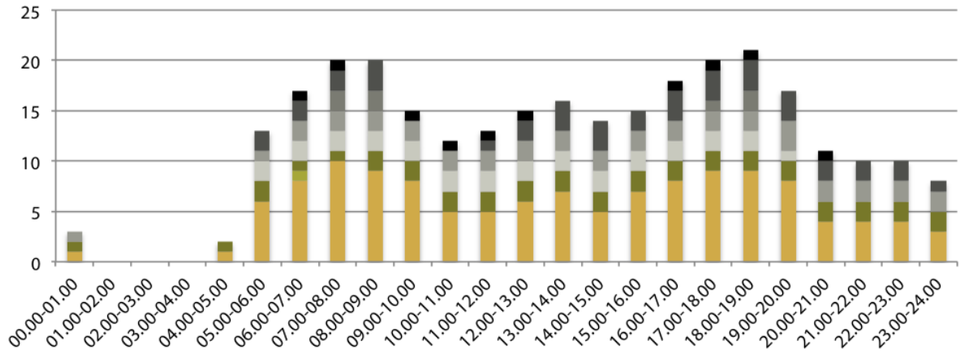
_Railway line 60/90

_Destinations
Luxembourg City
Dudelange
Pétange
Rodange
Volmerange-les-Mines (France)
Thionville (France)
Metz (France)
Nancy (France)

Bettembourg Gare counts 290 train connections per day, with a peak of 21 trains per hour (6pm-7pm).

Information retrieved from https://www.mobiliteit.lu
07/03/2018 served as reference day to analyse the frequency.

Train frequency

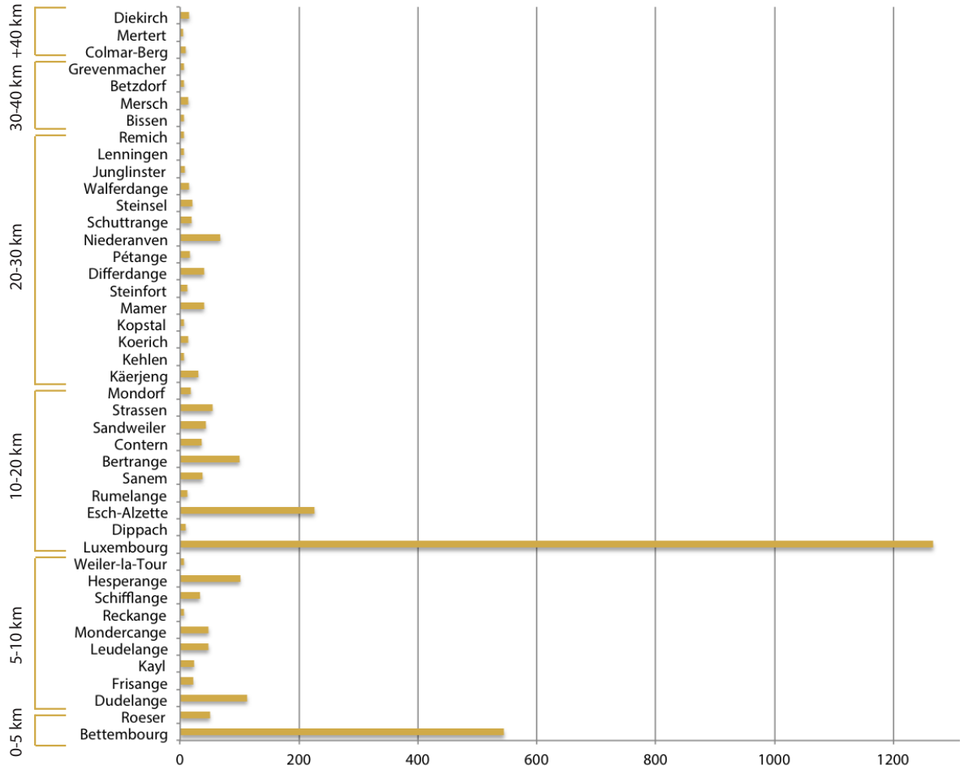


direction Luxembourg City
direction Dudelange
direction Volmerange-les-Mines (F)
direction Rumelange
direction Pétange
direction Rodange
direction Thionville (F)
direction Metz (F)
direction Nancy (F)

This graphic represents all train connections of Bettembourg Gare, both national and international ones.
Information retrieved from https://www.mobiliteit.lu
07/03/2018 served as reference day to analyse the frequency.

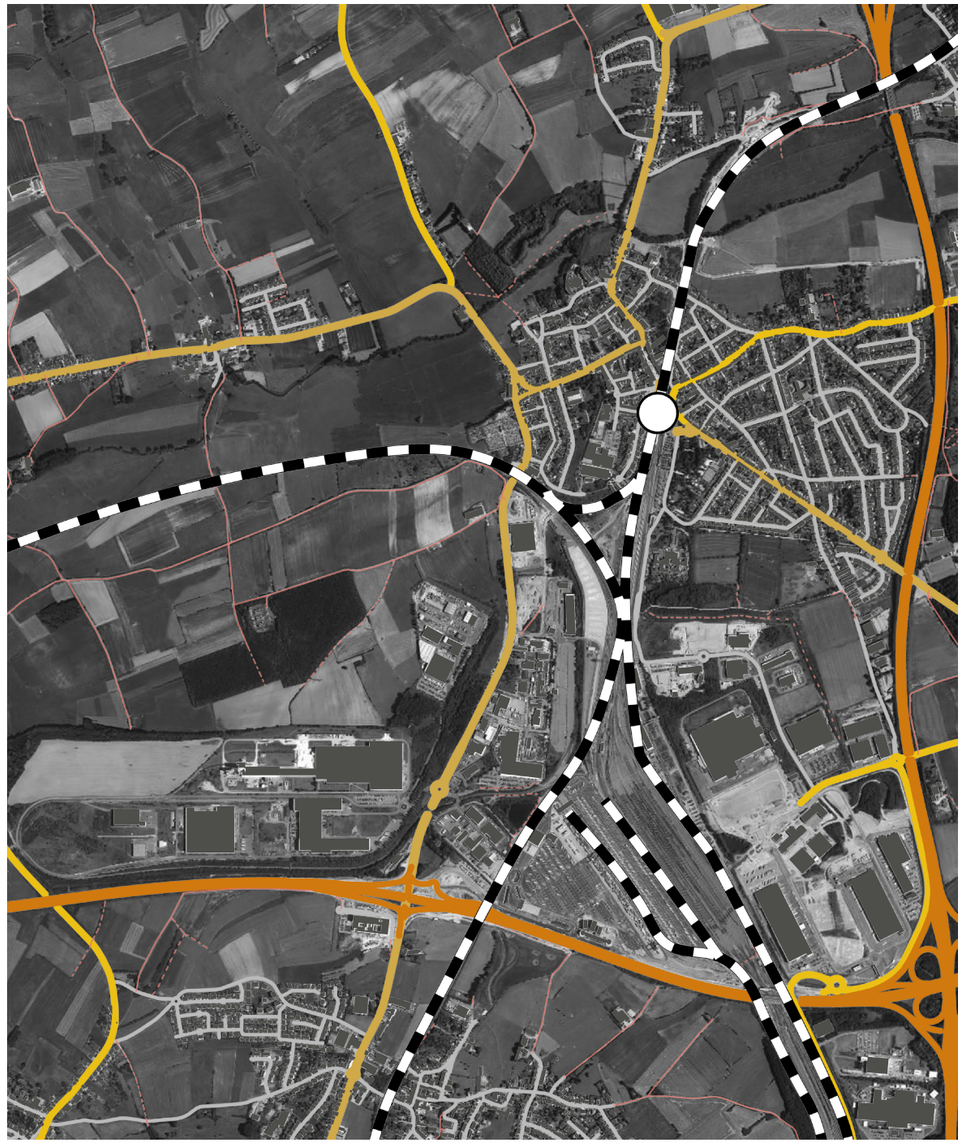
Own drawing

Place of work

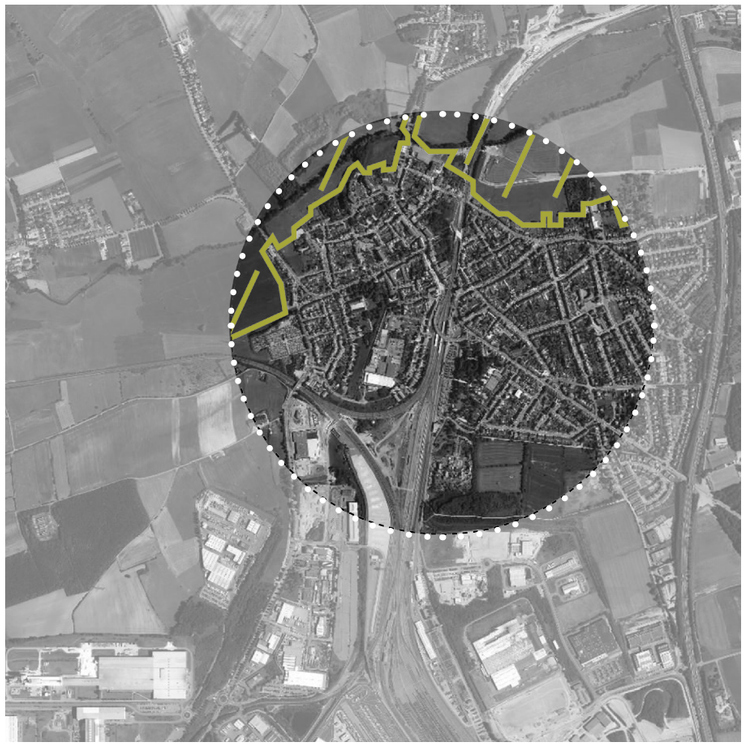


Total working population of Bettembourg (2011): 3 748. Whereof 523 employees (13,95%) did not provide information about their place of work.
Places of work with less than 5 employees have not been taken into account in the diagram, but are included in the total working population.

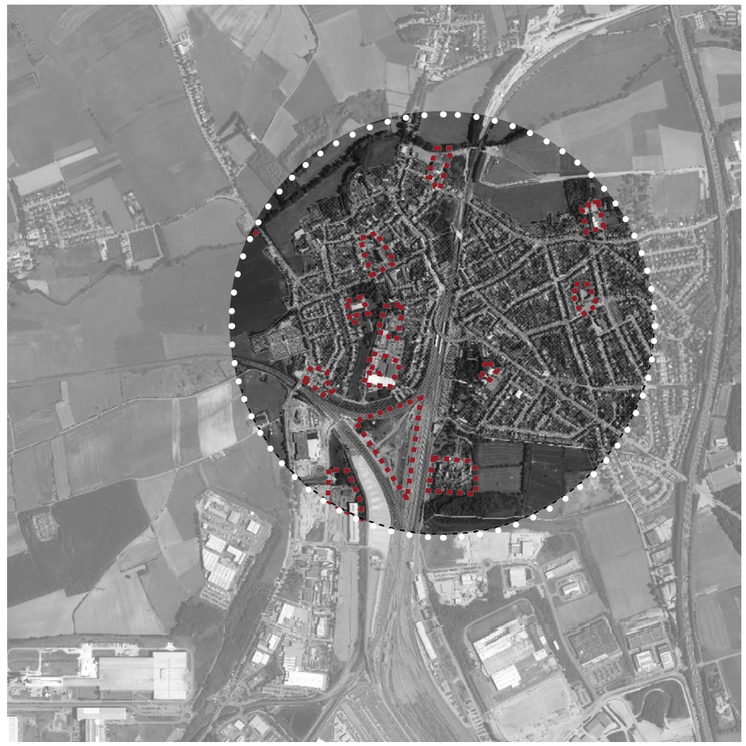
Data from year 2011. Information retrieved from http://www.statistiques.public.lu



Background image retrieved from http://map.geoportail.lu



Background image retrieved from
http://map.geoportail.lu



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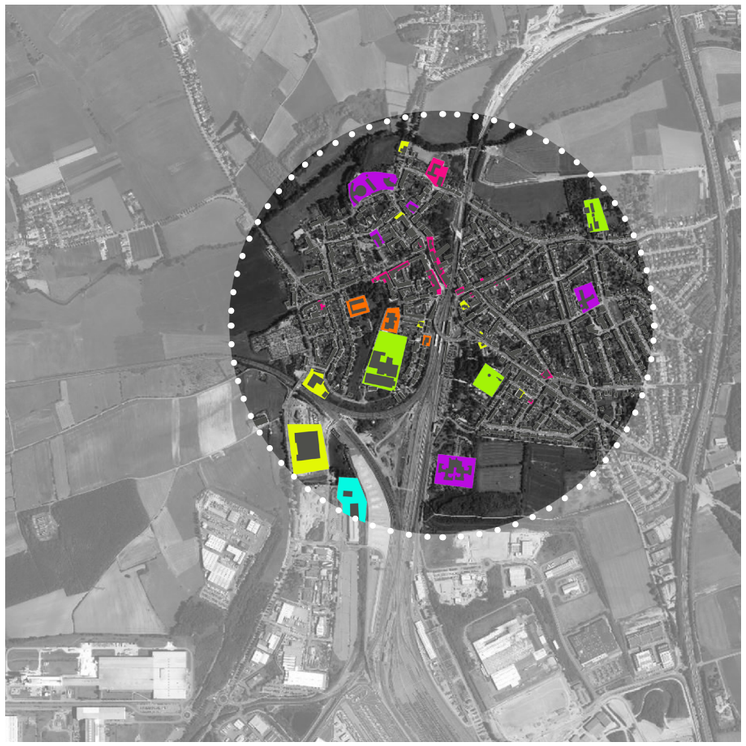


industrial use

educational use

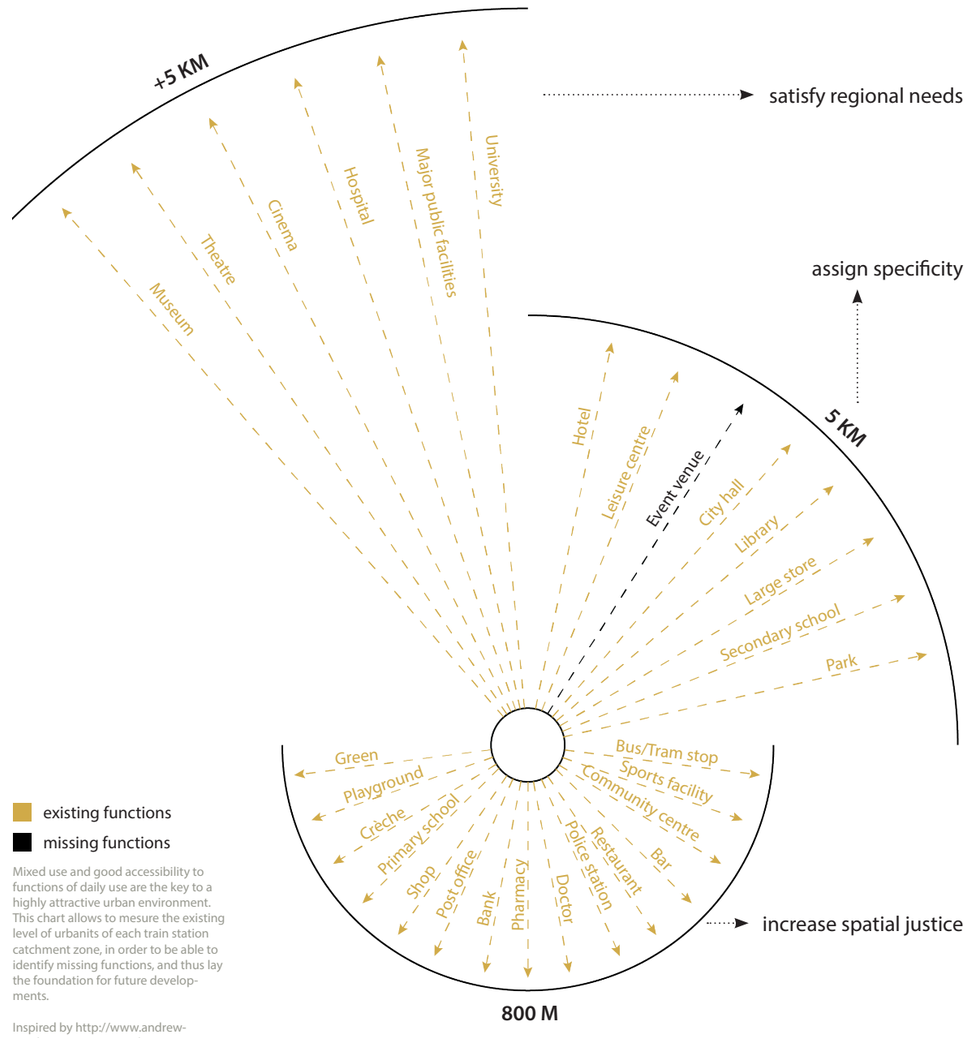
sports and culture

mixed use

administrative use and public services

commercial use

Background image retrieved from
http://map.geoportail.lu

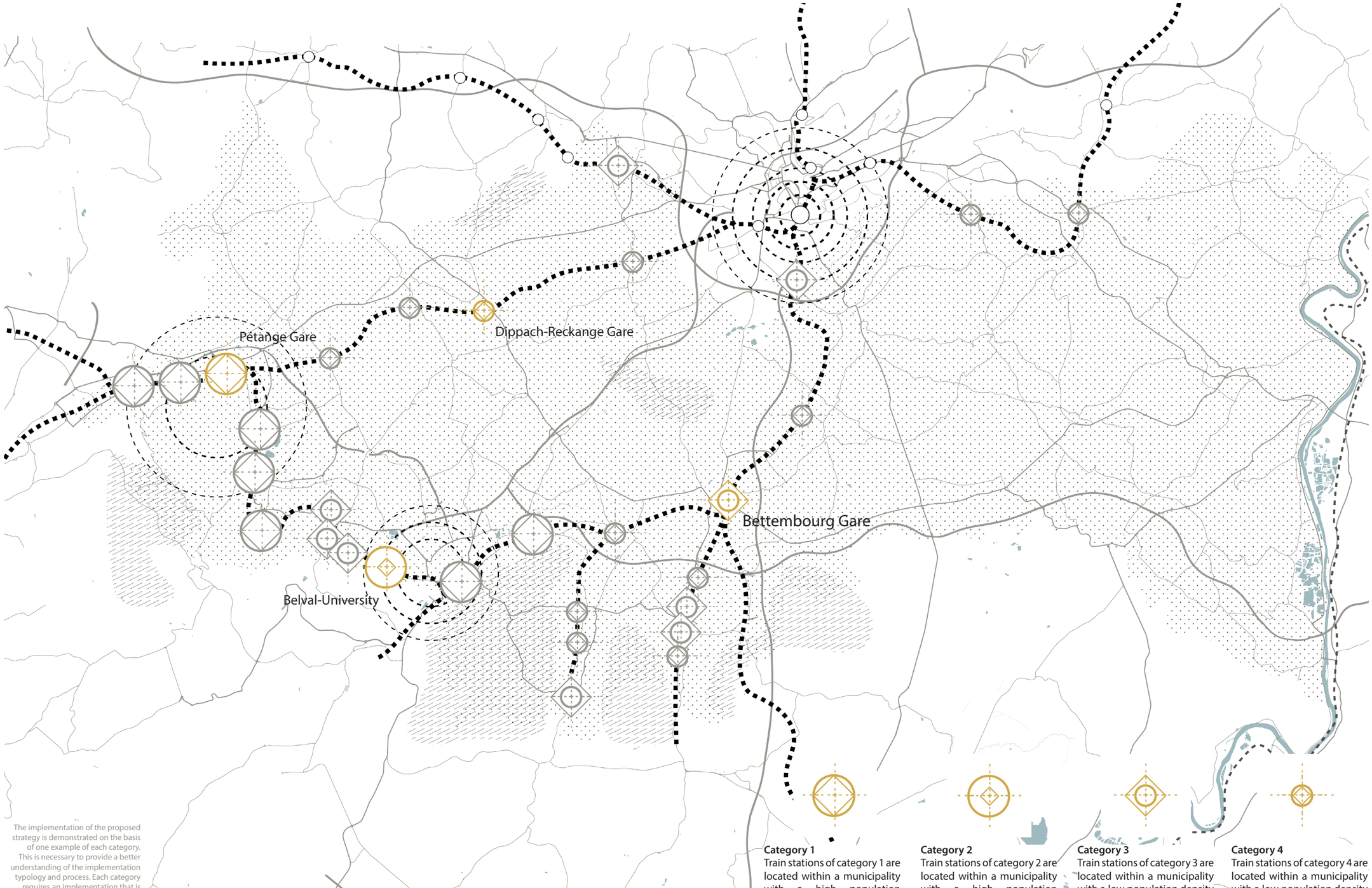


existing functions

missing functions

Mixed use and good accessibility to functions of daily use are the key to a highly attractive urban environment. This chart allows to mesure the existing level of urbanits of each train station catchment zone, in order to be able to identify missing functions, and thus lay the foundation for future developments.

Inspired by http://www.andrew-wrightassociates.com/docs/content.php?id=4:0:42 and adapted to the Luxembourgish context.
All information represented in the diagram has been retrieved from google maps.
Own drawing



The implementation of the proposed strategy is demonstrated on the basis of one example of each category. This is necessary to provide a better understanding of the implementation typology and process. Each category requires an implementation that is adapted to the given spatial conditions.

Own drawing

Category 1
Train stations of category 1 are located within a municipality with a high population density and are characterised by a high level of urbanity.

Category 2
Train stations of category 2 are located within a municipality with a high population density and are characterised by a low level of urbanity.

Category 3
Train stations of category 3 are located within a municipality with a low population density and are characterised by a high level of urbanity.

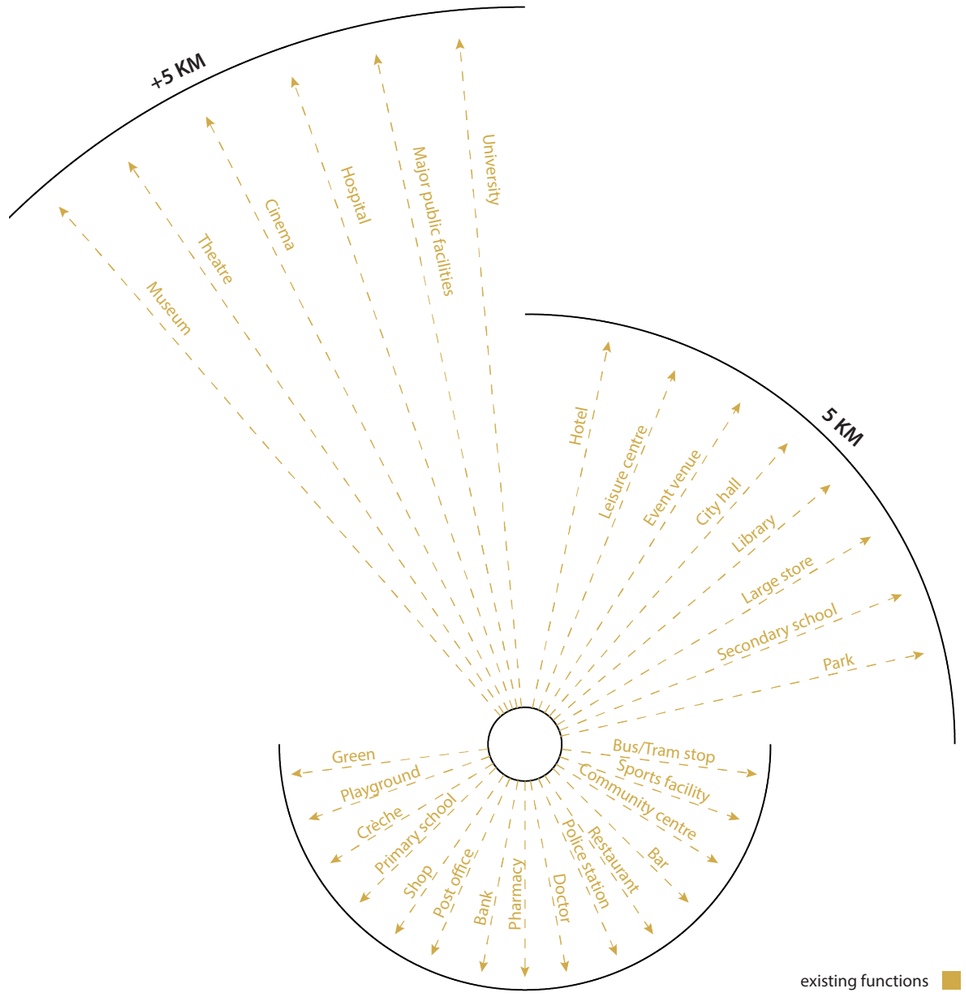
Category 4
Train stations of category 4 are located within a municipality with a low population density and are characterised by a low level of urbanity.

Plan and Partner
Category 1 - Pétange Gare

high population density

high level of urbanity

clustered intervention



This graph shows the current level of urbanity of the respective transit zone.

All information represented in the diagram has been retrieved from google maps.
Own drawing

Category 1

These photos show the existing situation of the transit zone of Pétange Gare. Pétange Gare is situated in the municipality of Pétange, a municipality with a high density and high level of urbanity.
The train station of Pétange Gare (photo 1) has a high frequency and has a bus terminal in front of the station. The main street is characterised by a high level of mixed use (photos 3-4). Furthermore, several special uses, as for example the town hall (photo 2) are also located along this major road.
The street which connects the main road and the train station (photo 5) also provides a certain level of mixed use, and thus contributes to the liveability of the neighbourhood.

All photos have been taken by the author.

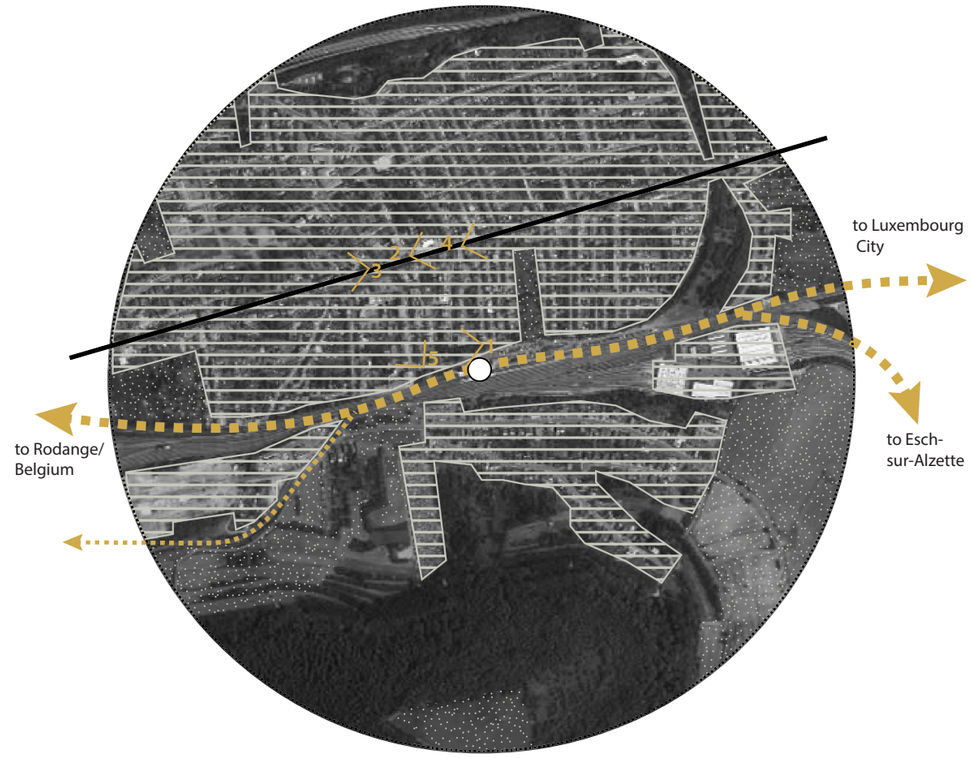

1


2


3

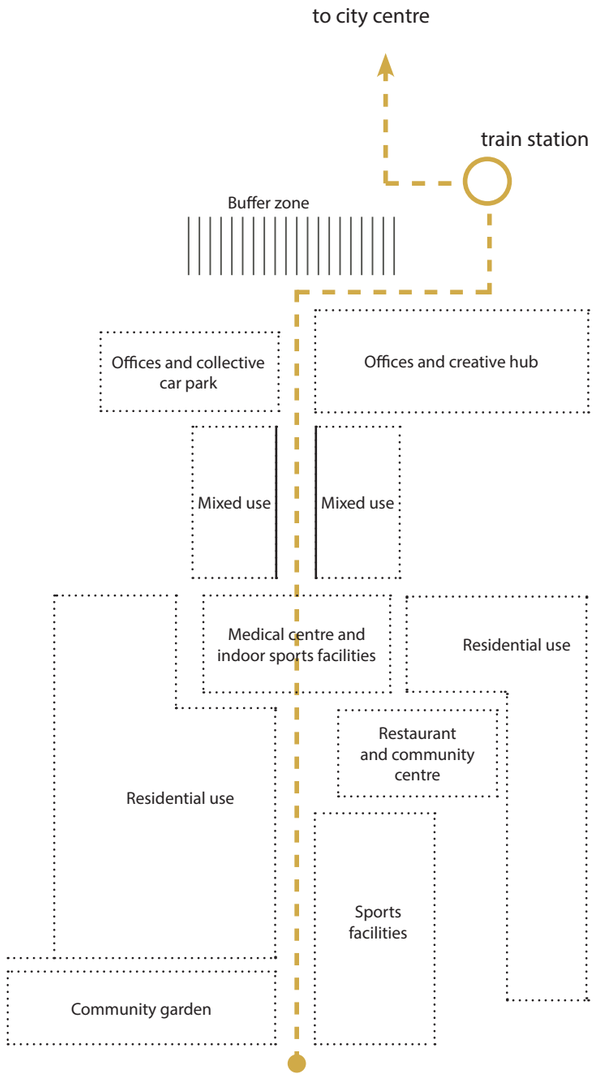

4


5



Background image retrieved from http://map.geoportail.lu

Own drawing



Concept for the development of the transit zone of Pétange Gare

Own drawing

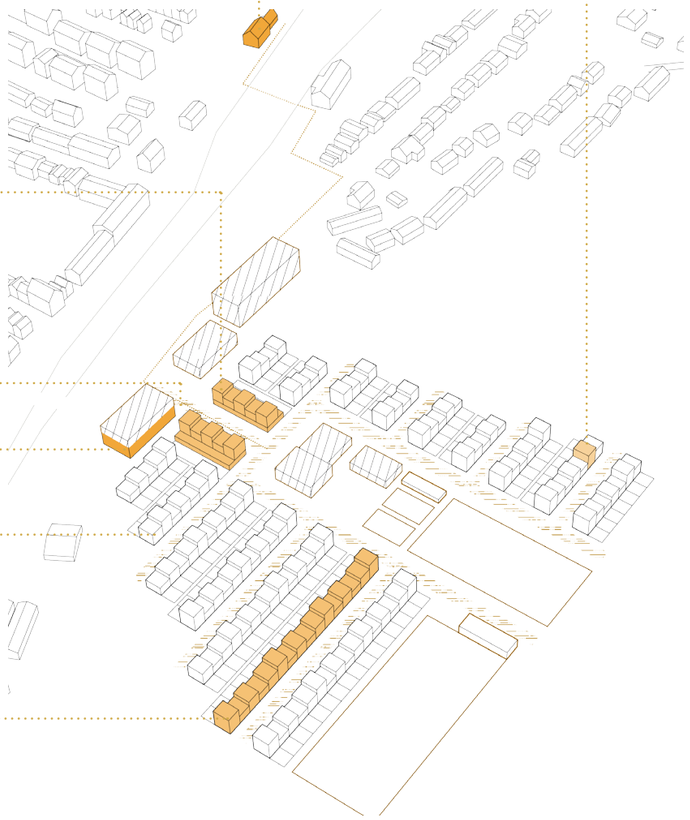
Design proposal for Pétange Gare: Plan and Partner

The proposed design intends to create an opposite pole to the existing urban core. However the new development does not intend to compete with the existing city centre, on the contrary, they work together in complementary way.
The type of intervention can be defined as clustered. For the reason that this specific proposal consists of a whole new neighbourhood, that fits in the existing spatial structure and enriches the catchment zone by offering new business opportunities, sports facilities, health care and functions of daily life. All this combined with high quality living and accessible by public transportation and slow mobility.
Through the composition and the specific design elements, a new development can result that not only increases the quality of life, but is also in line with the principles of spatial justice and circular economy.

Off-centre collective car parks increase the attractivity of soft mobility. In addition, car free zones increase the quality of life of the neighbourhood.

Train stations are important connecting elements in the regional network, and thus largely contribute to spatial justice.

A reduction of the living space per capita fosters a general decrease in land use for housing.



Mixed use is an important component of spatial justice as it enhances the access to facilities and a more equal distribution of functions.

Soft mobility reduces energy consumption and pollution, and increases liveability.

Increasing housing density implies a decrease in land consumption and environmental fragmentation, and potentially reduces sprawl.

To increase social justice, different house types are proposed, providing housing for all age and professional groups and thus create social diversity.

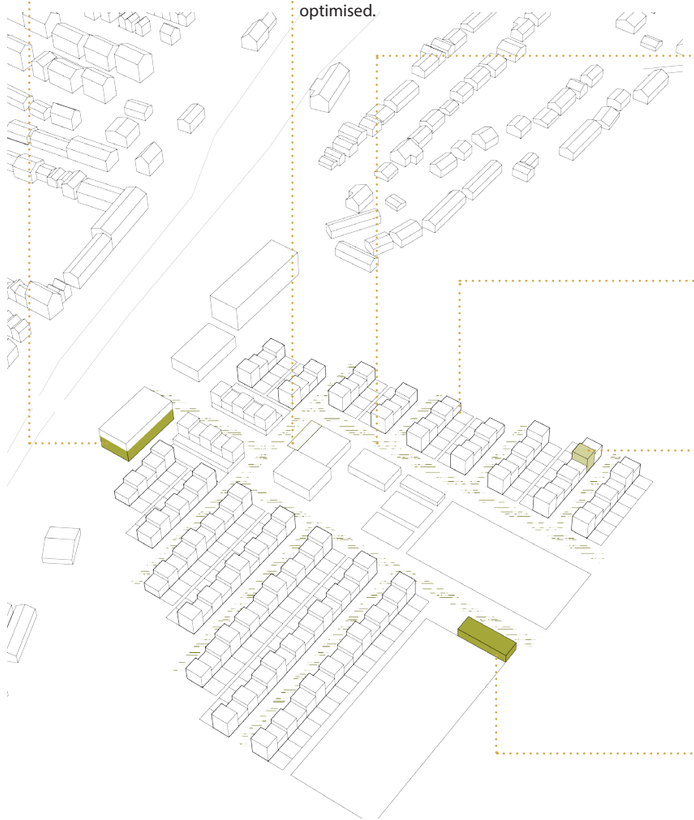
This illustration shows the proposed design elements that will increase spatial justice in the transit zone of Dippach-Reckange Gare.

Own drawing

Collective car parks increase the attractivity of soft mobility. Furthermore, the building structure provides the opportunity for repurposing at a later stage.

Sharing economy is an important aspect in the transition towards circularity. Through sharing vehicles living space and budgetary costs can be reduced, and simultaneously the usage is optimised.

Soft mobility implies a reduction in energy consumption, and thus preserves natural resources.



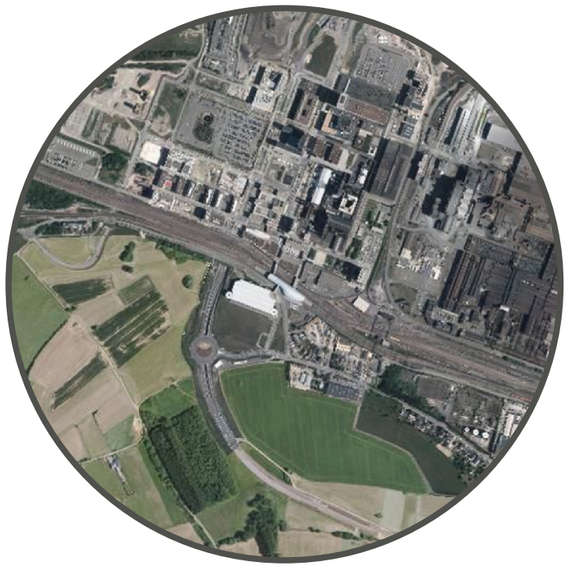
Density contributes to circularity as valuable resources are used more efficiently.

Compact living space and modular building constructions are drivers for circular economy. Besides the reduction of resource consumption, modular construction facilitate the recycling process and are cheaper in production.

Sharing economy is an important aspect in the transition towards circularity. Through sharing commodities living space and budgetary costs can be reduced, and simultaneously the usage is optimised.

This illustration shows the proposed design elements that will enhance the process towards circularity in the transit zone of Dippach-Reckange Gare.

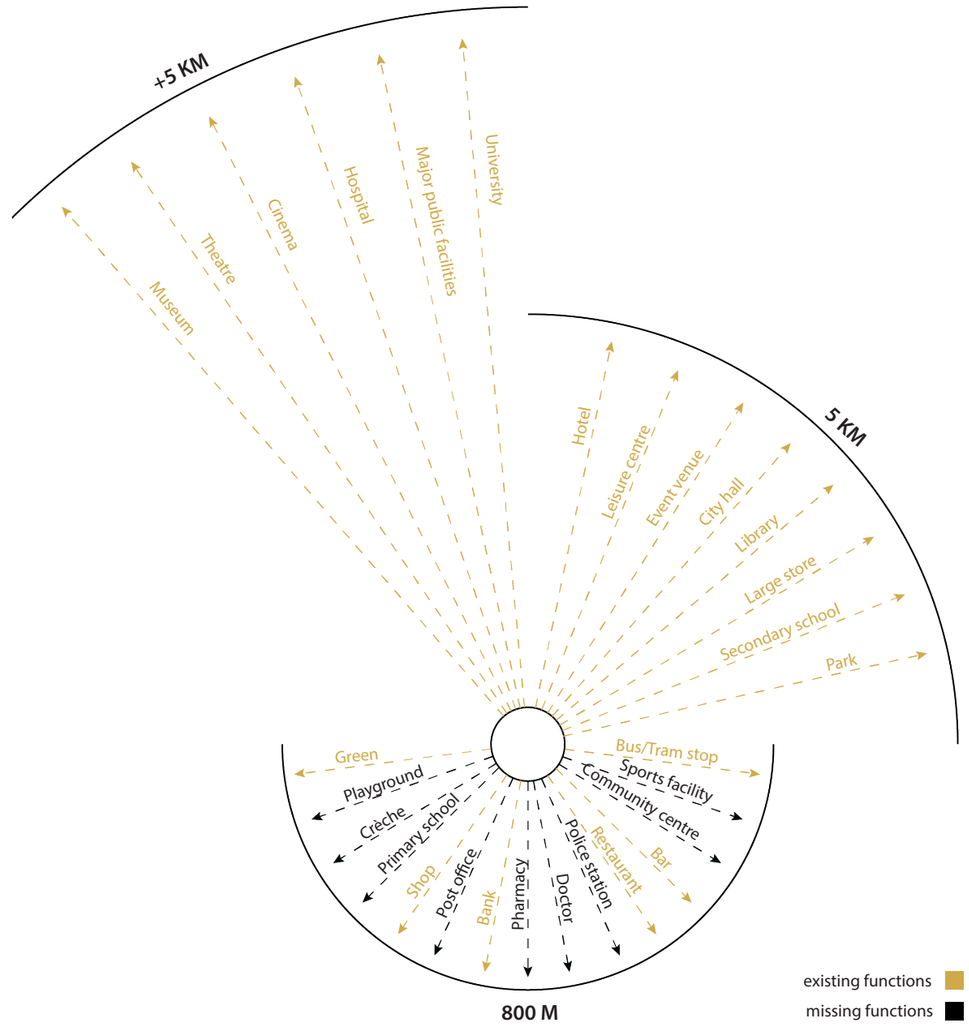
Own drawing



Category 2 - Belval-University

high population density

low level of urbanity



This graph shows the current level of urbanity of the respective transit zone.

All information represented in the diagram has been retrieved from google maps.
Own drawing

Category 2

Belval-University is located in the municipality of Esch-sur-Alzette, a municipality with a high population density and high level of urbanity. However, Belval can be considered as a district of its own and has only recently been redeveloped.
And the implementation of the redevelopment project will continue over decades.
First buildings have already been finished and give the area a new face, without neglecting its former use (photos 2-5).
However, due to the long development process, several functions of daily use are still missing. In addition, most of the housing areas have not been developed yet (photo 6), and therefore liveability is not given yet.

All photos have been taken by the author.


1

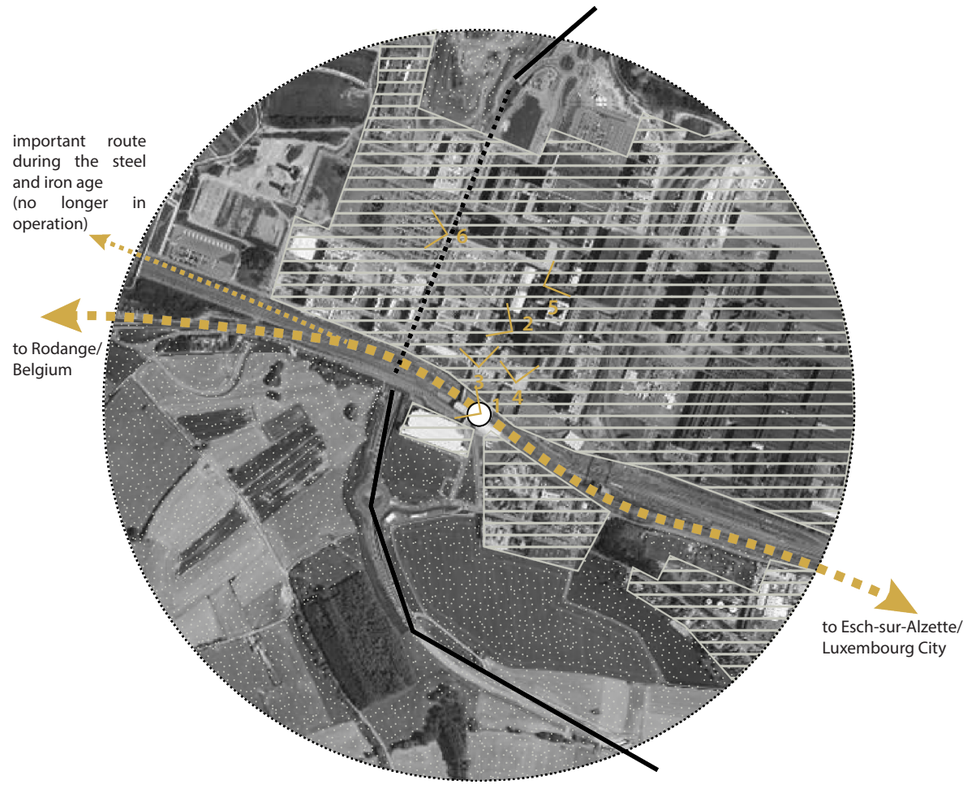

2


3


4


5


6



Background image retrieved from http://map.geoportail.lu

Own drawing

Illustration from Schroeder & Associés

As the transit zone of Belval-University is still under developement and the implementation of the proposed concept has not been finished yet, I did not propose a design concept for this location within my thesis.
The proposed master plan of Belval is very promising, promoting housing density and a very high level of urbanity.

Illustration from Schroeder & Associés

Infill and Enhance
Category 3 - Bettembourg Gare

low population density

high level of urbanity

targeted intervention

This graph shows the current level of urbanity of the respective transit zone.

All information represented in the diagram has been retrieved from google maps.
Own drawing

Category 3

Bettembourg Gare is located in the municipality of Bettembourg, which is characterised by a low population density but a high level of urbanity.
The existing train station is well connected by a bus terminal located next to it (photo 1-2).
The main road, accommodating all functions of daily use has recently been renewed according to the principles of shared space (photo 3). Furthermore, public squares have been renewed to increase the liveability of the area (photo 4).

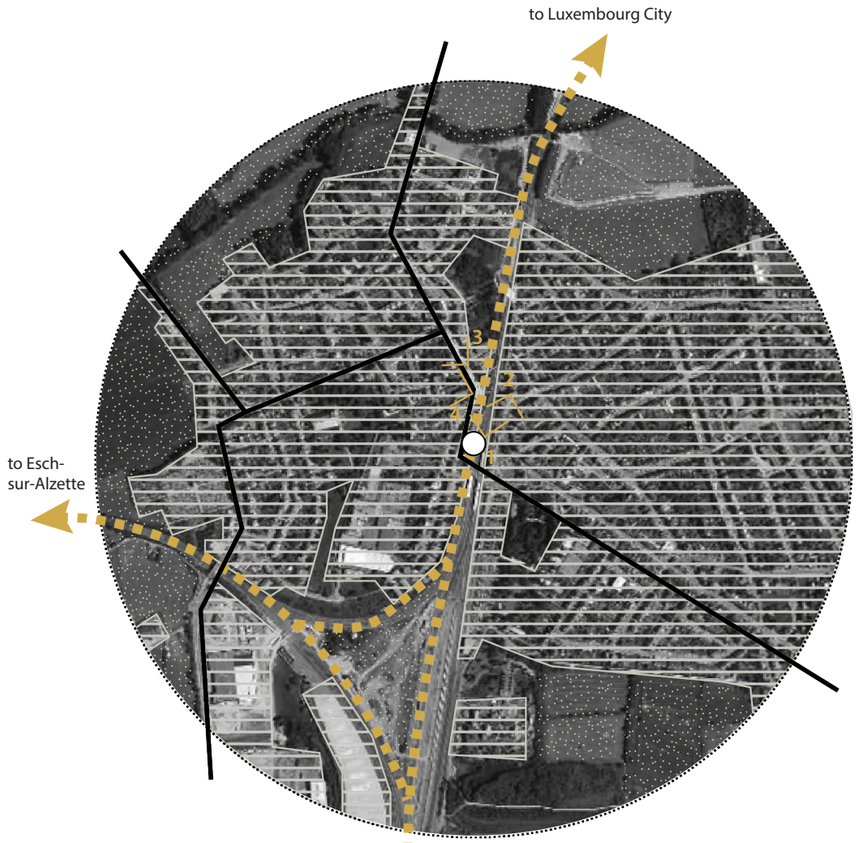
All photos have been taken by the author.


1


2


3


4



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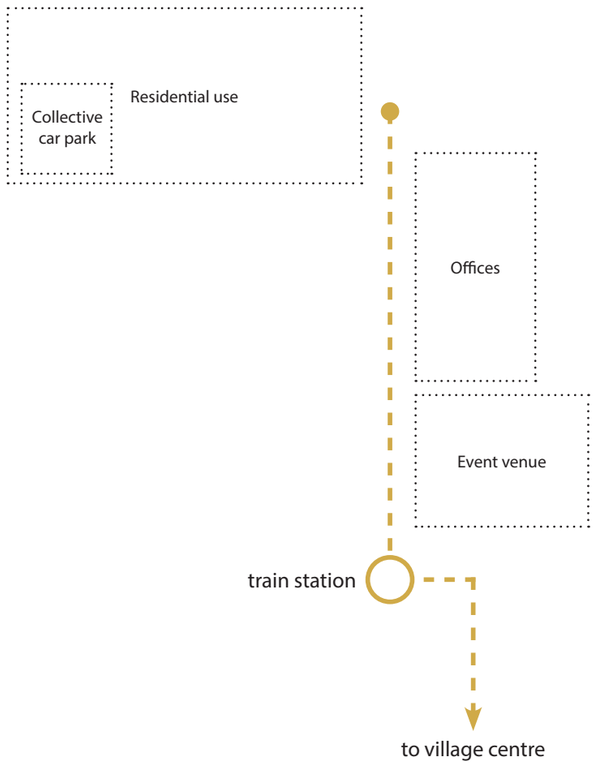


Concept for the development of the transit zone of Bettembourg Gare

Own drawing

Design proposal for Bettembourg Gare: Infill and Enhance

The design proposal for the catchment zone of Bettembourg Gare has the objective to introduce missing functions and increase the housing density.
In this case, all functions of daily use are already accessible within the 800m radius, however, on the larger scale, no event venue is located within the 5km radius. Therefore, the design proposal focuses on introducing an event venue, combined with business opportunities in the heart of the catchment zone, next to the train station. And thus give the transit zone a whole new image. At the same time, this new development serves as connecting element between the existing station and the new residential plots.
The proposed design enhances productivity within the catchment zone, increases spatial justice by adding new functions and combats resource consumption by introducing new forms of housing and sharing systems.

Off-centre collective car parks increase the attractivity of soft mobility. In addition, car free zones increase the quality of life of the neighbourhood.

Increasing housing density implies a decrease in land consumption and environmental fragmentation, and potentially reduces sprawl.

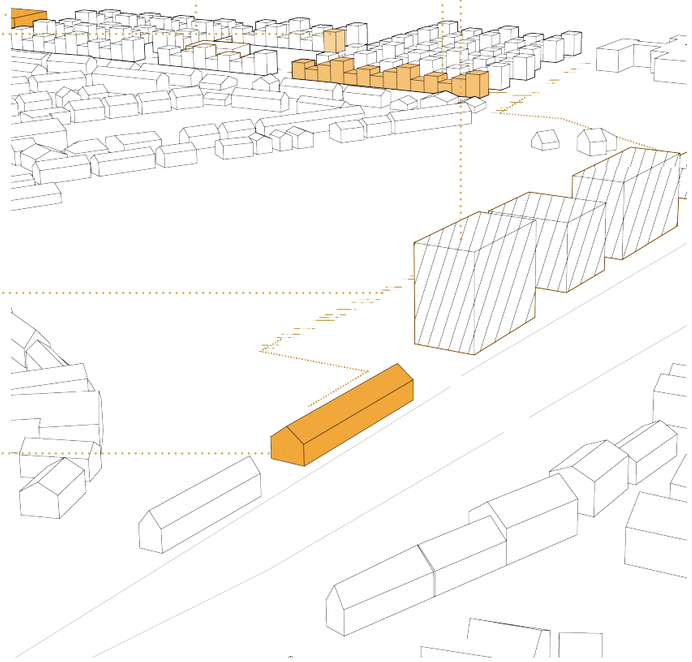
To increase social justice, different house types are proposed, providing housing for all age and professional groups and thus create social diversity.

Mixed use is an important component of spatial justice as it enhances the access to facilities and a more equal distribution of functions.

A reduction of the living space per capita fosters a general decrease in land use for housing.

Soft mobility reduces energy consumption and pollution, and increases liveability.

Train stations are important connecting elements in the regional network, and thus largely contribute to spatial justice.



This illustration shows the proposed design elements that will increase spatial justice in the transit zone of Dippach-Reckange Gare.

Own drawing

Collective car parks increase the attractivity of soft mobility. Furthermore, the building structure provides the opportunity for repurposing at a later stage.

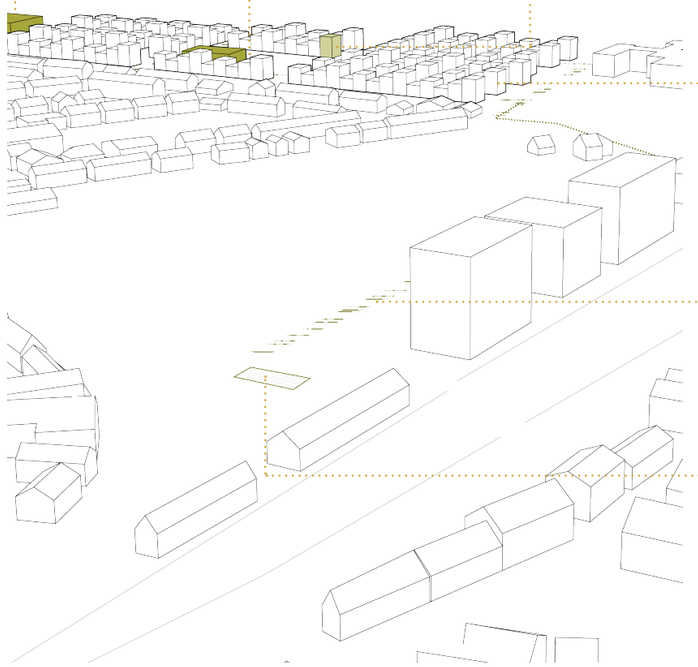
Sharing economy is an important aspect in the transition towards circularity. Through sharing commodities living space and budgetary costs can be reduced, and simultaneously the usage is optimised.

Compact living space and modular building constructions are drivers for circular economy. Besides the reduction of resource consumption, modular construction facilitate the recycling process and are cheaper in production.

Density contributes to circularity as valuable resources are used more efficiently.

Soft mobility implies a reduction in energy consumption, and thus preserves natural resources.

Sharing economy is an important aspect in the transition towards circularity. Through sharing vehicles living space and budgetary costs can be reduced, and simultaneously the usage is optimised.



This illustration shows the proposed design elements that will enhance the process towards circularity in the transit zone of Dippach-Reckange Gare.

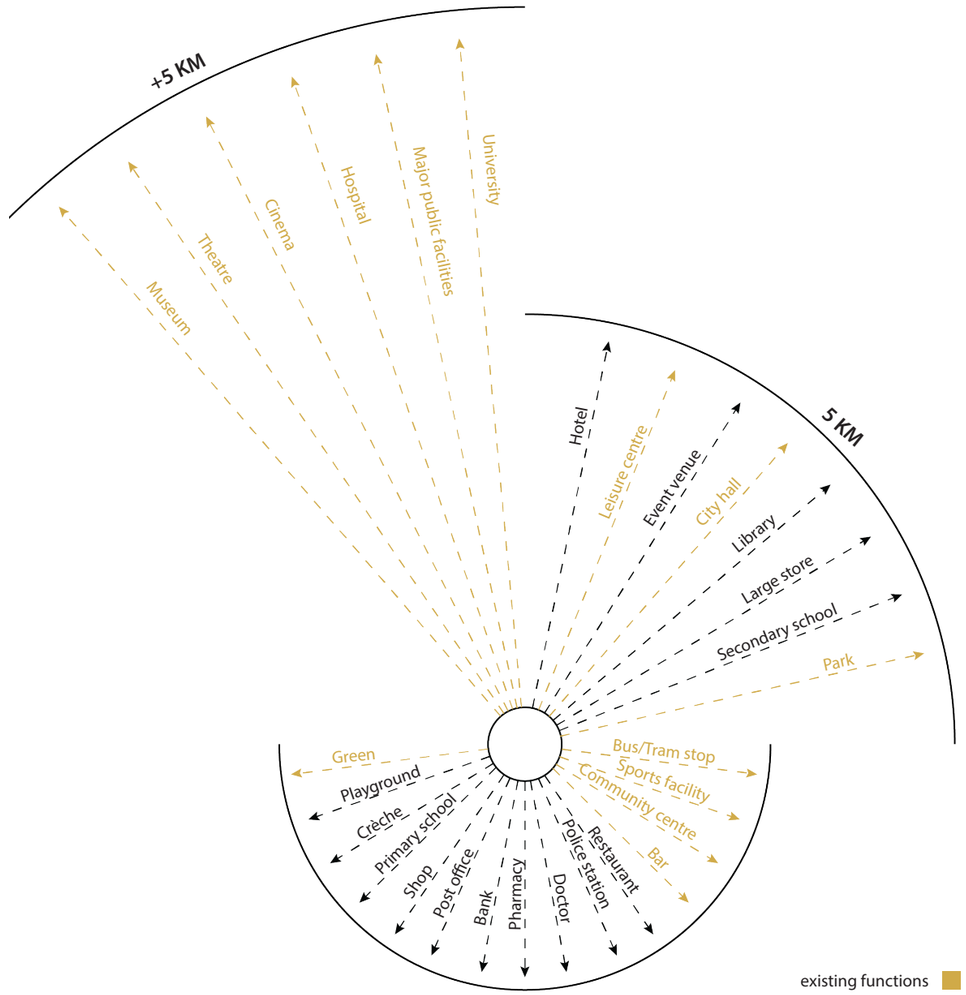
Own drawing

Catalyse and Connect
Category 4 - Dippach-Reckange Gare

low population density

low level of urbanity

linear intervention



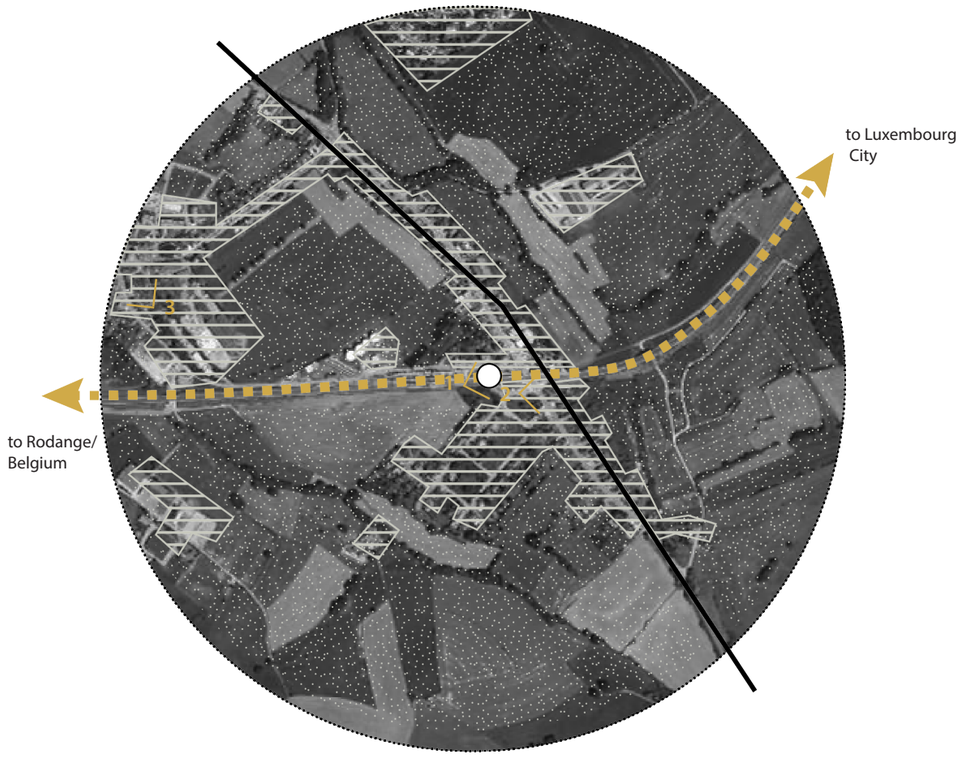
This graph shows the current level of urbanity of the respective transit zone.

All information represented in the diagram has been retrieved from google maps.
Own drawing

Category 4

Dippach-Reckange Gare is located in the municipality of Dippach, which is characterised by a low population density and a very low level of urbanity. The transit zone also shows a rural characteristics.
The train station (photo 1) is surrounded by residential plots and no mixed function is located in direct proximity.
The only special uses situated within the catchment zone, are located at the boundary. Consisting of a community centre and a café (photo 3).

All photos have been taken by the author.



Background image retrieved from http://map.geoportail.lu

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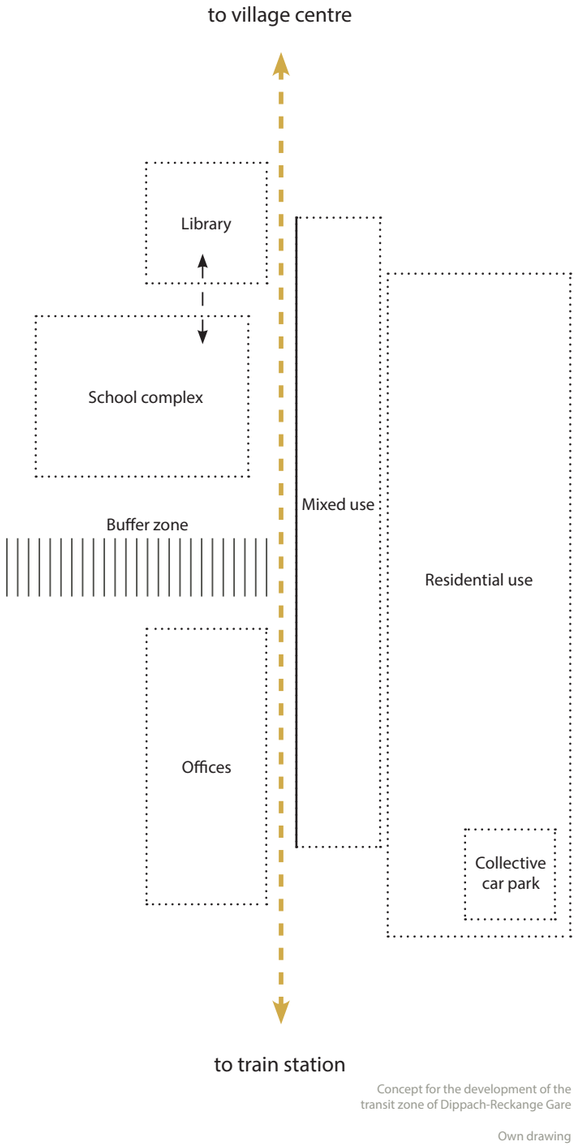

Concept for the development of the transit zone of Dippach-Reckange Gare

Own drawing

Design proposal for Dippach-Reckange Gare: Catalyse and Connect

With the proposed development within the catchment zone of Dippach-Reckange Gare, the potential of the location is recognised and used. All of this without losing the location's typical character. Therefore, the interventions should be limited in space and integrated within the existing spatial structure.

For this reason, the proposal focuses on strengthening the connection between the train station and the existing village core, which consists of a community centre and a bar. Along this line the future development takes place, providing all facilities of daily need and thus enhancing spatial justice within a circular framework.

By providing work opportunities and highly accessible housing, the quality of life increases considerably.

Mixed use is an important component of spatial justice as it enhances the access to facilities and a more equal distribution of functions.

To increase social justice, different house types are proposed, providing housing for all age and professional groups and thus create social diversity.

Off-centre collective car parks increase the attractivity of soft mobility. In addition, car free zones increase the quality of life of the neighbourhood.

Soft mobility reduces energy consumption and pollution, and increases liveability.

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Increasing housing density implies a decrease in land consumption and environmental fragmentation, and potentially reduces sprawl.

Train stations are important connecting elements in the regional network, and thus largely contribute to spatial justice.

This illustration shows the proposed design elements that will increase spatial justice in the transit zone of Dippach-Reckange Gare.

Own drawing

Soft mobility implies a reduction in energy consumption, and thus preserves natural resources.

Collective car parks increase the attractivity of soft mobility. Furthermore, the building structure provides the opportunity for repurposing at a later stage.

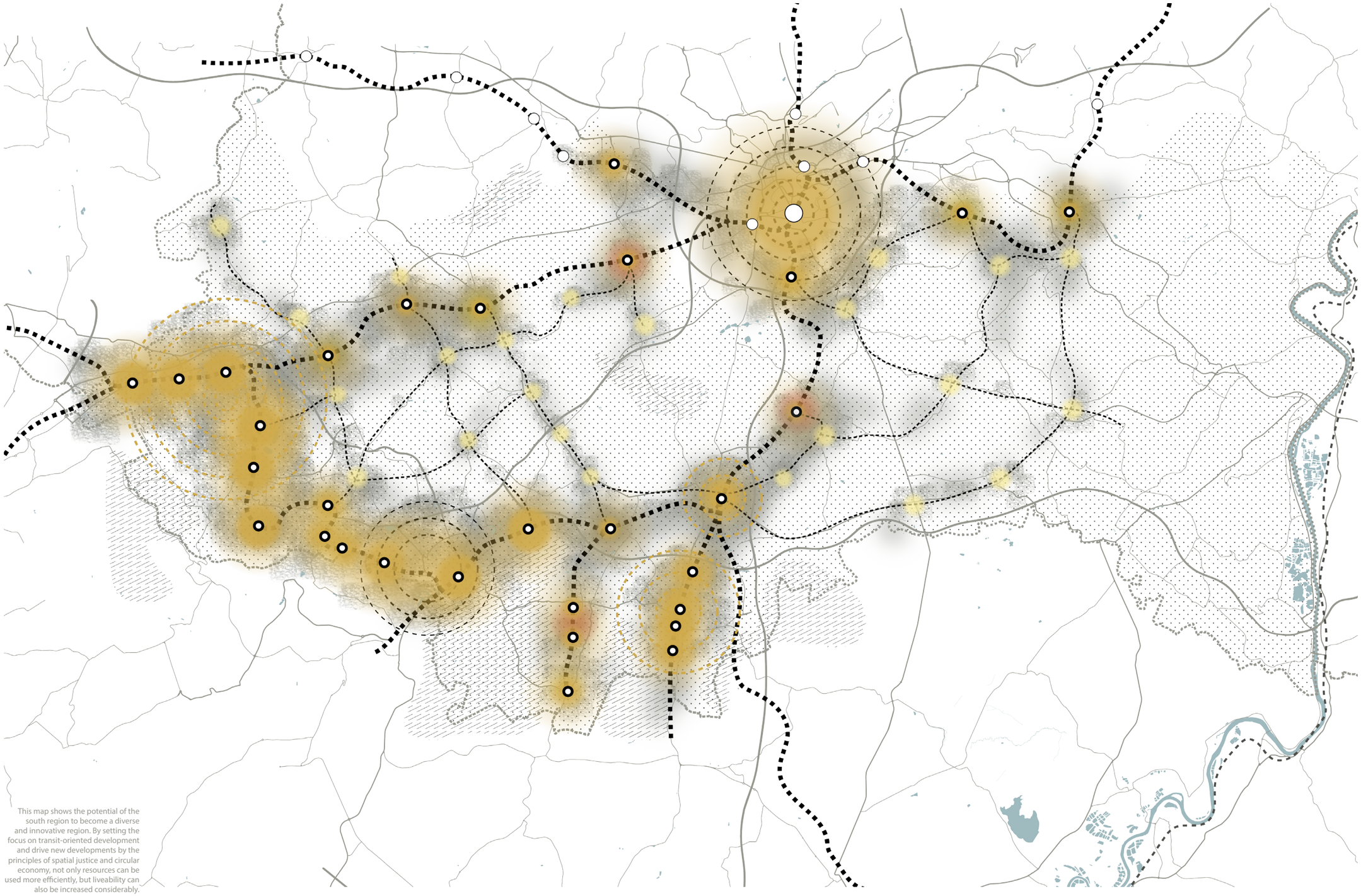
Sharing economy is an important aspect in the transition towards circularity. Through sharing vehicles and commodities living space and budgetary costs can be reduced, and simultaneously the usage is optimised.

Compact living space and modular building constructions are drivers for circular economy. Besides the reduction of resource consumption, modular construction facilitate the recycling process and are cheaper in production.

Density contributes to circularity as valuable resources are used more efficiently.

This illustration shows the proposed design elements that will enhance the process towards circularity in the transit zone of Dippach-Reckange Gare.

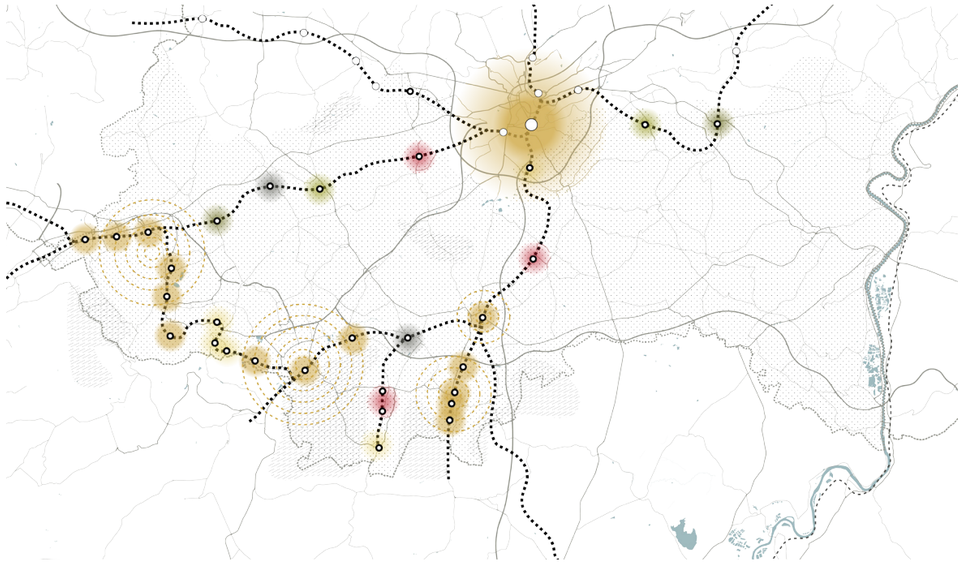
Own drawing



This map shows the potential of the south region to become a diverse and innovative region. By setting the focus on transit-oriented development and drive new developments by the principles of spatial justice and circular economy, not only resources can be used more efficiently, but liveability can also be increased considerably.

Own drawing

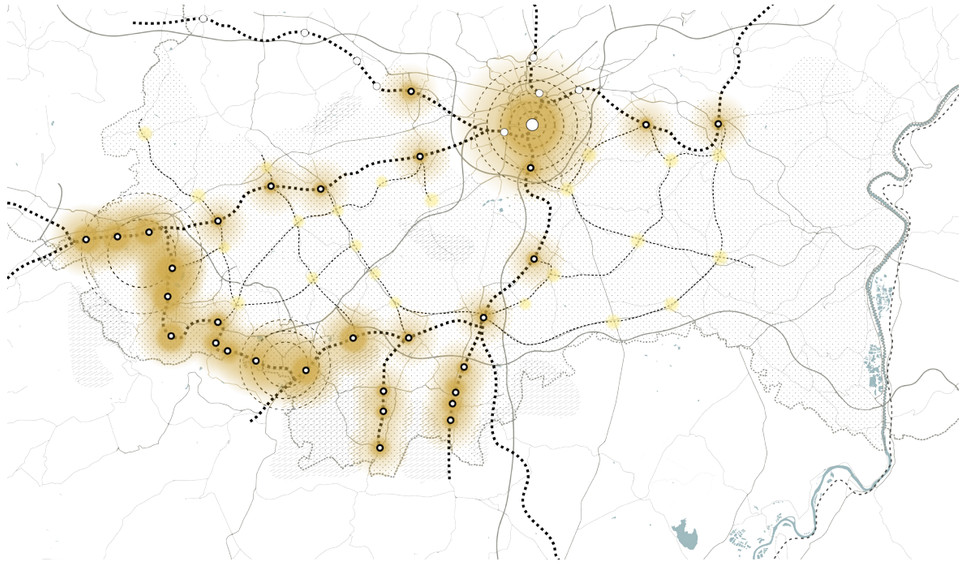
EXPLORATIONS FOR REGIONAL INNOVATION IN LUXEMBOURG



urban hub
emphasis on local recreation
emphasis on culture
emphasis on education
emphasis on public goods
emphasis on freetime activities

By means of the level of urbanity chart, spatial justice and diversity can be enhanced. A higher level of spatial justice can be achieved by focusing on a more equal distribution of functions, and prioritizing development in locations that are highly accessible by public transportation. On a larger scale a diverse landscape can be shaped by giving a specificity to each location and emphasising regional hubs.
The specificity of each transit zone is defined by its spatial conditions and specific potential.

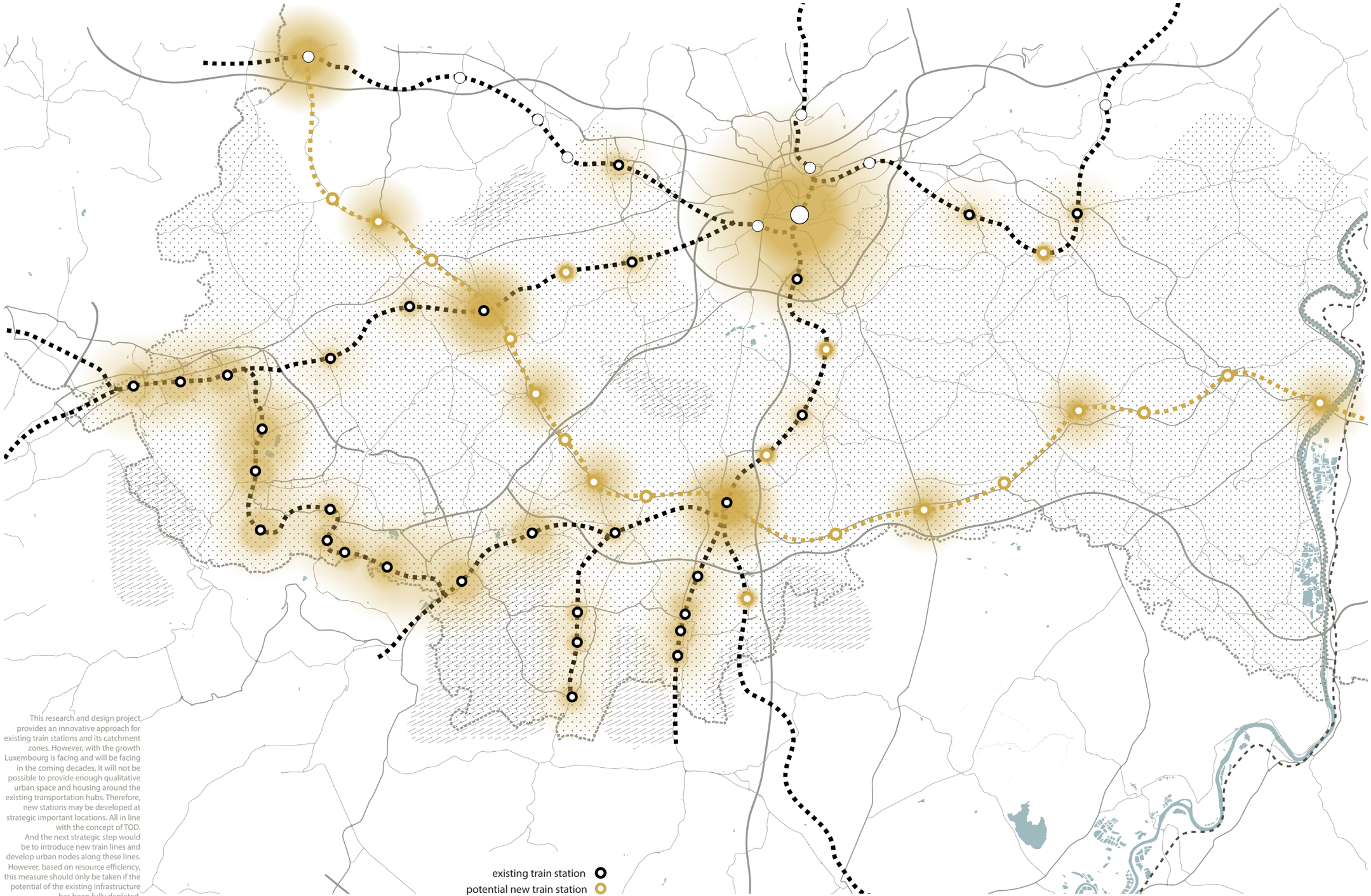
Own drawing



secondary urban core
secondary connections

This research and design project lays out the basic structure for futures developments in transit zones. However, there are also other means of public transportation that can contribute to the transition towards resource efficinet planning.
In order to connect urban cores that are not located in proximity to a railway line, another means of transport needs to be integrated.
This can be achieved, for example, through introducing a new tram network or a high-speed bus line.
By doing so, existing relations can be strengthened and new connections created.

Own drawing



This research and design project provides an innovative approach for existing train stations and its catchment zones. However, with the growth Luxembourg is facing and will be facing in the coming decades, it will not be possible to provide enough qualitative urban space and housing around the existing transportation hubs. Therefore, new stations may be developed at strategic important locations. All in line with the concept of TOD.
And the next strategic step would be to introduce new train lines and develop urban nodes along these lines. However, based on resource efficiency, this measure should only be taken if the potential of the existing infrastructure has been fully depleted.

Own drawing

EXPLORATIONS FOR REGIONAL INNOVATION IN LUXEMBOURG

5

Conclusions

The following pages highlight the opportunities and limitations of the research, give suggestions for future research, and offer a personal reflection on the thesis.

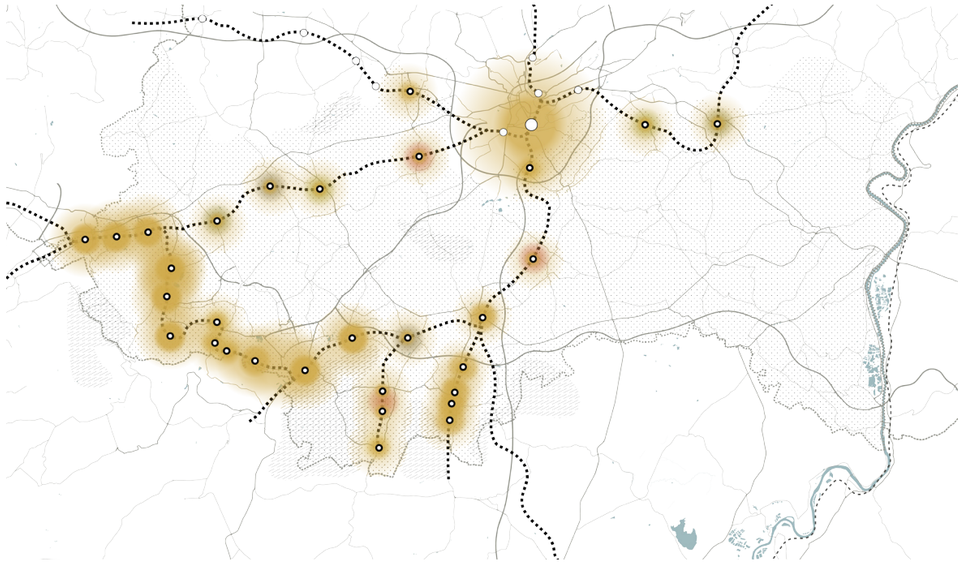
Reflection on the answers to the research questions

MAIN RESEARCH QUESTION

How can transit-oriented development practices be integrated in regional planning to enhance resource efficiency and spatial justice in the context of Luxembourg?

SUB-RESEARCH QUESTIONS

1.	What are the main trends and driving forces that may influence development strategies in Luxembourg?	→ ONGOING TRENDS and FACTS	PROBLEM FIELD
2.	What are the present locational policies and strategies for new developments?	→ CURRENT APPROACH	CONDITIONS
3.	What are the values and spatial conditions of spatial justice?	→ THEORY 'SPATIAL JUSTICE'	RESEARCH
4.	How do the principles of resource efficiency correspond to the concept of circular economy in the built environment?	→ THEORY 'CIRCULAR ECONOMY'	RESEARCH
5.	How can transit-oriented development be defined and what could be possible beneficial results for Luxembourg?	→ CONCEPT 'TRANSIT-ORIENTED DEVELOPMENT'	RESEARCH
6.	How can transit-oriented development contribute to resource-efficient planning and spatial justice within a circular framework?	→ GENERAL PRINCIPLES and DESIGN CONCEPT	STRATEGY

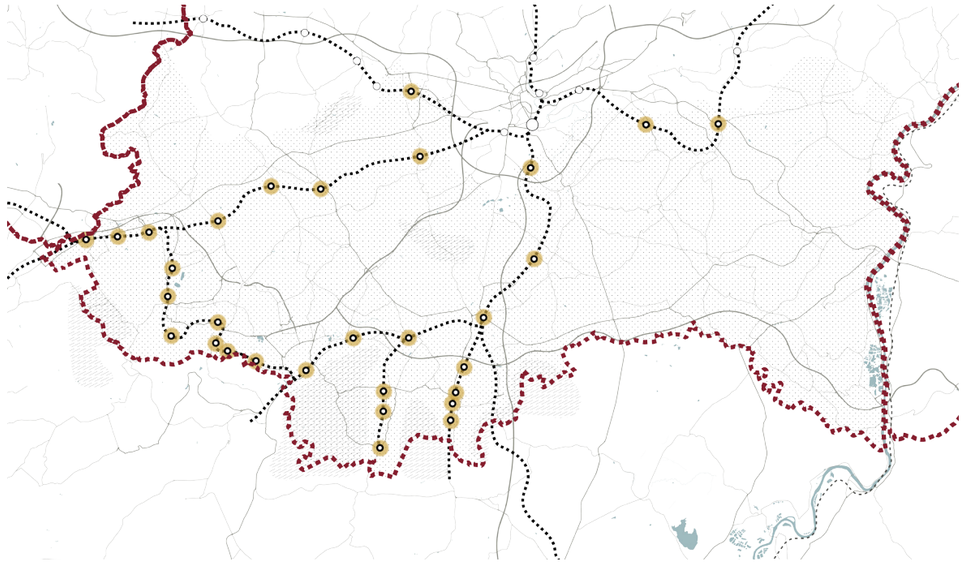


This map illustrates the opportunities for Luxembourg's south region that are opened up through the implementation of the proposed strategy.

Own drawing

Opportunities

By applying the proposed strategy and design concept, a more equal distribution of functions and economic activity across the territory can be achieved. Furthermore, by making use of the potential of the transit zones, resource efficiency can be enhanced through a reduction of resource consumption. It therefore appears that this proposal has the best prerequisites to increase the level of spatial justice through enhancing the potential and productivity of secondary cities, and thus creates a diverse landscape. All of that in a circular framework.



This map draws attention to the limitations of the proposal.

Own drawing

Limitations

Despite the extent and detail of my design and research project, some elements could not be taken into consideration. Cross-border integration, which has been the subject of my research paper, plays a crucial role in the Luxembourgish context due to the country's specific geography. However, it does not play a decisive role within my proposal. For the simple reason that the current challenges related to resource consumption are not directly linked to the cross-border context. They are rather a problem on the national level.
In addition, a detailed proposal has only been developed for the existing transit zones. However, future potential steps in the development process have been taken into account.

Therefore, there are certainly some suggestions for further research in the field of cross-border development and possible alternatives for highly accessible land development.

Personal reflection

The relation between my graduation project topic, the studio topic, my master track (A/U/BT, LA, MBE), and my master programme (MSc AUBS)

The Urbanism track, which I am enrolled in, is one of five specialisation tracks within the Architecture, Urbanism and Building Sciences master programme. The TU Delft advertises the Urbanism track as an interdisciplinary degree programme, combining urban design, landscape architecture, spatial planning and engineering. Encouraging students to expand their knowledge of social, cultural, economic and political perspectives with the natural and man-made conditions of the site in order to shape and plan for more sustainable development. (information retrieved from https://www.tudelft.nl/en/education/programmes/masters/architecture-urbanism-and-building-sciences/msc-architecture-urbanism-and-building-sciences/master-tracks/urbanism/)

Within the Urbanism track, I am part of the graduation research group Complex Cities. Complex cities is an association of researchers who assist MSc graduation at the Department of Urbanism, Faculty of Architecture and the Built Environment, Delft University of Technology. Researchers share an interest in the changing role of Urbanism that results from increasingly complex spatial and societal circumstances and internationalization. Their mission is to support specific aspects of MSc Urbanism graduations: trans-disciplinary approaches, internationalisation, institutional practices, planning methods, systems and cultures, and decision-making. (information retrieved from https://complexcitiesstudio.org/about-us/)

In my graduation thesis Redefining resource management in a fast growing urban setting: A laboratory for regional innovation I aim to analyse how resource efficiency can be achieved on a regional scale through important changes in current spatial development strategies. In this context, due to the ongoing challenges in the national territory, the focus of my thesis is on energy and land use consumption, collectively referred to as resource consumption. Both are closely interlinked with the growth and commuting trends in the Grand-Duchy. Therefore, my thesis proposes innovative solutions to improve the infrastructure network, thus reducing the current resource consumption.

Due to the high complexity of the problem field, also in relation to the cross-border aspect, I see a broad consensus with the interests of the Complex Cities research group. Furthermore, Luxembourg is known as a very international country, bringing together different cultures and also playing an important role in the global network as one of the most powerful financial centres in the world. Current national trends are driven by economic, social and environmental changes, calling for a trans-disciplinary approach. The government and decision-making actors, however, do not seem being up to the challenge resulting in insufficient planning tools and a lack of assertiveness. With this knowledge, I believe that my graduation topic is a really interesting field of research for the Imagining (European) cities group, which is a section of the Complex Cities research group.

The relationship between research and design in my project

Even though both aspects have been essential to carry out this thesis, this research and design graduation project has a stronger focus on research. Besides the in-depth context and problem field analysis, developing a corresponding theoretical framework and finding a fitting concept were key elements to this thesis. Furthermore, in the framework of a case study, an analysis and evaluation of the spatial conditions in Luxembourg's south agglomeration has been implemented.

This extensive research was necessary to form a solid basis for the design part, steer the focus of thesis in the right direction and thus achieve the most positive result possible.

The relevance of my graduation work in the larger professional and scientific framework

Addressing the question 'How can transit-oriented development practices be integrated in regional planning to enhance resource efficiency and spatial justice in the context of Luxembourg?', this thesis explores the potential of transit-oriented development to

enhance resource efficiency and spatial justice. Diving into the research field of resource-efficient planning, a highly relevant topic that is primarily associated with the theory of circular economy. And even though day-to-day you will inevitably be confronted with the concept of circular economy, there is still a lack of relevant planning approaches, translating the principles of circular economy into space. In turn, my research and design graduation project contributes to fill this gap in the existing scientific knowledge.
The developed methodology is innovative in the sense that it includes a transit zone categorisation based on specific analysis and evaluation criteria, reacting to the locational spatial conditions.

Within my thesis, with the aim of redefining resource management, the transit-oriented development model is used as a tool. Besides progressing towards resource efficiency, the concept of TOD also addresses the issues of spatial injustice. At the moment still characterised by a high degree of sprawl on one hand, and a strong economic concentration in Luxembourg City on the other hand, the Grand Duchy is given the possibility to increase spatial justice through the concept of TOD. By implementing TOD principles, the qualities and potentials of the secondary cities are revealed, and thus a more fair and equitable spatial distribution of socially valued resources and the opportunities to use them is set out.

Furthermore, in the context of resource depletion and constant population growth, the theme of resource-efficiency is of great global relevance. The research on sustainable urban structures and regions, and efficient energy management is a continuous process and outcomes have to be evaluated constantly in order to guarantee high-quality solutions that convince even the last critic.

The societal relevance of my thesis and how it addresses future generations
As stated in the foreword 'Luxembourg's continuous and rapid population growth, caused almost exclusively by immigration, has implied excessive energy and land consumption, and a general rise in resource consumption. These trends have caused major problems in the national territory: traffic jams, air pollution, environmental fragmentation, and a general threat to the livability.
The negative impacts of these trends harm the environment, and simultaneously affect the quality of life and health of the population. Even though the housing preferences and the general Luxembourgish lifestyle have largely contributed to today's situation, Luxembourg's residents are also mourners in this case.
Addressing the issues of resource consumption, and thereby solving problems that Luxembourg's society is currently facing, this thesis is of great societal relevance. Given the ongoing challenges that the Grand Duchy is facing and its apparent inability to deal with them, it is an absolute necessity for quick and adequate actions before more threatening conditions occur.

In the past, the government and the population have showed that they are open for new development strategies and economic models, and have the ability to quickly adapt to them (e.g. steel industry, financial industry). Precisely these virtues provide a solid basis for facilitating the implementation of new strategies, which will also have a considerable impact on the Luxembourgish lifestyle.

Not only the conditions are favourable for a change in strategy, the population is the direct beneficiary in many ways of a shift towards resource-efficient planning. A transit-oriented development model will decrease automobile dependency and thereby reduce the energy consumption, enhance the productivity of secondary cities and provide new job opportunities, lower the impact on the environment and thereby improve and maintain the quality of life. On this basis, my research and design project will benefit today's generation, and if pursued and adapted to changes, also the future generations. As especially with increasing scarcity of resources, developed approaches and concepts need to focus on future generations and their welfare.

Assessment of the ethical dimension of my research and design project
Within this thesis all aspects of the current resource management practices in Luxembourg are set out, as well as the inability to deal with the ongoing challenges. In response, this thesis appeals for

a more respectful dealing with resources, and thus protect the environment. Protecting the environment and its resources, and showing responsibility towards future generations is of high moral value. Another value that is emphasised within this thesis is the social value. By revealing the potential of secondary cities and increasing their productivity, residents are given the possibility to work and live in the same location. The saved commuting time can be spent with family and friends, or for hobby. Furthermore, living in a highly diverse urban environment and the opportunity to spend a lifetime in the same neighbourhood, if desired, promotes integrity and liveability.
As already mentioned, the proposed TOD model also responds to the current situation of spatial injustice. The lack of everyday activities of urban functioning is a primary source of inequality and injustice. By enhancing the qualities of different locations, and developing a diverse urban environment, a more equitable distribution of socially valued resources and the opportunities to use them can be achieves, and thus the level of spatial justice can be increased. Knowing that perfectly just development is never achievable.

I believe in the ethical principles of my thesis, advocating circular economy and spatial justice in order to reduce the environmental footprint caused by resource consumption.

My role
Within my thesis, I assume the role of the strategic planner and advocate for the environment and the society equally. Pursuing the aim of turning Luxembourg south into a laboratory for regional innovation, my thesis shows new ways to deal with the issues of resource consumption. The developed strategy and guiding principles intend to address first of all the governmental decision makers and the municipal authorities. The proposed strategy presupposes that both authority levels closely cooperate along the process, only then successes can be achieved. But besides the public actors, my thesis also addresses private investors and informs about development opportunities within a circular framework.

With my thesis 'Redefining resource management in a fast growing urban setting. A laboratory for regional innovation.' I intended to make a clear statement and raise awareness that natural resources are in short supply and that we have a responsibility towards future generations.

How I have learned from my own work
Along the process, I have learned that extensive and detailed research is key to innovative solutions. In order to propose an adequate and innovative solution, the respective problem needs to be tackled at its source. And for this, the problem needs to be understood in its entirety. Therefore, it is necessary to analyse the given spatial conditions, the existing planning approaches and tools and seek the necessary dialogue with experts from the field to gain a better understanding of the current situation and the necessity for change.

Besides the research, the design plays a determinant role, translating the research findings into spatial conditions. Through research by design, I became aware of the importance of the locational factor. Even though the findings are generally valid, they always need to be adapted in order to respond to the specific location of implementation.
Last but not least, I had to admit to myself that no research project stands on it own. Every research and design project is based on existing theories and concepts, adds to this existing knowledge and paves the way for new researches.

6

Appendices

The appendix contains further information that supports my thesis. Including the semi-structured interviews, my theory paper on cross-border integration, existing planning tools, a modal split study conducted by the government, and the bibliography.

Interview Ministry of sustainable development and infrastructure - Department of spatial planning

The ministry of sustainable development and infrastructure is in charge of the spatial development in the national territory. The regional strategy and sectorial plans, to name just a few, are the responsibility of the department of spatial planning.

Person interviewed:
Mrs Myriam Bentz - Head of department

Initial questions:
- What does the current governmental spatial strategy looks like?
- How do you handle the rejection of the national sector plans by the municipal authorities, and when will the new plans be presented?
- What do you think of the concept of TOD, and do you see a potential for implementation in the case of Luxembourg?
- From your experience, what is a desirable housing density for Luxembourg?
- What evaluation criteria do you use to determine new development areas?

Discussed topics:
- Population growth
- Housing densities
- Resource management
- Current infrastructure and development projects
- Limitations of current approaches
- Vertical power distribution

THE GOVERNMENT
OF THE GRAND DUCHY OF LUXEMBOURG
Ministry of Sustainable Development
and Infrastructure

Interview Cellule de facilitation urbanisme et environnement (CFUE)

The CFUE plays the role of a mediator in urban and land development projects. As the CFUE is a planning unit of the Luxembourgish government, it represents the interests of the general public. Its range of responsibilities include: identify involved actors, mediate between actors, make administrative procedures more transparent, ensure a smooth development of urban projects and make sure that projects are in line with the public interest.

Person interviewed:
Mr Frank Schreiber - Urban planner

Initial questions:
- What does the vertical power distribution look like in the case of Luxembourg?
- How exactly does the regional vision of the government look like? To achieve this, what strategies are adopted by the planners?
- Which planning tools are needed to guarantee a successful implementation of the national master plan?
- What is the role of the cross-border context?
- Studies have revealed the negative effects for decades now; if sprawl truly is destructive, why is it allowed to continue in Luxembourg?
- What criteria were used to select the new urban centres?
- Are there any spatial policies in place concerning resource efficiency?

Discussed topics:
- Societal trends
- Commuting patterns
- Land use patterns
- Importance of regional planning
- Strategic approaches to tackle these issues
- Vertical power distribution
- Disagreement between local and national authorities

Interview Institute of Geography and Spatial Planning - University of Luxembourg

The Institute of Geography and Spatial Planning, established in April 2006, is devoted to studying regional and local development, and planning (amongst others in Luxembourg and in the Greater Region), European urban and spatial policy and also sustainable spatial development. Major fields of research include environmental economic geography, urban studies and metropolitan governance, spatial statistics and modelling.

Person interviewed:
Prof Christian Schulz - Head of the Institute

Initial questions:
- Studies have revealed the negative effects for decades now; if sprawl truly is destructive, why is it allowed to continue in Luxembourg?
- The Grand Duchy of Luxembourg shows similar trends than North American cities, especially when looking at automobile dependency. However, there are big differences in scale. From an academic point of view, how do you see the potential of Transit-oriented Development in Luxembourg?
- Potential tools to facilitate the transformation towards TOD?
- How does spatial justice (e.g. social and environmental justice) manifest itself in space in the case of Luxembourg?

Discussed topics:
- Societal trends
- Planning trends
- Importance of regional planning
- Enforcement difficulties of national strategies and guidelines
- Spatial, social and environmental injustice
- Cross-border context

Interview Myenergy Luxembourg

Myenergy is the national actor to encourage and support the transformation of energy systems towards sustainability. Their mission is to assist Luxembourgish companies and municipalities in questions about energy efficiency and provide sustainable solutions. All of their activities ultimately aim to reduce energy consumption, to promote renewable energies, and sustainable building and living.

Persons interviewed:
Mr Fenn Faber - Director for strategic development
Mrs Lis Cloos - Project manager Climate Pact

Initial questions:
- Energy is more than just a question of resources; the energy system is actually driven by the demand for energy services. With this knowledge, what role does the individual play? And what are the responsibilities of the government?
- Transit-oriented development is often considered as an energy-efficient planning approach, do you see potential for energy savings in this strategy in the case of Luxembourg?
- Several studies have evidenced that there is a tight relation between energy and urban form, which also speaks for TOD as an energy-efficient planning approach. What energy policies could facilitate the process of implementing TOD?

Discussed topics:
- Energy-efficient measures on the municipal level (e.g. Climate Pact, Circular Economy Pact)
- Assertiveness of national energy strategies
- Power of markets (e.g. energy market, real estate market)
- Connection with international energy network

Interview PROGroup SA

PROgroup offers consulting and innovative solutions in a variety of sectors. Their aim is to creates positive and measurable impacts through circular economy based solutions.

Person interviewed:
Mr Romain Poulles - CEO of PROGroup, and President of the Ecoinnovation Cluster and expert in circular economy

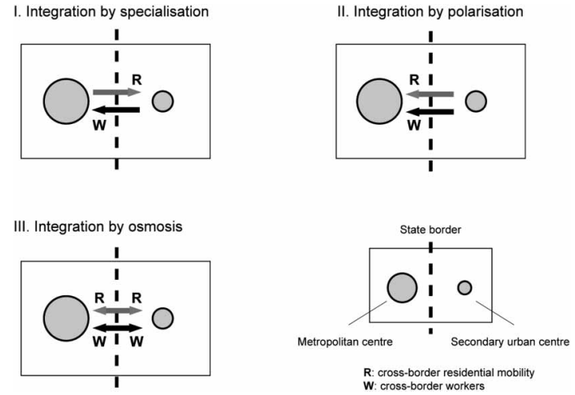
Initial questions:
- How do you understand circular economy?
- In your opinion, how relevant is circular economy on the regional level?
- Are there current projects about energy and land use on a regional scale?
- How do the principles of resource efficiency correspond to the concept of circular economy?
- In how far can TOD principles contribute to circularity?

Discussed topics:
- Circular economy
- Sharing economy
- Sustainability
- Efficient land use
- Efficient building use
- Circular energy production and consumption
- Flows

Theory paper

Taking account of Luxembourg's specific territorial configuration, its strategic location in the centre of Europe and its strong relations with the neighbouring countries, one element plays an important role in the country's existence: cross-border integration. Especially in the case of small sized countries, cross-border integration plays a central role in ensuring the economic success of a nation. To be able to write a review paper about cross-border integration in the European territory, I looked into different elements related to the topic: the meaning of spatial integration, current approaches, its limitations, and the specific case of Luxembourg.

Figure 5. Three Models of Cross-border Metropolitan Integration



Cross-border integration in the European territory:
A review of current approaches

Abstract
Over the last years, the interest to define a general framework for spatial planning within the European territory has significantly increased, creating a vertical exchange of ideas and concepts between the EU and the national institutions (Dühr, Stead, Zonneveld, 2007, p. 291). Within the context of cross-border integration, the EU pursues two key objectives: regional harmonisation and de-bordering process.

Several scholars have since the 1990s contributed to the research on adequate integration strategies and highlighted the importance of spatial integration. The concept of spatial integration is generally used to refer to the interactions between different territories, whether these relations are international, interregional, intra-metropolitan or between cities.
This review paper intends to reveal the limits of planning approaches targeting spatial integration and uncover missing evaluation criteria in existing strategies. This is done by referring to formulated strategies, which serve to facilitate cross-border planning in the European context. This research will offer a suggestion for a revised strategy and evaluation procedure to enable a more efficient process towards spatial integration in the cross-border context.

key words:
spatial integration
territorial cohesion
cross-border planning

Cross-border planning

At the latest since the 1990s, cross-border planning plays a significant role in the context of Europe and its territory. Even though, cross-border regions have already been forming up before that date, this period (since the 90s) recorded an extremely strong increase in the number of cross-border regions in Europe. Such regions are characterised specifically by a functional and institutional integration whereby its level of dynamism is strongly defined by the region's infrastructure networks. Economic, social and political integration play a crucial role in the achievement of successful spatial integration.

The first document from 1994, on European spatial planning issues and Europe 2000+, considers territorial disparity, spatial imbalance and the lack of coherence across borders and between countries, which might undermine the European objectives of social and economic cohesion. And thereby jeopardise the establishment of a balanced competitiveness within the EU.
Although sufficiently supported by the European commission, the council of Europe and the European Union; many European cross-border regions still have a weak performance today. This poor performance does not hinder the search for suitable and efficient organisational solutions on the European level as it is an ongoing process that keeps myriads of scholars busy.

Spatial integration

Even though there is no exact definition of the concept of spatial integration, it is generally used to refer to the interactions between different territories, whether these relations are international, interregional or between cities. Often expanding beyond administrative borders.

The necessity of an exploration of the different possible meanings becomes evident from the complexity of the concept of spatial integration on a cross-border level. When speaking about integration, the term territorial cohesion is often used as a synonym. This is attributable to the fact that there is a strong desire for spatial cohesion beyond administrative and political borders and to create increasingly homogeneous territories within Europe.
"As stated in the Journal of Borderlands Studies, the globalisation of economic and cultural exchange has led to a profound political and economic territorial reorganisation, especially within the European border regions. And this new regionalism is often interpreted in terms of the concept of integration, understood as a process of the intensification of the exchange of goods, services, capital, knowledge and people." (Decoville, Durand, Sohn, Walther, 2013, p. 221)
This is also confirmed by the authors of the research paper *The Europeanization of spatial planning through territorial cooperation* (2007). "Saying that the underlying explanation for the growth in cooperation across borders starts with globalisation and its effects on weakening the autonomy of nation states and increasing functional interdependencies between places. As in the globalising economy, cities and regions (rather than nation states) have become the focus for investment, leading to increasing competition between regions." (Dühr et al., 2007, p. 292)

Playing a crucial role in the spatial organisation of the European territory and contributing actively to a better performance, the importance of spatial integration cannot be neglected. Already at the national level, spatial integration is a long process, which is often countered by the different actors due to conflicts of interest. One can imagine that on the cross-border level, the concept of integration has to overcome even greater hurdles. On the European level, opinions differ in political attitudes, state structures and the pursuit of goals, to name just a few examples.
By this complexity, it is even more important to develop a general approach of Europe to deal with the challenge of integration.

Purpose

In general, spatial integration tends to be seen as a positive response to the disintegration of traditional structures caused by globalisation.
It can be concluded that the new opportunities and the wider network that has opened up through the process of globalisation, have endangered the existence of regional and cross-border cooperation. To strengthen the cooperative connections between direct neighbour states and regions and to reinforce the importance of their existence, the general

willingness to cooperate cross-border-wise has considerably increased over the last decades.

The idea of integration (in all aspects: social, economic and political) underpins the formation of the European Union. One of the main objectives of the European Union: A common European area with no internal borders. "In this context, the EU is widely perceived as being on the right scale to counterbalance the influence of the other major integrated regions in the world." (De Boe, Grasland, Healy, 1999, p. 7)
Simultaneously, efforts are made to encourage spatial integration even beyond the borders of the European Union. "The opening of the borders in Europe, defined in the Schengen treaty, constitutes an opportunity for cities to exploit the border differentials and to flourish from positive effects that they represent for businesses and workers." (Ratti, 1994) The cross-border metropolitan space, which results from this, can testify to a functional integration that extends beyond the border.

Process

The functional organisation of the cross-border metropolitan region is important. "Spatial development has cross-border and transnational dimensions that cannot be addressed by regions or nations acting independently." (Dühr et al., 2007, p. 293) Therefore, a close cooperation across borders and across power levels is needed to guarantee a positive outcome. A stronger awareness among planners and decision-makers of the need for improved horizontal, vertical and geographical coordination in an integrated Europe would be beneficial in the process of integration.

"The promotion of legal tools, initially by the states and then by the EU, and the provision of financial resources aimed at formalising cross-border projects, constitute a strong incentive for cities and cross-border regions to cooperate." (Scott, 2002)
"This is in line with the intended regional harmonization process and the political establishment of cross-border regions across the European Union. To facilitate the cross-border exchange, a strong emphasis was placed on the infrastructural enlargements of transportation networks to enable and connect parts of different EU regions with each other. In addition, the EU supports the facilitation of free flows of people, capital, goods and services in order to overcome physical and mental barriers." (Dörry, Decoville, 2013, p.70)
As stated by Dühr, Stead and Zonneveld (2007), "the impact of EU legislation and policies on domestic planning is considerable and growing. This reinforces the importance of the vertical exchange of ideas and concepts between the EU and the national/ regional institutions. As well as the horizontal exchange embodied by cooperation between states and regions. Planners across Europe are now routinely involved in transboundary cooperation networks and interregional collaboration initiatives and thus exposed to a variety of planning approaches from other European states." (Dühr et al., 2007, p. 299)
While the vertical exchange refers to the involvement of power entities through all scales in the integration process, the horizontal exchange targets the cross-border relationship of equivalent power bodies. In an optimum manner, the vertical and horizontal exchange takes place at the same time and with an equal importance. It is of utmost importance that spatial integration follows the same pattern across the European territory to provide an equal chance to every region. However, at the same time, the applied method should be adaptive to the given characteristics of each particular case. Therefore, an Europeanization of spatial planning is only partly desirable.
It is particularly difficult to find instruments to support cross-border integration on the European level. Whereas The European Union has at its disposal European funds and directives, the organisation and budgetary management are particularly complex on the European level with non-EU members.

"As a result of the recognition of the benefits achieved through collaboration on spatial development issues across national borders, a myriad of initiatives has set up. Initiatives such as CRONWE and INTERREG have been formed to help to increase awareness for the interlinkages between the nation states and regions of Europe and the need for coordinated spatial planning." (Dühr et al., 2007, p. 293)
The EU's primary instrument to support cooperation across national borders is INTERREG, financed by the European Regional Development Fund. The INTERREG

initiative was launched in 1990 to overcome the disadvantages presented by administrative boundaries of adjacent regions in the emerging single market. Later on with the start-up of INTERREG II, funding for transnational energy networks was awarded. And INTERREG III provided a budget for three objectives: cross-border cooperation, transnational cooperation on spatial planning across large contiguous areas and interregional cooperation to improve the effectiveness of regional development through information exchange and sharing of experience. "These measures are expected to contribute to the new strategic goal for the EU to become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth and greater social cohesion." (Dühr et al., 2007, p. 294)

Also on the European level, including the non EU members, three specific objectives are targeted:

convergence, competitiveness and territorial cooperation. But on this level, it is in general more difficult to provide a budget and put together an organisation team.

The role of the border

Within the context of a cross-border region, the border situation plays the essential role. With the regard to the free movement of people and goods, cross-border interactions have significantly increased since the foundation of the European Union and the implementation of the Schengen treaty.

"It also corresponds to the meaning given to the border in a context of globalisation and European integration, to the extent that the functions of contact and exchange tend to prevail over the barrier. Of course, the border is still a significant boundary from a political point of view, but it increasingly exercises a mediating role between two cultural systems. The border interface henceforth constitutes a privileged space of interactions between the protagonists located on one side or the other of the political and territorial discontinuities. Therefore, the extension of the infrastructure networks which reinforces the connectivity between the elements of a spatial system or the densification of the border areas illustrate a dynamic of cross-border integration." (Sohn et al., 2009, p. 925)

Especially microstates, such as Luxembourg, Liechtenstein and Monaco benefit from their particular territorial configuration and their membership of the European Union. Allowing them to maintain important economic and social relations with their neighbouring countries that benefit their own state. For example, by attracting qualified foreign labour force as it is not available in sufficient quantities within their own countries.

Conflicts

While the political will at the European level has been promoting cross-border integration for decades already, the criticism on an operational level however remains. This is precisely because states are generally unwilling to hand over portions of their sovereignty and political authority to the structured forms of cooperation. In particular due to conflicting interests. In addition, authorities often fear the risk of economic loss, which could on the other hand favour their cooperation partners.

Evaluation criteria

Despite having already been the focus of innumerable studies, there is no general definition of the term spatial integration and its assessment criteria yet. Over the last decades, various researchers have developed evaluation systems to measure spatial integration and thereby allow drawing comparisons between different spatial cases. This is particularly interesting but can lead to several problems. For instance, because of the separate interpretations on the subject and especially on the decisive criterion to define spatial integration.

After extensive research, I was able to notice that there is a general agreement on the term integration and its multiple variants. It is often primarily associated with the economic aspect, but the social and political aspects should not be underestimated.

As mentioned beforehand, there is a whole variety of indicators which can be used to measure integration. A study from 2013 (Decoville et al.) has "defined three statistical indicators as main drivers for functional integration:

1) the number of cross-border workers, which is frequently used to illustrate the permeability of borders to exchanges,

2) the differential of GDP per capita between the

border territories, which reveals economic disparities as a driving force for the process of functional integration,

3) the number of residents in a border region holding the nationality of the neighbouring country to illustrate the level of residential integration." (Decoville et al., 2013, p. 224)

Although these indicators allow a deeper understanding of the present cross-border flows, most of these studied indicators are stimulated by economic advantages and do not necessarily imply a positive integration in space. Social and cultural indicators play in fact a far more important role. A common language for instance or a complementary leisure and cultural programme, can be highly advantageous and enhance cross-border interactions. Especially the exchange during leisure time in relation to social integration is important in order to overcome the status of a purely functional integration.

"It is important to keep in mind that flows help to define a material dimension of spatial integration, but that they do not give directly information on the mental dimension of integration, which is probably the most important in a long-term perspective." (De Boe et al., 1999, p.13) An additional and much more complex dimension of spatial integration is the social structure. In contrast to the material dimension, the social dimension is more difficult to identify and allows a lot of room for interpretation. Also because each actor has its own priority list of relevant social factors, which however often do not show common interests. For that reason, there is no general agreement on criteria to evaluate the social dimension yet, and spatial integration is often reduced to the material dimension as this dimension seems to be more comparable.

Case studies

proved process of spatial integration, even though some procedures might be facilitated.

A case study on the cross-border metropolitan integration in Europe, released in 2009 (Sohn, Reitel, Walther), illustrated in detail a comparison between the three small cross-border metropolitan areas: Luxembourg, Basel and Geneva. "The aim of that study was to explore what are the dominant rationalities in the cross-border cooperation and the underlying challenges. It confirmed that the impact of the geographic configuration, in particular the proximity of the border in relation to the metropolitan core, the relationships between the private and the public sectors and the historical dimension play an important role as success drivers. In addition, the dynamics of cross-border metropolitan integration are part of a wider context dictated by the evolution of legal frameworks and financial incentives, both on the level of interstate agreements and at the European level." (Sohn et al., 2009, p. 924) Therefore, in order to be able to make a correct comparison, the functional and institutional evolution of the metropolitan area has been made, by questioning the role of the borders in the integration process. "The study concluded that in Luxembourg the metropolitan area of reference remains the national territory, whilst in Basel and Geneva the politicians seem to think in terms of cross-border urban agglomerations." (Sohn et al., 2009, p. 935)

Furthermore, in the Journal of Borderlands Studies, Decoville et al. (2009) stated the importance of the cross-border integration models. They differentiate between: integration by specialisation, integration by polarisation and integration by osmosis.

"The integration by specialization represents the implementation of a cross-border territorial system with crossed flows from the periphery towards the metropolitan centre. This type of integration is especially competitive in economic terms.

The integration by polarization, for which Luxembourg is a prime example, is based on a highly attractive metropolitan centre, both in economic and residential terms. Therefore, flows of labour and the residential displacements both primarily converge on the dominant urban centre.

Whereas the integration by osmosis has bi-directional flows both of cross-border commuting and residential movements. In this model, the integration of labour and housing markets appears to be balanced and a certain convergence of the border territories appears to be occurring. For this reason, integration by osmosis delivers the best performance in terms of cross-border integration. Studies

have also showed that this model of integration involves mainly cities with lower metropolitan profiles, such as Lille and Aachen-Liege-Maastricht." (Decoville et al., 2013, p. 232)
The idea of different forms of integration is not new. "In fact, already in 1897, both Durkheim and Ratzel differentiated between the organic and the mechanical form of integration. While the mechanical form is based on the structure of the system, the organic form refers to the flows between the members of a system (e.g. social and spatial structure)." (Sohn et al., 2009, p.925)

Conclusion

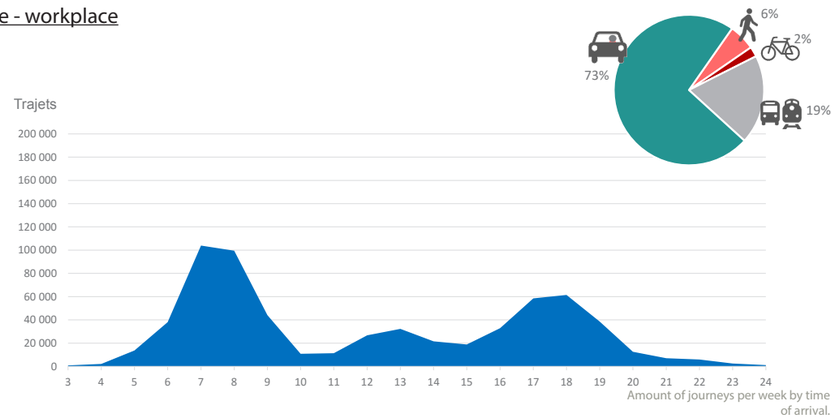
Since the 1990s, but especially in the last years, the concept of cross-border integration has gained great importance in the European territory. This is also borne out by the large available annual budget for this purpose and the growing number of working groups dedicated to this issue. Although there seems to be a common interest in this topic, there is a whole range of different approaches.

Over time, there has been repeated criticism about the evaluation procedure of spatial integration, as some of the proposed assessment criteria cannot or can only to a limited extend be confirmed by facts and figures. And therefore often rely on personal assessments, allowing neither an objective evaluation, nor a direct comparison. This was made very clear to me during the review of scientific papers on spatial integration. Spatial integration is often reduced to the infrastructure network that physically connects two territories of different national affiliation and to the flow of people benefitting of this spatial connection on a daily base. But this does not provide any information on the quality and level of integration. Other factors, especially those assessing the exchange on the social level, are more valid to define spatial integration. In this context, a common language and a common culture basis are the best endowments for a successful spatial integration, in the sense that it facilitates the cross-border exchange.
Furthermore, the model of cross-border integration plays a crucial role in the efficiency and success of the cross-border region. Studies (Decoville et al., 2013) have proven that integration by osmosis, a cross-border integration model with bi-directional flows of cross-border commuting and residential movements, shows the highest level of convergence of the border territories and seems to be the most balanced model.

Therefore, this review clearly revealed the need for a more in-depth research on alternative assessment criteria on the social level. Non-work related activities and exchanges in particular are an important factor for a territorial cohesion in the cross-border context, as they are mainly based on the free choice of the population and not on an economic decision.
In this context, I suggest a revision of the existing theories on cross-border integration with the aim of developing an evaluation system that allows the assessment of physical and social criteria of integration. This happens within the framework of developing a general applicable approach to enhance cross-border integration in the European territory, whether EU members or not.

Modal split study - Survey Luxmobil 2017

Journey home - workplace



Amount of journeys per week by time of arrival.

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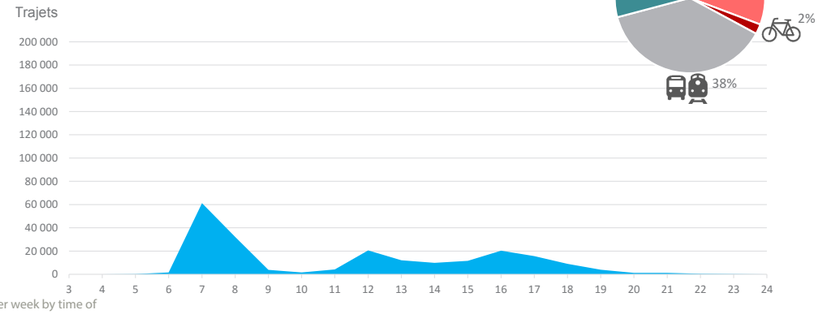
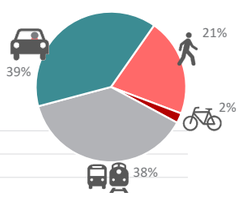
Journey home - educational institution





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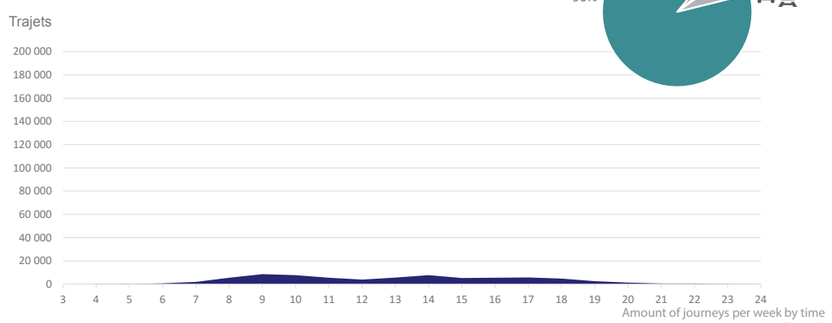
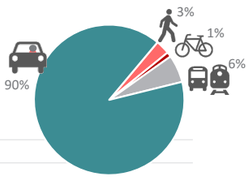
Business travels





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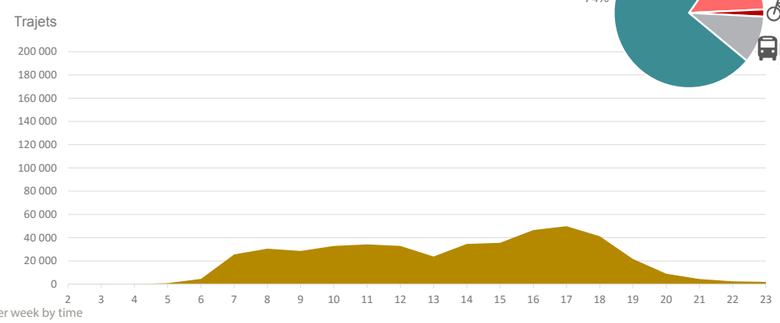
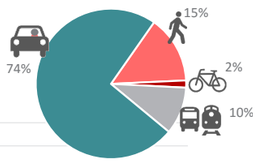
Private journeys - excluding freetime activities





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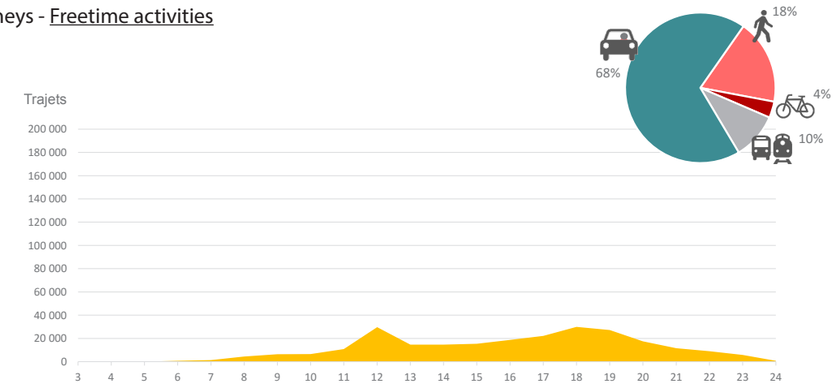
Private journeys - Freetime activities



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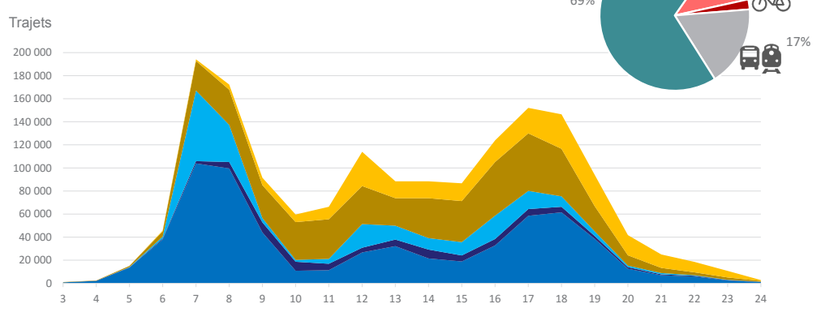
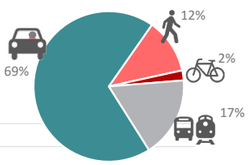
Total





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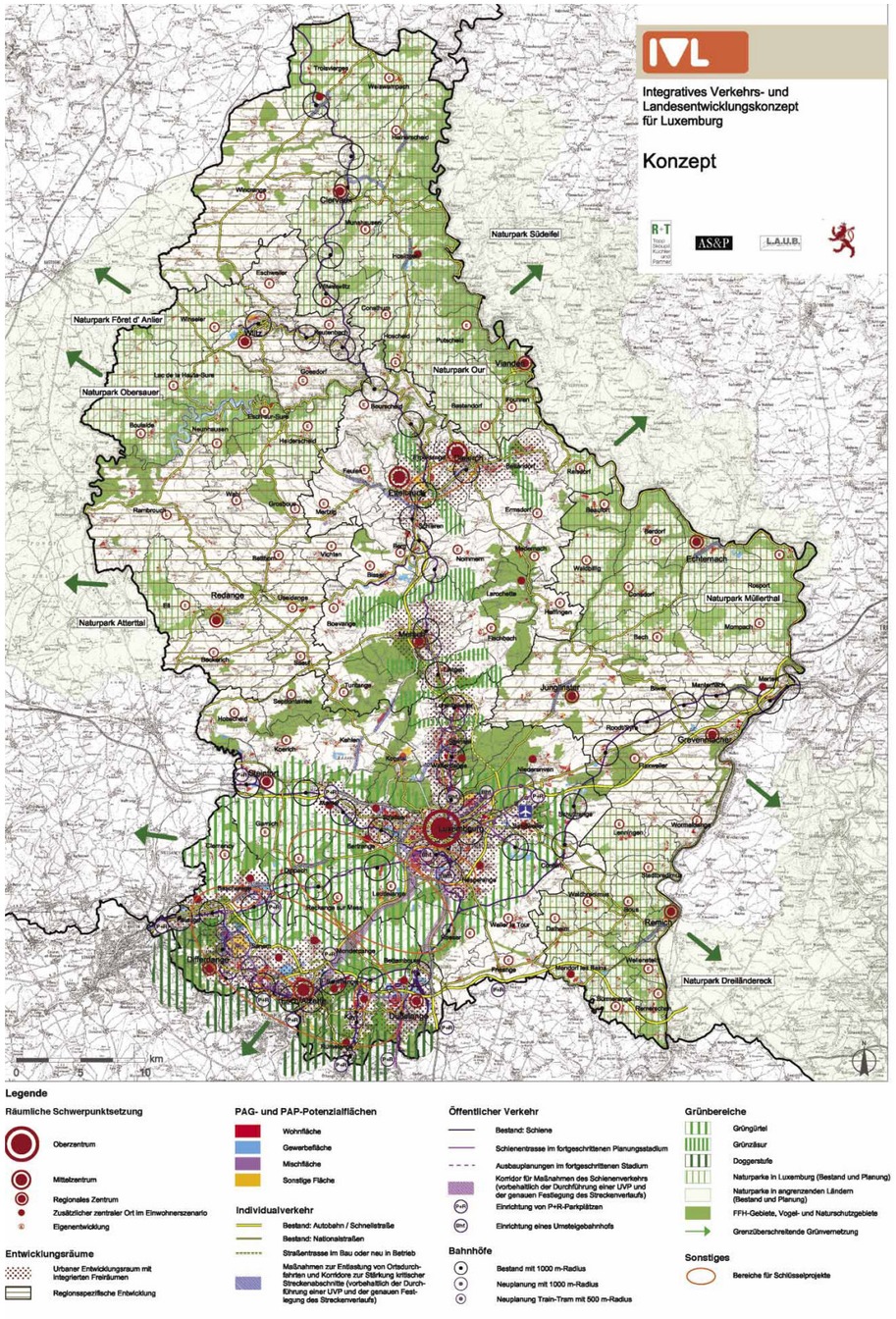
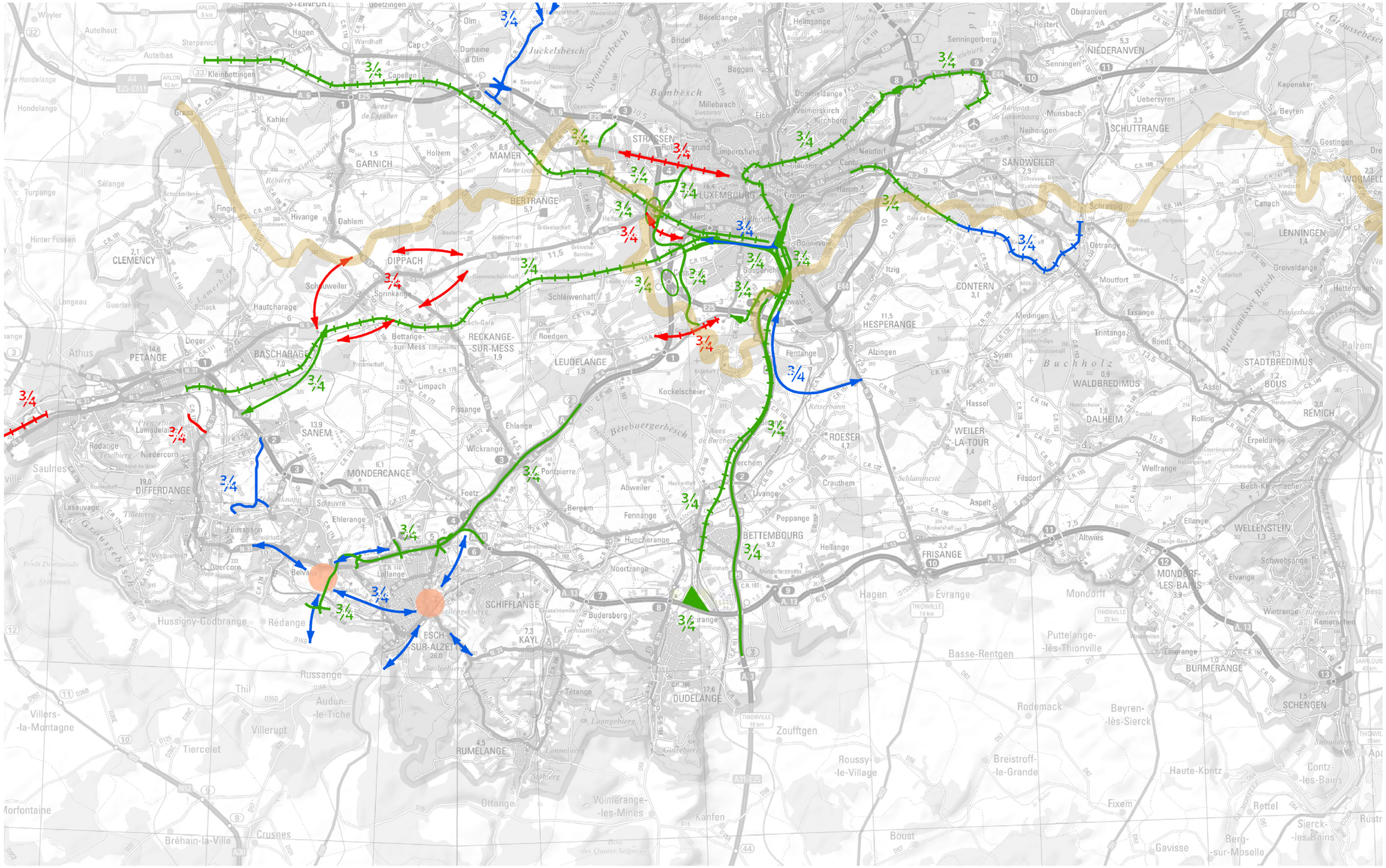


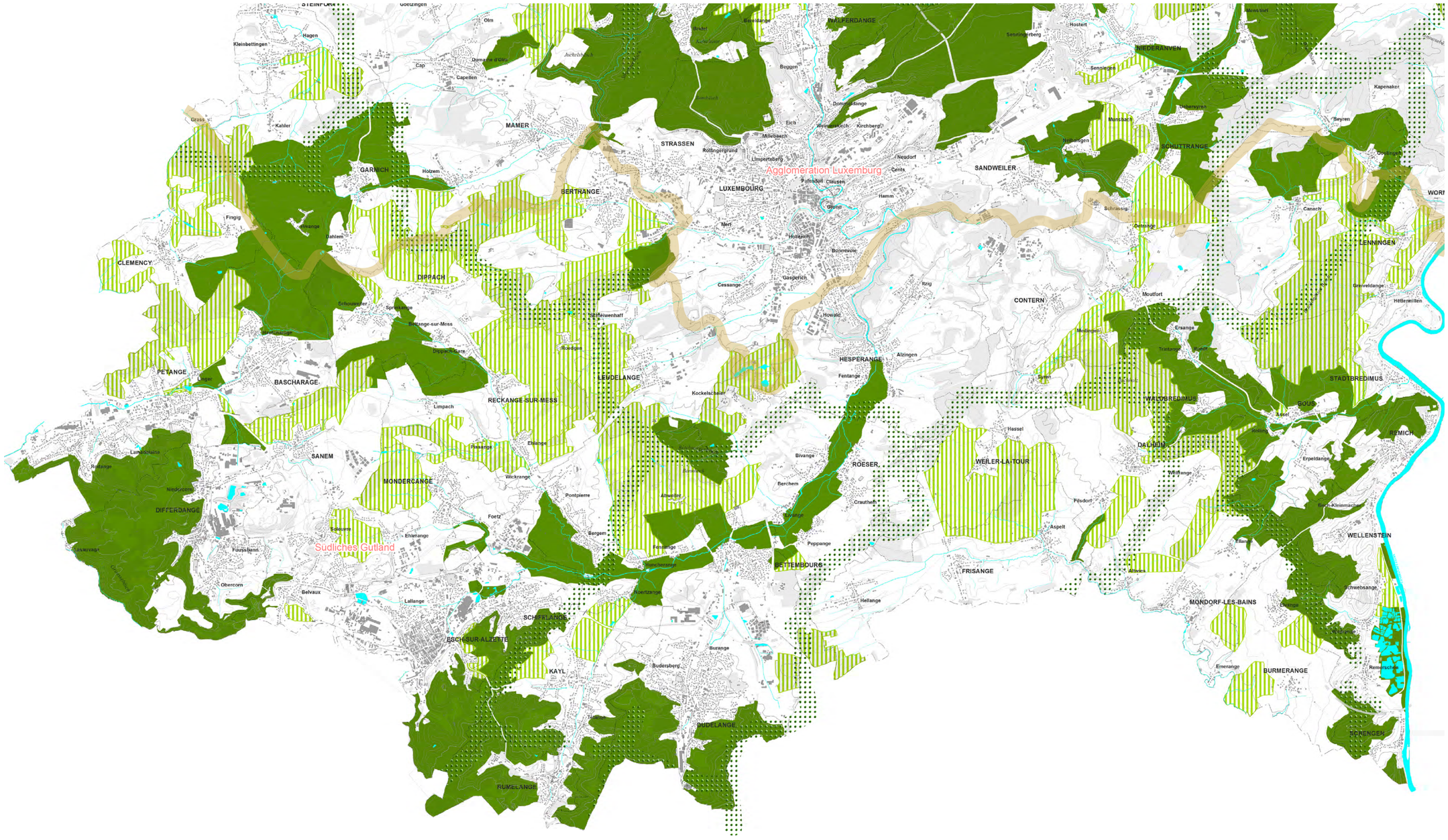
National vision IVL (2004) - Detailed version.

Image from http://docplayer.org/docs-images/56/38865341/images/169-0.jpg



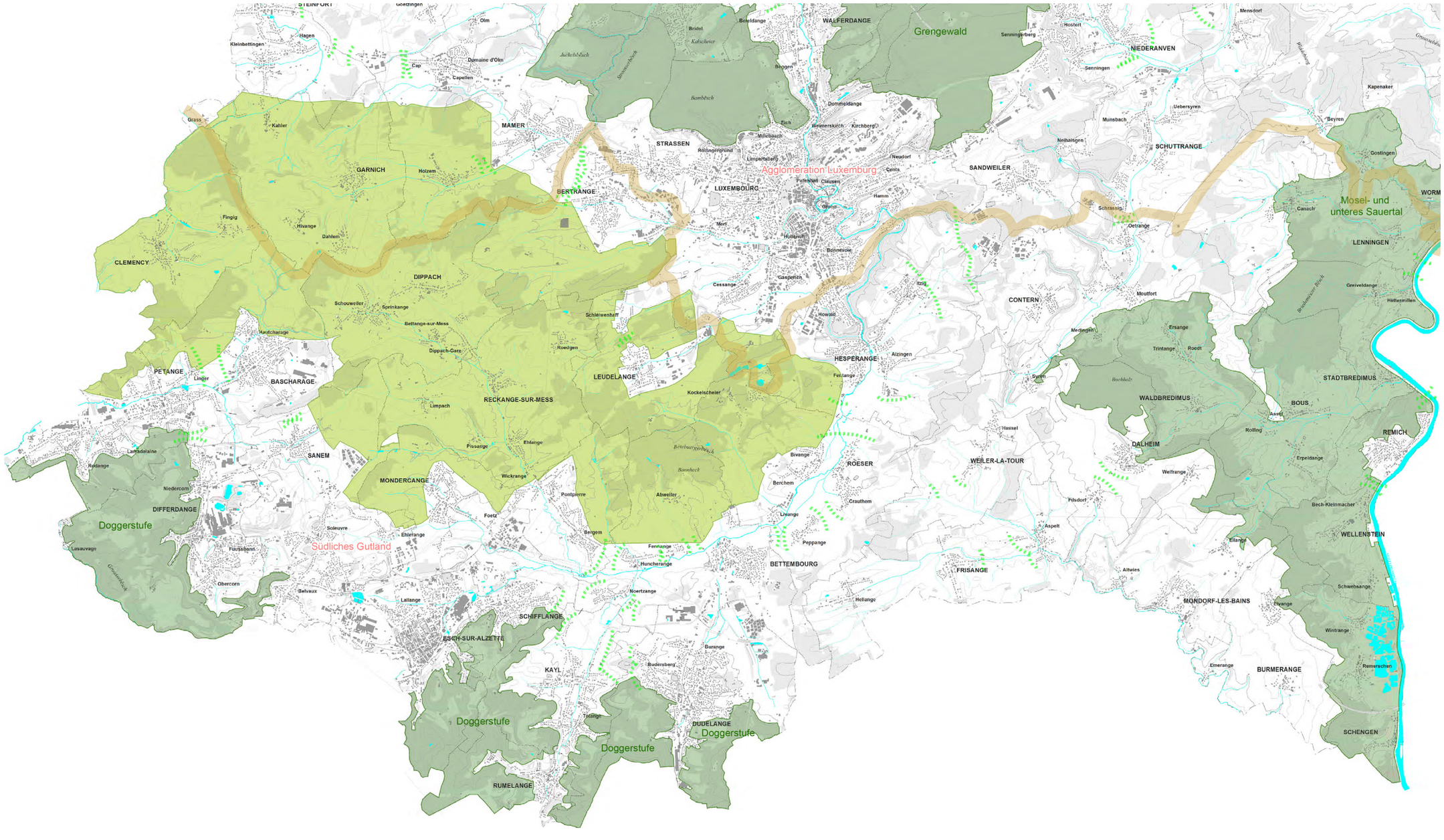
Development plan, sector TRANSPORTATION.

Figure from http://amenagement-territoire.public.lu/fr/plans-caractere-reglementaire/plans-sectoriels.html



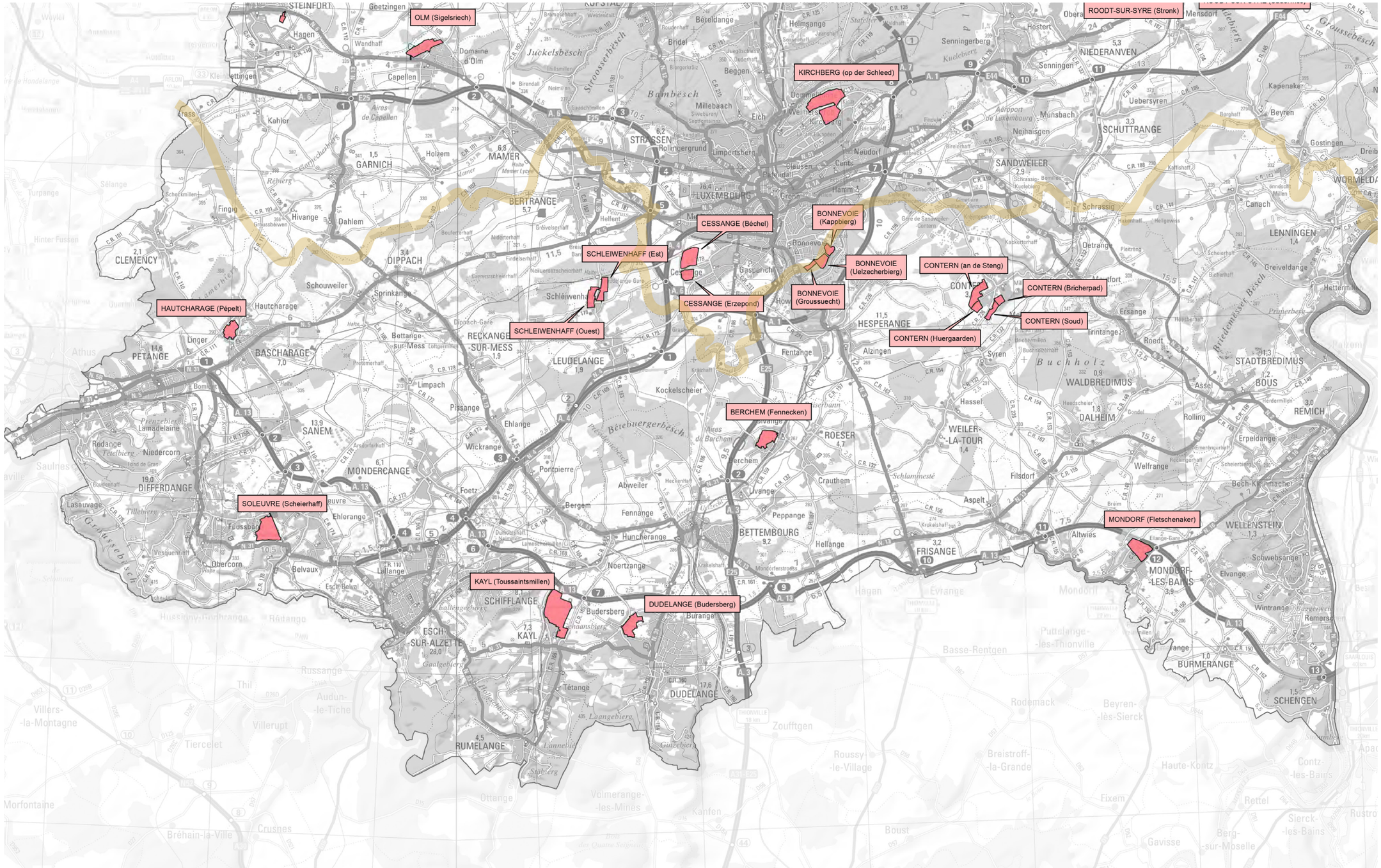
Development plan, sector ENVIRONMENT.

Figure from http://amenagement-territoire.public.lu/fr/plans-caractere-reglementaire/plans-sectoriels.html



Development plan, sector ENVIRONMENT.

Figure from http://amenagement-territoire.public.lu/fr/plans-caractere-reglementaire/plans-sectoriels.html



Development plan, sector HOUSING.

Figure from http://amenagement-territoire.public.lu/fr/plans-caractere-reglementaire/plans-sectoriels.html

Development plan, sector ECONOMIC ACTIVITY ZONES.

Figure from http://amenagement-territoire.public.lu/fr/plans-caractere-reglementaire/plans-sectoriels.html

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