Master thesis:

# De Randstad, a balanced poly-centric urban region with a global status

*An analysis of the competitiveness, sustainability and smartness of cities with a case study on the poly-centric urban region De Randstad in the Netherlands*

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# Foreword

In front of you lays the master thesis: *'De Randstad, a balanced poly-centric urban region with a global status'*. This research analyses the competitiveness, sustainability and smartness of urban regions, from where a case study was conducted on the Dutch poly-centric urban region De Randstad. This thesis is written for the master Human Geography: Economic Geography – Regional Development and Policy and for my internship at Arcadis in the period from March 2021 to August 2021.

My interest in urban sustainability and De Randstad were the main drivers for this research. I've always been fascinated by the high geographic proximity and the regions' position in the world economy. Arcadis is a global design and consultancy company for the build environment. Therefore there were many communalities and I was given the space to conduct my research.

This research can give more insight in the urban competitiveness as an important performance indicator in today's economy and how competitive cities perform on the concept of urban sustainability. Additionally, the research also touches on the concept of a Smart City as a potential solution for the current problems cities face. Because of the overarching approach of my research the guidance from my supervisor Sergio Petralia was very helpful. Therefore, I would like to thank him for helping me give direction to my research and for the motivational meetings during this six-month period. I would also like to thank my internship supervisor Auke Boomsma who has always been helpful during my period as an intern at Arcadis and was very supportive during this progress.

I hope you will enjoy reading my research.

Wouter van Oel
Amsterdam, 6 augustus 2021

# Abstract

The current changing climate is increasingly forcing policy makers and governments to look at the sustainability in urban areas and the effect on the economic development. The livability in cities is decreasing due to mass urbanization and the pressure of the changing climate. However, cities are also the main drivers of the global knowledge - based economy. Smart city technologies are emerging to manage the climate implications in cities while keep developing economically. The purpose of this research is to see how the competitiveness of a city is affected by the concepts of sustainability and smart city. The notion prevails that sustainability and economic development are contradicting (Herrschel, 2013; Spearing, 2021). Therefore, it is interesting to analyze to what extent this relation is visible in urban regions. Additionally, smart city implementations are described as a possible way to achieve sustainability without compromising on economic development (Caragliu et al., 2011; Lombardi et al., 2012; Nam & Pardo, 2011). Thus the level of smart city can indicate the ability of a city to manage these problems.

In addition, the poly-centric urban region De Randstad is explored in more detail to investigate how the region performs on these concepts. The central research question, *'To what extent is De Randstad a competitive urban region and is it thereby sustainable and smart?'*, has been answered by a comparison of 62 different cities through a secondary data analysis. Additionally, a case-study was conducted on De Randstad. This showed that the level of smart city has a positive impact on the probability of a city being competitive. However, there isn't a clear distinction to be made on the concept of sustainability between the subregions. De Randstad can be regarded as a balanced region as it performs above average on all three concepts. In the case of De Randstad, the region performs above average on both concepts. In relation to the cities studied, De Randstad can be seen as a balanced region where the North Wing performs better in terms of competitiveness and smart urbanity than the South Wing. The analysis and the case study should provide a good foundation for further research into De Randstad or other urban regions. Thereby, it provides more insight for new policy and how De Randstad can improve on collaboration within the subregions.

**Keywords:** *Competitiveness, sustainability, smart – city, De Randstad, poly – centric urban regions*.

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# Introduction:

Recently, the Financial Times published an essay proposing a way on how the current climate crisis can be solved. In this essay is stated that to achieve sustainability, the market should be bypassed and put on the 'second' place (Spearing, 2021). In other words, there is a tradeoff to be made, an urban region can be either sustainable or have economic growth. According to Herrschel (2013) these concepts are contradicting to each other and therefore a region can't be both. This can also be seen in the carbon footprint of regions, economically developed regions have a much higher ecological dioxide emission, higher resource use and higher material standards than less developed regions (Rees & Wackernagel, 2008). Due to this contradiction, it isn't surprising that the Green New Deal, the climate action plan of the Democratic party in the United States, encountered resistance. With the main arguments against this sustainable transition reform being the economic costs, the increase in tax and the risk of losing jobs (Grandoni & Clement, 2019).

However, because of the climate crisis, our current form of living is under pressure (Geels, 2002). In addition to this, it is expected that by the year 2030 over 60% of the world's population lives in urban regions (United Nations, 2015). This mass urbanization shows from the transition into the knowledge-based economy, because economic activities take disproportionately place in dense urban regions and in those regions the proximity is high. Thus, results in a high concentration of firms and high skilled people (Balland & Rigby, 2017). In addition to this, high skilled people attract other high skilled people, thereby stimulating the urbanization even more in competitive cities (Berger & Frey, 2016). Although this concentration of human capital, innovation and knowledge production makes cities competitive, it also makes them less resilient to the changing climate and thereby reducing the livability (Kamal-Chaoui & Robert, 2009).

These trends of mass urbanization and the changing climate threaten the livability of cities. These urban regions experience a higher presence of particulate matter emissions, which is according to the World Health Organization the second leading cause of death (2018). Cities also experience the so-called urban heat island effect. The presence of hard surfaces of buildings and infrastructure retains heat, which makes a city unable to cool down at night (Heaviside et al., 2017). Urban regions are sensitive to effects of the changing climate but, as stated earlier, are also large contributors. There carbon footprint is high, and they consume around 90% of the world's energy resources (Rees & Wackernagel, 2008). Thus, cities are increasingly becoming more important in the global economy, but also get more important in bringing the changing climate to a halt. In this context, the technological developments in big data and new forms of communications can add 'smart' elements to everyday life, including cities (Clarke, 2013). This datafication isn't a goal in itself but a possible solution for managing mass urbanization, urban sustainability and urban competitiveness (Nicolas, et al., 2020).

Besides the analysis of these concepts, this research includes a case study for De Randstad. This is a prime example of a poly – centric region, where there are multiple city centers without a leading city (Goess et al., 2016). The four main cities within the Randstad all have their own economic function, e.g., Amsterdam focuses on (financial) services, Utrecht on research and education, Rotterdam is concerned with logistics and port related activities and The Hague is mainly focused on politics (Lambooy, 1998). It is therefore interesting to see how these different cities perform on the concepts of competitiveness, sustainability and smart urbanity. Therefore, the central question is as follows:

*'To what extent is De Randstad a competitive urban region and is it thereby sustainable and smart?'*

The central question is answered by conducting a secondary data analysis, which is performed on a dataset constructed by means of a desk research. In addition to this there is a case study performed on De Randstad region to see how these concepts relate in this region and to see to what extent differences can be found on the sub-regional level.

Extensive research has been done on the competitiveness of cities (Boschma, 2005; Duranton & Puga, 2004; Martin & Simmie, 2008; Porter, 1990). In addition, the influence of urban regions on climate and how climate affects cities have been described in detail (Loorbach & Shiroyama, 2016; Madlener & Sunak, 2011; Rees & Wackernagel, 2008). However, Kamal-Chaoui and Robert (2009) also advocate in their article, for the sustainability of these competitive cities also being considered. This makes the research scientifically relevant because it analyses if the concepts of competitiveness and sustainability of urban regions impact each other and if so, to what extent. Therefore, it becomes clear if there is a tradeoff to be made and if smart urbanity can potentially bridge this gap. This research also looks at De Randstad by means of a case study. This analyses how the different cities perform on these aspects and whether there are similarities on the subregional level in De Randstad.

The expected mass urbanization and the current climate problems ensure that more and more attention is paid to the quality of life in cities. According to Kamal-Chaoui and Robert (2009) the ecological performance of a city has to be taken into account next to its physical capital. This research is also socially relevant because it gives more interpretation on the ecological modernization that policy makers in the cities within De Randstad use to present their city as 'green' (Goess et al., 2016). The research also looks at how this region performs in terms of competitiveness, sustainability, and smart urbanity, which can provide more insight for policymakers to increase cooperation between sub – regions.

The central research question is answered by the following three sub-questions. To see whether there is a relation, if so to what extent, between the concepts of competitiveness, sustainability and smart urbanity, a statistical analysis of 62 cities is conducted to answer the first sub – question: 1. *'To what extent is there a relation between the competitiveness, sustainability and smart urbanity of cities?'.* From there the research conducts a case study on De Randstad to see how these concepts relate to this region. This will be answered through the second sub – question: 2. *'How does De Randstad perform on these three concepts?'*. Because of the poly-centric nature of the region, there are sub-regional differences inside De Randstad. To answer how the subregions differ, sub-question three is answered: 3. *'How do the different urban centers in De Randstad relate to each other?'*.

This research has the following structure. Section 1 provides an overview of the relevant literature to three concepts and from where the hypotheses of the sub-questions are constructed. After this the case study about De Randstad is introduced. In section 2 the methodology is explained, with the operationalization of the three concepts into measurable variables. In section 3 the results of the statistical analysis of the 62 cities and should provide an answer to the first sub-question. In section 4 the most important results of the case study are given and thereby an answer to the second and third sub-question. In section 5 the answer to the main research question is given. Finally, section 6 shows the limitations of the research and presents recommendations for further research.

# 1. Theoretical framework

In the theoretical framework, the three different concepts will be described and how they relate to urban regions according to the reviewed literature. This section provides context for the analysis. First, the concept of urban competitiveness is explained and how cities have become the economic centers in the global economy. Secondly, the theoretical framework looks at the sustainability of cities and how citizens are affected, is discussed. After this the concept of a Smart city is defined and explained. Finally, these concepts form the basis of the first two hypotheses.

## 1.1. Urban competitiveness

The notion of competitiveness is a way to measure the economic performance of a city (Martin & Simmie, 2008). In the knowledge-based economy, the production and exchange of knowledge is important for a city to keep upgrading and improving, and to therefore stay competitive to other cities (Malecki, 2004; Martin & Simmie, 2008). Although, Porter (1990) introduced the notion of competitiveness, this was focused on nations and not so much on cities and regions. Nowadays however, cities have become the most important nodes in the global economy, as most complex economic activities are concentrated in cities (Balland et al., 2020). Therefore, also the focus shifted from the competitiveness of nations to that of cities (Huggins et al., 2013). Due to the improvements in communications technology, the relative distance between cities decreased, cities therefore form a network in the global economy (Audretsch & Feldman, 2004). Knowledge and services are the key drivers in this globalized economy (Cooke & Leydesdorff, 2006). But thereby it is also a key driver for the uneven growth and development between regions (Balland & Rigby, 2017). From the definition of Martin and Simmie (2008) it can be understood that urban competitiveness is the ability for a city to use the knowledge and skill of its business environment to further develop economically and thereby to innovate and achieve a high productivity.

At the base of the ability to be competitive, cities need to have a skilled labor force to attract international firms. Sassen (2002) emphasizes this by stating that the presence of advanced producer service companies with complex knowledge is what makes a city competitive in the global system. Firms are attracted by the high density of skilled workers (Moretti, 2004) This can further be explained through the agglomeration mechanisms by Duranton and Puga (2004). Cities with a high skilled labor force have more potential matches for firms, and vice versa. Therefore, firms attract high skilled workers as well. Berger and Frey (2016) even state that high skilled workers attract other high skilled workers, stimulating the urbanization in competitive regions. Moretti (2012) shows that a high skilled business environment is more competitive and therefore becomes more specialized which in turn is important for a city's ability to innovate.

As stated by Martin and Simmie (2008) and also Malecki (2004), is that for a city to be competitive, it must keep upgrading and innovating. With the transition into the knowledge-based economy the importance of goods and workers shifted to the production and exchange of knowledge and services (Steijn et al., 2020). In a globalized system, the region's competitive advantage relies heavily on the production of non-ubiquitous, complex and tacit knowledge (Balland & Rigby, 2017). This knowledge, however, is knowledge that isn't codifiable and therefore not transferable over greater distances (Audretsch & Feldman, 2004; Howells, 2002). This can be seen as an explanation for the increased importance of cities as well. The high proximity in cities makes it so that the complex knowledge can be exchanged. Boschma (2005) expands on this by distinguishing five different forms of proximity

*geographic proximity*, *social proximity*, *cognitive proximity*, *institutional proximity* and *organizational proximity*. The cognitive proximity explains the attraction of high skilled workers by other high skilled workers, as stated by Berger and Frey (2016). As they have the same level of knowledge which is needed to produce new knowledge and to innovate (Balland et al., 2015). The social, institutional and organizational proximity are key for a competitive business environment as it positively affects the exchange of knowledge (Boschma, 2005).

The concept of competitiveness is important for understanding a city's economic performance in the knowledge-based economy as it shows the ability to innovate through the human capital and complex knowledge that is present. Cities are the most important centers for knowledge intensive economic activities. But thereby it also shows the uneven development between different (urban) regions. Which in turn explains the trend of mass – urbanization. The following section shows how cities, although economically important are also important regarding the changing climate.

## 1.2 Sustainability and liveability in cities

In the previous section, it became clear how the importance shifted from nations to urban regions and cities, as this is where most economic activity is taking place in the knowledge-based economy. Which also determined the high living standard for citizens in competitive cities (Dunning, 2002). Next to trend of mass-urbanization the current climate crisis affects cities as well. Notwithstanding to the economic success, cities consume more than 70% of the world's resources (Madlener & Sunak, 2011; Rees & Wackernagel, 2008). Because of the mass urbanization and the knowledge intensive nature of our economy, cities are the largest contributors to the current changing climate, additionally the livability of its citizens is reduced dramatically (Kamal-Chaoui & Robert, 2009). The trade-off between economic development and sustainability in urban region is especially apparent in economically developed (western) cities. These cities have a large ecological footprint as introduced by Rees and Wackernagel (2008). This is a measure of the natural resource use and its impact on the ecosphere. The research of Newman (2006) shows how the impact of similar sized cities in India and the United States differ. Indian cities only have impacts on the local environment. Where American cities have a higher consumption level with much higher material standards and have therefore a disproportionate impact on the global environment. These cities have a exponentially higher ecological footprint than their political area supports (Rees & Wackernagel, 2008). But also, the density of people plays a role in the unsustainability of urban regions. Higher concentration of people have a higher energy use and therefore a larger contribution to greenhouse gas emissions (Bertoldi et al., 2018; Kamal-Chaoui & Robert, 2009; Loorbach & Shiroyama, 2016).

Cities have a major impact on the global climate, however the livability in urban regions is under pressure because of the current global climate crisis. Cities are often located at vulnerable locations and therefore not resilient to extreme weather conditions. Although, cities enjoy the benefits of the presence of firms and services, cities and their citizens also must endure the impact of the changing climate (Kamal-Chaoui & Robert, 2009). The livability in urban regions is therefore increasingly unsecure. The United Nations (2021) reported that the current average global temperatures are higher than ever measured before. The Paris Climate Agreements also focus on the 1.5$^{o}$C increase of global temperatures in relation to the pre-industrial average temperatures. Not only the location of cities, but also their overall infrastructure isn't aimed to withstand these conditions. Because especially in cities, heat has major health impacts on its citizens. Not only through the drought which in turn brings food and water insecurity, but also the heat itself. Another large impact of the rising heat for the urban population is the notion of Urban Heat Islands (UHI). Because of the 'hard' surfaces, like infrastructure and buildings,

they retain heat from the sun overnight. This doesn't allow the city to cool down and therefore temperatures are higher during the day- and nighttime (Heaviside et al., 2017; World Health Organization, 2018). This results not only in physical but also psychological health implications. Therefore, Parker and Simpson (2018) emphasize the importance of green space in cities, to cool the urban environment and therefore decrease the health impacts and improve psychological state. The amounts of greenhouse gas emissions affect the urban population. The main producers are also the largest contributors to air pollution and fine particulate matter. With over 90% of the worlds urban population breathes air that is above the World Health Organization's benchmarks, it is the second leading cause of death of non-communicable diseases (World Health Organization, 2018).

Cities are the largest contributors to the changing climate, its citizens are heavily affected by the climate. Therefore, city governments are aiming to improve their sustainability, to reduce the impact on its citizens and the environment. The United Nations Sustainable Development Goals focus with the eleventh goal on making cities sustainable resilient and safe. To meet the targets by 2030 cities must implement policies and reduce their ecological footprint (United Nations, 2015). For example, although cities consume 80% of the world's energy production, efforts can be made by switching to renewable sources having low- to zero carbon impacts (Kamal-Chaoui & Robert, 2009). Rees and Wackernagel (2008) emphasize this and state that cities have specialized knowledge to improve recycling and remanufacturing. As a result, there is less demand for occupied land and therefore less fuel for heating. Transportation can be reduced by promoting public transport over car use. Loorbach and Shiroyama (2016) state that cities are the perfect place for sustainable transitions. They can be actors to reform socio-technological structures into more sustainable systems, but most importantly they can facilitate innovation. However, policy makers and city marketeers also use this to promote their city as 'green' through the concept of ecological modernization. These cities are marketed as competitive economic cities but also sustainable (Goess et al., 2016). However, cities can be potential drives for sustainable development and radical innovation. As cities have a human capital it can be expected that they have the ability to overcome these implications (Loorbach & Shiroyama, 2016).

It becomes clear that cities are affected by the changing climate, however they are also the main contributors to the current climate crisis. Especially economically developed cities have a high resource and energy use. In the next section the concept of a Smart City is described and is thereby a possible way to manage the current implications, like the climate crisis and mass urbanization, that cities face.

## 1.3. The concept of a 'smart-city'

The transition to the knowledge-based economy also characterizes the current form of urbanity. This form not only increases global competitiveness between cities but also pressures the livability in cities (Clarke, 2013; Kamal-Chaoui & Robert, 2009). Kourtit et al. (2017) argue that this era is shaped by developments in information and communication technologies, whereby this has become an important component for policy makers and planners. The so-called fourth industrial revolution, or Industry 4.0, has changed the economic landscape and is at the root of the emergence of the Smart City concept. (Morrar et al., 2017). Smart solutions may be the solution for bridging the gap between sustainability and competitiveness.

The concept of a 'Smart – City' is increasingly getting implemented by urban policy makers all over the world (Hajduk, 2016). Its industry has an anticipated value of 2.1 trillion dollars in 2020 (Nicolas et al., 2020). However, the concept is fairly new in the regional and urban geography literature and therefore, the true definition remains ill – defined. In the article of Hajduk (2016) she gives a summary of few of smart city definitions. There is a consensus that can be made with the definitions of Hall (2000); Caragliu et al. (2011); Nam and Pardo (2011); Lombardi et al. (2012); Buntak et al. (2019). Namely, a smart city is where technology and big data are used to make the different functions of a city more efficient and to improve the quality of life of its citizens. Townsend (2013) also emphasizes the importance of ICT – technologies to manage, monitor and regulate a city in real – time through efficient control of urban services. The amounts of data that is aggregated can be used to further analyze and predict urban systems. Of course, the use of ICT – technologies for improving cities isn't new perse, however the way it is used in the concept of Smart City with big data and real time analytics will structurally change urban services. In addition to this these technologies will connect the different urban systems in an efficient way (Carvalho, 2015). Giffinger and Gudrun (2010) further elaborated on this by setting out six different elements a smart city consists of. These elements are: *Smart Economy, Smart People, Smart Governance, Smart Mobility, Smart Environment* and *Smart Living* (Giffinger & Gudrun, 2010). The smartness of a city describes the ability to what extent it can unite the different elements to work effectively and with the greatest efficiency. Getting a better understanding of the urban processes through data collection can make a city more attractive by efficiently increasing the quality of basic services and therefore improve the competitiveness and sustainability (Bibri, 2019; Buntak et al., 2019; Kourtit et al., 2017).

The Smart City concept is embraced by policy makers and governments as the solution for the problems of cities. However, it should remain clear that it's not a silver bullet that solves all problems, but merely a tool to effectively tackle the problems that the world and especially urban regions face (Taylor Buck & While, 2017; Zawieska & Pieriegud, 2018). Clarke (2013) emphasizes the different trends that drive Smart City Growth, increasing in global competition for talent, mass urbanization stresses urban infrastructures and systems, climate issues, crossing a digital divide between the government and its citizens and gathering big data. Currently smart city developments are still too fragmented to shift the current socio - technological regime (Carvalho, 2015; Taylor Buck & While, 2017). Smart cities can become one of the most disruptive transformations of urban system management, right now it still is in the beginning and needs more testing and experimenting, but also encounters challenges regarding privacy and (geo)surveillance (Bibri, 2019). The different urban experiments of smart city niches give policy makers and governments the possibilities to enhance and fine tune these technological projects to make them scalable. This will give them more technological learning and societal embeddedness (Carvalho, 2015). In the case of smart cities, the collected data provides a very refined microscopic

perspective of very complex urban dynamics which makes it very accessible to keep learning and improving (Kourtit et al., 2017).

The current regime of urbanism is being pressured by the climate crisis, therefore, in the 2030 agenda of the United Nations with the emergence of the sustainable development goals, came also Goal 11: Sustainable urban regions and cities (United Nations, 2015). For the purpose of this, the use of big data should improve the socio-economic development and protect the environment (Bibri, 2019). Because of the holistic perspective on urban systems through the use of data, A city can be more sustainable since the efficiency and us e of natural resources can be improved, which in turn helps improve the livability in high density regions (Bibri, 2019).

## 1.4. Conclusion

The articles of Rees and Wackernagel (2008), Newman (2006) and Kamal-Chaoui and Robert (2009) emphasize that economically developed cities have a large ecological footprint and a large impact on the global climate. The livability and the resource use is high in competitive cities as they have a high living standard (Dunning, 2002). It can be expected that these cities aren't sustainable. Therefore, the hypothesis for the first sub-question is as follows; *(1) The sustainability of a city negatively affects the competitiveness of city*. The competitiveness of a city stems from the human capital and present knowledge in a city (Townsend, 2013). Most smart city elements come from innovation in the communications and computer technology, additionally, the affinity and ability to use these implementations by governments and cities are essential for a smart city (Nicolas et al., 2020). Therefore, the second hypothesis for the first sub-question is;*(2) cities with a high level of smart urbanity are more likely to be competitive.* From these hypotheses an adequate answer to the first sub-question of this research, '*To what extent is there a relation between the competitiveness, sustainability and smart urbanity of cities?'* can be formulated.

# Case study: De Randstad

In the theoretical framework it became clear that urban regions are the center of economic activity in the global system. However, due to the heterogenic nature of regions, it is interesting to dive deeper in a region and how these concepts relate. Therefore, the research conducts a case study on De Randstad. This section also provides the context for the hypotheses for the second and third sub – question.

## Mono-centric agglomeration or a poly-centric urban region

De Randstad is often referred to in the scientific literature as the perfect example of a poly-centric urban region (Meijers, 2005). The region is described on the basis of a North Wing and a South Wing, with Amsterdam, Rotterdam, The Hague and Utrecht as the four main cities. De Randstad has an area of about 90 square kilometers with more than six million inhabitants being one third of the total Dutch population (van Oort et al., 2010). Figure 1.1 shows a map of the region with its two different wings. Lambooy (1998) explains that the four individual cities all have their own function. The South Wing is, economically speaking, focused on transport, logistics and port-related activities including the processing of oil and gas in Rotterdam and government-related activities in The Hague. The North Wing is diverse, with financial and business services located in Amsterdam and education and innovation mainly taking place in Utrecht.

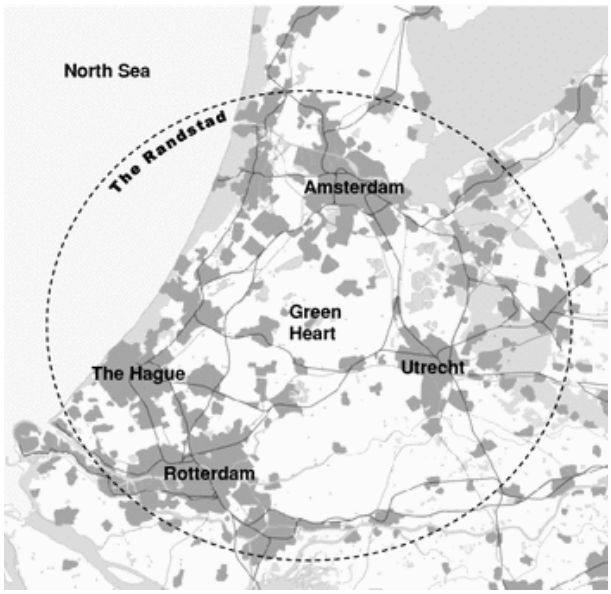


*Figure 1.1: The poly-centric urban region De Randstad, with the four main cities that make up the two different wings, embracing the Green Hart. (Lambregts et al., 2008).*

Goess et al. (2016) describe a poly-centric urban region as one that consists of several cities. Where none of these cities is more dominant than the others in the areas of politics, economy, and culture. These cities cooperate, but also compete with each other as well. Kloosterman and Lambregts (2001) add that these cities are historic cities in reasonable proximity, therefore allowing for commuting. The cities have approximately the same economic position as well as approximately the same size. In addition, they all have their own governmental bodies. Goess et al. (2016) state that there is an ambiguous relationship between cities within De Randstad, on the one hand there is the possibility to

cooperate in order to have an internationally strong position, but on the other hand they are competing with each other in order to have the best performance of the region.

In Hall's book World Cities (from Kunzmann, 1998), he states that the region known as De Randstad is a world city and part of the global system of cities. De Randstad is thus described as one large agglomeration that should benefit from the agglomeration advantages of high density of economic activities, businesses and a highly skilled workforce, all located in high proximity to each other (Duranton & Puga, 2004; Martin & Simmie, 2008). However, the question remains whether this is actually the case and if De Randstad is a closely cooperating entity or rather a collection of cities with slight forms of interaction. Meijers (2005) states that there are mainly horizontal connections between the cities, rather than vertical connections. In other words, there is more cooperation and complementarity than a hierarchical relationship. For example, Kloosterman and Lambregts (2001) state that De Randstad, as a name, suggests that it is a working entity. However, this does not mean that it is also a spatially functional whole. Van Oort et al. (2010) argue that there is no network or uniformity throughout De Randstad, but rather within the two different wings where interaction is mainly between the sub-regions rather than between the cities. Indeed, the cities remain more like a central point in their own urban region. Nevertheless, Lambregts (2006) argues that there is interregional connectivity. Whereby Amsterdam is best connected within the Randstad and Rotterdam on a national aspect. This can be explained by the port related activities and the logistic function of Rotterdam, as described by Lambooy (1998). In Table 1.1 an overview is given of the different perspective on De Randstad as one functional region or a poly-centric region with different sub - regions. Kloosterman and Lambregts (2001) argue that the improvements that are taking place in the technological field of transport and telecommunications has allowed polycentric regions to gain more agglomeration advantages and create an agglomeration economy similar to that of large mono-centric cities.

| **Article:** | **Mono centric metropole or poly – centric urban region** |
|---|---|
| Van Oort et al. (2010) | More connectivity inside the different wings. There isn't much interconnectivity between cities and more between regions. |
| Lambooy (1998) | Low commuter flows between Randstad cities, but more within the different wings. But from a global economic position it can be seen as one region. |
| Zonneveld and Nadin (2020) | The different cities are complementary with each having their different functions, but there isn't strong evidence for mono centricity. |
| Kloosterman and Lambregts (2001) | More clustering in the different wings than in the different main cities. |
| Goess et al. (2016) | It isn't one large metropolis, because it is fragmented administratively and organizational. There is more affiliation in the subregions. |
| De Vries (2012) | Amsterdam sees itself as the only metropolis in the region, not as a node of the poly centric network. |
| Meijers (2005) | No synergy between cities in De Randstad on economic level, but increasingly more co-operation is taking place on an organizational level. |

*Table 1.1: Overview of the literature review if De Randstad can be seen as one agglomeration or a poly – centric region.*

## De Randstad as a competitive hub in the world economy

Zonneveld and Nadin (2020) expect monocentric world cities to perform better due to their high concentration, density and diversity of economic activities. Lambooy (1998) argues that there is a single metropolis in which therefore these agglomeration advantages do apply. It is clear that within the Netherlands De Randstad is the most important economic region. Half of the national GDP comes from 25% of the total land area (Van Oort et al., 2010). Although this article is more than ten years old, due to increasing urbanization, it can be expected that this share has not decreased. From the international/global perspective, De Randstad is very much oriented towards the rest of the world. De Vries (2012) emphasizes this as metropolitan regions are increasingly becoming more important through the globalization that is taking place. In addition, De Vries (2012) also states that urban regions compete with each other globally and not so much national governments. Lambregts (2006) states that on a global level the Randstad is an important center for the services and knowledge sector. The high number of multi-national corporations that have their headquarters here shows this (Wall, 2009). However, there are differences between the cities and to what extent they are internationally oriented. Preeminently, Amsterdam is most important on a global scale, with The Hague operating on a regional and international scale. Utrecht and Rotterdam are relatively locally focused. However, all four major cities of De Randstad are the only cities within the Netherlands that truly operate on an international scale (Wall, 2009).

## Randstad as a 'livable' urban region

As shown in Figure 1.1, it is visible how the two wings embrace an area, also known as the Green Heart. A low-populated region that is protected by the government and kept intact as much as possible. This area is often used to describe De Randstad as sustainable and 'green'. Goess et al. (2016) show in their article how all cities in the Randstad present themselves as an economic and sustainable city, better known as ecological modernization. Cities are becoming more important, more valuable and more competitive while reducing their impact on nature. The article by Kloosterman and Lambregts from 2001 already states that the poly - centric region De Randstad agglomeration can benefit from the technological improvements for communication and transport. Kourtit et al. (2017) elaborate on this and argue that digital technology will play an important role in the urban policy of the region. It should, according to them, ensure urban governance and thus more citizen participation and innovation. The concept of De Randstad as a Smart City can ensure that it can compete with economies in high-density and connected cities, in this case mono -centric agglomerations. This digital transformation should ensure that urban intelligence takes place and cities perform better. The article by Goess et al. (2016) shows that all major cities in the Randstad also profile themselves as Smart City. With this they show that they are also competitive cities and fit within the concept of ecological modernization.

## Conclusion case study

From the literature review of De Randstad, it can be expected that the whole of De Randstad performs high on the concept of competitiveness as they produce half of the national GDP (Van Oort et al., (2010). Additionally, they all should score high on the concept of sustainability as they all market themselves as 'green' (Goess et al., 2016). From the same article it is stated that they all see themselves as a smart city as well (Goess et al., 2016). Therefore, the hypothesis for the second sub-question is as follows; (3) *De Randstad scores high on the concepts of competitiveness, sustainability and smart city.* This should provide an answer to the second sub-question of this research: *'How does De Randstad perform on these three concepts?'*.

From this section it also becomes clear that it can be expected to be subregional differences in De Randstad. Amsterdam should be leading as it sees itself as the prime city (de Vries, 2012). The economic function of Amsterdam and Utrecht is focused more on knowledge where The Hague and Rotterdam have less knowledge intensive functions (Lambooy, 1998). Therefore, the fourth hypothesis is; *(4) the North wing of De Randstad is more competitive than the South Wing.* Because of the present human capital and knowledge in the North Wing, the fifth hypothesis *(5) The North Wing scores higher on the Smart City ranking than the South wing.* As it is expected from the first hypothesis that a high sustainability has a negative impact on competitiveness of a city the hypothesis for the third sub-question is as follows, *(6) The South wing scores higher on the concept of sustainability than the North Wing.* From these hypotheses an answer to the third sub-question of this research: *'How do the different urban centers in De Randstad relate to each other?'*.

# 2. Methodology

## 2.1. Research design

This research shows to what extent there is a relation between the competitiveness of cities around the world and to sustainability and the extent to which they can also be regarded as a 'Smart City'. As discussed in the theoretical framework, within the literature sustainability is a component of a competitive city. To investigate this, a quantitative secondary data analysis is conducted. To do this, a dataset was constructed from multiple sources which helped to formulate an answer to the main research question. A logistic regression was used for this purpose. This method looks at the probability that something is or is not true. This is the dependent variable that is calculated from multiple independent variables. In addition to analyzing the central research question, the study looks at how De Randstad performs in relation to the rest of the cities and within the subregions. Therefore, sub-question two '*How does De Randstad perform on these three concepts?'* and sub-question three '*How do the different urban centers in De Randstad relate to each other?'* are answered through descriptive statistics of the collected and constructed data. Which was in turn visualized to gain more insight into this data.

## 2.2. Data collection

This research looks if there is a relation between the competitiveness of cities and the extent to which these cities are sustainable and can be designated as a Smart City. For this purpose, a number of cities are measured against these three concepts, each consisting of five to six indicators. The dataset constructed using these indicators is built from a variety of sources. These are mainly reputable sources, including the OECD, United Nations, Eurostat and the US Census Bureau. In addition, lesser-known sources have been used for specific indicators. In Appendix I - IV, the sources for each (sub) indicator are given.

In addition, De Randstad and how the four main cities, Amsterdam; Rotterdam; The Hague and Utrecht relate to each other has been explored in more detail. The cities selected for the statistical analysis of this study are mainly the cities of the Organization of Economic Co-operation and Development. In addition, the BRIC - Countries (Brazil, Russia, India and China) are added. The cities of both OECD and BRIC countries were selected based on the availability of data. The population of the cities was another selection criteria. Only cities with more than one million inhabitants were included in the analysis. Except for the cities within the Randstad, which, except for Amsterdam and Rotterdam, do not meet this requirement on their own. On this scale, there is limited information available for many cities. Some cities are no longer included in the analysis because there was not enough information available.

Given the diversity of the data and the difference in scale levels, it has not been feasible to retrieve data from the most recent year, 2020. The oldest sources that have been used are from 2018. Although the vast majority of the sources are from 2019 and 2020. This is not expected to negatively affect the reliability of the analysis because these aspects generally will not fluctuate much in such a short time frame. In addition, it concerns an indication of how cities perform on a particular aspect. As mentioned in the previous section, data is not always available for all cities at the urban scale level, to still analyze the cities the national scale level was used. Many of these indicators are settled a priori at the country level, so it should not negatively affect the analysis. Both the year and the scale level are indicated for each indicator in Appendix I - IV.

## 2.3. Operationalization

The dependent variable and the two independent variables were created from different abstract concepts. These have been addressed in the theoretical framework, where the definition is given. The variable 'urban competitiveness' is defined by Martin and Simmie (2008) as a city with the ability to continuously improve due to the presence of a highly skilled workforce so that businesses are attracted, innovation can take place and there is a high GDP and high employment rate. From this definition, the concept was constructed using the indicators in Table 2.1.

| **Sub – Indicators** | **Measures** | **Level** |
|---|---|---|
| Human Capital | University Rankings | City |
| | Share of population with a tertiary education (age 15 – 64) | City |
| Innovation | Share of the GDP for Research and Development | Country |
| | Share of start-ups per citizens | City |
| Labour Market | GDP per capita | City |
| | Employment rate | City |

*Table 2.1: Sub – indicators and measures for the level competitiveness of cities. In addition to this is the level of the measure given.*

The dependent variable competitiveness is constructed from the average sum of the three different indicators with six sub - indicators. Human Capital reflects the overall education level of a city. How good a university is and how many people actually used (this) university. Because some cities host several universities, the sum of the scores was chosen, the average would give a false picture. Innovation is also an important element of urban competitiveness. This is mean using the national budget of the government for research and development, in addition, the number of startups is calculated. Because the absolute value, probably, will be higher in cities with more inhabitants, this indicator is made relative to the number of inhabitants. The total number of startups / total number of inhabitants x 1.000. For the last indicator Labour market, the research looked at the Gross Domestic Product per capita and the employment rate. For this, the unemployment rate was taken and made positive by subtracting it from 100 and then dividing by 100, since a high employment rate has a positive effect on the performance of a city.

The first independent variable is the sustainability of a city. For this, the research looked at it from the ecological footprint of Rees and Wackernagel (2008). Whereby cities with a small ecological footprint with good livability for its inhabitants can be seen as a sustainable city. In Table 2.2 the sub indicators are given.

| **Sub – Indicators** | **Measures** | **Level** |
|---|---|---|
| Energy | Share of renewable energy sources | Country |
| | Greenhouse Gas Emissions per capita | City |
| Liveability | Annual Amount of PM 2.5 | City |
| | Share of urban area that is green space | City |
| Transportation | Share of population with access to public transport | City |

*Table 2.2: Sub – indicators and measures for the sustainability of cities. In addition to this is the level of the measure given.*

The independent variable of sustainability is constructed from the average sum of the sub – indicators presented in Table 2.2. Since cities use more than 70% of the global energy supply, it is important from the ecological footprint perspective to what extent this is renewable energy. In the same way, cities are also one of the largest contributors of GHG emissions. The lower this score the lower the footprint is. In addition, the sustainability of the city is important for the quality of life for its citizens. For this purpose, the amount of annual particulate matter measured in the city was examined. The World Health Organization (2018) state that this is the second most common cause of death from non - communicable diseases. Additionally, Parker and Simpson (2018) state that green space in a city is important for both the physical and psychological health of citizens. Finally, public transportation is considered for this concept. This is according to Rees and Wackernagel (2008) one of the larger contributors to the high energy consumption in cities.

For the measures; greenhouse gas emissions per capita and annual amount of particulate matter, the observation is made positive so that they can be measured with the rest of measures. The second independent variable looks at whether the cities can be seen as a Smart City. For this research the six elements that Giffinger and Gudrun (2010) set out that make up a smart city are used. These are given in Table 2.3 below:

| **Sub – Indicators** | **Measures** | **Level** |
|---|---|---|
| Smart Mobility | Share of electric vehicles | Country |
| Smart Economy | Share of smart city start-ups per 1.000 citizens | City |
| Smart Governance | Open government score | Country |
| Smart People | Score of digital skills for 'new economies' | Country |
| Smart Living | Average Internet speed (Mbps) | City |
| Smart Environment | Share of patents of environmental related technologies | Country |

*Table 2.3: Sub – indicators and measures for the score to what extent a city can regarded as a Smart City. In addition to this is the level of the measure given.*

The independent variable Smart City is constructed from the average sum of the sub – indicators presented in Table 2.3. Given that measuring smart city implementations at this scale is imprecise, the research looked at indicators that underlie a Smart City. For example, the number of electric vehicles compared to the rest of the cars is taken into consideration first. In addition, the number of smart city startups per 1,000 residents was taken to look at how the economy is oriented toward a smart city. This was done by dividing the total number of Internet of Things and Data startups by the number of inhabitants x 1,000. The government score is built based on the openness and availability of public data. The skill of its residents is also important for the use of potential implementations, therefore the digital skills score for such economies is considered. Given the large amounts of data that need to be processed and analyzed at a high rate, internet speed has been looked at. This underlies all Internet of Things related implementations in the city. Finally, for smart environment, the research looked at the number of patents filed for technologies to improve the environment.

In addition to the measures that construct the three different variables, a control variable was selected to limit the influence of the confounding and therefore to better understand the relation between the independent and dependent variables. The control variable that used is the Quality of Life Index (From Numbeo.com). This index is an overall performance of cities where data is collected through surveys on purchasing power, pollution, housing prices, cost of living, health care, climate and safety. The data

is collected throughout multiple periods and collected periodically. The most recent data is from the beginning of 2021.

## 2.4. Data analysis

The dataset was constructed using Microsoft Excel. This contains all the cities and variables. In preparation for the logistic regression, the data was prepared appropriately. First, the dependent variable was converted to a binary variable. This was done by testing observations of the measures of competitiveness against the median of the measure. This was chosen instead of the mean because the median is less sensitive to outliers. If a city's score was higher than the median, it was given a 1, if not a 0. If a city is more than three out of six measures above the median, the city is competitive. If this is not the case, the dependent variable is 0. The threshold is set in this way because it can be assumed that this selection of cities is already connected in the global system of cities. For the independent variable, first these had to be able to be made comparable. Some data is expressed in percentages, where other observations are given in absolute numbers. In addition, some measures are not comparable even though they are in the same form. To ensure that the independent observations are comparable, the data is normalized using the Min-Max method. $x^i$ is the normalized variable of the column in x. Min($x$) is the minimum value of that column, Max ($x$) is the maximum value of that column. This formula gives the normalized values of a column, expressed between 0 and 1:

$$\boldsymbol{x^i = \frac{x - \min(x)}{\max(x) - \min(x)}}$$

To answer the first sub - research question, *'To what extent is there a relation between the competitiveness, sustainability and smart urbanity of cities?',* the first two hypotheses were tested by performing a logistic regression. This gives the probability of an event happening, or in this case if a city is competitive or not. Both independent variables were also measured separately to answer the first research question more accurately. This probability is expressed between 0 and 1. In the formula below, P(y) is the probability that something is or is not true. In the formula below, P(y) is the probability that something is or is not true. The $\beta_0$ stands relates to the intercept, $\beta_1$ is the regression coefficient for variable $X_1$. In this case the Sustainability of a city. $B_2$ responds to the level of Smart City and $\beta_3$ represents the coefficient of the control variable: Quality of life Index.

$$\boldsymbol{P(y) = \frac{e^{\beta 0 + \beta 1 X1 + \beta 2 X2 + \beta 3 X3}}{1 + e^{\beta 0 + \beta 1 X1 + \beta 2 X2 + \beta 3 X3}}}$$

The analysis was done by using the statistical analysis program R Studio. This application is suitable and widely used for statistical (scientific) analysis. The visualization in the results section and in the case study in section 4 where made by using the online tool: Datawrapper. The analysis, the assumptions and the correlation matrix were done in R studio. To perform a logistic regression, the observations must meet several assumptions. The observations are independent, these were collected as described in section 2.2. and 2.3. There is a causal relationship of the independent variable with the dependent variable. The operationalization explains how the dependent variable was transformed into a dichotomous variable. The independent variables are on ratio scale. Finally, testing was done for the condition of no multicollinearity. The correlation matrix can be found in Appendix V. There is no r > [0.9].

# 3. Results

## 3.1. Descriptive statistics of the cities' performance

This research analyses 62 different cities, across the world, on the concepts of competitiveness, sustainability and smart urbanity. From the literature review it is expected that the sustainability and economic performance of cities are contradicting to each other (Herrschel, 2013). The aggregated scores of the different cities on the three concepts are shown in the map below. The map shows that the best overall performing cities are mostly located in the global north, with a few exceptions in Australia and Hong Kong. Next, the research dives deeper on the performance of the cities on the different concepts.

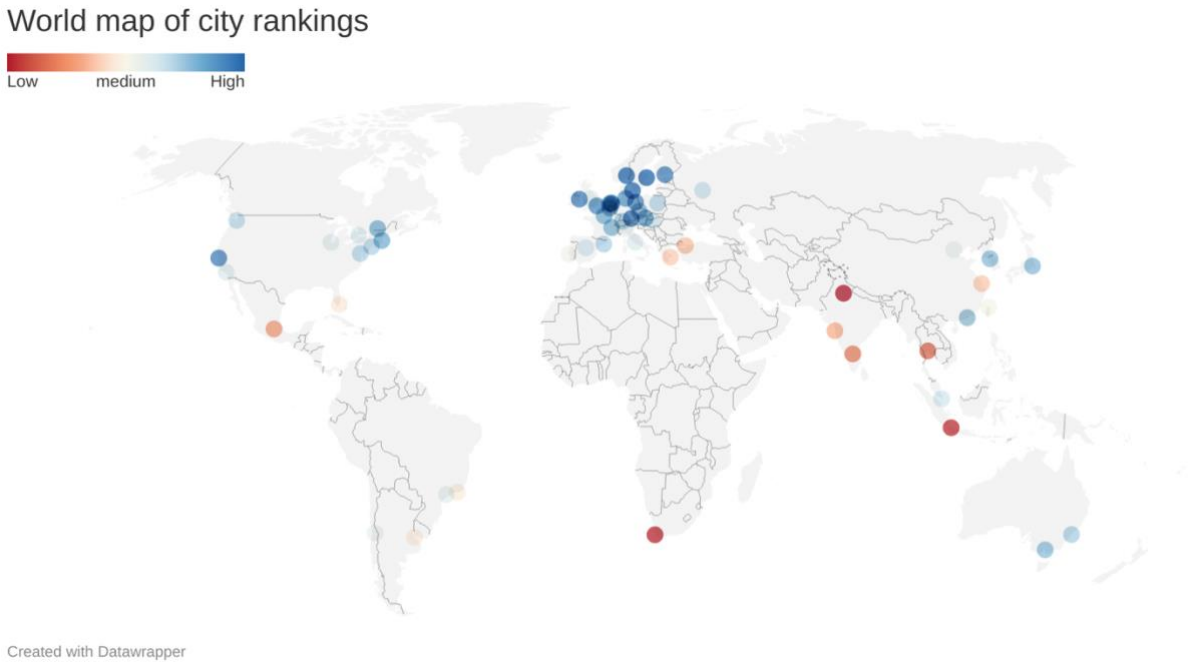


*Figure 3.1: World map of the analyzed cities and their overall scores. Blue nodes indicate a high ranking and red nodes indicate lower rankings. Source: own dataset and visualization.*

In the scatterplot in Figure 3.2 the competitiveness related to the sustainability is shown. The graph is divided into four different quadrants. The upper left shows cities that are competitive but lack sustainability, in the upper right cities are shown that are both sustainable and competitive and cities in this quadrant can therefore be considered as balanced urban regions. The lower right quadrant shows cities that are sustainable but lack competitiveness. In the lower left quadrant, the cities that underperform on both concepts are shown. From the scatterplot below in figure 3.2 it becomes clear that cities in the global south are less competitive than cities in global North. European cities perform better on sustainability than the other measured cities. However, these cities lack competitiveness compared to the cities in the United States. There isn't a particularly distinct relation visible from these two concepts. Although there is a slight negative effect from sustainability on the level of competitiveness visible.

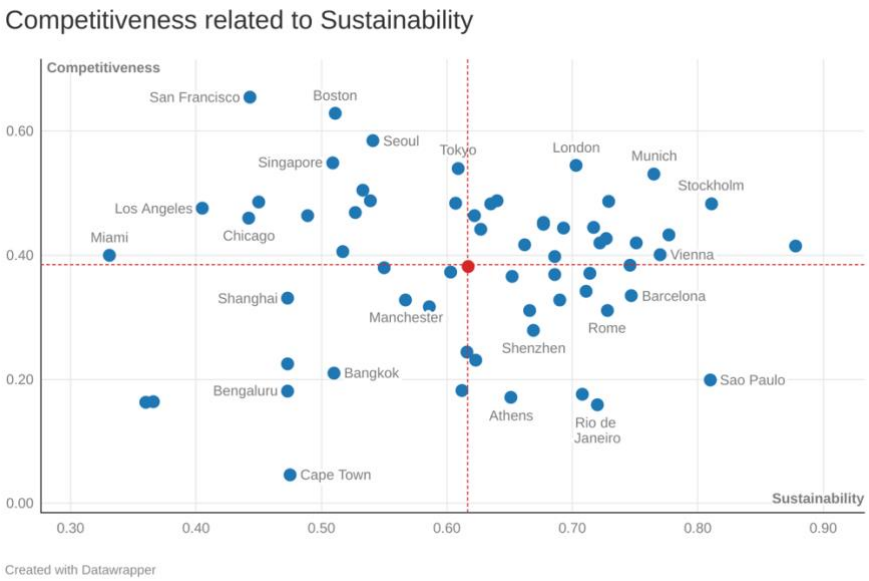


*Figure 3.2: Scatterplot of the competitiveness on y – axis and sustainability on the x – axis. Average ranking is given in red and indicates the four different quadrants. Source: own dataset and visualization.*

The scatterplot in Figure 3.3 below shows the competitiveness in relation to the Smart Urbanity. Just as in figure 3.2. the scatterplot is divided into quadrants. There is a stronger linear relation visible between competitiveness and smart city. This can be explained because of the knowledge intensive nature of 'smart' elements. This explains why most cities are in upper right and lower left quadrant. Most of the analyzed cities that aren't competitive, aren't 'smart' as well.

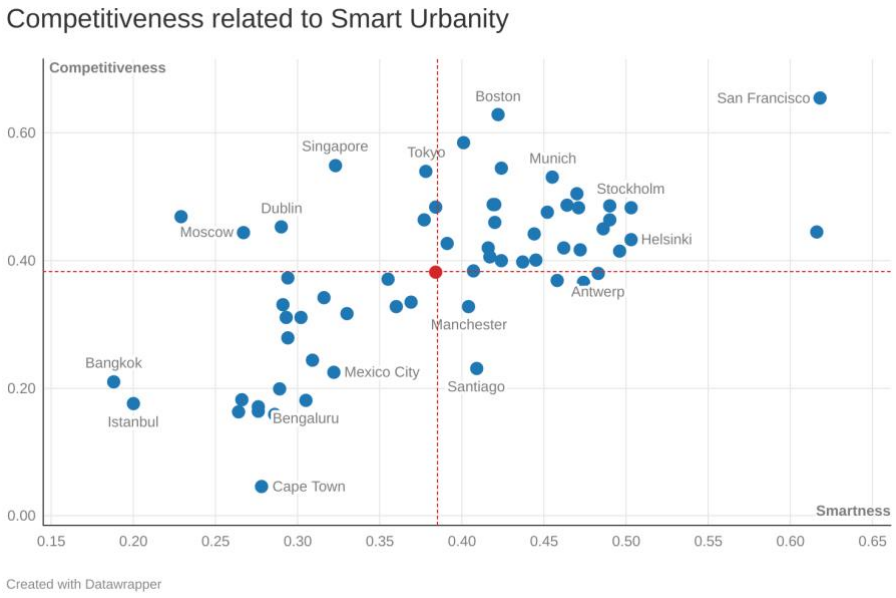


*Figure 3.3: Scatterplot of the competitiveness on y – axis and Smart City on the x – axis. Average ranking is given in red and indicates the four different quadrants. Source: own dataset and visualization.*

## 3.2. Predicting competitiveness of a city through sustainability and smart urbanity

To get a better understanding how the different concepts relate to each other and therefore to see to what extent there is a trade-off between competitiveness and sustainability and how this relates to smart urbanity, a logistic regression is used. This was done by first, analyzing through a threshold of the median of the analyzed cities to what a competitive city is. Secondly, the concepts of sustainability and smart city were analyzed to see what its effect is on the probability of city being competitive or not. From the article by Martin and Simmie (2008) in which they set out the different definitions and forms of urban competitiveness, it can be stated that sustainability isn't part of urban competitiveness. Herrschel (2013) emphasizes this by stating that the two concepts are contradicting to each other. Kamal-Chaoui and Robert (2009) advocate in their article and state that these concepts should be treated separately when looking at the performance of a city.

The first regression analysis that is performed, shows how the independent variables Sustainability, Smart City and the control variable Quality of Life Index predict if a city is competitive or not. In table 3.1 the outcomes of this regression analysis are shown.

| **Output table of the regression model of all three concepts.** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | **95% C.I. for Exp (B)** | |
| **Variable** | **B** | **S.E.** | **Wald** | **P** | **Exp (B)** | Lower | Upper |
| Intercept | -5,118 | 2,080 | 6,057 | 0,014* | 0,006 | | |
| Sustainability | -0,155 | 2,500 | 0,004 | 0,951 | 0,857 | 0,006 | 115,10 |
| Smart City | 11,267 | 4,226 | 7,107 | 0,008* | 7,818+e4 | 19,753 | 3,094e+9 |
| Quality of Life Index | 1,053 | 1,128 | 0,872 | 0,351 | 2,866 | 0,314 | 26,128 |
| $Chi^2$ (*df = 3*) | | | | | | | 16,361 |

*Table 3.1: Coefficients of the logistic regression model including all independent variables and control variables. Number of observations = 62. (Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1)*

The likelihood ratio test for the regression model shows that the constructed regression model has two coefficients that differ significantly from zero, $X^2 = 16,361$ df = 3, $p < 0,001$, $R^2n = 0,311$. The variable Smart City ($\beta = 11,267$, $p < 0,01$) is the only significant predictor for the competitiveness of a city. The variables Sustainability ($\beta = -0,155$) and Quality of Life Index ($\beta = 1,053$) are both not significant predictors if a city is competitive or not. The regression model with a Chi – squared of 16,361 with 3 degrees of freedom is a significant model with the variables *Sustainability*, *Smart City* and the *Quality of Life Index* that fits the data better than the model without variables.

To see how, and if, only the variable of Sustainability predicts if a city competitive or not, a logistic regression with only Sustainability and the control variable Quality of Life Index as independent variables is performed. In Table 3.2. the outcomes of this analysis are shown.

| **Output table of the regression model of Sustainability as a predictor for competitiveness** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | **95% C.I. for Exp (B)** | |
| **Variable** | **B** | **S.E.** | **Wald** | **P** | **Exp (B)** | Lower | Upper |
| Intercept | -1,812 | 1,470 | 1,520 | 0,218 | 0,163 | | |
| Sustainability | 0,038 | 2,287 | 0,000 | 0,987 | 1,039 | -0,012 | 91,964 |
| Quality of Life Index | 2,876 | 1,135 | 6,416 | 0,011* | 17,746 | 1,917 | 164,276 |
| $Chi^2$ (*df = 2*) | | | | | | | 8,238 |

*Table 3.2: Coefficients of the logistic regression model including all independent variables and control variables. Number of observations = 62. (Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1)*

The likelihood ratio test for the regression model shows that the constructed regression model has one coefficient that differ significantly from zero, $X^2 = 8,238$ df = 2, $p < 0,05$, $R^2n = 0,167$. Only the control variable *Quality of Life Index ($\beta$ = 2,876, p < 0,01)* is the only significant predictor for the competitiveness of a city. The variable *Sustainability ($\beta$ = -1,812)* is not a significant predictor if a city is competitive or not. The model with a Chi – squared of 8,232 with 2 degrees of freedom is a significant model with the variables *Sustainability* and the *Quality of Life Index* that fits the data better than the model without variables.

To see how only the variable of Smart City predicts if a city competitive or not, a logistic regression with only Smart City and the control variable Quality of Life Index as independent variables is performed. In Table 3.3. the outcomes of this analysis are shown.

| **Output table of the regression model of Smart City as a predictor for competitiveness** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | **95% C.I. for Exp (B)** | |
| **Variable** | **B** | **S.E.** | **Wald** | **P** | **Exp (B)** | Lower | Upper |
| Intercept | -5,203 | 1,567 | 11,029 | 0,000*** | 0,005 | | |
| Smart City | 11,248 | 4,211 | 7,133 | 0,008* | 7,669e+4 | 19,951 | 2,948e+8 |
| Quality of Life Index | 1,047 | 1,123 | 0,869 | 0,351 | 2,848 | 0,315 | 25,740 |
| $Chi^2$ (*df = 2*) | | | | | | | 16,357 |

*Table 3.3: Coefficients of the logistic regression model including all independent variables and control variables. Number of observations = 62. (Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1)*

The likelihood ratio test for the regression model shows that the constructed regression model has one coefficient that differ significantly from zero, $X^2 = 16,357$ df = 2, $p < 0,001$, $R^2n = 0,311$. The variable Smart City *($\beta$ = 11,248, p < 0,01)* is the only significant predictor for the competitiveness of a city. The control variable *Quality of Life Index ($\beta$ = 1,047)* is not a significant predictor if a city is competitive or not. The model with a Chi – squared of 16,357 with 2 degrees of freedom is a significant model with the variables *Sustainability* and the *Quality of Life Index* that fits the data better than the model without variables.

## 3.3. Conclusion from the statistical analysis

From the statistical analysis an answer to the first two hypotheses can be accepted or rejected. The first hypothesis; *The sustainability of a city negatively impacts the competitiveness of a city*, is rejected. Although from the scatterplot in Figure 3.2 there can somewhat of a negative relation between sustainability and competitiveness be found, from both logistic regressions it becomes clear that there isn't a relation between how sustainable a city is, and it is therefore also competitive. Which can be explained why Herrschel (2013) states that these concepts are contradictory, however from the analysis there isn't a relation found and therefore also not a contradiction. The p-value is far from significant and thereby shows that sustainability isn't a good predictor for the probability of a city being competitive. The second hypothesis; *cities with a high level of smart urbanity are more likely to be competitive* is accepted. From the logistic regression the variable Smart City is a significant predictor and has a positive effect on the probability that a city is competitive ($\beta = 11.248$). The two concepts where also analyzed separately to control for possible influence of other variables, the outcomes for the hypotheses were similar.

With the first hypothesis rejected and the second hypothesis accepted, an answer to the first sub-question, '*To what extent is there a relation between the competitiveness, sustainability and smart urbanity of cities?*', can be formulated. The second regression model shows that there isn't a relationship between the level of sustainability of a city and the probability for it to be competitive or not. This is in line with the article of Kamal-Chaoui and Robert (2009) where is stated that these concepts should be treated separately. In other words, a city can both be sustainable and competitive at the same time as the sustainability doesn't affect the competitiveness. The degree of smart urbanity does significantly positively affect the competitiveness of the city. The scatterplot in Figure 3.3 already showed some linearity between the two concepts. This can also be explained by the fact that the developments of a Smart City naturally rest on complex knowledge (Carvalho, 2015; Townsend, 2013). The elements of a Smart City according to Giffinger and Gudrun (2010) come from new inventions and innovations. In addition, a city, its inhabitants as its government, must also have a certain affinity for new technologies, which requires a certain degree of knowledge. In addition, of course, the level of demand for this type of development is also important (Nicolas et al., 2020).

# 4. Case Study: De Randstad

The results of the statistical analyses show that the sustainability of a city isn't a significant predictor if a city is competitive or not. The variable Smart City has however a significant positive impact on the probability. In this study, in addition to the overall analysis of the 62 cities the analysis dives deeper in the performance of De Randstad. This way the research aims to form an answer on the second and third sub – question:

- *How does De Randstad perform on these three concepts?*
- *How do the different urban centers in De Randstad relate to each other?*

Looking at the scatterplots from the results of section three where the competitiveness in relation to the sustainability is shown. When the four main cities In Figure 4.1. the four main cities and the average of De Randstad are highlighted. Amsterdam and Utrecht are the best performing cities, they are located in the upper right quadrant. In line with the results, the most competitive city, Amsterdam, is also the least sustainable. All four main cities perform better than average on the concept of sustainability, but are outperformed by cities like Munich, Stockholm and London.

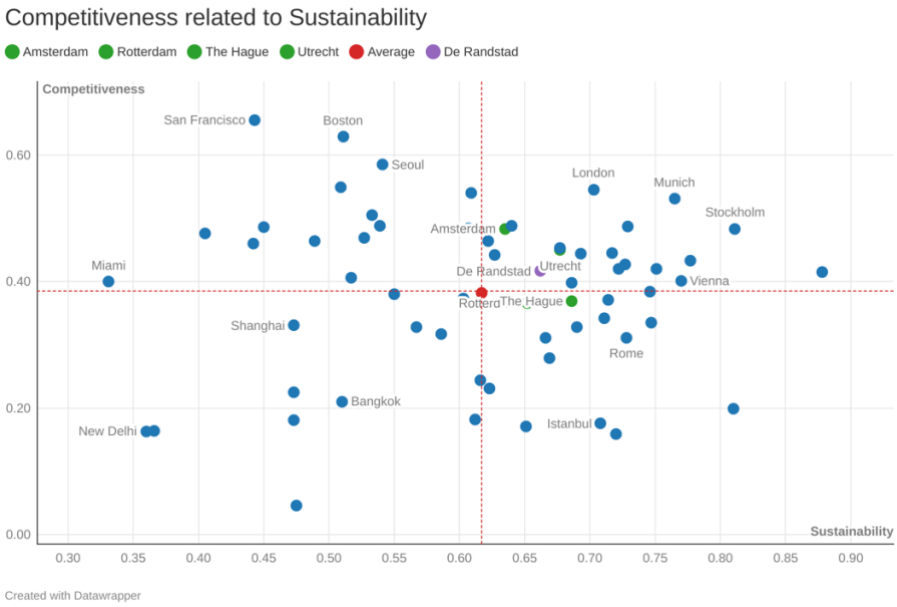


*Figure 4.1: Scatterplot of the city rankings. On the y – axis the scores of competitiveness, on the x- axis the scores of sustainability. De Randstad and its four main cities are highlighted. Source: own dataset and visualization.*

Figure 4.2 shows the competitiveness relative to the concept of a Smart City. The relation is more linear. It has become clear from the statistical analysis that the variable of a smart city has a positive impact on the probability if a city is competitive. The two Randstad cities that are most competitive cities are also the 'smartest'. Amsterdam and Utrecht are the best performing and are both in the upper right quadrant.

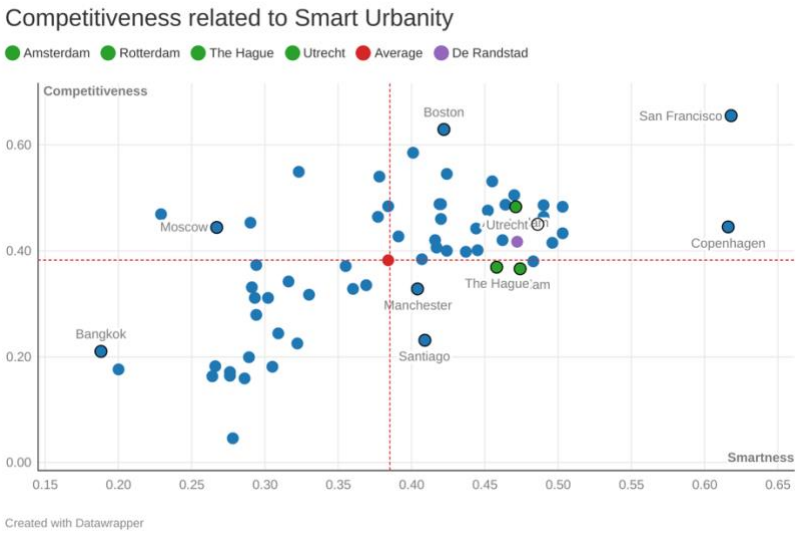


*Figure 4.2: Scatterplot of the city rankings. On the y – axis the scores of competitiveness, on the x- axis the scores of smart city. De Randstad and its four main cities are highlighted. Source: own dataset and visualization.*

In the following section the case study dives deeper into the performance of De Randstad on the different sub – indicators of the three concepts. This way the research aims to provide more insight on the positions of the cities on the scatterplots above and thereby to answer the two sub- research questions.

## 4.1. Competitiveness in De Randstad

From the literature review it has become clear that De Randstad is the most important and economically strongest regions of the Netherlands. It produces half of the national GDP on 25% of the political area and has an international 'world-class' status (Van Oort et al., 2010; Zonneveld & Nadin, 2020). However, as Balland and Rigby (2017) state that regions should keep producing and exchanging knowledge to innovate and stay competitive. To answer the second- and third sub-question the performance of De Randstad cities are analyzed.

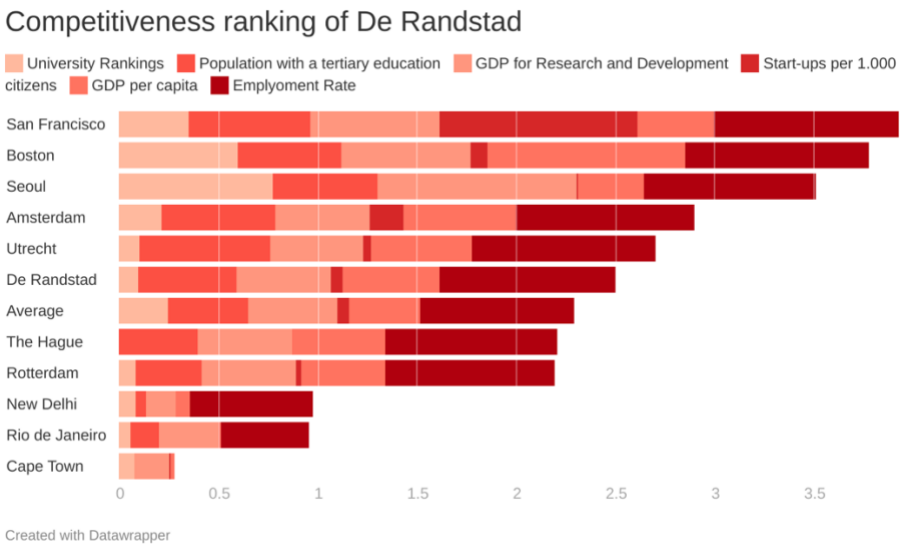


*Figure 4.3: Ranking of the four Randstad cities and the average score of the Randstad from the measures of the competitiveness indicator. Next to this the three best and worst performing cities. Source: own dataset and elaboration.*

The article of Moretti (2012) emphasizes the importance of high human capital in cities to be productive, regarding knowledge and economic value creation. Therefore, looking at the percentage with a tertiary education, high school and higher, shows how much human capital is present. But also, the rating of its universities shows how the quality of knowledge that is present is. Amsterdam and Utrecht both perform far above average on this indicator. This is in line with the article of Lambooy (1998) where he explains the economic functions of these cities, Utrecht having its research institutes and Amsterdam being an important center for knowledge intensive industries and its universities. That the overall score for De Randstad is low is because of the mere size of the region. Combining the university scores as is done with other cities the region compares to cities as Shanghai, Melbourne, and Los Angeles. The Hague and Rotterdam score below the average on this indicator. The first city can be explained through the absence of a university and the performance of Rotterdam through the kind of economy that is most present in the city, as it mostly focused on logistics and port-related industries and not so much on knowledge based economic activities (Zonneveld & Nadin, 2020).

Regarding the notion of innovativeness, the number of startups per 1.000 citizens and the share of GDP that goes to research and development is measured. de Vries (2012) states that Amsterdam sees itself as the only international leading city of De Randstad. On the indicator of innovation, the city is the highest scoring city. Amsterdam ranks with 40% at the second place, just below San Francisco which has 238%. Utrecht scores with over 10% among the most innovative cities. That the Northern wing is doing much better than the southern wing can be explained by the cooperation of the different wings that is taking place in De Randstad (Wall, 2009). Balland and Rigby (2017) emphasize that the competitiveness of an urban regions heavily on the production and exchange of knowledge. Lambooy (1998) also argues that the presence of human capital can also help a city become more competitive as it can diversify and specialize. This explains also why Rotterdam and The Hague don't score above the average.

De Randstad scores generally high on the measures of GDP per capita and the employment rate. With Amsterdam having the highest GDP per capita, it isn't much higher than Utrecht and Rotterdam. This shows that however these cities are economically performing well, that it doesn't necessarily mean that they are competitive. This can also be explained by the different functions from the articles of Zonneveld and Nadin (2020) and Lambooy (1998). But also, the article of Balland and Rigby (2017) shows that economic activity takes disproportionately place in cities that have a high knowledge complexity.

From the articles of Lambooy (1998), Kloosterman and Lambregts (2001), van Oort et al. (2010) and Zonneveld and Nadin (2020) it becomes clear that there is more cooperation inside than North wing and in the South wing instead of between the four main cities. The results from the competitiveness scores show a similar division of the subregions. The North wing is focused on knowledge intensive businesses and research, which are in turn the main drivers for a competitive city, or region. The South wing is focused more logistics and port – related industries, economic activities that are low in complexity and aren't knowledge based. The difference in human capital between the cities can become even larger over time. Competitive cities will keep attracting highly skilled workers (Berger & Frey, 2016). Even so, similar processes are taking place in the Netherlands as well. Kooiman et al. (2018) found that lower skilled workers have lower mobility than high skilled workers, who tend to move to places with already present human capital.

Next to the difference in human capital between the two wings, is there an even larger disparity related to innovation and the number of start-ups. The North is the most innovative region of the two. It scores the highest on the measure of startups per 1.000 citizens. Next to this, Wall (2009) states that both cities house the most international multinationals and Dutch firms of the Netherlands. An explanation can be found in the articles of Howells (2002) and Audretsch and Feldman (2004) where it becomes clear that the most innovative regions are the ones with the highest density of firms and high skilled workers. Not only from a geographical perspective but also for the social and cognitive proximity. Social networks that are being made with people that roughly have the same cognitive level exchange knowledge faster and easier. The geographical proximity helps in the exchange for the 'tacitness' of the knowledge (Boschma, 2005; Malecki, 2004). The North wing alone is already comparable regarding size and economic activity to that of regions like Lombardy and Catalonia (Jacobs et al., 2016).

Regarding the labor market the differences between the two wings are less distinct. Both regions perform very well related to the rest of the analyzed cities. The employment rate is almost equal. However, the North wing has a higher GDP per capita. As the most important economic activities are knowledge driven, it is logical that the cities with the most knowledge and knowledge related firms have a higher GDP per capita. Which is in line with article of Balland and Rigby (2017).

## 4.2 Sustainability in De Randstad

All four independent cities market themselves as a 'green' or sustainable city (Goess et al., 2016). From the statistical analysis it becomes clear that a city isn't likely to be competitive and sustainable at the same time. To get a better understanding of this and to answer the last two sub-questions the case study analyses the performance of De Randstad on the concept of sustainability.

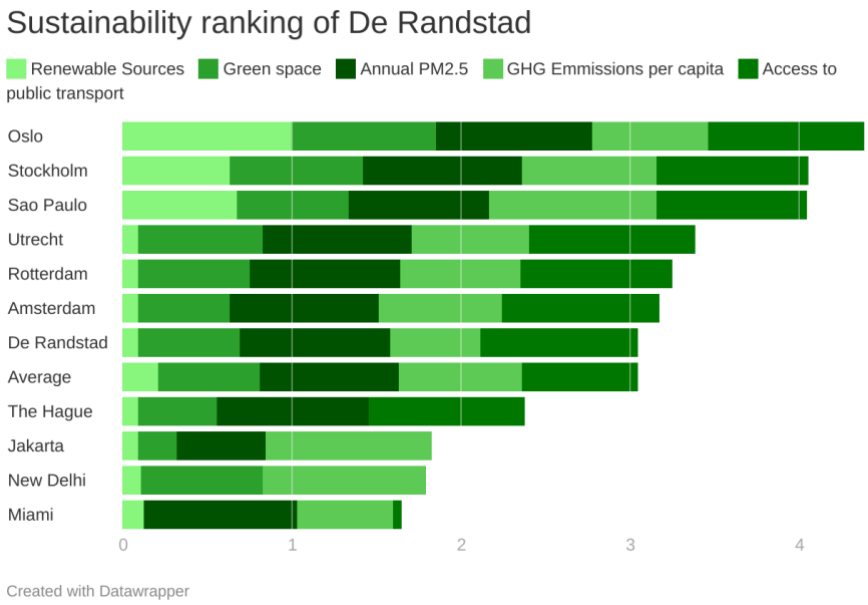


*Figure 4.4: Ranking of the four Randstad cities and the average score of the Randstad from the measures of the sustainability indicator. Next to this the three best and worst performing cities. Source: own data and elaboration*

The livability of De Randstad is measured through the green space as part of the city area and the annual emission of fine particulate matter ($PM_{2.5}$). Regarding the latter, Lambregts (2006) states that De Randstad was one of the pollution hotspots, although more recent research shows that the air pollution

of fine particulates is decreasing (Haakman et al., 2020). This analysis shows that De Randstad is scoring above average and without any large disparities between the cities. This can be explained through the high proximity of the cities and that this indicator isn't prone to city boundaries. On the indicator of the share of green space as the city area De Randstad scores above average. However, it must be stated that this analysis doesn't take the 'Green Heart' into consideration. Green infrastructure is important to minimize the urban heat island effect and has benefits for citizen's phycological and physical health (Haakman et al., 2020; Heaviside et al., 2017; World Health Organization, 2018). In addition to this the emissions of PM2.5 is one of the leading causes of death in cities, it can therefore be stated that the livability in De Randstad is above average.

The energy usage of De Randstad is also analyzed. This is done by measuring the share of renewable sources and the greenhouse gas emissions ($CO_2$) per capita. Rees and Wackernagel (2008), Loorbach and Shiroyama (2016) and Bertoldi et al. (2018) all emphasize that wealthy, highly developed cities have a larger carbon footprint than less economically strong cities. Similarly, De Randstad, high on the competitive ranking, scores below average on the performance of greenhouse gas emissions. The consumption level and energy usage are high in most of the four cities. Regarding the share of renewable sources, De Randstad ranks almost at the bottom and thus far below average. On the measure of energy most competitive cities score poorly.

The articles by Newman (2006) and Rees and Wackernagel (2008) emphasize the importance of public transport in reducing the ecological footprint. The overall energy consumption and emissions of gases and particulates are higher per person with car use than public transport use. Many western European cities score high on this indicator, as does De Randstad. However, Utrecht is in fourth place, which can be explained by the fact that it is the smallest city in this study in terms of population and surface area. The previously mentioned measure, Annual $PM_{2.5}$, in Utrecht is high, this is possibly because the use of public transport in cities with a high GDP per capita is lower because these residents have their own means of transport.

In terms of sustainability, there are also differences between the North and South wing. Looking at the greenhouse gas emissions, the north wing scores on average higher than the south wing. However, it is remarkable that the GHG emissions in Amsterdam are the lowest of the cities while the city has the highest GDP per capita within the Randstad. On the Randstad's overall sustainability score, the region scores just above average. The performance on sustainability can be explained by the absence of formal governance that relates to these problems. As many of these implications don't 'stop' at the border. This is not the case in the other measured cities.

## 4.3 Smart City and De Randstad

As discussed in the theoretical framework, a smart city shouldn't be the solution, but a tool to solve the issues cities face. E.g., the changing climate, decreasing urban livability and the mass urbanization. From the statistical analysis and the scatterplots in the beginning of the section it becomes clear that 'smart' cities are likely to be competitive as well. To get a better understanding of how De Randstad and it's four main cities perform on the concept of smart urbanity the six elements that Giffinger and Gudrun (2010) constructed for a Smart city are analyzed.

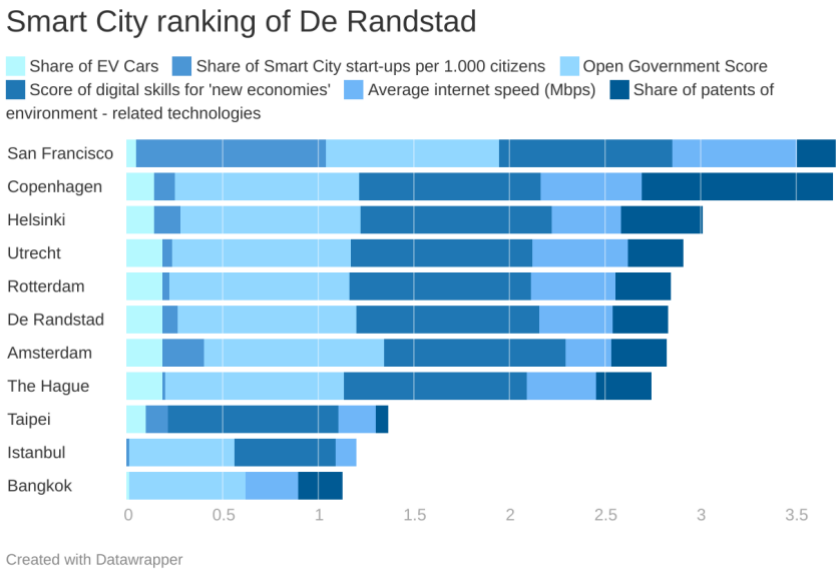


*Figure 4.5: Ranking of the four Randstad cities and the average score of the Randstad from the measures of the Smart City indicator. Next to this the three best and worst performing cities. Source: own data and elaboration.*

With Amsterdam and Utrecht being the most competitive cities of the four main cities in De Randstad, it can be expected that these cities score high on these measures. For Amsterdam this is indeed the case, however Utrecht scores below average. Both cities from the South wing score below the average of smart city startups. However, the research also shows that the overall number of patents for environmental technologies, De Randstad scores below average. The northern wing cities focus on urban living labs to experiment smart technologies, where the southern cities mostly focus on resiliency technologies (Goess et al., 2016).

The affinity and readiness for smart city implementations not only come from its citizens, but also from the government. A smart government is about the transparency and availability of public data. It must be stated, that from the literature it becomes clear that there is a lack of interregional governance in De Randstad (Lambregts et al., 2008; Salet, 2006). Cowell (2010) states however, that this can create more complementarity and create therefore more international competitiveness. Nonetheless, as became clear by the previous section, improvements regarding sustainability can still be made in De Randstad, potentially through stronger interregional governance and policy.

Regarding the smart mobility indicator De Randstad scores at the top three urban regions. The high share of electric vehicles can be explained through the article of Monzon and Lopez-Carreiro (2020) shows that smart forms of mobility is adapted faster in De Randstad due to the presence of highly educated people. In addition to this, for different forms of mobility and smart technologies, there has to

be some form of affinity with the technologies. This is also measured through the indicator of Smart people, where the share of people with digital skills is measured. De Randstad ranks second of all the analyzed cities.

## Conclusion case study analysis

The analysis of the performance indicators of de four main cities of De Randstad and the average sum of the performance of those cities provide an answer for the second and third sub – question of this research. The second sub-question, '*How does De Randstad perform on the concepts of competitiveness, sustainability and smart urbanity?*', can be answered through the formulated hypothesis; '*De Randstad scores high on the concepts of competitiveness, sustainability and smart city.*'. The scores and the scatterplot in Figures 4.1 and 4.2. show that De Randstad is in the upper right quadrant. Therefore, this hypothesis is accepted. This hypothesis derived from the literature review as the cities of De Randstad all market position themselves as green and smart (Goess, et al., 2016). The region has a global status and produces half of the national GDP (van Oort et al., 2010). It can therefore be stated that De Randstad performs overall above average and can be regarded as a balanced region as not one of the concepts is more present than the other.

The third sub-question of the research, '*How do the different urban centers in De Randstad relate to each other?',* is answered by testing the last three hypotheses. From the literature review it becomes clear that there are differences within the region. The fourth hypothesis, '*The north wing of De Randstad is more competitive than the south wing'* is accepted. This can be explained by the different economic functions of the cities, with Amsterdam and Utrecht being more focused around knowledge intensive economic activities (Lambooy, 1998). Both cities have a high level of innovations and high skilled workforce.

The fifth hypothesis, '*The north wing scores higher on the concept of Smart City than the south wing',* is accepted as well. However, there are differences between the cities, Amsterdam is below average, and Rotterdam is above De Randstad average. It is expected from the statistical analysis in section 3 that as Amsterdam is the most competitive city also scores high on the Smart City ranking, this is however not the case.

The last, sixth hypothesis, '*The south wing scores higher on the concept of sustainability than the north wing',* is rejected. This hypothesis is derived from the earlier hypothesis that competitive cities aren't likely to be sustainable. However, only Rotterdam scores higher than De Randstad average. The subregions centers within De Randstad do differ from each other. For the competitiveness there is clear distinction between the north and the south wing. Which can be explained through their economic function. However, the other two concepts differ more between the cities themselves than the subregions. Although Amsterdam sees itself as the prime city this only the case for the notion of competitiveness (De Vries, 2012). However, on the other concepts there isn't a clear prime city. This shows that the region is also balanced within the four main cities and thereby strengthens the argument that De Randstad is a poly-centric region and not a single agglomeration.

# 5. Conclusion

This research sought to answer the main research question: '*To what extent is De Randstad a competitive urban region and is it thereby sustainable and smart?*'. In order to answer this question, a secondary data analysis of 62 different cities and a case study has been conducted that elaborates on the specific urban region: De Randstad.

First of all, the research looked at how the different concepts relate to each other. The expectation that there should be a compromise between sustainability and competitiveness in urban regions is shown by the statistical analysis that there isn't a relation between these concepts. This is in line with Herrschel's (2013) article which emphasizes that these concepts are contradicting. In addition, it has become visible that the smartness of a city has a positive influence on the probability that this city is also competitive.

De Randstad can be seen as a balanced region. It performs mainly well on the two concepts of competitiveness and smart city. The region scores least well on the degree of sustainability. Although this was to be expected from the statistical analysis, it is visible that the contrast between competitiveness and smart urbanity and sustainability is less than in other regions. From the case - study it is also clear that as Kloosterman and Lambregts (2001), van Oort et al. (2010) and Zonneveld and Nadin (2020) state that the sub-regions are more connected than the four cities with each other. The North Wing is competitive and 'smart'. The South Wing is less competitive but scores higher on sustainability.

This research has thus shown that there isn't a relation between urban competitiveness and sustainability. Whereas urban competitiveness and Smart urbanity do go together. From the analysis of De Randstad on these three concepts it can be stated that De Randstad is a balanced region that performs above average in relation to the other cities studied. The high competitiveness ranking isn't affected by the sustainability of the region. Although there are differences within De Randstad between the two wings, except for the notion of competitiveness there isn't a leading city in this poly-centric region.

# 6. Discussion

This study looks at three different concepts related to urban regions. These concepts are built from different measurable indicators. This makes the variables less susceptible to possible discrepancies, in addition, a control variable was used in the analysis. Thus, an attempt was made to limit the influence of the variables on each other. The study looks at a selection of 62 cities, by the number of cities examined it can be said that external validity has been met. However, adding more cities and more variables on the urban aggregation level should strengthen the outcomes of the analysis more.

The statistical analysis of the 62 cities using the three concepts showed that the hypothesis that sustainability and competitiveness do not go together in urban areas can be assumed. This is line with the article Kamal-Chaoui and Robert (2009) who argue that these concepts should be considered separately. Although the articles of Rees and Wackernagel (2008) and Newman (2006) state that economically developed cities have a larger ecological footprint, this relation wasn't found in the analysis. In addition, the degree of smart city is a good predictor for the competitiveness of a city. This can be explained by the knowledge intensive nature of 'smart' elements (Kourtit et al., 2017). These smart city implementations come from innovations in the field of internet and communication technologies (Townsend, 2013).

The research also conducts a case study of De Randstad. De Randstad performs very high on these concepts and can be regarded as a balanced region. This can be explained by the performance of Amsterdam and Utrecht in the field of competitiveness. In particular, the proportion of innovations present in the cities is among the highest scoring cities. In addition, the sustainability of the region is just above average. It should be noted that this concept is less bound by city limits. Due to the high geographical proximity, it can be said that the performance of the cities on the concept of sustainability are to some extent relative to each other.

It can be said that it is a balanced region in which there are some differences between the North and South Wings. An explanation for this can be found in the economic function of the cities. In the North wing, knowledge intensive economic activities are present (Lambooy, 1998). Of which human capital is the basis and innovation stems from (Martin & Simmie, 2008). In addition, the higher score on sustainability of the South Wing can also be explained by article of Rees and Wackernagel (2008) and Newman (2006). However, this relation isn't been found in the statistical analysis.

This study looks at a fraction of all cities in the world. To paint a better picture, more cities could be included in the future if data is available. For example, this study collected data from urban and rural aggregation levels. In future research, it would be better to collect data only at the urban level. For the case study, only the four main cities were analyzed. The region consists of several smaller cities and does not include the Green Heart, for example. The study gives a high overview on these three concepts and mainly looks at how the four cities perform in that area. The organizational and political side of the cooperation of these cities was not in the scope of this research. Thus, no statement can be made about city cooperation based on these results. However, this research can provide insight for regional development policy makers.

The research complements the discussion between economic development and sustainability. It gives more insights on the competitiveness of cities. A concept that has developed in the new regional geography and stems from the transition to the knowledge-based economy. In addition, the research

attempts to relate the concept of Smart Cities to the economic development of a city. Through the case study, the research offers insights on De Randstad and how the main four cities relate to each other. This provides clarity for governments and policy makers for possible cooperation between the cities or sub-regions.

In a possible follow-up study, more specific attention can be paid to Smart City implementations in cities to better understand how this relates to sustainability and economic development within cities. Follow-up research could also look at other poly - centric regions to see how they differ from each other. In addition, further research can be done within De Randstad where the smaller cities of this region are taken into consideration.

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# Appendices

*Appendix I - III:*
The three different concepts, with its sub – indicators and measures. Next to this the scale level of the measure is given, the year from which the data is from and the code/abbreviation that is used in the analysis. In the column on the right is the source of the measure given.

*Appendix I: Competitiveness*

| **Sub – Indicators** | **Measures** | **Level** | **Year** | **Source** |
|---|---|---|---|---|
| Human capital | Sum of the university rankings | City | 2020 | QS University Rankings |
| | Share of the population with a tertiary education (age 15 – 64) | City/ Country | 2019 | Eurostat; OECD; US Census Bureau |
| Innovation | Share of GDP for Research and Development | Country | 2018 | UNESCO |
| | Share of start-ups per 1.000 citizens | City | 2020 | Start-Up Blink |
| Labour Market | GDP per capita | City | 2018 | OECD; CEIC; World Bank; Knoema; Statista |
| | Employment rate | City | 2018 | OECD; CEIC; CBS; Statista; Helsinki data; Cape Town data |

*Appendix II: Sustainability*

| **Sub – Indicators** | **Measures** | **Level** | **Year** | **Source** |
|---|---|---|---|---|
| Energy | Share of renewable sources | Country | 2019 | Our World in Data |
| | Greenhouse gas emissions per capita ($CO_2$) | City | 2018 | City Carbon Footprints |
| Livability | Share of green space of the city area | City | 2021 | HUGSI.green |
| | Annual emissions of fine particulate matter $PM_{2.5}$ | City | 2020 | IQAir |
| Public transport | Share of citizens with access to public transport | City | 2018 | European Commission; UN – Habitat; OECD |

*Appendix III: Smart City*

| **Sub – Indicators** | **Measures** | **Level** | **Year** | **Source** |
|---|---|---|---|---|
| Smart Mobility | Share of electric vehicles | Country | 2020 | IEA.org |
| Smart Economy | Share of smart city start-ups per 1.000 citizens | City | 2020 | Start-Up Blink |
| Smart Governance | Open government score | Country | 2020 | World Justice Project |
| Smart People | Score of digital skills for ‘new economies’ | Country | 2020 | World Economic Forum |
| Smart Living | Average Internet speed (mbps) | City | 2020 | Nomad list |

| | | | | |
|---|---|---|---|---|
| Smart Environment | Share of patents of environmental related technologies | Country | 2018 | OECD |

*Appendix IV: Control Variable*

| **Variable** | **Indicator** | **Level** | **Year** | **Source** |
|---|---|---|---|---|
| Control Variable | Quality of Life Index | City | 2021 | Numbeo.com |

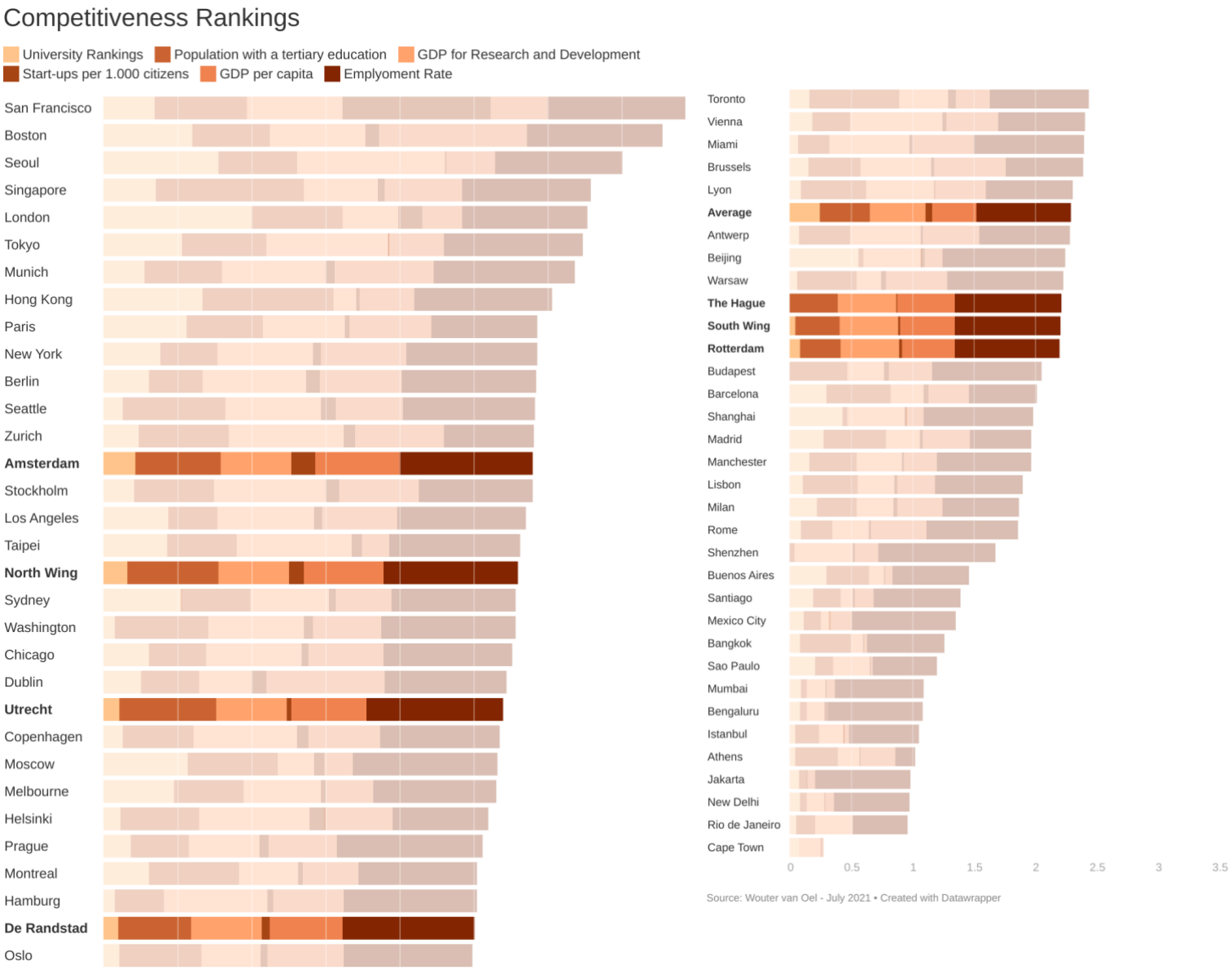
*Appendix V: Correlation Matrix*

Correlation matrix of the independent variables of the concepts Sustainability, Smart City and the Control variable: Quality of life Index.

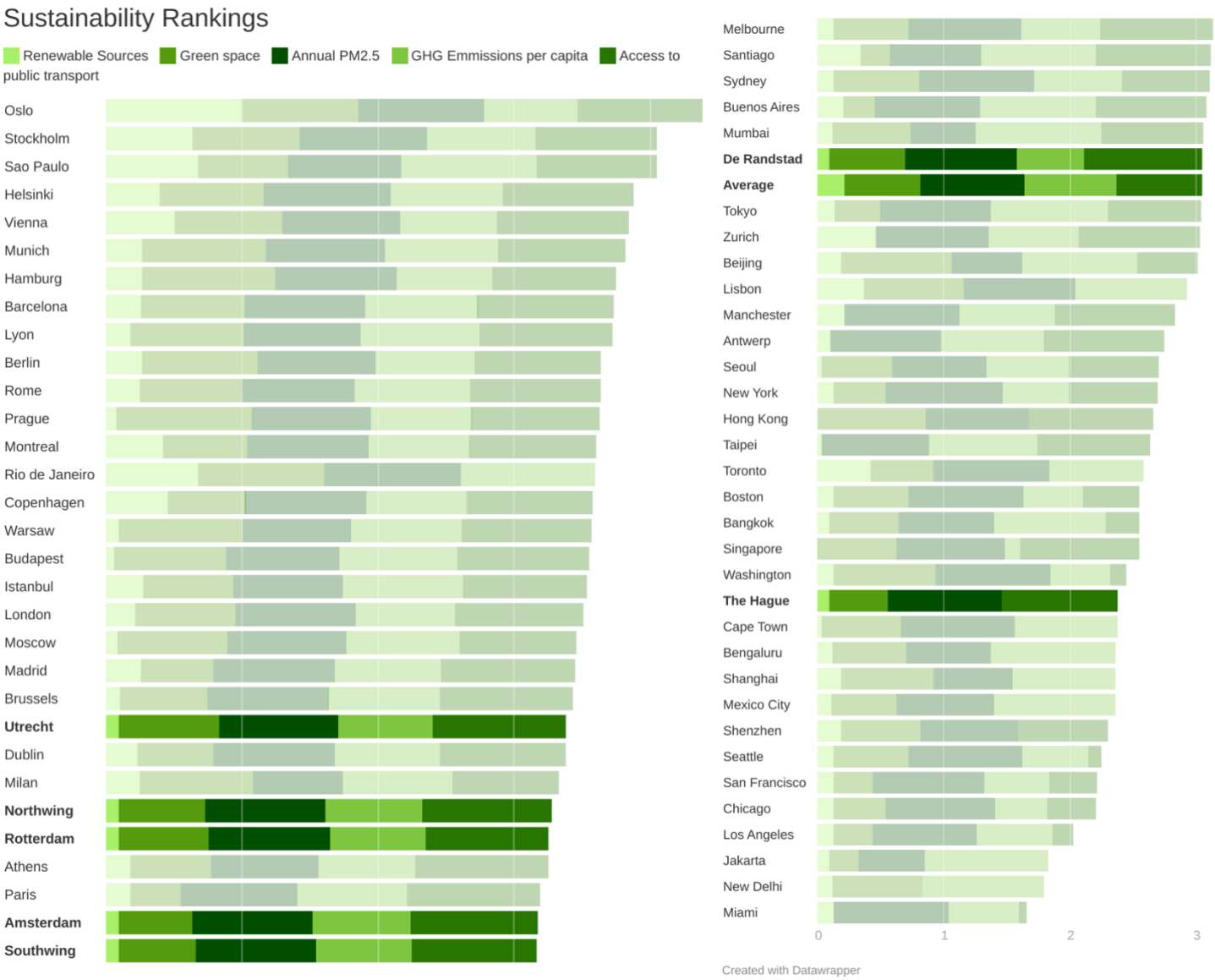
| **Correlation Matrix of the variables** | | | | |
|---|---|---|---|---|
| | Intercept | Sustainability | Smart City | Quality of Life Index |
| **Intercept** | 1,000 | - 0,657 | - 0,636 | 0,078 |
| **Sustainability** | - 0,657 | 1,000 | - 0,077 | - 0,088 |
| **Smart City** | - 0,636 | - 0,077 | 1,000 | - 0,383 |
| **Quality of Life Index** | 0,078 | - 0,088 | - 0,383 | 1,000 |

*Appendix VI:*

Rankings of the competitiveness of the analyzed cities and the different measures that make up the concept of competitiveness. The highlighted bars are from De Randstad, the two wings and the four main cities. Also, the overall average of the analyzed cities is highlighted.



*Appendix VII:*
Rankings of the sustainability of the analyzed cities and the different measures that make up the concept of sustainability. The highlighted bars are from De Randstad, the two wings and the four main cities. Also, the overall average of the analyzed cities is highlighted.



*Appendix VIII:*

Rankings of the Smart City of the analyzed cities and the different measures that make up the concept of Smart City. The highlighted bars are from De Randstad, the two wings and the four main cities. Also, the overall average of the analyzed cities is highlighted.