Unravelling the pillars of sustainability

A graph theory approach to the relations between the three capitals

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Name:		Paulien Schets
Student number:		s4199537
Discipline:		Mathematics
Host organization:		Telos
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University coach:		Raphaël Smals
Host organization coach:		Corné Wentink
Reader:		Wieb Bosma
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Abstract

This research aims to contribute to the field of sustainability by granting insight regarding the interdependence of the three capitals in the triple bottom line framework. It focuses on Telos' National Monitor of Sustainable Municipalities, which is developed in light of the Dutch context. In order to reach the goal of the study, the relations within and between different capitals are determined using correlations and literary research. The study uses a graph theoretical approach, developed by Demaine, Emanuel, Fiat, and Immorlica (2005), to determine clusters of indicators. This approach results in sixteen feasible clusters which are analysed and interpreted from multiple perspectives. This leads to a list of potential focus points in different fields of sustainability for the Netherlands and grants insight into these fields with respect to trade-offs between capitals and for sustainability approaches in general.

Keywords— Sustainability, Triple bottom line, Telos, Clustering, Graph theory

Executive summary

Ever since the Brundtland report in 1987, the attention to sustainable development has been increasing. Multiple initiatives regarding sustainability have been developed: global ones such as the Sustainable Development Goals, but also national ones, such as the National Monitor of Sustainable Municipalities by Telos, the Brabant Centre for Sustainable Development. Using the triple bottom line framework (People, Planet, Profit) as a starting point, this national monitor allows Telos to measure sustainability and advise municipalities based on the results of the indicators of the three capitals: the ecological, social-cultural and economic capital. These three capitals are connected through interfaces between each pair.

The existence of these interfaces demonstrates the potential occurrence of trade-offs between the capitals. This resulted in the question which indicators of the National Monitor of Sustainable Municipalities could be used as focus points in monitoring trade-offs, as well as the question which indicators could be used as focus points for monitoring and approaching sustainability in general in the context of the triple bottom line. In order to answer both questions, we used a graph theoretical approach for which three more research questions were needed: 1) What is the relationship between indicators within each capital? 2) What is the relationship between indicators between different capitals? 3) Which clusters of indicators can be found within these related indicators? Combined, these questions gave an insight into the interdependence of the three capitals which can aid Telos in the advice and explanations regarding their national monitor.

The first and second research question were answered through computation and analysis of correlations between the indicators within and between capitals of the National Monitor of Sustainable Municipalities. From the analysis of the correlations, several underlying factors were obtained which played an important part in the direction of these correlations. After this, the correlations between the underlying factors themselves as well as those between the underlying factors and indicators, were computed and examined. The entire list of correlations was then divided into direct and indirect correlations. The information obtained through this division of correlations provided enough information to answer the third research question.

The third question used correlation clustering to find groups of indicators and underlying factors within the National Monitor of Sustainable Municipalities. This resulted in seventeen clusters of which sixteen were suitable for the goal of this thesis. Analysis of the meaning of these clusters and of the interactions between them then led to a list of eight potential focus points for monitoring trade-offs. Considering the interactions within the sixteen clusters enabled us to extent this list to seventeen indicators which could serve as focus points for monitoring and approaching sustainability. These indicators originated from all three capitals, hence were distributed across the triple bottom line.

Besides finding focus points for monitoring trade-offs and for monitoring and approaching sustainability in the context of the triple bottom line, we could also deduce focus areas for municipalities based on their typology type. The inclusion of the underlying factors allowed us to determine the relation between the sixteen obtained clusters and the typologies as used by Telos. This relation can be used by Telos and municipalities to gain insight into the different needs of the typologies.

Combined, these results proved to be enough, to point at focus points for monitoring trade-offs as well as focus points for monitoring and approaching sustainability in the context of the triple bottom line. The results of this thesis can be used by Telos in their advice regarding sustainable development. Moreover, they could expand the outcome of this study by further analysis of the focus points for each typology.

Preface

For my fellow students of Algebra and Topology, it will hardly be surprising to hear that my love for mathematics covers anything containing even the smallest of diagrams. A glimpse of one is enough to make me smile. Therefore, it was only logical that as soon as I started to investigate the topic of this thesis, a diagram popped up before I even knew it.

I surely didn't think that I would be using graph theory at my internship at Telos. Yet it allowed me to combine two of my passions in life: mathematics and contributing to society. Something I never dreamed to be possible in such a way and for which I am grateful to everyone who made this possible.

First and foremost, I want to thank Corné for his trust in my abilities and for all the advice and sparring sessions, thesis related or not. You made me believe that I could tackle this topic. Moreover, you believed that my idea could actually work.

Where Corné helped me explore my abilities in research, I wouldn't be here without the support of my friends, family, supervisors and my colleagues at Telos. So a big thank you to Suzan for drawing my attention to Telos in the first place and for all the motivating and fun conversations. To Bas and Lieke-Rosa, for making room for me and for all the encouragements. To my parents, my father for always beaming his pride and my mother for always having my back despite everything else. To my supervisors at Radboud University, Raphaël and Wieb, for their feedback and open discussions. And last but not least, to the team at Telos, for the wonderful time I had with them.

Lastly, I would like to take this opportunity to thank those who made my time at university possible. Too many to mention but in particular Ben Moonen, for his faith and enthusiasm and for showing me the part of mathematics that I love, and to Ina de Vries, for coaching me through all those years. And to all those who told me I could do it, I actually did it!

I hope you enjoy reading,
Paulien Schets

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1 Introduction

1.1 Topic and problem

Already in 1798 the first concerns were raised about, what would later be called, sustainable development. That year, reverend Thomas Malthus published his famous work *An Essay on the Principle of Population* in which he covered the so-called Malthusian trap, stating that population growth must outgrow any increases in food production (Malthus, 1798). Nearly two centuries later, in 1972, Meadows, Meadows, Randers, and Behrens published their work Limits to Growth, predicting that economic growth would eventually stop, due to limitations in the availability of natural resources. However, it wasn't until the Brundtland Commission's report *Our Common Future* in 1987 that the concept of sustainable development was introduced as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland, 1987). The reason for this report was an urgent call by the General Assembly of the United Nations, who was in need of "a global agenda for change". The report gave the first official definition of sustainable development and provided suggestions for long-term environmental strategies and recommendations for achieving global objectives, taking into account the interrelations between people, resources, environment, and development. Moreover, it considered methods of effectively handling environmental concerns and helped defining shared views of long-term environmental issues.

The Brundtland report led to an increase in attention for sustainable development, leading to the Earth Summit in Rio de Janeiro in 1992 and eventually the adoption of the United Nations Millennium Declaration by world leaders in 2000, known as the Millennium Development Goals. In continuation of these goals, the world leaders came together again in 2015 to adopt a new sustainable development agenda for 2016 to 2030 in order to end poverty, protect the planet and ensure prosperity for all: the Sustainable Development Goals.

Already from the start of the run-up to the Sustainable Development Goals, Telos has been engaged in monitoring sustainable development, using Brundtland's definition of sustainable development as a starting point. Viewing sustainable development as a process, they used the triple P framework (People, Planet, Profit), or triple bottom line, as a starting point to develop ways of monitoring, resulting in, amongst others, their National Monitor of Sustainable Municipalities (Nationale Monitor Duurzame Gemeenten)[1].

Telos' methods for monitoring sustainability are based on the introduction of several indicators which have been shown to have an influence on the process of sustainable development. These indicators have been grouped under certain stocks, capturing the essence of the group of underlying indicators. Together, these stocks are part of the three capitals belonging to the triple bottom line: either of the ecological, the social-cultural, or the economic capital. This system allows for an overview of the overall development and shows the areas which need to be improved through looking at the indicators within each capital. The overall development is then visualised as an equilateral triangle of which every edge depicts a certain capital. This framework also depicts the existence of shared boundaries or interfaces between the three capitals. These interfaces cover the sustainability performance of the combination of the adjacent capitals and will be called Green Growth (the interface of the ecological and economic capital), Social Growth (between the economic and social-cultural capital), and Environmental Equity (between the social-cultural and ecological

[1] An explanation of this monitor will be given in Section 3.1.

capital)[2]. The capitals and performance areas are visualised in the following figure, according to the triple bottom line used by Telos:

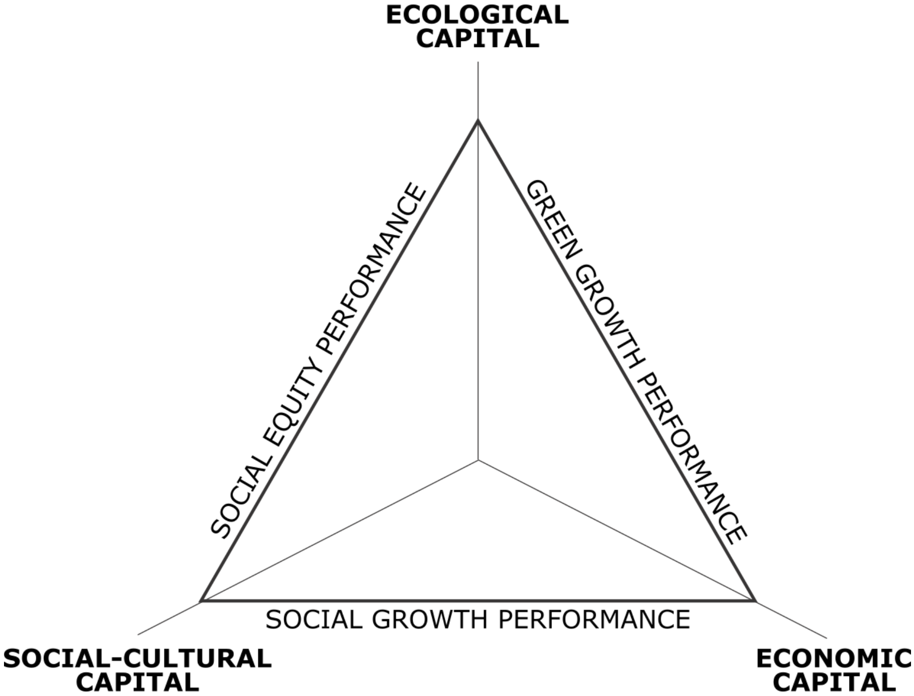

Figure 1: The triple bottom line depicted as an equilateral triangle. Each node represents one of the capitals (ecological, economic, or social-cultural). Each edge represents an interface (Green Growth, Social Growth or Environmental Equity) between the two adjacent nodes. Adapted from Telos, 2018.

The existence of interfaces between the capitals shows that indicators in one capital could lead to trade-offs in another. Therefore, knowing specifically which indicators in one capital cause such trade-offs, could provide valuable insight into the connections between each set of capitals. However, even though there have been several studies on the trade-offs between capitals,[3] hardly any of them cover the three capitals as a whole. Most of the studies focus on one or a few aspects of a single interface. Therefore, knowledge on the links between the capitals in general is still scarce. Furthermore, when looking at the outcomes of different studies, one has to be aware of the possible disparities in definitions of ecological, economic and/or social-cultural capital. However, even with these disparities, the studies already indicate that the three capitals are highly interrelated. Moreover, they show that one should take the aspects of each interface into account when considering approaches to promote sustainability, hence express the importance of acquiring knowledge on the links between all capitals.

This research aims to provide an insight into the links between the capitals through looking at the National Monitor of Sustainable Municipalities developed by Telos. Currently, Telos has investigated several correlations between their indicators and has looked at the links between indicators within the same capital (Telos, 2014; Smits, Roos, & Dagevos, 2013). This research aims to extend this analysis to the entire triple bottom line, hence covering all three capitals. This would not only fill

[2]Throughout the literature there is no uniformly adopted terminology for the interfaces. In this research, the terminology will be adopted as used by, for example, Zoeteman (2016); Kruize, Driessen, Glasbergen, and Van Egmond (2007); Wheeler, Ben-Shlomo, and Wheeler (2005) and World Bank (2012).

[3]See, for example, Downey, Crowder, and Kemp (2017); Klasen et al. (2016); Cushing, Morello-Frosch, and Wander (2015); Kruize, Droomers, van Kamp, and Ruijsbroek (2014); World Bank (2012); Iyer, Kitson, and Toh (2005); Adger (2000) and Whiteley (2000).

a gap in the knowledge regarding the interconnectedness of the three capitals, but would also help Telos in their advice and explanation of impacts of the indicators of their monitor. After all, knowing which indicators can be used to monitor trade-offs between capitals would allow them to explain why certain policies on one field have an impact (negative or positive) on an entirely different and perhaps seemingly unrelated one. Moreover, it would allow Telos to give pointed advice regarding which field could best be improved upon and which indicators would also benefit from this improvement.

As the indicators in Telos' National Monitor of Sustainable Municipalities are developed based on the situation of the Netherlands, this study will only include research concerning factors which are relevant for this country.

1.2 Research goal

The goal of this research is to determine clusters of indicators of the Telos' National Monitor of Sustainable Municipalities within and between different capitals, and point at fields in which trade-offs are likely to exist. Achieving this goal would result in an insight regarding the interdependence of the three capitals in the triple bottom line framework which is widely used in the field of sustainability, as well as aid Telos in their advice and explanation of impacts of the indicators of their monitor.

1.3 Research questions

The research goal can be separated into two different parts: determine linkages between the indicators within capitals as well as between capitals, and determining clusters of indicators. This leads to the following research questions, of which the third question can be seen as the main question:

1. What is the relationship between indicators within each capital?
2. What is the relationship between indicators between different capitals?
3. Which clusters of indicators can be found within these related indicators?
4. In the context of the triple bottom line framework:
    (a) Which indicators can be used as focus points for monitoring trade-offs?
    (b) Which indicators can be used as focus points for monitoring and approaching sustainability?

Combined with the most important concepts as defined in Section 1.1, these research questions form the theoretical framework as shown in Figure 2. Note that the triple bottom line can be visualised inside the blue and red areas as these concern the relationships within and between capitals.

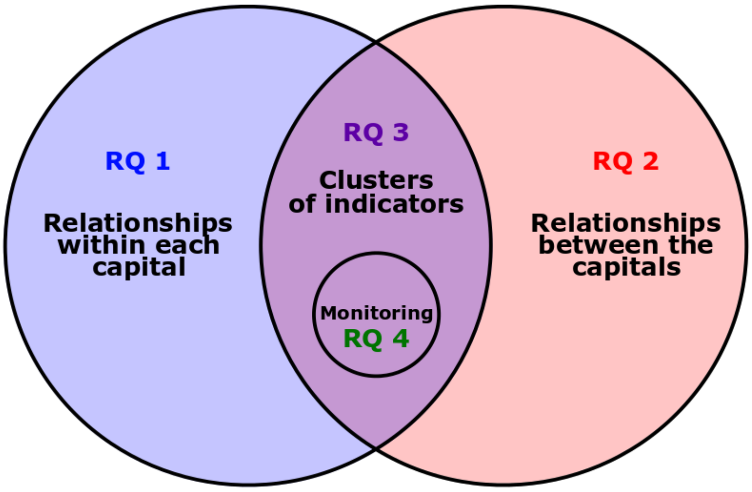

Figure 2: Visualisation of the theoretical framework. Each circle indicates a concept within the research and consists of indicators belonging to that particular concept. The blue and purple areas belong to research question 1, the red and purple to question 2 and the purple area to research question 3. Question 4 concerns a part of the answer obtained from question 3, hence is depicted as a small circle within the purple area.

1.4 Reading guide

This thesis aims to give an insight in the relations between the three capitals through answering the four research questions given above. Before these questions can be solved, it is essential to gain an understanding of the National Monitor of Sustainable Municipalities as well as of the three capitals and their interfaces. The theoretical framework, in which these aspects are defined, can be found in Section 3. This section is followed by the methodology which will be outlined in Section 4. After this, the four research questions will be covered into two parts. The results of the first two research questions will be shown in Section 5 and the results of the last two questions can be found in Section 6. The results of these sections are used to answer the four research questions and connect these to the research goal in Section 7. Moreover, this section will give recommendations to both Telos and policy makers regarding the outcomes of this study. Then Section 8 will conclude this thesis by discussing the results, looking into the limitations of the study, and giving recommendations for future research.

2 Notation

In order to make the figures in this thesis accessible and clear, we will denote the indicators using the following notation *capital stock indicator*. In this notation, we use the following abbreviations for the capitals:

- N (nature) for the ecological capital;
- S (social-cultural) for the social-cultural capital;
- E (economic) for the economic capital.

The stocks within each capital will be denoted by a number as follows:

Ecological (N)	**Social-cultural (S)**	**Economic (E)**
1) Soil	1) Social Participation	1) Labour
2) Air	2) Economic Participation	2) Spatial Local Conditions for Businesses
3) Annoyance and Emergencies	3) Arts and Culture	3) Competitiveness
4) Water	4) Health	4) Infrastructure and Mobility
5) Nature and Landscape	5) Safety	5) Knowledge
6) Energy and Climate	6) Residential Environment	
7) Resources and Waste	7) Education	

In turn, each indicator within a stock will be illustrated by a small letter. Using this notation, one could, for example, talk about N6e, which stands for the indicator Energy label houses belonging to the stock *Energy and Climate* in the ecological capital. For a complete overview of all stocks and indicators with their corresponding symbols, see Appendix A.1.

3 Theoretical Framework

3.1 Telos' National Monitor of Sustainable Municipalities

In order to monitor sustainability, Telos has created the National Monitor of Sustainable Municipalities. This monitor has been developed using the triple bottom line or triple P framework (People, Planet, Profit) as a starting point. The systemic background of the triple bottom line and its ability to show the dynamic and interconnected nature of sustainability of this framework make it particularly suited for Telos' goal. Based on the ideas behind People, Planet and Profit, Telos uses three capitals in order to analyse and describe sustainability. These three capitals show the uniform growth and improvement of the quantity and quality of nature (the ecological capital), the physical and mental well-being of people (the social-cultural capital), and economic growth and development (the economic capital). Determining the essential elements of each capital has been done through critical review of the theory belonging to that capital, all from a systemic point of view. These elements are represented by stocks, each belonging to one of the three capitals. Moreover, as a framework for sustainability also calls for a normative facet, requirements have been determined for each of these stocks based on either analysis and research, legislation, or in depth discussions. The combination of the underlying theory and requirements leads to an overall monitor consisting of 109 indicators, each belonging to a covering stock which in turn falls under one of the capitals, as can be seen in Figure 3:

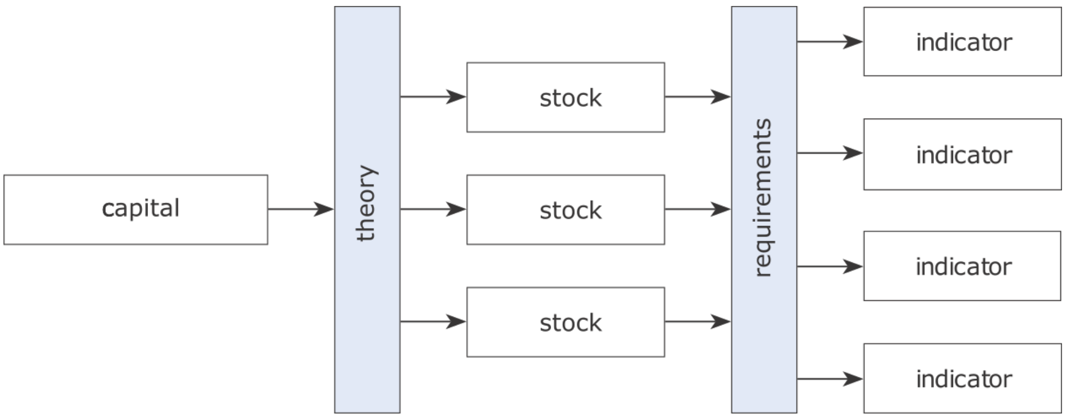

Figure 3: The relations between capital, stocks and indicators, connected through underlying theory and requirements. Source: Telos (2018).

After the development of these indicators for the National Monitor of Sustainable Municipalities, Telos has determined concrete and measurable thresholds based on legal norms, geographical comparisons between municipalities, and/or discussions with experts. These thresholds are colour-coded as to make the entire monitor insightful and clear. Moreover, as the role of some indicators could be seen as more important than that of others, Telos has visualised the final scores of their indicators using a pie chart. In these charts, the percentage covered by a certain indicator indicates its weight and importance, and the radius of its wedge shows its score. An example of such a chart is given in Figure 4.

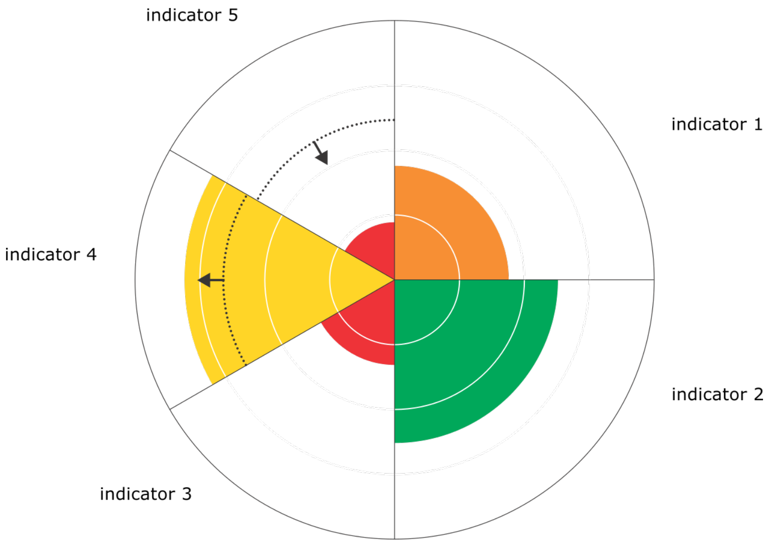

Figure 4: Pie chart depicting five indicators with their score and weight. Source: Telos (2018).

After these computations are completed, the combined scores of all stocks of a capital result in the overall score of that capital. The above then results in an interconnected system consisting of the three capitals and their stocks and indicators, as depicted in Figure 5.

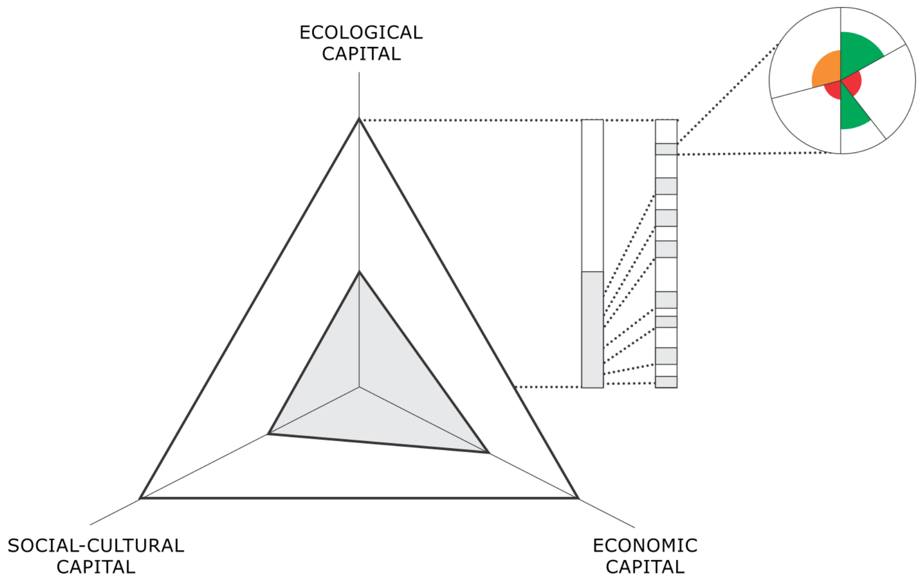

Figure 5: The relations between the capitals, stocks and indicators and their scores and weights. Source: Telos (2018).

3.2 The three capitals

3.2.1 Ecological capital

Before we can look at the ecological capital, we need to take a closer look at the theory behind it, originating from biology, ecology and environmental sciences. Where biology mainly focuses on systems of plants, animals, and microbes: the biotic environment, ecology focuses on both the interactions within this environment, and the interactions outside this environment with abiotic components in the environment. Environmental sciences can be found within each of these fields, and mainly study the human impact on biotic and abiotic environments. The combination of these three fields leads to the introduction of ecosystems which can contain structural and functional aspects, including a precise description of the features and elements of the environment or the energy flows and cycling of nutrients respectively. This makes an ecosystem a dynamic structure of components and processes. One can use an ecosystem in multiple ways, either through looking at either its structural or its functional aspects, or at both at the same time. Telos uses the ecosystem by looking at both aspects and consider an ecosystem to consist of both biotic (living organisms) and abiotic elements (energy and material flows) together with their interactions with one another, as well as human usage and experience of nature and its resources. For the first aspect, involving the intrinsic value of an ecosystem, the flow of energy, biotic structures and material cycles have been considered as main components (Telos & IMSA, 2015; Telos, 2002; Odum, 1969). The second aspect adds extrinsic values to the system, for instance through looking at usage of a landscape. Before fully understanding ecosystems, a better understanding of these components is essential.

The first component, the flow of energy, finds its origin mostly in the sun but can also be derived from other processes. These flows can be stored or exported beyond the boundaries of the ecosystem. This component has an impact on the biotic structures in the system as these process the energy flows, and need it to sustain themselves. Biotic structures consist of all living organisms such as plants, animals, bacteria and viruses and are highly dependent on one another, making nature a dynamic whole. When looking at biotic structures, one can state that an ecosystem is stable if the variety and number of different living organisms is high and rather constant.

For the other component, material cycles, an ecosystem is considered to be stable if the material cycles are almost entirely closed. Such systems are characterised by the absence of primary resources and waste materials, since every material functions as a nutrient for a living organism of the biotic structure. Materials in this component consist of both factors of the biotic structure that function as a nutrient, and of abiotic factors. These abiotic factors can be divided into three covering stocks: soil, water and air, between which several interactions can be observed. Combined, these stocks can be seen as sources and sinks which are exhaustible and saturable. Moreover, the three stocks soil, water and air do not only interact among each other, but also have a large influence on the biotic structure.

The stability of an ecosystem can be disturbed in multiple ways which are either caused by natural events or through human activity, both of which can be classified using the categorization by Walker and Meyers (2004). Most of these causes have an impact on the material cycles, resulting in either a surplus or deficit of certain sources. If this impact is large, the surplus leads to pollution and the deficit to exhaustion. Some causes, however, do not impact material cycles by leading to a surplus or deficit, but disrupt the ecosystem by altering the physical environment. In this case, the disrupted part of the environment becomes unsuitable for the living organisms to settle or migrate.

Sustainable development should be such, that it does not have a negative influence on ecosystems. When considering the functionality of an ecosystem, Telos always puts its intrinsic value first. The intrinsic value consists of the benefits and values of the ecosystem excluding those for humans. However, there are also several kinds of functions which are beneficial for humans (extrinsic values), namely: regulation functions, habitat functions, production functions, and information functions (De Groot, Wilson, & Boumans, 2002). Though these functions mostly concern the intrinsic value of an ecosystem, some of them also involve extrinsic values. Regulation functions, for example, provide many services with benefits to humans, either direct or indirect, such as maintaining clean air, water and soil. Information functions are even more involved with human benefits, contributing to the maintenance of human health and giving the ecosystem an amenity value for humankind. This has been captured by Telos through the introduction of the stock Landscape, which focuses on the design and experience of the landscape. With this stock, they also include other stocks that contain aspects that affect these focus points, such as annoyances and alterations. Note that the recreational use of ecosystems as well as aspects such as cultural heritage are not part of the ecological capital as used by Telos, but will be included in the economic capital, respectively social-cultural capital.

All this leads to the following stocks in the ecological capital as used by Telos:

1) Soil;
2) Air;
3) Annoyance and Emergencies;
4) Water;
5) Nature and Landscape;
6) Energy and Climate;
7) Resources and Waste.

These stocks all interact with each other through the functions and relations within the ecosystem. A change in the soil, for example through soil sealing, can result in a decrease in diversity in nature and landscape (Scalenghe & Marsan, 2009). An increase in phosphorous emissions to surface water can result in a decrease in biodiversity among, for instance, aquatic plants as this stimulates growth of surface algae, which ultimately prevents the aquatic plants from obtaining sunlight (Jackson & Jackson, 1996).

3.2.2 Social-cultural capital

As stated before, the social-cultural capital concerns the physical and mental well-being of the people. The definition of this capital as used by Telos has been based on several concepts regarding social interactions and mainly focuses on the concepts: participation and freedom (Telos, 2006). These concepts are essential since a social-cultural sustainable society is founded on principles of social justice and social participation. In such a society, everyone should experience equal chances, freedom, accessibility to facilities and services, safety, and solidarity. In order to understand the social-cultural capital, it is necessary to gain insight in these main concepts.

However, before looking at both participation and freedom, one has to look at social capital as a whole. Throughout the literature, there are several differences in definition and use of this concept. The amount of research on these differences is wide and also consists of critical reviews of the performed studies (Huygen & De Meere, 2008; Woolcock & Narayan, 2000; Woolcock, 1998). These studies also show some key elements of social capital which return in almost every definition: trust, reciprocity and networks. The concept of social capital can therefore be considered as an important determinant of aspects such as social integration, political participation, and economic achievement (Telos, 2002). This importance is backed by looking at the impact of social capital on multiple factors such as economic participation and safety (Huygen & De Meere, 2008; Iyer et al., 2005). Therefore, the concept of social capital already leads us to that of participation. Considering this concept, one should note that each individual functions in a certain group or network. Access to such group or network is essential as they allow for the acquisition of social capital which, as stated before, in turn allows for creation and distribution of trust (Brehm & Rahn, 1997; Putnam, 1993). The essence of this concept within the social-cultural capital is that each individual has a right to participate in political, economic, social and cultural activities, hence a right to actively participate in society.

When looking at the other concept, freedom, one should recall that the principle of social justice is fundamental in the aspect of a social-cultural sustainable society. This principle is based on the Western notion that everyone has an equal right to well-being, meaning that everyone should have equal access to the resources needed for a good life. Therefore, a just society allows for cultural diversity and equal citizenship.

In their definition of the social-cultural capital, Telos' vision is that every society should aim for participation without (im)material exclusion. In other words, everyone should be able to gain access to education and housing, participate in the economy and in politics, and be healthy and safe. This would lead to and be increased through cohesion and trust. Combined with the above, this leads to the following stocks for the social-cultural capital:

1) Social Participation;
2) Economic Participation;
3) Arts and Culture;
4) Health;
5) Safety;
6) Residential Environment;
7) Education.

As in the ecological capital these stocks are interrelated, hence subject to influences from one another. An example of such an impact can be seen when looking at social and economic participation, focusing in particular on political participation and financial assets of households. Research has shown that in this case, the level of financial assets of households has an effect on political participation with a lower level corresponding to less political participation (Solt, 2008). Moreover, it has also been shown that political participation is strongly influenced by education level and age (La Due Lake & Huckfeldt, 1988). Lastly, education is also related to health as a higher level of education is shown to have a strong impact on self-rated health, or assessment of own health (Jiao et al., 2016).

3.2.3 Economic capital

As with the other elements of the triple bottom line, the concept of economics used in the economic capital should allow for a conclusion of its state at a specific time, place and in a certain context. Since Telos mostly monitors sustainability at the level of municipalities, this conclusion should be possible at a regional level. In order to achieve this, Telos has started their search by considering the approaches regarding sustainability of the Dutch National Institute for Public Health and the Environment (RIVM) (Milieu- en Natuurplanbureau, 2004).

The economic view as held by the RIVM focuses on the distribution and allocation of scarce sources required to reach a certain goal. This corresponds with the economic principle of prosperity which can be divided into two distinct concepts: prosperity with external effects and prosperity without external effects. However, these external effects, such as pollution or hindrance, are already included in the ecological and social-cultural capital as defined by Telos. Therefore, the economic capital focuses on prosperity without external effects.

Using this type of prosperity as a guiding principle, the aim of the economic capital is to ensure a production of goods and services, and income level which is sufficient to provide the society and each individual with the means to satisfy their needs. To reach this goal, it is essential to consider the related influential factors which in general can be divided into the concepts competition and factors of production (labour, capital goods and natural resources). In addition to these general factors, one should also include the aspect of economic geography, involving spatial local conditions for businesses, infrastructure and mobility, and the regional production environment and structure, as these are essential for the regional economic approach required by Telos.

Combined, the previous factors allow for a description and measurement of a regional economy as this economy can roughly be seen as a relation between the regional production structure and production conditions. Moreover, examination of the underlying aspects of the mentioned factors shows that these aspects can almost directly be translated into the following stocks of the economic capital:

1) Labour;
2) Spatial Local Conditions for Businesses;
3) Competitiveness;
4) Infrastructure and Mobility;
5) Knowledge.

As in the previous capitals, the stocks in the economic capital are connected to one another. In this capital, this can already be observed through viewing the definition of the capital itself and the definitions and ways of measurement of the underlying indicators. For example, Competitiveness and Spatial Local Conditions for Businesses can influence one another through Bankruptcies on one side and Vacant office or retail spaces on the other. Moreover, research has shown that Competitiveness and Knowledge are connected through aspects such as innovation and creation of new knowledge combined with entrepreneurship (Caiazza, Richardson, & Audretsch, 2015; Gartner & Carter, 2003).

3.3 The interfaces of the capitals

As stated in Section 1.1, the capitals defined in the previous sections are connected through interfaces, or performance areas. In the following subsections, each of these interfaces will be elucidated by examining the existing literature on these topics. Though the mentioned studies are but a few of the existing amount of research, they will already show the extent to which the three capitals are interrelated. Moreover, they will also demonstrate the lack of knowledge on the links in general, as none of the studies cover all aspects of the three capitals but mostly focus on one or a few of these aspects.

Most of the studies on aspects of the triple bottom line are based on countries such as the United States. In order to gain insight into the scope of the problem and the three interfaces, these studies will be included in this theoretical framework. However, as stated before, the analysis of this research will only include studies concerning factors which are applicable to the Netherlands, ensuring their relevance to the National Monitor of Sustainable Municipalities.

3.3.1 Green Growth interface

The interface of Green Growth has already been studied for a long time. One of the studies in this area is a research by Berkes and Folkes (1991) on the systems perspective on the interrelations between human-made capital, natural capital, and cultural capital. Seeing the cultural capital as the capital covering all factors of importance to ecological economics from an evolutionary sense, they consider the human-environmental relationship from a systems perspective. Through this, they show the existence of a fundamental interrelation between the three capital types, namely that natural capital is the precondition for cultural capital, and human-made capital is generated in the interaction between the other two. Moreover, the research states that synergistic feedbacks between societies and their environment allow for sustainability of the structure and function of the ecosystem.

A year after this research, separate studies continued down this path to show the relation between ecology and economy and their impact on one another, such as Arrow et al. (1995); Daly (1992), and Rees (1992). The research by Arrow et al. (1995) criticised the statement of that time that economic growth is beneficial for the environment. Though the statement might be true in some cases, it ignores impacts from, for example, long-term pollutants on the environment. Therefore, the study stresses the importance of the content of economic growth, namely the inputs and outputs including environmental resources and waste products, for environmental quality.

The views of Arrow et al. are backed by a more recent work by the World Bank (2012). The key message from this book is that green growth is necessary, efficient, and affordable. The latter is in contrast to common belief that green policies and growth come at a high cost. Moreover, the World Bank states that economic growth and environmental sustainability should go hand in hand as this improves efficiency and because environmental benefits could lead to economic growth and vice versa. Beside this, the World Bank mentions the occurrence of trade-offs and the fact that not all of these trade-offs are inevitable but that some of them can be minimised or even eliminated through innovation. In their pursuit to promote green growth, the book also contains some guidelines for the creation of a green growth strategy with the emphasis on two dimensions: synergy and urgency.

3.3.2 Social Growth interface

Contrary to the Green Growth interface, Social Growth is still a relatively underexposed field of study, mostly because the differences in definition of the social-cultural capital as mentioned in Section 3.2.2. Research on this interface mainly consists of studies on the relation between social capital and economic growth, economic development or income. An example of such a research is a study by Rupasingha, Goetz, and Freshwater (2000) which tested the hypothesis that social capital, seen as civic engagement, has additive effects on economic growth in the United States on county-level. Taking effects of conventional measures of growth into account, they looked at the density of connections, financial support for charitable organisations, political participation and crime rates, and studied the impact of these aspects on economic growth rate. They found that in the US social capital has an important, independent impact on economic growth as there was significant evidence that per-capita income growth was higher in the case of counties with high levels of social capital than in those where these levels were lower.

Another research in the United States concerned the relation between social capital and household income distributions (Robison & Siles, 1999). This study showed that social capital leads to positive externalities concerning economics. However, as stated in the research itself, this conclusion was based on results from a very restricted model which needs additional examination in other settings. Still, the results show the need for a deeper investigation on the success of income redistribution in case those whose income is being transferred, have insufficient levels of social capital.

A more global study is a research by Whiteley (2000) which looked at the relationship of social capital and economic growth in a sample consisting of thirty-four countries from 1970 to 1992. In this study, social capital is seen as the willingness of citizens to trust others. It showed that high levels of social capital lead to a less risk averse society, which creates more incentives to invest in physical as well as human capital. Moreover, these higher levels lead to a better diffusion of innovation of new techniques. Even though the study showed that the relationship is more apparent between trust and income levels than between trust and economic growth, it clearly demonstrates the close relation between social capital and economic growth. Furthermore, as their sample did not only consist of countries with democratic governments or market-based economies, the results from this study are independent of these factors, hence show the importance of social capital as a causal factor for clarifying cross national variations in economic growth.

Lastly, there has been a study on the relation between social capital and economic growth on a regional level (Iyer et al., 2005). Here, social capital is seen as all networks, norms, relationships, values and informal sanctions which shape the society's social interactions in terms of quantity and cooperative quality, including aspects such as trust and civic responsibility. The study states that one has to take into account both macroeconomic and microeconomic levels when looking at the importance of social capital for economic growth. It showed that, on macroeconomic level, greater social capital leads to higher economic growth. Moreover, it showed that individual welfare is influenced by social capital at the micro-level through creation of externalities by social behaviour. These externalities are reflected in macroeconomic impact of these microeconomic processes. These impacts are however difficult to measure and to unravel as they may vary across time and location. This is one of the reasons given by the researchers considering the need for an analysis on regional level. Moreover, the findings of the study show that regional factors are important for many of the indicators of social capital and that social capital needs to be combined with other kinds of capital in order to gain a higher efficiency.

3.3.3 Environmental Equity interface

Research on the Environmental Equity interface has only recently really started to increase. Until a few years ago, most of the research only concerned comparisons of single aspects of the social-cultural and ecological capital, focusing mainly on aspects such as the environment and health, and resilience (Adger, 2000; Stiffman, Hadley-Ives, Elze, Johnson, & Doré, 1999). This led to several models and frameworks for social-ecological systems centred around key aspects like resilience, empowerment, social capital formation, adaptability and transformability (Peeters, 2012; Folke et al., 2010).

However, together with these models and frameworks, critique arose regarding the lacking nature of the included aspects (Howe, Suich, Vira, & Mace, 2014; Lehtonen, 2004; Chiesura & De Groot, 2003). As stated in these critiques, it was insufficient and undesirable to look for a single measure or framework in order to analyse the Environmental Equity interface. For instance, different geographical or temporal scales and situations need different measurements and frameworks. Moreover, most developed frameworks consider social and cultural functions from an ecological perspective, instead of looking at both capitals from their own angle.

In order to be able to meet the demands for an appropriate framework, it is vital to consider the relation between the ecological and social-cultural capital. Note that developing such a framework is beyond the scope of this thesis. However, gaining insight in the relation between the two capitals and the aspects that could be involved in such a framework will give an understanding of the Environmental Equity interface required for this thesis.

Even though some research states the importance of including the economic capital into the analysis of Environmental Equity, because of the complicated link between all three capitals (Lehtonen, 2004), there is still a numerous amount of studies solely focusing on the relation between ecological and social-cultural aspects. For instance, several studies have shown the existence of a relationship between socio-economic status and environmental quality. While considering different aspects of the social-cultural capital, these studies all reach a similar conclusion, namely that the social rank within the group is positively correlated to environmental quality (Downey et al., 2017; Cushing et al., 2015; Kruize et al., 2014, 2007). Moreover, other studies have paid attention to the relation between environmental green in residential areas and health, showing a positive relation as well (Orban, Sutcliffe, Dragano, Jöckel, & Moebus, 2017; Cutts, Darby, Boone, & Brewis, 2009; Kuo, Bacaicoa, & Sullivan, 1998).

4 Methodology

This research focuses on the relationships between indicators within and between the ecological, economic and social-cultural capital. In order to answer the research questions stated in the previous section, this study will take the approach as defined below for each research question. The data used in each research question will be provided by Telos. Before using the data from Telos however, the data will be investigated to understand its nature and origin, and to reveal possible areas in which the indicators might fall short. This will be done in Section 4.5.

4.1 What is the relationship between indicators within each capital?

In order to answer this research question, this study will build on studies performed by Telos concerning correlations and links between indicators (Telos, 2014; Smits et al., 2013). Using data regarding these indicators, the correlations and links will be determined for all indicators within each capital. In all three cases, we will first determine all correlations between indicators in a certain capital, only keeping those whose correlation c is either medium ($0.3 \leq |c| \leq 0.5$) or strong ($0.5 \leq |c| \leq 1$). The weak correlations ($0 \leq |c| \leq 0.3$) will be excluded as these relations between indicators are insufficiently strong. The correctness of each of these remaining correlations will be checked by looking at their theoretical background which will also lead to the inclusion of underlying factors. This way, we ensure that all relevant and important correlations are taken into account before making our selection of indicators and underlying factors based on the directness of the correlation. Note that this selection will not take place until the third research question, after which the final results will be used to determine the weight of each relationship between the indicators.

4.2 What is the relationship between indicators between different capitals?

When looking at the relationship between indicators between different capitals, thus on each different interface, this study will further investigate the relations found by Telos. As in the first research question, this research will compute the correlations and links between the indicators using data provided by Telos, this time between different capitals. As before, these correlations will be verified using their theoretical background and the results from the first research question. This analysis might again lead to the inclusion of additional underlying factors. Moreover, as in the first research question, the final results will be used to determine the weight of each of these relationships between different capitals.

4.3 Which clusters of indicators can be found within these related indicators?

The answers to the previous two research questions are necessary for the third research question as the weights of the relationships between indicators are used by the chosen clustering method. Moreover, the results of these questions allow for theoretical assessment which results in a selection of indicators to work with. This could also lead to the inclusion of underlying factors which are not part of the National Monitor of Sustainable Municipalities but according to the theory might play an important role in the process of trade-offs.

In order to obtain the desired clusters of indicators the results from the previous questions will be combined in a (hyper)graph $G = (V, E)$, where V denotes the vertices and E the edges. In this graph,

V consists of the indicators selected for the first and second research question and E contains all the edges between indicators for which a link has been found in these questions with their determined weights.

After the construction of this graph, a graph clustering method will be applied to find the desired clusters of indicators. The chosen method will depend on the outcome of the previous two research questions as each clustering method has its own conditions regarding weights and graph density. For example, some methods can only find clusters in the case of a graph with a high density, while others need this density to be lower. A useful and likely method could be the algorithm ROUND by Demaine et al. (2005). This method is designed for correlation based clustering and applicable on general graphs. Therefore, this method will be thoroughly explored. In order to ensure that this algorithm is in fact the most feasible one for the graph of the National Monitor of Sustainable Municipalities, several other methods will be investigated as well, such as Markov chain models, hierarchical clustering, Kernighan-Lin algorithm, spectral based clustering or a combination of such methods (Abrams, Baldwin, Gonda, & Chen, 2017; McSherry, 2016; Rosén & Brunzell, 2006; Capocci, Servedio, Caldarelli, & Colaiori, 2004). Each of these methods has its own preferences and advantages and disadvantages. Furthermore, the chosen method will be investigated to see if it allows for overlap between clusters. This can be an advantage as it allows the method to point at indicators that span multiple clusters. Therefore, the possibility of overlap between clusters will be taken as a prerequisite.

One of the main challenges will be to avoid levels of such high degrees of complexity that it would reduce the likelihood of finding relevant clusters. Such a high degree of complexity could be, for instance, that the density of the graph is so high that it becomes hard to determine distinct clusters. One way of reducing these levels of complexity is through the use of thresholds on for example the edge weights, excluding all edges with a weight under a certain value (Abrams et al., 2017). Moreover, since this research aims to find clusters, all isolated vertices can be left out. In the case of disjoint subgraphs, the choice of included edges has to be inspected through theoretical review. If this case is backed by theory, the subgraphs can be studied separately. These methods reduce the density as well as the complexity of the final graph while ensuring the correctness of the results.

In the case that determining clusters in the graph containing the three capitals turns out to be too complicated, another possible approach is to first determine a separate clustering for each capital. The next step would then be to determine relations between these clusters, after which the same methods can be applied as mentioned before. This would result in a more global clustering of the indicators but would still give an insight into the connections between the capitals.

The choice for a graph theoretical approach is a result of considering the nature of the indicators as well as looking at previous studies to find clusters of the indicators by Telos. These studies have been performed using different methods such as factor analyses, causal models, and stocks and flows (Telos, 2015, 2016b). These approaches, however, did not completely manage to distinguish between direct and indirect relations between indicators, which can be achieved through the use of a graph theoretical approach as the actual cause can be included as another vertex. The study by Smits et al. (2013), which resulted in causal models and stocks and flows, showed the complexity of the problem when using equations. Each edge in the obtained models contains a vast amount of underlying equations, making the overall model complex and difficult to use for the creation of clusters. By using correlations as condition for an edge in the graph this complexity can be reduced. Therefore, a graph theoretical approach can tackle both problems from previous studies, hence can be seen as a valid choice for the determination of clusters of indicators.

4.4 Which indicators can be used for monitoring trade-offs between capitals, and for monitoring and approaching sustainability?

The clusters found in the third research question can and most likely will contain indicators from more than one capital. Therefore, the obtained results from the third research question can give valuable insight in the connections between the three capitals. This insight allows for determining which indicators can be used to monitor trade-offs between capitals as they are the ones which play a role in more than one capital. Moreover, the results can also be used to find focus points for approaching and monitoring sustainability. These focus points will be obtained through considering two cases: the interaction between clusters including underlying factors and the interaction excluding underlying factors. These two cases are taken as they lead to different perspectives of focus points.

Excluding underlying factors in the analysis of the interaction between clusters can lead to concrete focus points within the National Monitor of Sustainable Municipalities as it involves relations exclusively between indicators. This analysis will be done through looking at the connections between clusters via shared nodes or connecting edges. Examining these connections could point at specific indicators which have a stronger connection to the rest of the National Monitor of Sustainable Municipalities than other indicators. These indicators can be promising as focus points for monitoring and approaching sustainability. After determining these indicators, their connectivity and importance will be examined to ensure their reach within the triple bottom line.

Including the underlying factors in the interactions between clusters allows us to consider the relation between the clusters and the typologies of municipalities as defined by Telos (2017). This relationship will be determined via the underlying factors from the first and second research question. In this case, the connection between the clusters and underlying factors will once more be done through computation of correlations. The connection between underlying factors and typologies will be determined through the use of a Welch Two Sample t-test. In this test, the data will be divided into two groups: municipalities with a certain typology, and municipalities without that typology. The Welch Two Sample t-test then compares the means of these groups with respect to an underlying factor which gives an indication of the relation between the typology and that factor. This study will then illustrate how to combine the results of the correlations and t-tests in order to obtain focus points for monitoring and approaching sustainability for each typology.

Together, the outcomes of these two cases will give an insight in focus points for municipalities, which can be implemented as concrete advice as they point at aspects that can have a large influence on the overall process towards an increased sustainability. Moreover, the outcomes can shine a light on the interdependence of the three capitals in the triple bottom line, hence extend the knowledge in this field.

4.5 The data

As stated before, all data used in this study will be provided by Telos. Before this data can be used to obtain answers to the research questions, it is important to understand its characteristics. Therefore, this section will delve into the nature of the data, explaining the sources used by Telos and the date at which this data has been retrieved, as well as point at possible areas in which the indicators might fall short.

For each of the three capitals, the data consists of all computed indicators belonging to that capital. These indicators are computed using data from the 388 municipalities in the Netherlands,[4] which has been obtained from several sources of which Statistics Netherlands (CBS) can be seen as the most important one. For the ecological capital, other important sources are executive and supporting agencies as well as research centres and databases,[5] and local sources such as municipalities and provinces. Important additional sources for the social-cultural capital are public services as well as executive and supporting agencies,[6] and several databases containing, for example, information concerning elections. For the economic capital, the most important sources besides CBS are databases and registries[7] regarding, for instance, business parks or labour. Moreover, all indicators are based on quantitative data and are all either on an interval or ratio scale, with the underlying data being on nominal and interval scales as well.

The obtained data for 2017 come from a wide period of time, ranging from 2010 to 2017 with most of the data originating from 2015. Data originating from 2010 regard indicators which hardly change over time such as Distance to public green or Inland recreational water. Moreover, some indicators are computed based on running averages, because of the dynamic nature of the indicators which can not be attributed to or influenced by the municipality. Using running averages allows for moderating the impact of a sudden change in the indicator. The differences in periods of time and years of origin make it difficult to look at longitudinal relations between indicators.

Besides these differences in year of origin which might have an effect on the relation between indicators, there are other possible areas of concern that should be taken into account during this research. For example, though the list of indicators is extensive, one could argue that some indicators are still missing, such as soil subsidence or trust. These indicators, however, are either already partly covered by others or require data which are not yet available at the level required by Telos. Trust, for instance, is partly covered by cohesion (Van Slageren, 2015; Moody & White, 2003), while data for soil subsidence are still unavailable on the level of municipalities.

A last possible area in which the indicators might fall short could be their way of measuring. The indicators of the National Monitor of Sustainable Municipalities are in general measured on municipal level which in some cases should be considered with caution. For example, when looking at Distance to performing arts, one should take the difference between rural and urban areas into account as theatres are more often found in cities than villages. However, since this research uses correlations to investigate relations between indicators, this will not have a great impact on the outcomes.

Another observation regarding measurement is that a few indicators result from sources which are derived from indirect indicators. In these cases, indirect means that the data needed for the indicators of the national monitor are not available themselves, but can be represented using related indicators. Furthermore, some indicators are based on data resulting from small samples or which are measured on COROP (Coordination Commission Regional Research Programme) or police district level. In these cases, these are the only data available. Therefore, the choice of using this data is in fact the same as choosing whether to include the indicator in question or not. Furthermore, note that these concerns only apply to a select group of indicators.

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[4]Using the division in municipalities as of January 1st 2017.

[5]Such as the National institute for Public Health and the Environment or the European Environment Agency.

[6]Such as the Public Health Service (GGD) and the Education Executive Agency.

[7]Such as LISA (employment register) and IBIS (Integral Industrial Site Information System Business Districts).

5 Correlation analysis

In the following sections, the correlations between indicators within and between the capitals are computed and analysed. Note that all these computations have been performed with RStudio using data provided by Telos. All resulting correlation matrices for the capitals and interfaces are included in Appendix A.2, showing only the medium and strong correlations and their significance levels, or p-values. Moreover, note that all our medium and strong correlations in the capitals and interfaces have probability value $p < 0.001$, hence are statistically significant.

In order to understand the found correlations, the analysis in the following subsections will focus on determining several underlying factors, first within each capital and then within each interface, using expert analysis combined with literature research. Even though the indicators of the National Monitor of Sustainable Municipalities express the current status of a certain matter, they are defined in a way which doesn't take their regional context into account. Therefore, the addition of underlying factors is essential as they put the indicators and their correlations in context as well as show the directness of the correlations. Note that throughout this investigation, the goal is to remain as close to the National Monitor of Sustainable Municipalities as possible. Because of this, a helicopter view is maintained throughout the analysis as this ensures that the underlying factors do not overshadow the indicators nor change the goal and concept of the monitor.

The following sections first state the underlying factors found while investigating the list of correlations in that capital or interface. After this, each factor is explained in turn, using the obtained literature and examples of correlations between indicators in which this factor is involved. Note that as each underlying factor explains multiple correlations, not every corresponding indicator will be mentioned explicitly since this would only complicate the analysis.

5.1 The relationship between indicators within each capital

5.1.1 Ecological capital

Looking at each of the results in the ecological capital in turn, we can deduce several common underlying causes of the correlations. Most of them can be seen as being induced by factors such as *population/building density*, *area type* (rural, urban, or industrial area), *soil type*, and *sector structure* (agriculture, industry, or service) (O'Neill et al., 2012; Jorgenson & Clark, 2010; York, 2007). In order to justify the choice of these factors, we will clarify the role of each proposed factor on the correlations in this capital.

Considering the factor *population/building density*, one can see that this factor already explains a large share of the correlations found in the ecological capital. If we take, for example, the indicator Soil sealing (N1f) in this capital, one can see that this indicator correlates with many others. As Soil sealing describes the share of the surface that has been covered by man-made structures, it is usually highest in areas with a high *population/building density* such as urban areas and industrial zones (Salvati, 2014; European Commission, 2012; Reilly, Maggio, & Karp, 2004; Paul & Meyer, 2001). It is also in these areas that correlated indicators such as Emissions and Concentrations (N2e, N2f), and Noise intensities and annoyance (N3a, N3c) usually reach higher levels than in areas where population/building densities are lower. Therefore, we will include the factor *population/building density* in our further analysis.

For the next factor, *area type*, one should note that residents of rural areas appear to separate their waste more than their urban counterparts (Rijkswaterstaat, 2015; Snel & Van der Zaag, 2015; Gevulei, 2011; CBS, 2004). Therefore, indicators regarding waste collection (N7c, N7d, N7f) are usually higher in rural areas than in urban areas. The distinction between rural and urban areas can be made by only looking at *population/building density.* However, simply distinguishing between rural and urban areas is not enough. For instance, indicators such as Risk of road transport of dangerous chemicals (N3e), Land surface with a 10^{-6} risk contour (N3f), and Nitrogen emissions to surface water (N4c) can most often be found in industrial areas instead of rural or urban ones. Therefore, one has to consider further investigation of the effect of the factor *area type* on the National Monitor of Sustainable Municipalities.

Looking at the next factor, *soil type*, one has to take into account the historical aspects of a region. When observing rural or urban areas in the Netherlands, it is important to remember the historical ways in which villages, towns or cities grew (Hammer et al., 2011). In most cases, development of a settlement has been influenced by the soil type on which it was based and by the expansion of the industry, which in turn can be linked to the type of soil in the area. This way of development has resulted in the formation of a certain sector and of agglomeration effects. Together with these effects and deliberate planning, this resulted in specific industrial areas. Nowadays, such areas encounter several environmental concerns and come with high levels of Contaminated sites (N1a, N1b, N1c). Though the factor *soil type* does not cover all aspects of a settlement which could explain historical ecological influences, it already provides a good indication regarding these influences and is at the same time linked to the qualitative typology *Old industrial municipality* by Telos through these historical influences. Therefore, this factor could be perceived as an important underlying factor in the ecological capital and will be included in our analysis.

Even though the soil type might not directly affect the industrial development of a region, it does impact the type of industries that settle in that region. Therefore, as stated before, the expansion and development of the industry in a region, and through this its sector structure, can be linked to its soil type. This relation can be depicted as follows:

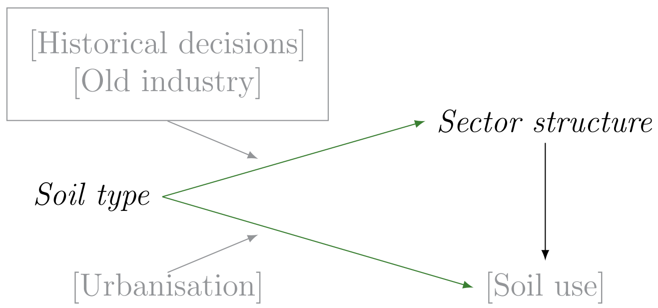

Figure 6: Schematic diagram of the relation of *soil type* to *sector structure* and soil use in green and those of other external factors in grey and black.

Because of this, *soil type* almost immediately leads us to the factor *sector structure.* Looking at this factor in relation to the ecological capital, one has to take into account that different sectors can influence different aspects of the environment. For instance, where activities in sectors such as agriculture may lead to high scoring indicators regarding Nitrogen emissions (e.g. N2b, N4c), these scores will most likely be lower for activities in service sectors. Other indicators, such as Average energy consumption (N6f, N6g), could be higher for the industrial sector than for others. (RIVM, 2014; Van Leeuwen, De Kleijn, Pronk, & Verhoog, 2014). Therefore, each sector structure may have a different impact on the environment and thus affect other aspects of the ecological capital, showing the need to take this factor into consideration during our research.

5.1.2 Social-cultural capital

Looking at the social-cultural capital, one can already note that most of the correlations could be explained through looking at some of the factors found in the previous capital, namely *population/building density* and *area type*. In addition, one should also consider some other underlying factors such as the *level of education*, *level of income*, *religion*, *socio-economic status* and *population age*. Before analysing these factors, note that the first two additional factors are greatly linked, since a higher level of education often leads to a higher income (Moonen, Otten, & Pleijers, 2011).

First, looking at the factors already found during the analysis of the ecological capital, *population/building density* and *area type*, one can see that these factors play an important role in correlations between indicators regarding distances to, for example, GP practices (S4c) or daily goods and services (S6b). A higher density of buildings often comes with a closer proximity to facilities, hence a shorter distance. Moreover, though the level of social cohesion in rural areas is changing, it is still stronger in these areas than in others (Pouwelse, 2013; Weenink, 2009). Therefore, one needs the inclusion of both *population/building density* and *area type* to distinguish not only between rural and urban areas, but also between urban and industrial ones as *population/building density* alone does not make this distinction.

Next, one should note that the factors *level of education* and *level of income* already explain a large part of the correlations and can even be seen as determinants for many indicators. An example of such an indicator is political turnout, either for municipal or national elections (S1c, S1d). A number of studies have shown that in the case of political involvement, the education and income level play a differentiating role (CBS, 2017, 2011; Levin, 2010; Arawatari, 2009; Rosenstone, 1982). In fact, political participation increases with the level of education, and the same holds when looking at different levels of income.

This is, however, not the only aspect in which these two possible factors play a role. In fact, multiple studies have shown that the levels of education and income are also related to volunteering, stating that an increase in education level increases the likelihood of becoming involved in volunteer work (Son & Wilson, 2017; Rochester, Paine, Howlett, Zimmeck, & Paine, 2016; Son & Wilson, 2011; Egerton & Mullan, 2008; Wilson & Musick, 1997). Together with the previous example, this already illustrates a number of correlations in which the *level of education* and *level of income* can be considered as underlying factors. As *level of income* combined with Education level population (S7g) already sufficiently covers *level of education*, we will only consider the factor *level of income* during further analysis.

When looking at volunteer work and informal help, one cannot limit themselves to solely education and income levels. Instead, one also has to consider the role played by the factor *religion*. Several studies demonstrate the positive impact of this factor on volunteer work (Son & Wilson, 2017; Bennett & Einolf, 2017; Son & Wilson, 2011; Bekkers & Schuyt, 2008; Donk, Jonkers, Kronjee, & Plum (red.), 2006; Wilson & Musick, 1997). Considering *religion* in the Netherlands, one can see that even though secularisation is increasing and the number of churchgoers is decreasing, religion still plays an important role in society. The Dutch legislation, for instance, is still influenced by the religious values. Likewise, one could consider the altruistic values and modern politics as being shaped by religion (Bennett & Einolf, 2017; Bekkers & Schuyt, 2008; Donk et al., 2006). Therefore, though this relationship is a complex one, the above shows the importance of considering *religion* when looking at the indicators in the social-cultural capital as well as during further investigation.

Another observation can be made when looking at someone's *socio-economic status* (SES) which can be determined using *level of income* and Education level population (S7g). Research has shown that there exists a significant relationship between SES and child and adolescent antisocial behaviour in which a lower SES results in a higher likelihood of such behaviour (Piotrowska, Stride, Croft, & Rowe, 2015). Moreover, other studies have shown the existence of a link between SES and health, stating that higher levels of SES are associated with better health statuses (Elgar et al., 2015; Quon & McGrath, 2014). Therefore, this aspect will be taken into account through consideration of the factor *level of income*.

The final factor to consider when looking at the social-cultural capital is the factor *population age*. This factor could explain several correlations which might, for instance, involve shrinking regions, i.e. municipalities facing a decrease in population. As these regions often cope with an increase in average age, the proposed factor could be used to indicate such regions and, more importantly, indicators connected to them. Moreover, as certain indicators in this capital are related to age (e.g. Youth crime (S5d), Youth unemployment (S7a), Dropouts (S7d)), inclusion of this factor already explains a number of correlations regarding these indicators. Therefore, the age structure of a municipality has to be taken into account in order to explain and understand the correlations in this capital, hence will be included in subsequent analysis.

5.1.3 Economic capital

Looking at the medium and strong correlations in the economic capital, one has to be aware of the definitions of the indicators as these already partly explain some of the correlations. The reason for this is the fact that most of the indicators are computed as a fraction of the same total, e.g. working population or number of businesses, which is less often the case in the previous two capitals. The numerators of these totals are not always independent of one another. For example, Human resources exploitation (E1b) and Unemployment (E1c) are both shares of the total potential working population, with Human resources exploitation being the share regarding the total working population and Unemployment the share consisting of potential workers which are looking for an occupation. As members of either group cannot be part of the other, these indicators have dependent numerators yet share the same denominator.

Another explanation for the economic capital can be found when looking at the factor *sector structure*. Research has shown that lack of diversity in or connections between sector structures can lead to higher risks of unemployment as the area in question is less resilient to sudden shocks (Sikkens, 2017; Weterings, Diodato, & Van den Berge, 2013). This in turn has an impact on the labour intensity of the municipality which is highly related to several indicators of the economic capital. Moreover, other studies have demonstrated that peripheral regions are more susceptible to shocks caused by reallocation of jobs, most likely because of their specific sector structures (Edzes et al., 2015). Therefore, we will consider this factor during our further analysis of the indicators of the National Monitor of Sustainable Municipalities.

5.2 The relationship between indicators between different capitals

5.2.1 Green Growth interface

When looking at the correlations belonging to the Green Growth interface, one has to note the influence of the correlations within the ecological and economic capital on those of Green Growth. For example, one can easily see similarities in the correlations between indicators such as Soil sealing (N1f) and Noise intensity (N3c) of the ecological capital. Within the ecological capital, Soil sealing and Noise intensity are strongly correlated (0.8085) and when considering their correlations with indicators of the economic capital, it turns out that all their correlations but one are with the same set of indicators (E1c, E2d, E3a, E3b, E4a, E4d, E5a, E5b). Because of such influences from within the capitals and the definition of Green Growth as the interface between them, it is hardly surprising that the underlying factors for the Green Growth have a large overlap with those of the ecological and economic capital. Therefore, as in the ecological and economic capital, the correlations of Green Growth can be explained through the factors *area type*, *population/building density*, *soil type* and *sector structure*.

5.2.2 Social Growth interface

When investigating the correlations within the Social Growth interface, one can make some noteworthy observations regarding the interconnectedness of the social-cultural and economic capital. For instance, when considering the indicators belonging to each capital based on their causal relationships, one can note that some of these indicators could be placed under either one. Half of the indicators belonging to the stock Knowledge of the economic capital (E5a, E5b) could also fit in the stock Education of the social-cultural capital. The other way around, one could support moving several indicators from Economic Participation from social-cultural capital (S2a, S2b, S2c, S2d) to the economic capital. Though the causal relations between these indicators would allow for such different arrangement of the indicators in the National Monitor of Sustainable Municipalities, the current structure has been based on a systematic approach using the definitions of each indicator. For instance, though Economic Participation is connected to several indicators from the economic capital, this stock indicates the extent to which a person can take part in the society in an immaterial and material way. The main focus of this stock is therefore the degree of participation in the society in the long-run, which is enabled through employment. Looking at the indicators of the stock Knowledge, one can see that these could be considered as part of the social-cultural capital. However, they are in general labour-related, leading to the present definition of both stocks. Because of this interrelatedness of the social-cultural and economic capital, a large part of the correlations found in Social Growth can be explained through several factors found in the involved capitals, namely *area type*, *population/building density*, *level of income*, and *population age*.

5.2.3 Environmental Equity interface

As in the previous cases, the correlations of the Environmental Equity interface show the influence from the involved capitals. Therefore, as before, one can see that a large number of correlations can already be explained using the overlap in underlying factors from the ecological and social-cultural capital. For instance, almost all correlations consist of indicators which are most often present in residential areas, such as between Poor households, Financial assets household (S2a, S2c) and Soil sealing and Noise intensity (N1f, N3c). Important factors to take into consideration in this interface are *population/building density*, *area type*, *level of income*, and *soil type*. Note, however, that based on the empirical results, this interface can be considered as the weaker interface of the three as it contains the least correlations, and because of the links of this interface to the economic capital.

5.3 Important relations between and within capitals

Looking back at the previous sections, we can already derive an important conclusion, namely that since correlations are not always as direct as they seem, one has to be aware of underlying causes while considering the correlations between indicators within and between capitals. This finding resulted in the inclusion of several underlying factors, namely: *sector structure*, *soil type*, *area type*, *population/building density*, *religion*, *education level*, *income levels*, *socio-economic status* and *population age*. Note that *education level* is already part of the indicators belonging to the social-cultural capital but that *level of income* and *population age* are both only indirectly or partly covered by the capitals. Moreover, through inclusion of the factor *level of income*, we have already covered the factor *socio-economic status*. Including the last factor as well would therefore lead to an overlap in our underlying factors, hence is unnecessary for finding clusters of indicators and answering our research questions. Thus, the extra factors which will be included in our selection are the following:

1) *Income*;

2) *Soil type*;

3) *Sector structure*;

4) *Religion*;

5) *Population/Building density*;

6) *Area type*;

7) *Population age.*

Each of these factors will be denoted using the same notation as applied to the three capitals. In the case that a factor does not contain a subdivision, the last letter will be dropped. For example, the factor *population/building density* will be denoted by F5, while the sector Industry, part of the factor *sector structure*, shall be denoted by F3b. For an overview of the notation belonging to each, see Appendix A.1.

5.3.1 Overlapping relations

Before we can combine these results into a graph, we first need to determine their relations with the indicators of each of the capitals. This has been done in the same way as before, through considering the correlations within each factor and the indicators. Moreover, as the underlying factors might also influence one another, these possible relationships have also been analysed through computation of the corresponding correlations. The resulting correlation tables of both analyses can be found in Appendix A.2.

While considering these correlation results, the first thing to notice is that the indicator Share of forest and natural area (N5a) almost perfectly positively correlates to Forest and natural area (F6d) belonging to the factor *area type* (0.9999) as they are essentially the same indicator. Therefore, taking both this indicator and area results in an overlap in the graph. Since this thesis focuses on the National Monitor of Sustainable Municipalities and because of the nature of the data belonging to the indicator and the factor aspect, only the indicator Forest and natural area will be included in the remaining analysis.

A similar instance occurs when examining the relation between Soil sealing and the underlying factor *population/building density*, from now on also called *density*. Though the correlation between these two is not as high as the previous pair (0.7834), all correlations with Soil sealing are contained in the correlations with *density* and these are all almost equally strong. The number of correlations with *density*, however, largely exceeds that of Soil sealing. In part, this can already explain the degree of relatedness between the two, as it highlights the fact that *density* encloses some aspects not contained in the indicator, mostly visible through consideration of sectors or areas. Yet, as the correlations with Soil sealing are included in those with *density* and because of the overlap in the definition of the indicator and factor, including both will only lead to an increased complexity of the graph. In this case, however, we have chosen to exclude the indicator Soil sealing as *density* has numerous additional, important correlations. Moreover, note that using *density* and *sector structures* will be sufficient to cover the aspects of Soil sealing.

5.3.2 Direct and indirect relations

Looking at the other found relations one should note that a distinction has to be made between direct and indirect correlations. In part, this has already been covered in our search for underlying factors. For example, in the ecological capital we have found a correlation between Emission of NOx (N2b) and Average electricity consumption businesses (N6g) (0.5144) which can be explained through considering *sector structure*. On the interface Social Growth, the indicators Vandalism (S5a) and Share starters (E3a) (0.4564) could be considered to be indirect through the underlying factors *sector structure* and *density*. Through making this distinction, one can ensure that the graph which will be constructed in the next section only includes direct relations, hence allows for a visualisation of the way one indicator might be related to another.

The analysis of directness of the correlations has, as stated in the previous paragraph, partly been covered by the studies used in determining the underlying factors. The directness of the remaining correlations have been determined using expert analysis (C. H. M. Wentink, personal communication, March, 2018). In this investigation of direct and indirect relationships, we made some noteable conclusions. For instance, though as expected, all found underlying factors correlated with at least one indicator of the National Monitor of Sustainable Municipalities. However, two of these factors, *religion* and *soil type*, encompassed no direct correlations. Most of their correlations were explicable through either *population/building density*, *area type* or *sector structure*. Therefore, these two factors will not be included in the construction of our graph.

In the same way, this analysis of the correlations resulted in the exclusion of some indicators for which a medium or strong correlation with either another indicator or underlying factor had been found. Main reasons for excluding these indicators were their way of measurement or occurrence throughout the Netherlands. For instance, the indicator Earthquakes (N3g) is highly concentrated in Groningen, a region with a specific characterisation, concerning for instance rural and urban areas. Though this indicator is important for measuring sustainability in the Netherlands, including correlations with this indicator could lead to a distorted image of the relations between indicators as well as factors. Because of this, indicators which are found to be only part of indirect correlations will be excluded from our graph.

Now, note that the tables in Appendix A.2 also contain indicators which only have a weak correlation with the other indicators. If these indicators are not part of any medium or strong correlation, they will turn out to be an isolated vertex in the graph of the next section. Therefore, these indicators will not be taken into consideration in the remainder of this thesis. Examples of such indicators are Chemical quality of surface water (N4a), Informal care (S1e), and Net/gross area ratio business parks (E2b). Note that excluding these indicators does not imply that they are less important or relevant than others. In fact, there might be excluded indicators which can be or, in the literature, have been linked to some included ones. However, as the used data do not lead to a correlation, including the indicator means that the strength of the expected correlation has to be determined independent of the data, which is beyond the scope of this thesis.

6 Cluster analysis

6.1 Clusters of indicators

With the results from the previous sections, we have gained enough information to start our search for clusters of indicators using a graph theoretical approach. In order to obtain these clusters, we will first give the definition of a graph in general and construct the graph belonging to the National Monitor of Sustainable Municipalities. After this we will deduce the properties of our graph which are required to choose a cluster method. Next we will delve into this cluster method and look at the additional definitions and properties required for this method. Thereafter, we will consider potential adaptations of the chosen method in order to obtain a solution feasible for our goal.

Once the method has been well-defined and analysed, we will apply the method and its adaptations on our graph. The resulting clusters will then be examined using the requirements belonging to the National Monitor of Sustainable Municipalities. This will lead to an understanding of their contents as well as allow for a thorough review of the algorithm's outcome. The obtained clusters will then be viewed from the perspective of capitals to acquire a full understanding of their coverage of and relation to the triple bottom line.

6.1.1 Choice of the cluster method

As stated in the previous paragraphs, the results from the previous sections allow us to construct a graph G of the National Monitor of Sustainable Municipalities. In general, a graph G consists of a set of nodes, V, and a set of edges, E, leading to the notation $G = (V, E)$. As an example, if we have six nodes and seven edges we could define, amongst others, the following graphs:

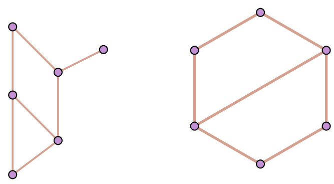

Figure 7: Two examples of a graph G with six nodes and seven edges.

In the case of the National Monitor of Sustainable Municipalities, our sets of nodes and edges are based on the results of the previous sections and defined as follows:

- A set of nodes V consisting of all indicators and underlying factors belonging to at least one direct correlation as found in Section 5.3.1;
- A set of edges E consisting of all these direct correlations with weights c_e equal to the corresponding correlation.

So for instance, based on the results of Section 5.3.1, the indicators Employment function (E1b) and Human resources exploitation (E1c) will be included in our graph as nodes. These indicators share a correlation of weight -0.6600, leading to an edge $e_{E1b,E1c}$ between them with this weight. Because of our method of inclusion and exclusion of indicators and underlying factors in the previous section, every pair of nodes in our graph shares at most one edge, so we will not allow double edges between two nodes. Furthermore, our graph does not contain any loops as we do not include correlations of an indicator or factor with itself. Lastly, as every indicator or underlying factor is correlated to at least one other indicator or underlying factor, our graph does not contain any isolated nodes, i.e. nodes without any edges. This leads to a graph with 107 nodes and 384 edges, shown in Figure 12 at the end of this thesis (Appendix A.5).

Using this information we can already derive an important property, namely the density of the graph. The density of a graph is the ratio of the number of actual edges and the number of possible edges, i.e. $D = 2|E|/(|V|\,(|V|-1))$. A high density is a ratio close to 1, and a high sparsity a ratio close to 0. This ratio can tell us the average number of edges one needs to cross to get from node u to node v, i.e. the amount of edges in the shortest route from u to v. The higher the density of a certain graph, the shorter the average route between two nodes, hence the lower the average number of edges in the shortest route. The lower the density, i.e. the sparser the graph, the longer the route between two nodes.

In our case, $|V| = 107$, hence the total number of possible edges is $\frac{1}{2}|V|(|V|-1) = \frac{1}{2} \cdot 107 \cdot 106 = 5671$. As the number of actual edges is $|E| = 384$, this results in a density of $D = |E|/(\frac{1}{2}(|V|\,(|V|-1))) = 2|E|/(|V|\,(|V|-1)) = 384/5671 = 0.0677$. Therefore, one can easily see that our graph is quite sparse. This already gives some insight in the directness of our relations, as it shows that most indicators and underlying factors need to cross multiple other indicators or factors before being able to reach one another. For our cluster method, which should find a partitioning of G into sets of nodes (clusters), it is important to take this sparseness into account as some methods are more efficient on dense graphs than they are on sparse ones. Note that when including all medium and strong correlations, both direct and indirect, our graph would have a density of $1232/7381 = 0.1669$. Therefore, the choice of excluding the indirect correlations from our graph has not considerably affected its density.

In search for a cluster method, several articles concerning algorithms for (network) clustering have been considered, such as Abrams et al. (2017); Rosén and Brunzell (2006); Demaine et al. (2005), and Capocci et al. (2004). Of the algorithms found in these articles, the majority is not applicable in our case because of the size and sparseness of our graph or because of the methods' definition or outcome. For instance, the outcome of the algorithm by Rosén and Brunzell (2006) is a hierarchical clustering without any overlap. This overlap, however, is an option which would be ideally included in the method of our choice as this could point at focus points for monitoring trade-offs in sustainability. Therefore, as this algorithm was not very insightful, it was, though applicable, not the method of our choice. Considering the algorithm by Capocci et al. (2004), one should note that this algorithm is dependent on the choice of a constraint matrix M, with each matrix leading to a different eigenvalues problem and thus likely to a different kind of result. Moreover, as was the case with the algorithm by Rosén and Brunzell (2006), the algorithm by Capocci et al. does not allow any overlap between the found clusters. Therefore, it is not the method of our choice either.

A promising algorithm turns out to be the algorithm Round by Demaine et al. (2005). Besides focusing on correlation clustering, this algorithm allows various sizes of clusters and does not require a predetermined number of clusters but lets the amount of clusters depend on the given graph. Moreover, it is insightful and allows for certain changes to increase its usefulness and suitability in our case. For instance, this method could be adapted to allow overlap between clusters. Before we go into detail regarding these changes, we first need to understand what the base algorithm Round entails.

6.1.2 Algorithm Round

The algorithm ROUND by Demaine et al. (2005) is based on a general correlation-clustering problem by Bansal, Blum, and Chawla (2004). This correlation-clustering problem uses a complete graph, i.e. a graph with density equal to 1, with n nodes and edges indicating similarity $(+)$ or difference $(-)$ as input. In this problem, the aim is to find a clustering, i.e. a partitioning of nodes, which maximises the number of similar edges within each cluster, while minimising the number of different ones.

Demaine et al. extend this problem to the case of general weighted graphs, hence include graphs of any density and add a certain positive value to each edge in addition to the (dis)similarity label. This corresponds to taking a general graph G with n nodes and m edges with negative values indicating the degree of difference or positive values indicating the degree of similarity. In our case, this is equal to taking the correlations as weights on the edges. A positive correlation then corresponds to two nodes being similar, and a negative one to two nodes being dissimilar. In order to translate this to a functional algorithm, the authors introduce some additional notation.

Let $G = (V, E)$ be a graph with n nodes and m edges. Unless stated otherwise, we define an edge $e \in E$ to be $e = (u, v)$ with $u, v \in V$. For such $e \in E$, let c_e (or c_{uv}) denote the edge weight. Since c_e can be either positive or negative, the set of edges, E, can be divided into two parts: $E^{(+)} = \{e \in E \mid c_e \geq 0\}$, the set of edges with positive weights, and $E^{(-)} = \{e \in E \mid c_e \leq 0\}$, the set of edges with negative weights. Lastly, if $C_1, \ldots, C_k$ denote k clusters of graph G, then the weight of a cluster C_i, $i \in \{1, \ldots, k\}$, is defined as follows:

$$w(C_i) = \sum_{\substack{e \in E^{(-)} \\ u,v \in C_i}} |c_e| + \sum_{\substack{e \in E^{(+)} \\ u,v \in C_i}} c_e.$$

The goal of the algorithm ROUND is to minimise this value $w(C_i)$ for every $i \in \{1, \ldots, k\}$, hence to minimise the number of negative edges within each cluster. This can be extended to minimising the weight of the set containing all the clusters, $\mathcal{C} = \{C_1, \ldots, C_k\}$, where $w(\mathcal{C})$ is defined as follows:

$$w(\mathcal{C}) = \sum_{e \in E^{(-)}} |c_e| \, (1 - x_e) + \sum_{e \in E^{(+)}} c_e x_e, \tag{6.1}$$

where $x_e = 0$ if u and v are in the same cluster, $x_e = 1$ if they are in a different one. Finding clusters with a minimal weight, means that we have found clusters of indicators which have the highest degree of similarity. In our case, we want to find clusters with the highest degree of correlations between their included nodes. As will be further clarified in Section 6.1.3, we will adjust the signs of our correlations in order to ensure that finding the highest degrees of similarity corresponds to finding the highest degrees of correlation. After this, finding clusters with a minimal weight, means finding clusters consisting of indicators with the highest relation to one another as will be needed for our goal.

A valid assignment of the values of these x_e is essential to minimise (6.1). Therefore, Demaine et al. (2005) have relaxed the demand that x_e should be either 0 or 1 to the following linear program:

$$\begin{aligned} \min \quad & \sum_{e \in E^{(-)}} |c_e| \, (1 - x_e) + \sum_{e \in E^{(+)}} c_e x_e \\ \text{s.t.} \quad & \\ & x_e \in [0, 1] \\ & x_{uv} + x_{vw} \geq x_{uw} \\ & x_{uv} = x_{vu} \end{aligned}$$

The results of this linear program are essential for the further definition of ROUND as they give an indication whether u and v should be in the same cluster or not. A high value for x_{uv} would mean that u and v would ideally not be in the same cluster, while a low value would indicate the opposite.

Besides these values x_e, the authors introduce some other notation required for the algorithm. First of all, they give the definition of a ball $B(u, r)$ within a graph G which is an essential element of the algorithm. Let r be a positive, real value, denoting the radius of the ball and let $u \in V$ be any node in G. Then the ball $B(u, r)$ is the subgraph consisting of all nodes $v \in V$ such that $x_{uv} \leq r$, all $e \in E$ with both endpoints in $B(u, r)$, and the fraction $(r - x_{uv})/x_{vw}$ of edges (v, w) with only one endpoint in $B(u, r)$. Later, this ball will correspond to the clusters found in the algorithm. However, in order to find these clusters there are two more definitions that need to be introduced, namely the cut and volume of a (sub)graph.

Let S be a subgraph of G. The cut of S is the weight of all positive edges with exactly one endpoint in this graph, which can be computed as follows:

$$\text{cut}(S) = \sum_{\substack{|\{v,w\} \cap S| = 1 \\ (v,w) \in E^{(+)}}} c_{vw}.$$

For a ball $B(u, r)$, this cut is precisely the cut of the subgraph consisting of all nodes v in $B(u, r)$.

The volume of a subgraph S of G denotes the total sum of the weighted distance of edges with both endpoints in S, so:

$$\text{vol}(S) = \sum_{\substack{\{v,w\} \subset S \\ (v,w) \in E^{(+)}}} c_{vw} x_{vw}.$$

Looking at the ball $B(u, r)$, this volume is a bit more complicated. Since the ball $B(u, r)$ also consists of fractions of edges, the volume of $B(u, r)$ is the volume of the subgraph $B(u, r)$ without these fractional edges together with the fractional weighted distance of all positive edges leaving $B(u, r)$. Thus the volume of $B(u, r)$ can be defined as:

$$\text{vol}(B(u,r)) = \sum_{\substack{\{v,w\} \subset B(u,r) \\ (v,w) \in E^{(+)}}} c_{vw} x_{vw} + \sum_{\substack{|\{v,w\} \cap B(u,r)| = 1 \\ (v,w) \in E^{(+)}}} c_{vw}(r - x_{vw}).$$

Moreover, contrary to the cut of a subgraph or ball, the volume requires an initial value which is taken to be equal to I. This also means that $B(u, 0)$, i.e. the ball around node u with zero radius, has this volume.

Now that we have defined these properties, we have enough notation to look at the algorithm ROUND by Demaine et al. (2005). The idea of this algorithm is that it picks an arbitrary node inside G and enlarges a ball around this node by increasing its radius such that it contains a new entire edge, until this ball reaches a certain boundary. Then this ball is removed from G and saved as a cluster after which the algorithm starts again until the entire graph is partitioned into sets of nodes.

Looking at our graph, this would roughly mean that the algorithm would start at an arbitrary node and enlarge a ball around it through considering all the surrounding nodes with which this starting point is connected through a correlation. If the boundary has been met, the obtained cluster will consist of the starting point together with the indicators and underlying factors, whose correlations to this node are strong enough to be part of the ball.

The authors of ROUND have shown that the termination condition, i.e. the boundary, can be expressed in terms of the nodes of the graph, and the cut and volume of the ball $B(u, r)$. This leads to the following boundary:

$$\text{cut}(B(u, r)) \leq b \ln(n + 1)\text{vol}(B(u, r)),$$

where n denotes the number of nodes and b is a real value (slightly) greater than 2. Using this boundary and mathematical expressions of each step, the algorithm ROUND can be expressed as follows:

1) Pick any node u in V;

2) Take the initial radius r as zero;

3) Until $\text{cut}(B(u, r)) \leq b \ln(n + 1)\text{vol}(B(u, r))$, increase r by $\min\{(c_{uv} - r) > 0 \mid v \notin B(u, r)\}$;

4) Save the nodes of $B(u, r)$ as one of the clusters of G;

5) Remove all nodes and edges of $B(u, r)$ from G;

6) Repeat steps 1 to 5 until graph G is empty.

Demaine et al. (2005) have shown that this algorithm runs in polynomial time and terminates with a valid solution satisfying the constraints. Because the algorithm is independent of choice of number of clusters, has an origin in correlation-based clustering, and allows for possible alterations, this gives us enough grounds to test this algorithm on the graph of the National Monitor of Sustainable Municipalities. However, before actually performing these tests, the next section will look into some adaptations of the algorithm.

6.1.3 Adaptations

In order to use the algorithm ROUND to obtain clusters of indicators of the National Monitor of Sustainable Municipalities, we need to consider some adaptations. These adaptation are required to ensure that the found clusters will in fact point at fields in which trade-offs within and between the three capitals are likely to exist. Without these adaptations, the obtained clusters could be considered a feasible solution out of context of the monitor, but will likely not correspond to fields which turn out to be relevant in this context. When looking at the base algorithm ROUND, one can distinguish three areas that allow for adaptation, namely the choice of the starting point, the choice of the boundary, and the choice of the removal method. Of course, these possible adaptations all have their advantages and disadvantages, mostly surrounding the meaning of the outcome and the dependence of choice of starting point or removal method.

Considering the choice of the starting point, the base algorithm ROUND starts each iteration of steps 1 to 5 by selecting an arbitrary node u in V in the first step. However, because of the sparseness of our graph, this method leads to a wide variety of obtained clusters. Even looking at the smallest graph, belonging to the economic capital, random selection of a starting point already gives 4 to 10 different clusters. As the goal of this study is to find clusters containing indicators with the highest degree of relatedness to one another, one possible alternative would be to look at the degree of the nodes. The degree of a node is the number of edges which start or end in that node. So, for example, if a node has a degree of three, this number would indicate that a node is correlated with three other nodes.

This leads to three possibilities for choosing a starting point: selection of a random node, selection of the node with the highest degree, and selection of the node with the lowest degree. Considering the last two options, one also has to consider whether one considers the degree as was the case in the original graph, or if one calculates the new degrees after each iteration. Besides this, one could also choose to exclude the underlying factors from the set of starting points, as our goal aims at finding clusters of indicators.

In step 3, the base algorithm ROUND expands a ball around the starting point until a certain boundary is crossed. This boundary is dependent on the ball itself through its cut and volume, but also on a chosen constant value $b \in \mathbb{R}$ and on the number of nodes n. As stated by Demaine et al. (2005), the constant value b should be at least slightly larger than 2. Therefore we have chosen to start with defining b to be 3. As for the number of nodes n, one can discern two possible choices: either this number is fixed to be the number of nodes of the initial graph G, or this number decreases in each iteration by being dependent on each subgraph G_i. Choosing the first definition of n ensures that the obtained clusters follow the same boundary criteria. The second, however, could lead to a decrease in size of the clusters after each iteration.

As stated before, the base algorithm ROUND removes all nodes and edges within an obtained cluster from the graph before starting with the next iteration. This removal method ensures that one finds distinct clusters. When looking at the relations between indicators of the National Monitor of Sustainable Municipalities, one could expect that some indicators have a strong connection to multiple groups of indicators, hence might belong to multiple clusters. Therefore, a possible adaptation of ROUND would be to allow overlap between clusters. This can be achieved through changing the removal method. Changes in this method could be made regarding the removal of nodes and the removal of edges. Looking at the nodes within an obtained cluster, one could, for instance, only remove the starting point from the graph before continuing to the next iteration or remove all nodes from the list of possible starting points but not from the graph. Regarding the removal of edges, one could consider removing only those edges that lie entirely in the obtained cluster or just those attached to the starting point. In order to gain an overview of the possible adaptations of the base algorithm ROUND, stated in the previous paragraphs, we have summarised all these choices in Table 1.

Before we can test any of these combinations, we have to look at the properties of our graph. As the algorithm ROUND is developed such that it includes as few edges with negative weight as possible, we need to ensure that the signs of the weights of our graph correspond to their intended meaning in the algorithm. For example, a correlation such as between Employment function (E1b) and Human resources exploitation (E1c) (-0.6600) is strongly negative, but at the same time indicates the existence of a strong relation. Since we are looking for clusters involving nodes with such relation to one another we will adjust the weights such that the order of their strength remains preserved but that these negative weights are considered by the algorithm as positive ones. This can been achieved through taking $|c_{vw}| - |c_g|$, where c_{vw} is the weight of the correlation belonging to edge (v, w) and c_g, a boundary value which will be defined later.

Starting point	*Random selection*	Including underlying factors	-
		Excluding underlying factors	-
	Highest degree	Including underlying factors	Each iteration
		Excluding underlying factors	Based on original graph
	Lowest degree	Including underlying factors	Each iteration
		Excluding underlying factors	Based on original graph

Boundary	*Constant b*	Real number $b > 2$
	Number of nodes n	Based on the original graph
		Based on every subgraph after each iteration

Removal method	*All cluster nodes*	In overall graph	All edges with at least one node inside the cluster
			All edges with both nodes inside the cluster
		In selection list	All edges with at least one node inside the cluster
			All edges with both nodes inside the cluster
	Only the starting point	All edges with at least one node inside the cluster	
		All edges with both nodes inside the cluster	
		Only the edges attached to the starting point	

Table 1: Possible choices for adaptations of the algorithm Round.

In order to understand the impact of each of these adaptations, we have looked into several combinations. The following list gives a summary of these combinations sorted by their starting point:

- *Starting point:* Random selection including underlying factors,
  Boundary: $b = 3$ and both $n = |V_G|$ and $n = |V_{G_i}|$,
  Removal method: removal of starting point and all nodes in the overall graph, and all removal methods regarding edges;

- *Starting point:* Highest degree (all possible sub adaptations),
  Boundary: $b = 3$ and both $n = |V_G|$ and $n = |V_{G_i}|$,
  Removal method: removal of starting point and all nodes in the selection list of starting points, and all removal methods regarding edges;

- *Starting point:* Lowest degree including underlying factors,
  Boundary: $b = 3$ and both $n = |V_G|$ and $n = |V_{G_i}|$,
  Removal methods: only remove the starting point and all edges attached to this point.

Note that in all three cases the tested choices of the boundary cover all options. However, the chosen combinations do not include all possible (sub)adaptations for the starting points and removal methods. Nevertheless, through analysing the outcomes of the tested combinations, we already gain enough insight to know whether further analysis of possible adaptations is required. For example, when considering the lowest degree with the chosen removal method (only remove the starting point and all edges attached to this point), one can already compare the outcome with the result of the algorithm starting at the highest degree which uses the same removal method.

For the first tests of the combinations named before, we will take $c_g = 0$. All the weights in our graph therefore become positive and only state the degree of relatedness between two nodes. In order to understand the results found in the testing phase of the algorithms, we have used the graph belonging to the economic capital as this is the most insightful graph and its density (0.0769) is similar to that of the graph of the National Monitor of Sustainable Municipalities (0.0677).

In all cases, the tests have shown that choosing either $n = |V_{G_i}|$ or $n = |V_G|$ does not make any difference in the resulting clusters found in the testing phase. When considering the clusters found by each adaptation, one can see that some results could be considered better than others. The main difference lies in the number of clusters, their starting points and their focus. The algorithms that included underlying factors in their list of starting points all resulted in clusters based around these factors. Though these clusters are correct, they only explain the underlying factors themselves rather than the relations between indicators in the National Monitor of Sustainable Municipalities. The algorithms that excluded underlying factors as a starting point did result in clusters explaining these relations. As the resulting clusters do include underlying factors as well, this allows us to use these factors to interpret the clusters rather than the other way around. Therefore, one can see that the choice of the starting point has an influence on the focus of the clusters. This observation will be discussed in full in Section 8.

For the algorithms excluding underlying factors, one can see a clear difference in the outcomes regarding numbers of clusters when selecting a starting point within each iteration or based on the original graph. Nevertheless, even with this large variety in number of clusters, the obtained clusters from each algorithm overlap to a large extent. Based on these observations, we have chosen three adaptations as being the most promising. These adaptations use the same criteria regarding the starting point and boundary, and differ with respect to their removal method. Compared to the other tested adaptations, the clusters of the chosen adaptations are the most insightful and allow for a clear overview of the connections within the economic capital. These adaptations are:

- ALGORITHM 1:
  Starting point: Highest degree within each iteration excluding underlying factors,
  Boundary: $b = 3$ and $n = |V_{G_i}|$,
  Removal method: remove all nodes from the starting list and edges with at least one node inside the cluster;

- ALGORITHM 2:
  Starting point: Highest degree within each iteration excluding underlying factors,
  Boundary: $b = 3$ and $n = |V_{G_i}|$,
  Removal method: only remove the starting point and edges with at least one node inside the cluster;

- ALGORITHM 3:
  Starting point: Highest degree within each iteration excluding underlying factors,
  Boundary: $b = 3$ and $n = |V_{G_i}|$,
  Removal method: only remove the starting point and edges with both nodes inside the cluster.

These adaptations are also tested on the ecological and social-cultural capital before running them on the entire graph of the National Monitor of Sustainable Municipalities. During these tests we have also looked at the impact of changing the value of c_g, hence changing the way the edge weights are altered. For $c_g = 0$, $c_g = 0.6$ and for $c_{vw} = 1 - |c_{vw}|$, the obtained clusters were all equal. This will most likely be the result of the sparseness of our graph combined with the equal choices of starting points. Moreover, a change in edge weights also changes the initial radius of each ball. Since the weights are altered linearly, this results in a similar volume and cut for each ball, leading to the same clusters. The same held when changing the boundary value b to 2, 30 and even 1, which as before will most likely be a result of the sparseness of our graph.

Overall, the results of the three chosen adaptations on the graph of the monitor are quite similar. In fact, the clusters obtained through the first two algorithms are equal. This is also a result of the sparseness of our graph, as the only difference between ALGORITHM 1 and ALGORITHM 2 is the number of nodes which are removed from the list of starting points. ALGORITHM 1 removes all nodes from a found cluster from the list of starting points, while ALGORITHM 2 only removes the used starting point itself. However, observing the degrees belonging to the subgraph in each iteration, one can see that the node with the highest degree after each iteration has not been part of any previous cluster. Therefore, though the two algorithms are distinct in definition, their resulting clusters are equal.

The third algorithm does differ from the other two as it finds more clusters than the others. More specifically, ALGORITHM 3 adds to the list of clusters found by ALGORITHM 1 and ALGORITHM 2. All clusters found by these two algorithms are contained in the list of clusters obtained by ALGORITHM 3. The additional clusters mainly contain nodes from several other clusters, hence cause an overlap between several clusters.

6.1.4 Comparison of the results

In order to find out which of the three algorithms leads to a partitioning of our graph into clusters which satisfies the requirements of our goal, we need to understand the outcomes. As stated before, the clusters found by ALGORITHM 1 and ALGORITHM 2 are equal. These two algorithms find a total of 17 clusters and 15 isolated nodes. On the other hand, ALGORITHM 3 finds 46 clusters and no isolated nodes. Of these 46 clusters, 29 clusters are new, while the other 17 clusters are equal to those found by the first two algorithms.

Before we can look at the 29 additional clusters found by ALGORITHM 3, we will need some additional definitions which will also be used further in this thesis, namely the definitions of connecting edges and shared nodes. As connecting edges we take all edges e with endpoints u and v in two different clusters, which together are not contained in any of the other clusters. So if we take C_i be the i-th cluster, then the set of connecting edges E_C is defined as follows:

$$E_C = \{e_{ij} \in E \mid \exists C_i, C_j \colon e_{ij} = (u, v), u \in C_i, v \in C_j, u, v \notin C_i \cap C_j, \forall C_k \colon \{u, v\} \not\subseteq C_k\}.$$

The definition of shared nodes between two clusters is more straightforward, as this set of nodes N_C consists of precisely those nodes that are included in multiple clusters, i.e.:

$$N_C = \{u \in V \mid \exists C_i, C_j \colon u \in C_i \cap C_j\}.$$

Combined, these two definitions can be used to describe the connections between clusters. For a visualisation of these definitions, see Figure 8.

Considering the 29 new and 17 recurring clusters obtained through ALGORITHM 3, shows that the majority of new clusters covers the connecting edges between the recurring ones or their shared nodes. Therefore, the 29 new clusters turn out to overlap the connections between the 17 clusters found by all three algorithms. Because of this, it is sufficient to consider the shared nodes and connecting edges between the 17 clusters instead of the new clusters. Therefore, we will continue our analysis by only considering the 17 clusters found by all three algorithms.

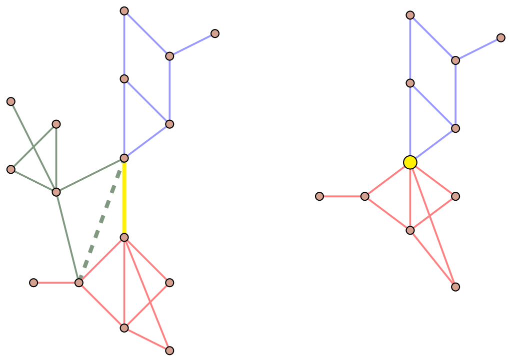

Figure 8: Example of the connection between two clusters (red and blue) through a connecting edge (thicker, yellow edge, left) and a shared node (larger, yellow node, right). The green, dotted edge in the left graph is an example of an edge which is not considered as a connecting edge as both endpoints are included in the third cluster (green).

6.1.5 Inside the clusters

Of the 17 clusters found by the three algorithms, one cluster contains only one indicator and one underlying factor node (N3b, F3a). As the goal of this thesis is to find clusters of indicators, this cluster will be left out. This leads to the list of sixteen clusters shown in Table 2, including each indicator using the colour from its covering capital. For an overview of the clusters including the corresponding indicator and factor names, see Appendix A.3.

1						**2**		**3**		**4**	
S2a	F1	N6b	S3a	S5d	S7c	E5a	S3a	N3a	N3d	E4d	N2e
E1b	F5	N6c	S4g	S6b	S7e	E3a	S4b	E4a	S1a	F3c	N2f
E1c	F7b	N7c	S4i	S6c		E3c	S6d	F3b	S6c	F5	N2g
E1d	F7c	S2b	S5a	S6f		E5b	S7g	F5	S6e	F7b	
E1e	F7d	S2c	S5b	S7a		F3b		F6b	S6f	F7c	
E3b	N3c	S2d	S5c	S7b		F5		N3c		F7d	

5	**6**	**7**		**8**	**9**	**10**	**11**
N2a	N3f	N5b	S4c	N7b	E1a	N4d	N6e
N2b	E2a	F5	S6b	N7a	E1d	F5	F6a
N2c	F6b	F6a	S7c	N7d	E2d	N4c	F6c
N2d	N1a	F6b		N7e	E4c	N4e	N6d
N6f	N1c	N5c			F7b		
	N3e	N5d			F7c		

12		**13**	**14**	**15**	**16**
S1b	S1d	E4b	N1d	S3b	S4f
E1c	S2b	E4a	N1e	S3c	F7a
E1e	S3a	S4a			F7d
F5	S4i				S4g
S1a					S4i
S1c					

Table 2: Overview of the remaining sixteen clusters with the underlying factors in grey. The first indicator name in each cluster is the starting point of the algorithm in that iteration. The colours of the indicators correspond to their capital.

The relations within and between clusters will be studied in more detail in Section 6.2. In the current section, we will focus on understanding the global meaning of each cluster as well as their location within and their connection to the triple bottom line. In order to understand the clusters, we look at the requirements belonging to each stock within the three capitals, as defined by Telos. Every indicator of the National Monitor of Sustainable Municipalities is part of one of these requirements. This allows us to consider the degrees to which a certain cluster covers each requirement. This has been done by considering the percentage of indicators belonging to a requirement which are also contained in the cluster in question. For instance, if a requirement R consists of four indicators, of which three are part of cluster C, then the overlap between C and R is 75%. These results have been used to determine the degree to which each requirement is represented in a cluster. So for example, if the overlap between cluster C and requirements R_1, R_2 and R_3 is 50%, respectively 33% and 100%, the degrees to which the three requirements are represented in cluster C are 27%, respectively 18% and 55%. This allows us to find the lists of requirements for each cluster as given in Appendix A.3.1. Furthermore, these lists give us enough information to give each of the clusters a title covering their contents, leading to the following names of clusters:

Cluster 1: *Living conditions*;

Cluster 2: *Income and capabilities*;

Cluster 3: *Living environment*;

Cluster 4: *Air quality*;

Cluster 5: *Emissions*;

Cluster 6: *Industrial soil use*;

Cluster 7: *Accessibility*;

Cluster 8: *Waste*;

Cluster 9: *Labour market*;

Cluster 10: *Water quality*;

Cluster 11: *Residential energy use*;

Cluster 12: *Social involvement*;

Cluster 13: *Infrastructure*;

Cluster 14: *Manure*;

Cluster 15: *Cultural heritage*;

Cluster 16: *Health*.

Considering these titles, one can already see that the clusters cover a variety of perspectives, ranging from social aspects such as *Living environment* and *Health*, to ecological aspects such as *Emissions* and *Manure*, and to economic aspects such as *Labour market*. However, in order to gain better insight in the clusters it is also useful to know the origin of the nodes within each cluster. Looking back at Table 2, a quick glance at the indicators within each cluster shows that a large number of indicators within a cluster are contained in the same stock in the National Monitor of Sustainable Municipalities, as can be seen through considering the numbers of each indicator (e.g. **E1**b and **E1**c). As these stocks consist of indicators which are likely to be correlated, this could indicate that the obtained clusters satisfy the systemic definition of the monitor by Telos.

This result might raise the question whether our choices regarding the directness of the correlations, as determined in Section 5.3.1, has influenced the clusters found by our algorithm. In order to check whether this has been the case, the algorithm has also been applied to the graph containing all medium and strong correlations as edges, hence without our choice of directness. The overlap between the clusters found through this computation and the sixteen found in our graph is large, as each of the sixteen clusters is covered by the clusters found in this computation[8]. Therefore, one could state that the influence of our choice of directness of the correlations is rather limited.

[8]As this analysis is only meant to test the influence of our choice, the results of this analysis are not included in this thesis.

Another observation is that while indicators of the ecological capital (N) are most often either contained in clusters with only other ecological indicators or underlying factors, those from the social-cultural (S) or economic capital (E) can mostly be found in clusters spanning multiple capitals. To clarify this observation, we will compute the shares of nodes belonging to each of the three capitals both including and excluding the share of nodes belonging to the list of underlying factors. An overview of these percentages can be found in Table 3.

Cluster	**Ecological capital**	**Social-cultural capital**	**Economic capital**	**Factors**
1	13% (15%)	56% (67%)	16% (19%)	16%
2	0% (0%)	40% (50%)	40% (50%)	20%
3	27% (38%)	36% (50%)	9% (13%)	27%
4	33% (75%)	0% (0%)	11% (25%)	56%
5	100% (100%)	0% (0%)	0% (0%)	0%
6	67% (80%)	0% (0%)	17% (20%)	17%
7	33% (50%)	33% (50%)	0% (0%)	33%
8	100% (100%)	0% (0%)	0% (0%)	0%
9	0% (0%)	0% (0%)	67% (100%)	33%
10	75% (100%)	0% (0%)	0% (0%)	25%
11	50% (100%)	0% (0%)	0% (0%)	50%
12	0% (0%)	70% (78%)	20% (22%)	10%
13	0% (0%)	33% (33%)	67% (67%)	0%
14	100% (100%)	0% (0%)	0% (0%)	0%
15	0% (0%)	100% (100%)	0% (0%)	0%
16	0% (0%)	60% (100%)	0% (0%)	40%

Table 3: Overview indicating the shares of nodes per capital or underlying factors for each cluster. The percentages between brackets denote the shares when omitting the underlying factors.

As can be seen in this table, the share of underlying factors within the clusters themselves is rather high. For example, the majority of nodes of Cluster 4 *Air quality* are underlying factors. Excluding these factors in this cluster therefore results in a large change in degrees within the capitals (from 33% to 75% for the ecological and from 11% to 25% for the social-cultural capital). Therefore, the connection between the underlying factors and the obtained clusters should not be overlooked and will be examined in Section 6.2.3.1.

In order to gain an insightful overview, we can also depict these shares on the triple bottom line as first shown in Figure 1. This results in the visualisation of the clusters as shown in Figure 9 in which each cluster is represented by a node with the coordinates $(x, y, z) \in \mathbb{R}^3$, with x, y, z the shares of nodes in the ecological, respectively social-cultural and economic capital. As there are multiple clusters which consist of nodes of a single capital, these are combined into nodes A and B, indicating clusters 5, 8, 10, 11, and 14, respectively 15 and 16.

Looking at Figure 9 shows that the sixteen clusters are equally divided between either being fully contained inside a single capital or in one or multiple interface areas. Moreover, it provides a clear overview of the location of each cluster, which will prove to be useful in the search for indicators to monitor trade-offs which will be performed in the next section.

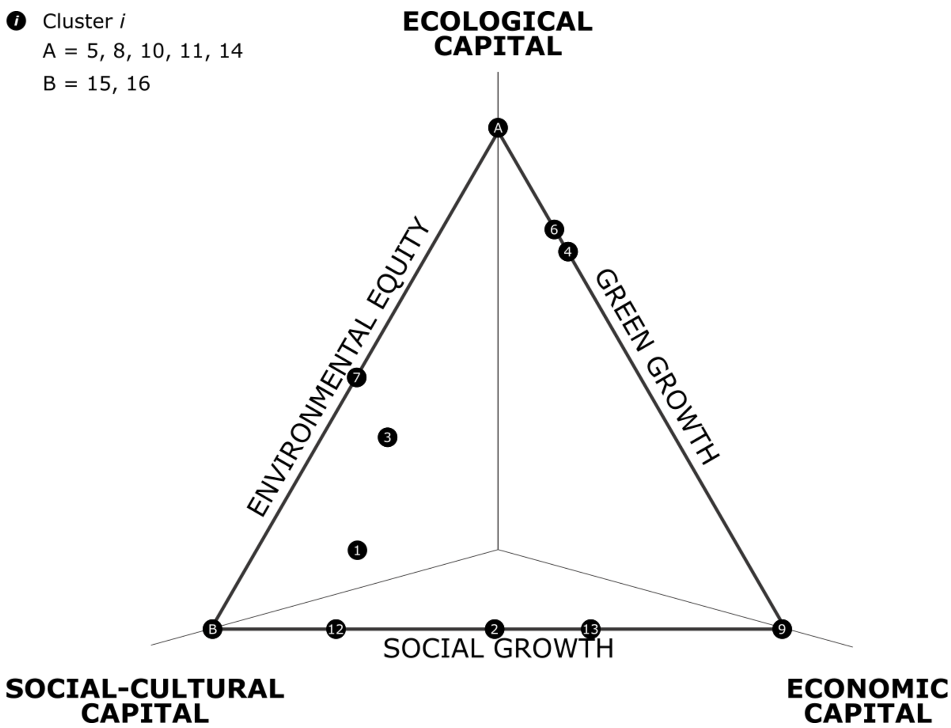

Figure 9: Visualisation of the location of each cluster within the triple bottom line. The number within each node indicates the cluster, the A and B indicate clusters 5, 8, 10, 11, and 14, respectively 15 and 16.

6.2 Focus points for monitoring trade-offs and approaching sustainability

6.2.1 Interaction between clusters

In our analysis of Algorithm 3 in Section 6.1.4, we have already mentioned the necessity of considering the overlap between clusters through connecting edges and shared nodes. In this section, this was done in order to distinguish which clusters should be taken into further consideration and which clusters almost solely pointed to areas of interaction. In the previous section, we have already seen that some clusters greatly interact with one another through connecting edges and shared nodes, meaning that these clusters are related to one another. This relation will be used in the next section to deduce several focus points for monitoring trade-offs as well as to determine focus points for monitoring and approaching sustainability. These focus points are indicators which are highly connected within the graph and turn out to be largely related to other indicators. Such indicators can give insight into the relations between the capitals and between clusters, as they can point at potential trade-offs and interactions through their connections. Because of this, these indicators can be of importance to Telos as well as policy makers.

In the current section, we will mainly focus on the existence of interactions between clusters. In order to gain insight in the interactions, we will visualise them using graphs. In these graphs, the set of nodes consists of all clusters, numbered 1 to 16. The edges of these graphs denote the existence of a connecting edge or shared node between the clusters, with their widths indicating the number of connecting edges or shared nodes, a wider edge indicating a higher number. This leads to the two graphs shown in Figure 10.

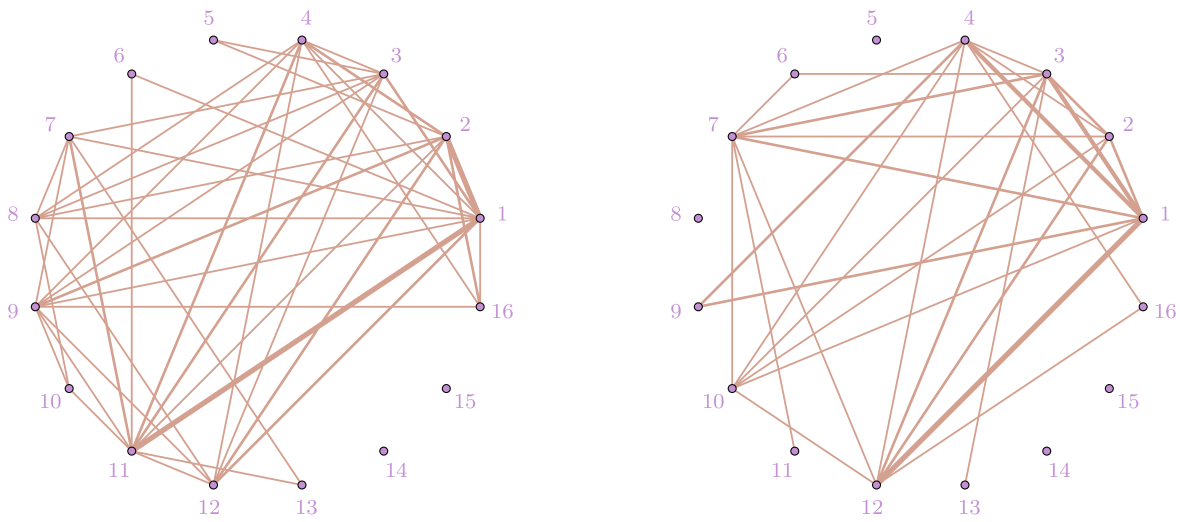

Figure 10: Graph showing the interaction of clusters through a connecting edge (left) or a shared node (left). The edge width indicates the number of connecting edges or shared nodes, a wider edge indicating a higher number.

There are a number of observations that can be made when observing these graphs. One can see, for instance, that in general, clusters are more likely to have a connecting edge than a shared node. Moreover, two clusters that share a node do not necessarily have a connecting edge between them, as can be seen when looking at, for instance, Cluster 3 *Living environment* and Cluster 13 *Infrastructure*. The same holds when considering connecting edges, since clusters containing a connecting edge do not always share a node. For example, even though Cluster 11 *Residential energy use* has connecting edges with ten other clusters, it has an overlapping node with just one, namely Cluster 7 *Accessibility*.

The difference in occurrences of connecting edges or shared nodes between clusters already gives an insight into the type of relations for a cluster of a certain nature. Clusters with the majority of their nodes within the social-cultural or economic capital mostly have shared nodes with other clusters, while those with a large share in the ecological capital seem more likely to be part of a connecting edge. The reason for this already becomes visible when looking at our graph of the National Monitor of Sustainable Municipalities, see Figure 12 in Appendix A.5. In this graph, most of the clusters with a large share of their nodes in the ecological capital can be found on the border and are connected to the rest of the graph through one node which is in most cases an underlying factor. This underlying factor is then also included in other clusters, leading to a shared node. Because of this, we will also look at connecting edges and shared nodes, excluding underlying factors in order to focus solely on the indicators as this is needed to find focus points. This will be done at the end of this subsection.

Other observations can be made when looking at Cluster 14 *Manure* and Cluster 15 *Cultural heritage*. These clusters have no connecting edge or shared node with any of the other clusters. This can easily be checked when looking at the graph of the National Monitor of Sustainable Municipalities as these two clusters are disconnected subgraphs, i.e. there is no path from the nodes in these clusters to a node outside that cluster. As both clusters lie entirely in a single capital (the ecological and social-cultural capital), the indicators within these clusters will not be part of any trade-offs in the triple bottom line.

In order to understand the interactions through connected edges or shared nodes, we need to know the main type of interaction (connecting edge or shared nodes) in which each cluster is involved and the degree of these interactions. Therefore, we will consider the number of connecting edges and shared nodes belonging to each cluster. Moreover, as a number of these connecting edges and shared nodes consist of underlying factors, we will also look at the shares of factors within the total numbers of connecting edges and shared nodes. For instance, looking at Cluster 1 *Living conditions* shows that this cluster has seven connecting edges with other clusters of which 63% contains a start and/or endpoint which is an underlying factor. The same cluster has seven shared nodes with other clusters of which 48% is an underlying factor. An overview of the numbers and shares of all clusters can be found in Table 4.

Table 4 shows the extent to which the underlying factors are present in the relations between the obtained clusters. Looking at the shares of the factors in each cluster already shows that they represent a large part of the relations between clusters. This representation demonstrates the need to consider the underlying factors when looking at focus points to monitor trade-offs and approach sustainability.

Cluster	**Connecting edges**	**Share factors**	**Shared nodes**	**Share factors**
1	7	63%	7	48%
2	9	66%	6	78%
3	8	65%	8	64%
4	8	77%	8	100%
5	2	100%	-	n.a.
6	2	100%	2	100%
7	7	93%	8	82%
8	6	100%	-	n.a.
9	8	90%	2	80%
10	4	100%	6	100%
11	10	85%	1	100%
12	7	50%	7	43%
13	2	100%	1	0%
14	-	n.a.	-	n.a.
15	-	n.a.	-	n.a.
16	4	83%	2	50%

Table 4: An overview of the number of connecting edges and shared nodes of each cluster with their respective shares of underlying factors.

Besides this, we will need to consider these relations excluding underlying factors as well, since this could give us insight in the nature of the relations between clusters based on their indicators. Therefore, instead of considering all connecting edges and shared nodes, we remove all edges containing an underlying factor as endpoint, and all shared nodes which are underlying factors. This results in the graphs shown in Figure 11. Looking back at Figure 10, one can easily see the impact of removing the underlying factors from the lists of connecting edges and shared nodes. Of the fourteen clusters having a connecting edge in the left graph in Figure 10, only nine are left. For the clusters that contain shared nodes, this is a reduction from twelve to eight clusters. The biggest impact in both cases, however, can be seen when considering the numbers of edges in the graphs as these have been significantly reduced. Moreover, the remaining edges have almost all reduced in width, hence in number of connecting edges or shared nodes between the clusters.

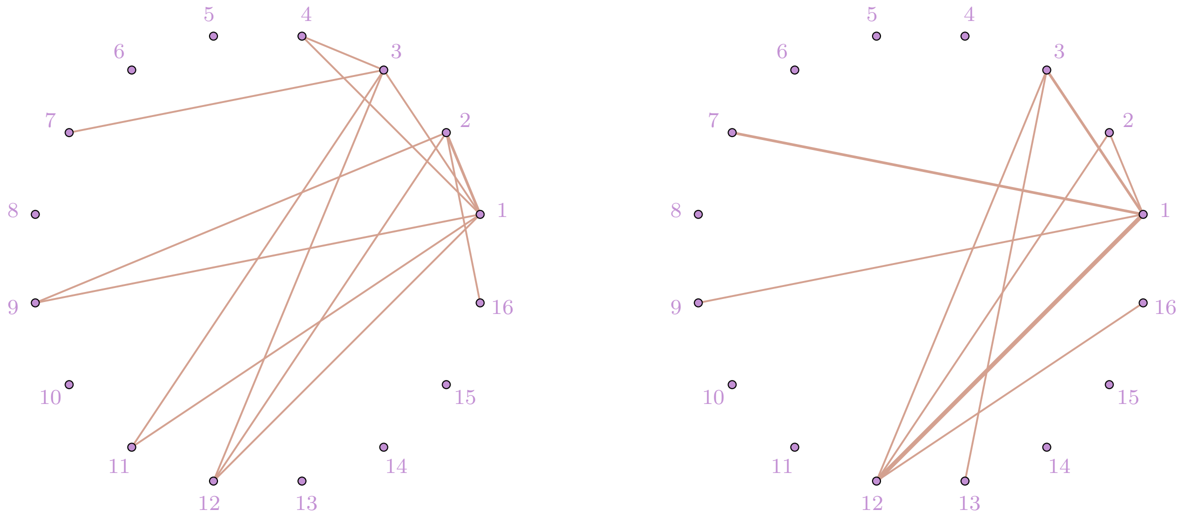

Figure 11: Graph showing the interaction of clusters through a connecting edge (left) or a shared node (left) excluding underlying factors. The edge width indicates the number of connecting edges or shared nodes, a wider edge indicating a higher number.

If we consider the four graphs of Figures 10 and 11, we can highlight four clusters as having the most relations with other clusters, both in- and excluding underlying factors, namely: Cluster 1 *Living conditions*, Cluster 2 *Income and capabilities*, Cluster 3 *Living environment*, and Cluster 12 *Social involvement*. This could indicate that these clusters can be considered as more significant than others both for trade-offs and for monitoring and approaching sustainability. Looking back at Table 4, one can see that these are the clusters with the lowest shares of factors for both connecting edges and shared nodes. Moreover, if we look back at Table 3 and Figure 9, one can see that a large share of the nodes from these clusters are part of the social-cultural capital, with for Cluster 2 *Income and capabilities* the share of nodes originating from the economic capital being just as large. If we consider the clusters that interact with these four through a shared node, we can easily see that in most cases the majority of their nodes also belongs to either the social-cultural or the economic capital.

Studying the precise list of connecting edges between clusters shows that the majority of these edges (85%) belong to one of the three capitals, meaning that both endpoints are part of the same capital. Only 3 out of 20 edges are in fact part of an interface and none are part of the Green Growth interface. Therefore, one could state that though the clusters are equally distributed between capitals and interfaces, the main interaction between clusters turns out to be within the three capitals or via the underlying factors. This latter part could mean that the focus points for monitoring and approaching sustainability for municipalities, which will be investigated in the next section, will most likely be found through considering the specific characteristics of that municipality, since these characteristics are highly connected to the underlying factors. Moreover, the first part of the statement would indicate the importance of considering the overlap between clusters based on their capitals. As the interactions within the National Monitor of Sustainable Municipalities could be situated within the three capitals rather than between them, these overlaps between clusters could point at areas within capitals that are important for monitoring trade-offs. These assumptions will be fully specified and examined in the next sections.

6.2.2 Focus points for monitoring trade-offs

As stated before, the main interaction between clusters seems to be within a certain capital or through underlying factors. In order to use this result in monitoring trade-offs between capitals, we need to examine whether there are any specific indicators causing these interactions between clusters. Since the clusters consist of precisely those indicators which are highly connected to one another and can span multiple capitals, these clusters can be seen as the fields in which trade-offs occur. Therefore, understanding which indicators play an important role in the interactions between the clusters can lead to an insight in focus points for monitoring trade-offs.

In order to find the indicators which can be considered as focus points, we will look at all interactions excluding underlying factors. This allows us to zoom in on the level of indicators within each cluster, rather than looking at the number of connecting edges and shared nodes between these clusters. Because of this, we can find indicators within one cluster that are related to other clusters, either through a connecting edge or because they are a shared node. We will take another look at both cases, as well as at the case when an indicator is both part of a connecting edge and a shared node.

One should note that not all indicators within our graph are part of a cluster. Either because their correlation is not strong enough to be considered by the algorithm, or because the iteration of the algorithm has reached its boundary before that particular node has been added. Indicators which are excluded from the sixteen clusters are called external indicators. As some of these external indicators do in fact correlate strongly with indicators inside certain clusters, we will also need to consider these external nodes in our search for focus points.

Connecting edges
Any change in value of an indicator that is part of a connecting edge between two clusters can have a direct effect on its own cluster, and could affect the other cluster through its connecting edge. This could result in an indirect impact. Therefore, such an indicator can be considered as an indirect influence.

When excluding underlying factors, we find 21 connecting edges with weights varying from medium to strong. The majority of these edges (90%) starts or ends in Cluster 1 *Living conditions* and the main part of these edges ends in Cluster 2 *Income and capabilities*. Looking even closer at the edges, one can see that connecting edges from a cluster mostly involve the same indicator within that cluster. For instance, all connecting edges from Cluster 11 *Residential energy use* contain the indicator Average electricity consumption households (N6d). For Cluster 2 *Income and capabilities* indicators Share starters (E3a) and Risky behaviour (S4b) both take up a share of 33% of the connecting edges with this cluster. This indicates that these indicators play an important role both inside and outside their own cluster.

Shared nodes
Shared nodes between two clusters can be considered as having a direct relation to both clusters since an increase or decrease in value of the shared node could affect both clusters at the same time. When we exclude underlying factors, we can find 15 shared nodes between the sixteen clusters. As was the case with the connecting edges, the majority of these shared nodes (80%) is part of Cluster 1 *Living conditions*. Contrary to the previous case, the main part of these nodes is shared with Cluster 12 *Social involvement*, closely followed by Cluster 3 *Living environment*. One should note that this strong involvement of Cluster 1 *Living conditions* is a result of the composition of this cluster as this cluster contains indicators from different stocks within all three capitals.

Another observation can be made when looking at the capitals belonging to the shared nodes. The majority of nodes (67%) originate from the social-cultural capital, with only one shared node coming from the ecological capital. Looking at the level of stocks, it appears that the main part of shared nodes is part of either the stock *Labour* of the economic capital, or the stocks *Health* and *Residential Environment* of the social-cultural capital. This suggests that these stocks can be seen as particularly important when looking at monitoring trade-offs.

Both a connecting edge and a shared node
Looking at the indicators that are both a shared node and part of a connecting edge, we find 10 indicators satisfying this condition (E1c, E1d, E1e, N3c, S2b, S4g, S4i, S6b, S6c, S6f). As before, the main share of these indicators is from the social-cultural capital, followed by the economic. Only one of the indicators comes from the ecological capital. Zooming in once more on the level of stocks, we see that the share of indicators which are part of the three stocks named before has increased. As before, this might indicate that these stocks play an important role in our search for focus points regarding trade-offs.

External nodes
As stated at the start of this subsection, there are a number of indicators that are not part of any of the sixteen clusters, but which could have an effect on at least one of the clusters through a correlation with an indicator inside that cluster. For instance, through the chosen boundary and starting point of our algorithm, the indicator Dropouts (S7d) is not part of any of our clusters. Nevertheless, this indicator is strongly connected to nine other indicators of different clusters, namely clusters 1, 3, 9 and 12.

A large share of external indicators (55%), however, are part of just one edge ending in only one cluster. For instance, the external indicator High- and medium tech employment (E5c) is only connected to Capacity university education/higher professional education (E5b), which is only contained in Cluster 2 *Income and capabilities*. Such external indicators can mostly be found at the edges of our graph in Figure 12. As the connection of these indicators to the National Monitor of Sustainable Municipalities as a whole can be considered as being weaker than that of the other cases, we will only include the external indicators which are connected to indicators from more than one cluster. This resulted in the inclusion of 4 external indicators out of 17 possible ones in our analysis, namely S3d, S4h, S5f, S7d, all from the social-cultural capital. Indicators such as these can be seen as bridges between the involved clusters, hence could play an important part in monitoring trade-offs.

Through consideration of the complete list of indicators which are a shared node, part of a connecting edge, or an external node, we can deduce several links between this group of indicators themselves. Investigating their interrelations and observing their connections with the other indicators in the graph leads to eight indicators of clear importance. Between these indicators, some have stronger connections than others as they have more or stronger correlations with other indicators. Moreover, some of the indicators in this list are direct or indirect neighbours in the graph, i.e. are connected by either one or two edges. Therefore, we will distinguish between first and second order indicators, leading to the division of indicators ordered by their capital on the next page.

First order indicators	**Second order indicators**	(6.2)
Unemployment (E1c)	Concentration of NOx (N2e)	
Noise intensity (N3c)	Turnout national elections (S1d)	
Poor households (S2c)	Satisfaction with living environment (S6c)	
Risky behaviour (S4b)		
Dropouts (S7d)		

One should note that both first and second order indicators are part of a connection between two clusters, either as a shared node or through a (connecting) edge between these clusters. In case of a connection through an edge, it is important to remember that the role of the first or second order indicator in the field of trade-offs operates through another node as well which is not necessarily part of this list. Moreover, one should take the unit of the involved indicators into account in order to determine the direction of these connections.

6.2.3 Focus points for monitoring and approaching sustainability

Besides looking for focus points to monitor trade-offs, we want to find focus points for monitoring and approaching sustainability. In this case, it is useful to distinguish between two cases: including underlying factors and excluding underlying factors. Including underlying factors will allow us to delve into specific focus points for typologies of municipalities. Excluding underlying factors will lead to focus points which can be considered important in general.

6.2.3.1 Focus points including underlying factors

When considering focus points for approaching sustainability including underlying factors, we are considering all connecting edges and shared nodes, including those edges of which both endpoints are underlying factors. As this results in a list of 73 possible focus points, this is too elaborate to use in monitoring and approaching sustainability. It could, however, allow us to indicate the influence of several aspects within society on elements of sustainability. After all, each underlying factor could indicate which cluster is highly related to a certain type of municipality. Therefore, we will use the list of possible indicators and underlying factors to deduct possible fields of interaction for the different typologies of municipalities as defined by Telos (2017).

The typologies of municipalities as defined by Telos can be distinguished into two types: quantitative and qualitative typologies. A combination of these types then leads to a typology of a municipality. The quantitative typologies used by Telos all concern the size of the municipality, allowing a distinction between small, medium, and large municipalities. As our underlying factors include the underlying factor *density* (F5), these quantitative typologies are already sufficiently covered. Therefore, we will only focus on the qualitative typologies as defined by Telos (2017). In their report, Telos states eleven qualitative typologies, shown in Table 5.

1)	Growing municipality	Municipality with an increase of at least 5% in residents in 2007-2017.
2)	Shrinking municipality	Municipality with a decrease of at least 2% in residents in 2007-2017.
3)	New Town	Municipality of which at least 40% of the residences is built after 1985.
4)	Historical Town	Municipality of which at least 8% of the residences is built before 1905 and which has at least 1 monumental city/village view.
5)	Residential town	Municipality with an employment function of at most 60.
6)	Commuter town	Municipality with an employment function of at least 100 and at least 14,000 jobs.
7)	Green municipality	Municipality with a share of forest and natural area of at least 30%.
8)	Agricultural municipality	Municipality with a share of agricultural land of at least 75%.
9)	Centre municipality	Municipality with at least 15% of the residents in a COROP area and a score of more than 50 on facilities.
10)	Old industrial municipality	Municipality of which at least 53% of its residents in 1960 used to work in the industry.
11)	Tourist municipality	Municipality of which at least 10% of its business is focused on tourism or of which at least 14% of its working population is active in the tourism sector.

Table 5: List of all qualitative typologies of municipalities as defined by Telos (Telos, 2017).

Before we can look at the connection of the clusters and these typologies, we first need to consider the relation between the underlying factors, used in the analysis of our graph, and the clusters found in the previous section. This is essential as the connection between clusters and typologies can be examined through looking at these underlying factors. In order to determine the relation between the underlying factors and clusters, we will look at the normed values of the indicators in each cluster. These normed values ensure that the data of each indicator are in the same unit. This is essential as we will use the averages of the normed values within each cluster to compute the correlations between clusters and underlying factors.

Using these correlations, we can gain insight in the relation of each underlying factor with a cluster. The resulting correlations between each factor and the sixteen clusters can be seen in Table 6. In this table, all correlations are shown by a sign, --, -, 0, +, or ++, denoting either a strong negative, medium negative, weak, medium positive, or strong positive relation, using the same definitions as before. The exact (medium and strong) correlations can be found in Appendix A.2.8.

As most clusters contain underlying factors besides indicators, the factors included in these clusters have been highlighted. In most cases, the clusters show a medium or strong correlation with at least their included factors. For some clusters, however, this is not the case with all their factors. A rather extreme, yet illustrative example is Cluster 4 *Air quality*. This cluster contains several underlying factors, namely F3c, F5, F7b, F7c and F7c, yet the correlations between this cluster and any of the underlying factors are weak. This particular case is, however, a special one and can be explained through the nature of its indicators. Cluster 4 *Air quality* contains besides the factors named before, the three indicators concerning concentrations from the ecological capital

	F1	F3a	F3b	F3c	F3d	F5	F6a	F6b	F6c	F7a	F7b	F7c	F7d
Cluster 1	++	+	0	0	-	-	--	-	++	0	-	0	0
Cluster 2	+	0	-	0	0	++	+	0	-	0	0	0	0
Cluster 3	0	0	0	0	0	-	-	-	+	0	-	0	0
Cluster 4	0	0	0	0	0	0	0	0	0	0	0	0	0
Cluster 5	0	0	-	0	0	+	+	0	0	0	0	0	0
Cluster 6	0	+	0	0	0	--	-	-	+	0	-	0	0
Cluster 7	0	-	-	0	0	++	++	++	--	0	+	-	0
Cluster 8	0	0	0	0	0	0	0	-	+	0	0	0	0
Cluster 9	0	0	0	0	0	0	0	0	0	+	+	-	0
Cluster 10	0	0	0	0	0	0	0	0	0	0	0	0	0
Cluster 11	--	0	0	0	0	+	+	+	-	0	+	-	0
Cluster 12	++	0	0	0	0	-	-	-	+	+	0	0	0
Cluster 13	0	0	0	0	0	0	0	0	0	0	0	0	0
Cluster 14	0	0	0	0	0	0	0	0	-	0	0	0	0
Cluster 15	0	0	0	0	0	0	0	-	0	0	0	0	0
Cluster 16	++	0	0	0	0	0	0	0	0	+	0	0	0

--: $-1 \leq c \leq -0.5$, - : $-0.5 \leq c \leq -0.3$, 0: $-0.3 \leq c \leq 0.3$, +: $0.3 \leq c \leq 0.5$, ++: $0.5 \leq c \leq 1$.

Table 6: Overview of the correlations c between the underlying factors and clusters, -- and - indicating a negative, 0 a weak, and + and ++ a positive correlation. The highlighted combinations are part of the corresponding cluster.

together with the indicator Share of clean cars (E4d) from the economic capital. Looking at the connections in our graph, one can see that indicator E4d is in fact the only indicator of this cluster which is connected to all included underlying factors. The other indicators are only connected to the underlying factor *density* (F5). Therefore, the correlation with the average normed values of the indicators within this cluster turns out to be only weakly correlated to the involved underlying factors, while the correlations in the graph itself are rather strong on average.

This special case is just an example of why certain correlations might be weaker than expected through simple observation of the cluster's elements. Note that this does not mean that the obtained clusters correlate weakly within themselves. It does, however, show that one cannot simply state that an underlying factor included in a cluster always has a direct relation to all indicators in that cluster. Nevertheless, it is always indirectly related through the other indicators inside each cluster.

Table 6 also shows several relations between factors and clusters that do not contain that specific factor, such as Cluster 1 *Living conditions* and F6a. The reason for this can be found through considering the connecting edges between clusters. As shown in Table 4 in the previous section, the underlying factors take up a large share of the connecting edges in most clusters. Therefore, the found correlations between clusters and underlying factors which are not part of that cluster can be the result of taking the average normed values of the indicators within each cluster. Taking this average can be seen as combining the connected edges from that cluster to the underlying factor in question, leading to a medium or strong connection with this factor as shown in Table 6.

In order to understand what these correlations mean for monitoring and approaching sustainability, we will look at the correlation between Cluster 12 *Social involvement* and Income (F1). Looking at Table 6, one can see that this relation is strongly positive, meaning that social involvement is higher when income is higher as well. The reason for this can be found when observing the contents of Cluster 12 *Social involvement*. The indicators of this cluster all cover aspects related to income levels, such as employment and social assistance. Therefore, in the case of a high income, the normed values of the indicators of this cluster are higher as well, leading to a strongly positive correlation between the cluster and F1.

Considering Table 6, we can now continue by looking at the relation between the underlying factors and the typologies. In order to determine this relation, we will perform a Welch Two Sample t-test. This will give an indication whether an underlying factor has a significantly different effect on municipalities with a certain typology. For each t-test we will divide our data sample into two groups: municipalities with typology T, municipalities without typology T. We will then perform the t-test on these two groups to determine whether they have equal means regarding an underlying factor F. If the outcome is significant with a p-value of $p < 0.01$, we will denote the effect of factor F on typology T by -- or ++ (strong negative, strong positive effect respectively). A p-value of $p < 0.05$ will result in - or + (negative, positive effect respectively). If the outcome is not significant, hence $p > 0.05$, we will denote this by 0, stating that there an insignificant effect. The results of the t-tests are combined into the following table, using the enumeration of the typologies as defined before:

	F1	**F3a**	**F3b**	**F3c**	**F3d**	**F5**	**F6a**	**F6b**	**F6c**	**F7a**	**F7b**	**F7c**	**F7d**
Typology 1	0	0	--	++	0	++	++	++	--	++	++	--	--
Typology 2	--	0	0	--	++	--	0	0	0	--	--	++	++
Typology 3	++	0	-	++	--	++	0	0	0	++	++	-	--
Typology 4	--	0	0	0	0	0	0	0	0	0	0	0	0
Typology 5	+	0	-	0	++	--	0	--	0	--	--	++	++
Typology 6	--	--	--	+	0	++	++	++	--	+	++	--	--
Typology 7	++	--	--	0	++	0	--	--	--	0	--	0	++
Typology 8	0	+	++	--	0	--	--	--	++	0	--	++	0
Typology 9	--	-	--	0	++	++	++	++	--	+	++	--	--
Typology 10	--	--	++	0	--	+	++	++	-	--	0	0	+
Typology 11	--	0	--	0	++	0	0	0	-	--	0	+	++

Table 7: Overview of the outcomes of the t-test between the underlying factors and the qualitative typologies by Telos, -- and - indicating a negative, 0 a weak, and + and ++ a positive relation.

A quick glance at Table 7 already shows that the underlying factors and typologies of Telos greatly interact. This shows that the underlying factors are well suited as a way of gaining insight in the relation between certain typologies and clusters. This relation can be obtained through comparing Tables 6 and 7. In other words, the results from both tables allow for an insight in fields of interaction for a certain type of municipality, hence could be used by a municipality in its search for focus points. In order to illustrate how the results from both tables can be combined, we will look at the municipality of Oss.

The municipality of Oss has exactly one typology: typology 10. It is an old industrial municipality which will have to be considered when determining a sustainability approach. Looking back at Table 7, one can see that typology 10 has the following relations with the underlying factors:

- a strong positive relation with Industry, Residential area, and Industrial area (F3b, F6a, F6b);
- a positive relation with Density and Age: 65 and above (F5, F7d);

- a negative relation with Agricultural area (F6c); and
- a strong negative relation with Income, Agriculture, Non-commercial services, and Age: 0 to 25 (F1, F3a, F3d, F7a).

We can now use the relations between clusters and factors to determine the relation between the typology of Oss and the sixteen clusters. We will do this through combining the strengths of the relations between cluster C and factor F, and between typology T and factor F. This can be done using the conversion table given in Table 8.

	Relation F **and** T				
Relation F **and** C	++	+	0	-	--
++	++	+	0	-	--
+		+	0	-	-
0			0	0	0
-				+	+
--					++

Table 8: Conversion table of the strength of the relationships between an underlying factor F and cluster C, and between F and a typology T into the strength of the relation between C and T.

Using this conversion table, the municipality of Oss turns out to have a typology which is, amongst others, negatively related to Cluster 6 *Industrial soil use* and positively related to Cluster 7 *Accessibility*. In their approach of sustainability such indications of interactions could be used by, for instance, policy makers of this municipality, to determine whether an idea in a certain field or cluster might result in interactions with other fields or clusters as well. This can give users such as policy makers a way of taking the characteristics of the municipality and their potential impacts into account. Moreover, it could give them a starting point from which they could orientate towards finding focus points related to the underlying factors and their typology.

To give an example, we will look at the relation between the typology of Oss and Cluster 7 *Accessibility*. As stated before, the municipality of Oss is an old industrial municipality. Combined with a good accessibility, this has attracted several industries leading to aspects such as soil pollutions. When considering new approaches in sustainability, the municipality of Oss should take their accessibility into account and focus on sustaining this advantage, while at the same time taking care of possible environmental consequences. Policy makers could therefore use the knowledge of the positive relation between Cluster 7 *Accessibility* and typology 10 as a starting point but at the same time as advice regarding aspects that have to be taken into consideration.

Note that though the combined results of Tables 6 and 7 allow for an insight in the relation between the characteristics of a municipality and the clusters, they can only suggest possible side-effects caused by a sustainability policy. These suggestions can until now only be used as possibilities, as the results do not allow for a detailed foundation of these side-effects. Investigating these side-effects would go beyond the scope of this thesis.

This approach can of course be used by other municipalities as well, as the municipality of Oss was simply an example to clarify the use of the obtained relations between underlying factors, clusters, and typologies. Furthermore, the differences in fields of interactions between municipalities of a certain typology, underlying factors and clusters show that it is not possible to state a general focus point for all municipalities for monitoring and approaching sustainability. However, the results of this section do provide a way of finding which clusters are related to a certain typology and therefore allow for an insight in the different needs of the eleven typologies by Telos.

6.2.3.2 Focus points excluding underlying factors

As stated before, another approach to find focus points for monitoring and approaching sustainability is to exclude underlying factors. When investigating focus points to monitor trade-offs, this has been done through considering those indicators which serve as connections between clusters. Besides these indicators, there are also some indicators which have a strong connection with the majority of indicators within their cluster. Therefore, these indicators could be considered as the most important within their cluster.

The indicators with strong connections inside their cluster are mostly the nodes which served as starting point in an iteration of our algorithm. These starting points were the nodes with the highest degree in the graph, hence the nodes with the most connections. However, having the most connections does not always mean that that indicator in particular has the strongest connections. Therefore, we have examined each cluster in order to ensure that we do not overlook an indicator with a stronger connection than the starting point of that cluster. This leads to the following list of indicators, of which all but one (N2b) are indeed the starting point of the algorithm in that cluster:

1) Financial assets household (S2a);
2) Share highly educated people (E5a);
3) Noise annoyance (N3a);
4) Share of clean cars (E4d);
5) Emission of NOx (N2b);
6) Land surface with a 10^{-6} risk contour (N3f);
7) Distance to public green (N5b);
8) Residual waste (N7b);
9) Employment function (E1a);
10) Phosphorous emissions to surface water (N4d);
11) Energy label houses (N6e);
12) Volunteers (S1b);
13) Access to main roads (E4b);
14) Chronically sick people (S4f).

Note that we have excluded indicators from Cluster 14 *Manure* and Cluster 15 *Cultural heritage* from this list as these clusters both contain precisely two elements which are both indicators and because these clusters are disconnected from all others. Therefore, both indicators could be considered as equally important inside these clusters but are not related to the graph as a whole.

Besides being important for monitoring trade-offs, the focus points found in the previous section can also be considered as focus points for monitoring and approaching sustainability in general. These focus points are strongly connected to other indicators, either directly through one, or indirectly through two edges. Therefore, these focus points should be considered in this section as well. This also holds for the stocks *Labour*, *Health* and *Residential Environment* of the economic, respectively the social-cultural capital. As in the previous section, these stocks can be seen as important in monitoring and approaching sustainability.

Looking at the relations between the indicators in the list above and those given in the previous section, (6.2), four of the indicators (E5a, N3a, S1b, S2a) that have the strongest connections within their own cluster are directly related to one or more first order indicators from (6.2). Other indicators (E1a, E4d, N5b, N6e, S4f) are connected to these first order indicators through two edges, hence indirect. For the other indicators (E4b, N2b, N3f, N7b), this is not the case. Most of these indicators are part of clusters which are on the edge of the graph, such as Cluster 5 *Emissions* and Cluster 13 *Infrastructure*. Taking these observations into account, we can extend the list of first and second order nodes given in (6.2), leading to the following list of seventeen indicators, ordered by their capital:

First order indicators	**Second order indicators**	(6.3)
Unemployment (E1c)	Employment function (E1a)	
Access to main roads (E4b)	Share of clean cars (E4d)	
Emission of NOx (N2b)	Concentration of NOx (N2e)	
Noise intensity (N3c)	Distance to public green (N5b)	
Land surface with a 10^{-6} risk contour (N3f)	Energy label houses (N6e)	
Residual waste (N7b)	Turnout national elections (S1d)	
Poor households (S2c)	Chronically sick people (S4f)	
Risky behaviour (S4b)	Satisfaction with living environment (S6c)	
Dropouts (S7d)		

Looking at the connections from all these indicators combined, it turns out that with just the first order indicators we can already directly reach 53% (50 out of 94) of the indicators in our graph. Including the second order indicators as well, this increases to 69% (65 out of 94), showing once more the strong degree of connectivity of these indicators. Therefore, one can see the list of indicators in (6.3) as potential focus points for monitoring and approaching sustainability.

The results from including and excluding underlying factors once more highlight that the main interactions between clusters are through the underlying factors and within the three capitals as stated in Section 6.2.1. Moreover, they give an indication for several focus points within the three capitals, as well as providing insight in the different needs regarding the clusters for each municipality based on their typology. Therefore, combining the information from (6.3) with the insights from observing both Tables 6 and 7 could provide useful focus points for monitoring and approaching sustainability.

7 Conclusion

This thesis aimed to provide an insight into the interdependence of the three capitals in the triple bottom line framework. This has been done by determining clusters of indicators within and between different capitals and through pointing at fields in which trade-offs are likely to exist. In order to achieve this, the following four research questions have been investigated:

1. What is the relationship between indicators within each capital?
2. What is the relationship between indicators between different capitals?
3. Which clusters of indicators can be found within these related indicators?
4. In the context of the triple bottom line framework:
   (a) Which indicators can be used as focus points for monitoring trade-offs?
   (b) Which indicators can be used as focus points for monitoring and approaching sustainability?

In search for an answer to the first and second research question, each capital and interface has been considered in turn. During this analysis, all correlations were examined for their strength and whether they were direct or indirect. Many of the correlations turned out to be indirect, leading to the inclusion of seven underlying factors in the further analysis in this thesis.

Studying the relations of these underlying factors then showed that only five of them were part of a direct relation between indicators and factors. The other two were not part of any direct correlation and were excluded from further analysis. The same held for some indicators of the National Monitor of Sustainable Municipalities which were therefore not taken into consideration in the remainder of the research either. This investigation ensured that all correlations between the remaining indicators and underlying factors were direct ones. These correlations were, therefore, precisely the relations between indicators within and between capitals, which answered the first and second research question.

Together, the answers to the first two research questions provided a suitable basis for the third. In this question, a graph was constructed consisting of the remaining indicators and underlying factors connected by their direct correlations. After this, a clustering method was investigated and adapted, leading to an adapted version of the algorithm ROUND[9] (Demaine et al., 2005). The adaptations of ROUND were made to ensure that the obtained clusters were suitable for the goal of this thesis. Application of the adapted algorithm to the graph of the National Monitor of Sustainable Municipalities resulted in seventeen clusters of which sixteen satisfied the goal of this thesis. The excluded cluster only contained one indicator and one underlying factor, hence did not meet the requirement that a cluster should have at least two indicators. This requirement was needed as the aim of the third research question was to find clusters of indicators within the related indicators.

The sixteen remaining clusters were investigated in more detail regarding both their meaning and contents, as well as their interactions within themselves and with the other clusters. The composition of each cluster as well as their connection to other clusters gave insight regarding the interdependence of the three capitals in the triple bottom line: the second part of our goal. They showed that the main interaction between clusters turns out to be within the three capitals or through the underlying

[9] See Appendix A.4 for the adapted algorithm ROUND.

factors. This implied that the majority of trade-offs would originate from within the three capitals rather than between them and would indirectly work on the interfaces via the obtained clusters. This statement has been supported by the discovery of eight focus points for monitoring trade-offs, namely:

First order indicators	**Second order indicators**
Unemployment (E1c)	Concentration of NOx (N2e)
Noise intensity (N3c)	Turnout national elections (S1d)
Poor households (S2c)	Satisfaction with living environment (S6c)
Risky behaviour (S4b)	
Dropouts (S7d)	

The eight focus points in the previous list all have a correlation with at least one other indicator in the graph, denoting precisely a potential trade-off between two indicators. Trade-offs are situations concerning two aspects in which a positive change in one, with respect to sustainability, results in a negative change in the other. Therefore, these focus points for monitoring trade-offs can give users such as policy makers insight in the potential impact of a policy in one field of sustainability on another field. Taking these connections into account could help both policy makers and Telos in monitoring and approaching sustainability as it shows areas in which potential undesired effects could take place.

Besides leading to these focus points for monitoring trade-offs, the clusters also point at indicators which can be seen as focus points for monitoring and approaching sustainability. These indicators were determined using two perspectives: including underlying factors and excluding underlying factors. The first perspective resulted in a way of finding focus points for each qualitative typology as defined by Telos, which can be used by municipalities to determine core areas in their sustainability approach. The second perspective led to a list of indicators which serve as core indicators within the clusters for monitoring sustainability. Combining this list with the list of focus points for monitoring trade-offs led to the following list of focus points for monitoring and approaching sustainability:

First order indicators	**Second order indicators**
Unemployment (E1c)	Employment function (E1a)
Access to main roads (E4b)	Share of clean cars (E4d)
Emission of NOx (N2b)	Concentration of NOx (N2e)
Noise intensity (N3c)	Distance to public green (N5b)
Land surface with a 10^{-6} risk contour (N3f)	Energy label houses (N6e)
Residual waste (N7b)	Turnout national elections (S1d)
Poor households (S2c)	Chronically sick people (S4f)
Risky behaviour (S4b)	Satisfaction with living environment (S6c)
Dropouts (S7d)	

This list was then divided into first and second order indicators based on the strength of their connections. Together, these first and second order indicators are sufficient to reach 69% of the included indicators through a direct connection.

7.1 Recommendations to Telos and policy makers

The knowledge obtained from the previous lists of indicators and the insight in the interactions between clusters can be of assistance to Telos in their advice and explanations regarding the National Monitor of Sustainable Municipalities and aid policy makers in their decisions regarding sustainability approaches. Based on the results found in this thesis, there are a number of recommendations which can be given to Telos. In order to give these recommendations, both for Telos and policy makers, one has to look back at the clusters found in this thesis and in particular at the list of first and second order indicators derived from these clusters. As stated before, these indicators serve as focus points for monitoring and approaching sustainability and can be used by Telos and policy makers as guideline and starting point when defining a new sustainability approach.

Considering the clusters, one can see that indicators from the social-cultural and economic capital are well represented. These indicators can be used by policy makers to identify and determine key objectives regarding growth and welfare. Considering those clusters containing both indicators from the ecological capital and indicators from either the social-cultural or the economic capital can enable the policy makers to identify environmental objectives and lock-in risks. Through this, policy makers could build on the guidelines of the World Bank (2012) as stated in Section 3.3. For Telos, these guidelines could be of use in their advice and explanations of the National Monitor of Sustainable Municipalities and in their aid regarding sustainability in general.

In both cases, it is recommended to combine the results of this thesis with the characteristics of the municipality or region in which the policy is implemented. Moreover, both Telos and policy makers are advised to thoroughly examine the applicability of the focus points and clusters found in this thesis in the concerning municipality or region. A potential approach could be to combine the results of this thesis with the knowledge obtained from the overview of influential factors on a municipal level, found by Telos (2016a). Though this has been beyond the scope of this thesis, this will be recommended for further research by Telos.

Another recommendation for Telos concerns the composition of the National Monitor of Sustainable Municipalities itself. Looking at the stocks of the national monitor, one could wonder whether the clusters found in this thesis suggest the need for different or new stocks. When considering the indicators within each cluster, one can see that a large number of indicators within a cluster are part of the same stock in the National Monitor of Sustainable Municipalities. Therefore, one could state that the current stocks as defined by Telos are feasible for monitoring sustainability, and that, based on these clusters, it does not seem necessary to define new stocks.

If one takes a closer look at the indicators inside each cluster, one can see that the ecological capital tends to group itself in distinct clusters. Looking at the indicators of this capital shows that these are defined from an extrinsic perspective rather than from an intrinsic one. The reason for this mostly lies in the availability of data. Still, a recommendation to Telos is to look at the possibility of including more ecological indicators that measure the intrinsic value of sustainability.

Through using these recommendations, the outcome of this thesis can aid Telos in their advice and explanation of impacts of the indicators of their monitor. With this, the last part of the research goal of this thesis has also been covered. Through this, this thesis has granted insight in the interdependence of the three capitals in the triple bottom line, and has highlighted several focus points for monitoring and approaching sustainability, something which, to the best of our knowledge, has not been done before.

8 Discussion

In this thesis, several choices have been made, each with their own limitations. Most of these limitations have already been mentioned and clarified in the previous sections of this thesis. In the current section, we will cover these limitations in detail, divided by their overarching subject, and give indications for further research.

8.1 Limitations of the study

8.1.1 Theoretical framework

One of the choices made during this thesis concerned the selection of our conceptual framework. In this thesis, we have used the triple bottom line framework as point of departure. The decision to use this framework was mainly because Telos has used this framework as a foundation for their National Monitor of Sustainable Municipalities. Though this conceptual framework is widely used in the field of sustainability and backed by some scientific literature, one should note that this framework itself is not a real scientific framework. Therefore, we have to consider the validity of this framework for measuring sustainability.

Looking back at the results of this thesis, these results clearly show the existence of the three capitals as almost half of the obtained clusters fall in one of the three capitals. The same holds for the majority of the interactions between the clusters. Looking at the three interfaces, this thesis has shown that almost half of the obtained clusters fall in one of the three interfaces or are part of all three capitals. This would indicate the existence of the three interfaces though this can be considered as less apparent, as the main share of the connections are part of the capitals, rather than the interfaces. Therefore, the results show the soundness of the three capitals and suggest it for the three interfaces.

In order to determine whether the use of the triple bottom line for measuring sustainability was a valid choice, one also needs to look back at the literature used in the theoretical framework, Section 3. Looking back at the theoretical framework, one should recall the observation that hardly any research covers all three capitals. The studies used in this section were meant to explain the most important concepts of this thesis. Because of this, there are a number of studies which are focused on such a specific element that it cannot be covered by the outcome of this thesis. For example, the study by Rupasingha et al. (2000) looked specifically at the relationship between trust and income levels and between trust and economic growth. As this thesis has focused on the entire triple bottom line, and not specifically on facets of the aspect social capital itself, the results of this thesis are too broad to allow for a support of the study by Rupasingha et al. (2000).

Still, the outcomes of this thesis can be used to state something about the more general aspect covering the relationships studied by Rupasingha et al. (2000): social capital. While examining social capital, key elements which returned in almost every definition were: trust, reciprocity, and networks. The clusters obtained in this thesis contain these components as well. For instance, Cluster 12 *Social involvement* covers several aspects of these components through its included indicators. As this cluster was also part of the four clusters which had the most relations with other clusters, the results of this thesis seem to support the importance of these three components in the definition of the social-cultural capital.

Looking once more at the clusters found in this thesis, one can see that the indicators from the economic capital are very well represented in the obtained clusters, especially when considering the clusters containing multiple capitals. This observation suggests that the economic capital is involved with many aspects of sustainability. Considering the correlations between indicators of the ecological and economic capital, one can see that a large share of these correlations are negative. This seems to support the critique by Arrow et al. (1995) mentioned in the theoretical framework which states that economic growth is not always beneficial for the environment.

Section 3 also stated several studies stressing the importance of including the economic capital into the analysis of the Environmental Equity interface. The clusters found in this thesis, however, do not suggest the importance of this inclusion. This could be a result of the indicators of the ecological capital. As stated in the previous section, the indicators from this capitals are defined from an extrinsic perspective rather than from an intrinsic one. This could have played an important role in the distinct way in which the ecological indicators are clustered. Therefore, with the current data, the results of this thesis seem to be unable to support or reject need of including the economic capital into the analysis of the Environmental Equity interface.

The above shows that the outcome of this thesis can be connected to several studies from the theoretical framework, either by adding to the results or by supporting them. Therefore, the triple bottom line allows for the use and support of the discussed studies. Combining this with the observation that the outcome of this thesis shows the soundness of the three capitals and suggests it for the three interfaces, confirms that using the triple bottom line framework is in fact a valid choice.

8.1.2 The data

Another important choice in this thesis regards the data, namely the decision to use the indicators of the National Monitor of Sustainable Municipalities. The data of these indicators were provided by Telos and the possible areas in which it could have fallen short have already been covered in Section 4.5. Summarised these areas were the differences in periods of time and years of origin, possible missing indicators, and ways of measurement. Each of these areas could have a potential impact on the outcomes of this thesis and will therefore once more be examined in turn.

Looking at the differences in periods of time and years of origin, one remark could be that this might result in different benchmarks between indicators. This could have lead to inaccurate correlations as it compares two indicators based on different years while they could have been correlated in another way if one would compare them in the same year. This thesis has attempted to prevent this inaccuracy from having a large impact on the final result through critical assessment of the direction of the correlations. With this assessment, correlations that could have been the result of this time difference were excluded from further analysis. Furthermore, note that this difference in year of origin could also have caused that some correlations did not appear. As already stated in Section 5.3.2, including these correlations ourselves meant that their strengths had to be determined independent of the data, which was beyond the scope of this thesis.

Considering possible missing indicators, Section 4.5 already noted that most of these indicators are either already partly covered by others or require data which are not yet available at the level required by Telos. As the goal of this thesis was to provide an insight into the interdependence of the three capitals of the triple bottom line, these missing indicators should have come up as an underlying factor during our analysis. Therefore, the impact of these missing indicators on the overall results can be considered as minimal.

The last possible area in which the data may have fallen short, the way of measurement, could be considered as the most important limitation of our data. As stated in Section 4.5, some of the indicators are obtained from small samples or are measured on COROP or police district level. Especially this second part could have had an impact on the obtained correlations as the COROP regions and police districts cover areas which differ from those covered by municipalities as used by CBS. However, as before, this thesis has tried to reduce the influence of this limitation through critical assessment of the obtained correlations using expert analysis. Furthermore, as this limitation only concerns a limited amount of indicators, its effect on the outcome of this thesis is small.

8.1.3 Correlation analysis

During this critical assessment we have found and analysed several underlying factors. As stated in Section 5, these factors were chosen based on their connection to the National Monitor of Sustainable Municipalities with as goal to stay as close to this monitor as possible. Naturally, these choices come with their disadvantages. For instance, even though the literature seems to suggest the importance of the chosen factors, there might be other factors which play a significant role in sustainability in general or in the context of the Netherlands. In order to ensure that factors of such significance are included, the literature research has been combined with expert analysis. Still, including more factors in the analysis could be an idea for future research as this could be used to improve and fine tune the results when comparing them to the outcomes of this thesis.

Another limitation of the correlations in this thesis concerns the strength of the correlations. This strength could have been affected by the difference in year of origin of the indicators and underlying factors. Moreover, the strength of a correlation is a combination of direct and indirect relations. This could have influenced the clusters as the algorithm might have reached its boundary at a different rate than it would have with different values. This thesis, however, did not account for this when determining the weights of the correlations as this was not possible with the available data.

Without a doubt, the critical assessment of our correlations itself could also be considered as a possible limitation of the study. After all, even though the decision whether a correlation is taken to be direct or indirect is based on expert analysis combined with a literary background, it can still be seen as an influential, and possibly even subjective choice. Yet, as stated in Section 6.1.4, applying the chosen method on the graph containing all medium and strong correlations as edges led to a similar result. Therefore, one can state that the influence of our choice of directness of the correlations has been rather limited with respect to the outcome of the chosen method.

8.1.4 Cluster analysis

This critical factor leads us to the choice of our clustering method. This thesis has used the algorithm by Demaine et al. (2005). Yet, one should note there are multiple other methods which could have been chosen to partition our graph into sets of nodes and which might have resulted in different clusters. Two examples of these methods are the method by Rosén and Brunzell (2006) and by Capocci et al. (2004). As stated in Section 6.1.1, the main motivation to choose the method of Demaine et al. over the other two was the possibility of allowing overlap between clusters and the comprehensibility of this algorithm. Despite this, the algorithms by Rosén and Brunzell (2006) and Capocci et al. (2004) could have resulted in different clusters feasible for our goal.

Besides the choice of the algorithm itself, one should also critically examine the choices made to alter the algorithm ROUND. These adaptations concerned the starting point, boundary, and removal methods. The last two aspects were both tried in full, and turned out to lead to either no difference at all or a large overlap in outcomes, already suggesting the robustness of the algorithm ROUND for sparse graphs. All three adaptations has been fully covered in the analysis of the algorithm's outcomes in Section 6.1.4. In this discussion, we will take a closer look at the first aspect.

In applying the algorithm ROUND itself, it appeared that this algorithm was strongly dependent on the choice of its starting point. This could have been a result of the sparseness of our graph, but could also be true for graphs in general. Still, one might wonder how much our choice for a starting point of highest degree has influenced our final result and whether another condition might have been better instead. We will look at both questions in turn.

The choice of the algorithm's starting point has been based on both the properties of our graph and the requirements of the outcome. During this stage, we have considered the outcomes of multiple tests of the base algorithm as well as the adapted algorithms. These tests have been performed on the graph of the economic capital as this graph is the most insightful and has a density comparable to that of the graph of the National Monitor of Sustainable Municipalities. The tests showed a large variety in outcomes of each application of the base algorithm as this algorithm used random selection of the starting point in each iteration. Because of this variety, the method of random selection was deemed unsuitable for our graph and goal. As this variety indicates the dependence of the algorithm ROUND on the choice of the starting point, the method of choosing the starting point could have a large impact on the algorithm's outcome. Therefore, one has to ensure that the starting point meets the requirements of our goal in order to obtain a feasible algorithm.

The criterion of the starting points has been obtained through considering the requirements of the outcome's meaning. As the clusters should indicate which indicators are strongly related to one another, we need to ensure that the condition regarding the choice of starting point satisfies this requirement. This almost immediately leads to the degree of the nodes in our graph as this gives an indication of the connections of a node with respect to the other nodes in the graph. This might have been achieved through other conditions as well, such as the average strength of all connections of a certain node. The chosen condition, however, could be considered as the most insightful and applicable option as it satisfies our goal, yet does not require a large change in the algorithm itself or the required data.

As mentioned at the beginning of this section, the majority of the limitations of the study named before have already been mentioned and discussed during the thesis itself. Through this method, most limitations have already been covered during the study as much as possible within the scope of the research. Therefore, despite these limitations, this study has been able to address its research questions and goal to the best of its abilities, leading to an understanding of the relations between the three capitals and uncovering of several focus points for monitoring and approaching sustainability.

8.2 Ideas for future research

Based on the limitations covered in the previous paragraphs, there are several possibilities for future research. For instance, one could look into other methods such as Rosén and Brunzell (2006) and Capocci et al. (2004) and compare the outcomes of these methods to the results of this thesis. This could be combined with the inclusion of more underlying factors and might result into a fine tuned outcome related to this thesis' outcome.

Other possible areas for future research lie within the data and use of typologies. The data for the National Monitor of Sustainable Municipalities are gathered and updated on a yearly basis. Therefore, there is a possibility of obtaining an improved set of data which is suitable for longitudinal research. This longitudinal research could lead to additional insight in the relations between several aspects of sustainability. For example, such research is essential when it comes to assessing trade-offs as it demonstrates the influence of one indicator on another over time. Therefore, longitudinal research would strengthen the research in the field of sustainability.

As for the use of typologies, this thesis has given some indications for municipalities of a certain typology regarding the relation between their typology and the sixteen obtained clusters. During this study, this has been illustrated using an example. In future research, these indications might be turned into a clear overview of relations for each typology. Moreover, the profound knowledge resulting from this overview could be used to gain new insights in the typologies of municipalities and possibly even lead to different definitions of these typologies, as well as to an extension and enhancement of the focus points found in this thesis.

Another possibility for future research is to combine the outcome of this thesis with the results from the overview of influential factors on a municipal level, found by Telos (2016a) as stated in Section 7. This could be done through, for instance, the development of chains of causation starting from the focus points. This could lead to a result which is easier to apply and understand for policy makers, hence would facilitate the advice given by Telos. Furthermore, combining the outcome of such a study with those from a more elaborate investigation of the relation between typologies and the sixteen obtained clusters could result in a profound model for monitoring and approaching sustainability.

As stated before, the current amount of research on trade-offs between all three capita ls is rather limited as studying these trade-offs on the entire triple bottom line is rather complex. A suggestion for future research in this field is to investigate these trade-offs through looking at the relation between aspects of two interfaces or an interface and a capital. For instance, one could take a specific relation between the social-cultural and economic capital, so from the Social Growth interface, and study its link with an aspect of the ecological capital or a relation from the Green Growth interface. The potentiality and feasibility of this method have been shown in this thesis through considering the contents and interactions of the obtained clusters. Through this method, the interconnectedness of the three capitals can be investigated in parts, allowing for a focus on all capitals rather than on only one interface. This would lead to an improved insight in the overall triple bottom line framework.

References

Abrams, J. R., Baldwin, D., Gonda, R., & Chen, Z. (2017). Analysis of Equity Markets: A Graph Theory Approach. , 190–210.

Adger, W. N. (2000). Social and ecological resilience: are they related? *Progress in Human Geography*, *24*(3), 347–364. Retrieved from http://journals.sagepub.com/doi/10.1191/030913200701540465 doi: 10.1191/030913200701540465

Almende B.V., Thieurmel, B., & Robert, T. (2018). *visNetwork: Network Visualization using 'vis.js' Library.* Retrieved from https://cran.r-project.org/package=visNetwork

Arawatari, R. (2009). Informatization, voter turnout and income inequality. *Journal of Economic Inequality*, *7*(1), 29–54. doi: 10.1007/s10888-007-9062-z

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C. S., ... Pimentel, D. (1995). Economic growth, carrying capacity, and the environment. *Ecological Economics*, *15*, 91–95. doi: 10.1016/0921-8009(95)00059-3

Bansal, N., Blum, A., & Chawla, S. (2004). Correlation Clustering. *Machine Learning*, *56*(1-3), 89–113. doi: 10.1023/B:MACH.0000033116.57574.95

Bekkers, R., & Schuyt, T. (2008). And who is your neighbor? Explaining the effect of religion oncharitable giving and volunteering. *Review of Religious Research*, *50*(1), 74.

Bennett, M. R., & Einolf, C. J. (2017). Religion, Altruism, and Helping Strangers: A Multilevel Analysis of 126 Countries. *Journal for the Scientific Study of Religion*, *56*(2), 323–341. doi: 10.1111/jssr.12328

Berkelaar, M., & Al., E. (2015). *lpSolve: Interface to 'Lp_solve' v. 5.5 to Solve Linear/Integer Programs.* Retrieved from https://cran.r-project.org/package=lpSolve

Berkes, F., & Folkes, C. (1991). A systems perspectives on the interrelationships between natural, human-made and cultural capital. *Ecological Economics*, *5*(1), 1–8.

Brehm, J., & Rahn, W. (1997). Individual-Level Evidence for the Causes and Consequences of Social Capital. *Source: American Journal of Political Science*, *41*(3), 999–1023. Retrieved from http://www.jstor.org/stable/2111684

Brundtland, G. H. (1987). Our Common Future: Report of the World Commission on Environment and Development. *United Nations Commission*, *4*(1), 300. doi: 10.1080/07488008808408783

Caiazza, R., Richardson, A., & Audretsch, D. (2015). Knowledge effects on competitiveness: from firms to regional advantage. *Journal of Technology Transfer*, *40*(6), 899–909. doi: 10.1007/s10961-015-9425-8

Capocci, A., Servedio, V. D. P., Caldarelli, G., & Colaiori, F. (2004). Detecting communities in large networks. Retrieved from http://arxiv.org/abs/cond-mat/0402499%0Ahttp://dx.doi.org/10.1016/j.physa.2004.12.050 doi: 10.1016/j.physa.2004.12.050

CBS. (2004). *Animo voor afvalscheiding vermindert.* Retrieved from https://www.cbs.nl/nl-nl/nieuws/2004/32/animo-voor-afvalscheiding-vermindert

CBS. (2011). *Verkiezingen : Participatie , Vertrouwen en Integratie* (Tech. Rep.).

CBS. (2017). Politieke betrokkenheid in Nederland. (December).

Chang, W., Cheng, J., Allaire, J. J., Xie, Y., & McPherson, J. (2018). *shiny: Web Application Framework for R.* Retrieved from https://cran.r-project.org/package=shiny

Chiesura, A., & De Groot, R. (2003). Critical natural capital: A socio-cultural perspective. *Ecological Economics*, *44*(2-3), 219–231. doi: 10.1016/S0921-8009(02)00275-6

Csardi, G., & Nepusz, T. (2006). The igraph software package for complex network research. *InterJournal*, *Complex Sy*, 1695. Retrieved from http://igraph.org

Cushing, L., Morello-Frosch, R., & Wander, M. (2015). The Haves, the Have-Nots, and the Health of Everyone: The Relationship Between Social Inequality and Environmental Quality. *Annual*

Review of Public Health, *36*(1). Retrieved from https://cloudfront.escholarship.org/dist/prd/content/qt4nh830b7/qt4nh830b7.pdf doi: 10.1146/annurev-publhealth-031914-122646

Cutts, B. B., Darby, K. J., Boone, C. G., & Brewis, A. (2009). City structure, obesity, and environmental justice: An integrated analysis of physical and social barriers to walkable streets and park access. Retrieved from https://ac.els-cdn.com/S0277953609005395/1-s2.0-S0277953609005395-main.pdf?_tid=fdf6c9a6-1654-11e8-9710-00000aab0f6b&acdnat=1519141673_11ae8b334c6c005ee9e22ac5840a9a0c doi: 10.1016/j.socscimed.2009.08.020

Dahl, D. B. (2016). *xtable: Export Tables to LaTeX or HTML.* Retrieved from https://cran.r-project.org/package=xtable

Daly, H. E. (1992). Steady-State Economics: Concepts, Questions, Policies. *GAIA - Ecological Perspectives for Science and Society*, *1*, 333–338.

De Groot, R. S., Wilson, M. A., & Boumans, R. M. (2002, 6). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*, *41*(3), 393–408. Retrieved from https://www.sciencedirect.com/science/article/pii/S0921800902000897 doi: 10.1016/S0921-8009(02)00089-7

Demaine, E. D., Emanuel, D., Fiat, A., & Immorlica, N. (2005). Correlation Clustering in General Weighted Graphs *. , 1–20. Retrieved from https://pdfs.semanticscholar.org/2454/c84c71d282b95bc99d05adda914361905ffe.pdf

Donk, W. v. d., Jonkers, A., Kronjee, G., & Plum (red.), R. (2006). *Geloven in het publiek domein: verkenningen van een dubbele transformatie - 13.* Amsterdam: Amsterdam University Press.

Downey, L., Crowder, K., & Kemp, R. J. (2017). Family Structure, Residential Mobility, and Environmental Inequality. *Journal of Marriage and Family*, *79*(2), 535–555. doi: 10.1111/jomf.12355

Edzes, A., Middeldorp, M., Noback, I., Venhorst, V., Broersma, L., & Dijk, J. (2015). *Dynamiek op de arbeidsmarkt: Over carrièrelijnen, baan- en werknemersdynamiek.* Rijksuniversiteit Groningen. Faculteit Ruimtelijke Wetenschappen.

Egerton, M., & Mullan, K. (2008). Being a pretty good citizen: An analysis and monetary valuation of formal and informal voluntary work by gender and educational attainment. *British Journal of Sociology*, *59*(1), 145–164. doi: 10.1111/j.1468-4446.2007.00186.x

Elgar, F. J., Pförtner, T. K., Moor, I., De Clercq, B., Stevens, G. W., & Currie, C. (2015). Socioeconomic inequalities in adolescent health 2002-2010: A time-series analysis of 34 countries participating in the Health Behaviour in School-aged Children study. *The Lancet*, *385*(9982), 2088–2095. doi: 10.1016/S0140-6736(14)61460-4

European Commission. (2012). Soil sealing. *Science for Environment Policy. In-depth Report*(March), 1–41. Retrieved from http://ec.europa.eu/-environment/archives/ doi: 10.2779/75498

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience Thinking: Integrating Resilience, Adaptability and Transformability. *Nature Nanotechnology*, *15*(4). Retrieved from http://www.ecologyandsociety.org/vol15/iss4/art20/ doi: 10.1038/nnano.2011.191

Gartner, W. B., & Carter, N. M. (2003). Entrepreneurial Behavior and Firm Organizing Processes. *Handbook of Entrepreneurship Research*(January), 195–221. Retrieved from http://link.springer.com/10.1007/0-387-24519-7_9 doi: 10.1007/0-387-24519-7{_}9

Gevulei. (2011). Eindrapportage Sorteeranalyses huishoudelijk afval. Retrieved from http://www.leidenincijfers.nl/onderzoeksbank/9933-EindrapportageGevulei2011Definitief.pdf

Hammer et al., S. (2011). *Cities and Green Growth : A Conceptual Framework* (Vol. 08). Retrieved from http://www.oecd.org/gov/regional-policy/49330120.pdf doi: http://dx.doi.org/10.1787/5kg0tflmzx34-en

Harrell Jr, F. E., Dupont, C., & Al., E. (2018). *Hmisc: Harrell Miscellaneous.* Retrieved from https://cran.r-project.org/package=Hmisc

Howe, C., Suich, H., Vira, B., & Mace, G. M. (2014). Creating win-wins from trade-offs? Ecosystem services for human well-being: A meta-analysis of ecosystem service trade-offs and synergies in the real world. *Global Environmental Change*, *28*(1), 263–275. Retrieved from http://dx.doi.org/10.1016/j.gloenvcha.2014.07.005 doi: 10.1016/j.gloenvcha.2014.07.005

Huygen, A., & De Meere, F. (2008). De invloed en effecten van sociale samenhang. *Utrecht: Verwey-Jonker Instituut*(April). Retrieved from http://www.verwey-jonker.nl/doc/vitaliteit/Deinvloedeneffectenvansocialesamenhang_1169.pdf

Iyer, S., Kitson, M., & Toh, B. (2005). Social capital, economic growth and regional development. *Regional Studies*, *39*(8), 1015–1040. doi: 10.1080/00343400500327943

Jackson, A. R. W., & Jackson, J. M. (1996). *Environmental Science: The Natural Environment and Human Impact.* Longman. Retrieved from https://books.google.nl/books?id=6-HaAAAAMAAJ

Jiao, J., Drewnowski, A., Moudon, A. V., Aggarwal, A., Oppert, J. M., Charreire, H., & Chaix, B. (2016). The impact of area residential property values on self-rated health: A cross-sectional comparative study of Seattle and Paris. *Preventive Medicine Reports*, *4*, 68–74. Retrieved from http://dx.doi.org/10.1016/j.pmedr.2016.05.008 doi: 10.1016/j.pmedr.2016.05.008

Jorgenson, A. K., & Clark, B. (2010). Assessing the temporal stability of the population/environment relationship in comparative perspective: A cross-national panel study of carbon dioxide emissions, 1960-2005. *Population and Environment*, *32*(1), 27–41. doi: 10.1007/s11111-010-0117-x

Klasen, S., Meyer, K. M., Dislich, C., Euler, M., Faust, H., Gatto, M., ... Wiegand, K. (2016). Economic and ecological trade-offs of agricultural specialization at different spatial scales. Retrieved from https://goescholar.uni-goettingen.de/bitstream/handle/1/13142/1-s2.0-S0921800916000021-main.pdf?sequence=1&isAllowed=y doi: 10.1016/j.ecolecon.2016.01.001

Kruize, H., Driessen, P. P. J., Glasbergen, P., & Van Egmond, K. (2007). Environmental Equity and the Role of Public Policy: Experiences in the Rijnmond Region. Retrieved from https://link.springer.com/content/pdf/10.1007%2Fs00267-005-0378-9.pdf doi: 10.1007/s00267-005-0378-9

Kruize, H., Droomers, M., van Kamp, I., & Ruijsbroek, A. (2014). What causes environmental inequalities and related health effects? An analysis of evolving concepts. *International Journal of Environmental Research and Public Health*, *11*(6), 5807–5827. doi: 10.3390/ijerph110605807

Kuo, F. E., Bacaicoa, M., & Sullivan, W. (1998). Transforming Inner-City Landscapes: Trees, Sense of Safety, and Preference. *Environment and Behavior*, *30*(1), 28–59. Retrieved from http://journals.sagepub.com/doi/pdf/10.1177/0013916598301002

La Due Lake, R., & Huckfeldt, R. (1988). Social Capital, Social Networks, and Political Participation. *Political Psychology*, *19*(3), 567–584. Retrieved from http://www.jstor.org/stable/3792178

Lehtonen, M. (2004). The environmental-social interface of sustainable development: capabilities, social capital, institutions.
doi: https://doi.org/10.1016/j.ecolecon.2004.03.019

Levin, I. (2010). Political Participation is More than Just Resources: A New Approach to the Study of Civic Engagement. , 51.

Malthus, T. R. (1798). *An essay on the principle of population.* London: Johnson; re-printed, Oxford: Oxford University Press, 1993.

McSherry, F. (2016). Spectral methods for data analysis. (May), 113. Retrieved from http://www-bcf.usc.edu/~dkempe/seminars/mcsherry-thesis.pdf

Meadows, D., Meadows, D., Randers, J., & Behrens, W. (1972). *The Limits to Growth.*

Milieu- en Natuurplanbureau. (2004). *Kwaliteit en Toekomst. Verkenning van duurzaamheid* (Tech. Rep.). Bilthoven: RIVM. Retrieved from https://www.rivm.nl/dsresource?objectid=29bf2434-25dd-4b44-acd2-6b6355b490c9&type=org&disposition=inline

Moody, J., & White, D. R. (2003). Structural Cohesion and Embeddedness: A Hierarchical Concept of Social Groups. *American Sociological Review*, *68*(1), 103. Retrieved from http://www.jstor.org/stable/3088904?origin=crossref doi: 10.2307/3088904

Moonen, L., Otten, F., & Pleijers, A. (2011). Inkomens en positie op de arbeidsmarkt. *Sociaal-economische trends*.

Odum, E. P. (1969, 4). The Strategy of Ecosystem Development. *Science*, *164*(3877), 262 LP - 270. Retrieved from http://science.sciencemag.org/content/164/3877/262.abstract

O'Neill, B. C., Liddle, B., Jiang, L., Smith, K. R., Pachauri, S., Dalton, M., & Fuchs, R. (2012). Demographic change and carbon dioxide emissions. *The Lancet*, *380*(9837), 157–164. Retrieved from http://dx.doi.org/10.1016/S0140-6736(12)60958-1 doi: 10.1016/S0140-6736(12)60958-1

Orban, E., Sutcliffe, R., Dragano, N., Jöckel, K. H., & Moebus, S. (2017). Residential Surrounding Greenness, Self-Rated Health and Interrelations with Aspects of Neighborhood Environment and Social Relations. *Journal of Urban Health*, *94*(2), 158–169. doi: 10.1007/s11524-016-0112-3

Paul, M. J., & Meyer, J. L. (2001). Streams in the Urban Landscape. *Annual Review of Ecology and Systematics*, *32*(1), 333–365. Retrieved from http://www.annualreviews.org/doi/abs/10.1146/annurev.ecolsys.32.081501.114040 doi: doi:10.1146/annurev.ecolsys.32.081501.114040

Peeters, J. (2012). Social work and sustainable development: Towards a social-ecological practice model. *Journal of Social Intervention: Theory and Practice*, *21*(3), 5–26. doi: 10.18352/jsi.316

Piotrowska, P. J., Stride, C. B., Croft, S. E., & Rowe, R. (2015). Socioeconomic status and antisocial behaviour among children and adolescents: A systematic review and meta-analysis. *Clinical Psychology Review*, *35*, 47–55. Retrieved from http://dx.doi.org/10.1016/j.cpr.2014.11.003 doi: 10.1016/j.cpr.2014.11.003

Pouwelse, S. (2013). *Komend tot de (dorps) kern: Sociale cohesie door een ruimtelijke bril* (Unpublished doctoral dissertation). Universiteit Utrecht.

Putnam, R. D. (1993). *Making Democracy Work: Civic Traditions in Modern Italy.* Princeton, NJ: Princeton University Press. Retrieved from https://books.google.nl/books?id=gKZP8_Tp27UC

Quon, E. C., & McGrath, J. J. (2014). Subjective socioeconomic status and adolescent health: A meta-analysis. *Health Psychology*, *33*(5), 433–447. doi: http://dx.doi.org/10.1037/a0033716

Rees, W. E. (1992). Ecological footprints and appropriated carrying capacity: what urban economics leaves out. *Environment and Urbanization*, *4*(2), 121–130.

Reilly, J., Maggio, P., & Karp, S. (2004). A model to predict impervious surface for regional and municipal land use planning purposes. *Environmental Impact Assessment Review*, *24*(3), 363–382. doi: 10.1016/j.eiar.2003.10.022

Rijkswaterstaat. (2015). *Samenstelling van het huishoudelijk restafval, sorteeranalyses 2014; Gemiddelde driejaarlijkse samenstelling 2013* (No. november).

RIVM. (2014). *Grootschalige Concentratie- en Depositiekaarten Nederland* (Tech. Rep.). Retrieved from http://www.rivm.nl/gcn

Robison, L. J., & Siles, M. E. (1999). *Social capital and household income distributions in the United States: 1980, 1990* (Vol. 28) (No. 1). doi: 10.1016/S1053-5357(99)00012-8

Rochester, C., Paine, A. E., Howlett, S., Zimmeck, M., & Paine, A. E. (2016). *Volunteering and Society in the 21st Century*. Palgrave Macmillan UK. Retrieved from https://books.google.nl/books?id=RVN7CwAAQBAJ

Rosén, F., & Brunzell, T. (2006). Correlation based clustering of the Stockholm Stock Exchange.

Rosenstone, S. J. . (1982). Economic Adversity and Voter Turnout. *American Journal of Political Science*, *26*(1), 25–46. Retrieved from http://www.jstor.org/stable/2110837

Rupasingha, A., Goetz, S. J., & Freshwater, D. (2000). Social Capital and Economic Growth: A County-Level Analysis. *Journal of Agricultural and Applied Economics*, *32*(3), 565–572. Retrieved from http://aese.psu.edu/nercrd/community/social-capital-resources/examples-of-studies-that-have-used-these-numbers/social-capital-and-economic-growth-a-county-level-analysis

Salvati, L. (2014). The spatial pattern of soil sealing along the urban-rural gradient in a Mediterranean region. *Journal of Environmental Planning and Management*, *57*(6), 848–861. Retrieved from http://dx.doi.org/10.1080/09640568.2013.770730 doi: 10.1080/09640568.2013.770730

Scalenghe, R., & Marsan, F. A. (2009). The anthropogenic sealing of soils in urban areas. *Landscape and Urban Planning*, *90*. Retrieved from https://ac.els-cdn.com/S0169204608001710/1-s2.0-S0169204608001710-main.pdf?_tid=cef09509-75c5-4b93-8750-2dc6452efd90&acdnat=1521126998_fbd1641e901c69d932d11792587ac811 doi: 10.1016/j.landurbplan.2008.10.011

Sikkens, N. (2017). Veerkracht van binnenstedelijke economieën.

Smits, M., Roos, E., & Dagevos, J. (2013). Rapport Dynamisering Duurzaamheidbalans 2012. , 1–29.

Snel, K., & Van der Zaag, J. (2015). *Hoe hoort het eigenlijk... in Nederland?* Gottmer Uitgevers Groep b.v. Retrieved from https://books.google.nl/books?id=IH4eBAAAQBAJ

Solt, F. (2008). Economic Inequality and Democratic Political Engagement. *American Journal of Political Science*, *52*(1), 48–60. Retrieved from http://www.jstor.org/stable/25193796%5Cnhttp://about.jstor.org/terms doi: 10.1111/j.1540-5907.2007.00298.x

Son, J., & Wilson, J. (2011). Generativity and Volunteering. *Sociological Forum*, *26*(3), 644–667. doi: 10.1111/j.1573-7861.2011.01266.x

Son, J., & Wilson, J. (2017). Education, Perceived Control, and Volunteering. *Sociological Forum*, *32*(4), 831–849. doi: 10.1111/socf.12377

Stiffman, A. R., Hadley-Ives, E., Elze, D., Johnson, S., & Doré, P. (1999). Impact of environment on adolescent mental health and behavior: structural equation modeling. *The American Journal of Orthopsychiatry*, *69*(1), 73–86. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9990438 doi: 10.1017/CBO9781107415324.004

Telos. (2002). *De Duurzaamheidbalans van Noord-Brabant 2001: De Verantwoording.*

Telos. (2006). *De Duurzaamheidbalans van Brabant 2006: De Verantwoording* (Tech. Rep.). Tilburg.

Telos. (2014). Nationale monitor gemeentelijke duurzaamheid.

Telos. (2015). *Final Cluster Centers [Microsoft Excel spreadsheet].*

Telos. (2016a). Duurzaamheidsportret gemeente Teylingen 2016.

Telos. (2016b). *Factor Analyses Clusters [Microsoft Excel spreadsheet].*

Telos. (2017). *Nationale monitor duurzame gemeenten 2017* (Tech. Rep.). Tilburg: Telos.

Telos, & IMSA. (2015). De Waddenbarometer.

Van Leeuwen, M., De Kleijn, A., Pronk, A., & Verhoog, A. (2014). *Het Nederlandse agrocomplex 2013* (Tech. Rep.). Wageningen: LEI Wageningen UR. Retrieved from http://library.wur.nl/WebQuery/wurpubs/fulltext/294855

Van Slageren, J. (2015). De invloed van sociale inbedding op het niveau van vertrouwen. , 1–27.

Walker, B., & Meyers, J. A. (2004). Thresholds in ecological and social-ecological systems: A developing database. *Ecology and Society*, *9*(2). doi: 3

Weenink, D. (2009). *Samen leven in het dorp* (Tech. Rep. No. 261). Wageningen University.

Weterings, A., Diodato, D., & Van den Berge, M. (2013). *De veerkracht van regionale arbeidsmarkten* (Tech. Rep.). Den Haag: PBL. Retrieved from http://www.pbl.nl/sites/default/files/cms/publicaties/PBL_2013_Veerkrachtvanregionalearbeidsmarkten_669.pdf

Wheeler, B. W., Ben-Shlomo, Y., & Wheeler, B. W. (2005). Environmental equity, air quality, socioeconomic status, and respiratory health: a linkage analysis of routine data from the Health Survey for England. *J Epidemiol Community Health*, *59*, 948–954. Retrieved from http://jech.bmj.com/content/jech/59/11/948.full.pdf doi: 10.1136/jech.2005.036418

Whiteley, P. (2000). Economic growth and social capital. *Political Studies*, *48*(3), 443–466.

Wilson, J., & Musick, M. (1997). Who Cares? Toward an Integrated Theory of Volunteer Work. *American Sociological Review*, *62*(5), 694–713.

Woolcock, M. (1998). Social Capital and Economic Development: Toward a Theoretical Synthesis and Policy Framework. *Theory and society*, *27*(2), 151–208. doi: 10.2307/657866

Woolcock, M., & Narayan, D. (2000). Social Capital: Implications for Development Theory, Research, and Policy. *World Bank Research Observer*, *15*(2). Retrieved from http://deepanarayan.com/pdf/papers/woolcock.pdf

World Bank. (2012). *Inclusive green growth : the pathway to sustainable development.* World Bank. Retrieved from https://books.google.nl/books?id=_-dLBmoHFP0C&dq=trade+off+green+growth+ppp&lr=&hl=nl&source=gbs_navlinks_s

York, R. (2007). Demographic trends and energy consumption in European Union Nations, 1960-2025. *Social Science Research*, *36*(3), 855–872. doi: 10.1016/j.ssresearch.2006.06.007

Zoeteman, B. (2016). Measuring urban green growth.

A Appendices

A.1 Indicator list

Ecological (N)	1. Soil	a.	Contaminated sites with unacceptable human risks
		b.	Contaminated sites with high ecological risks
		c.	Contaminated sites with high distribution risks
		d.	Manure- Nitrogen quantity produced
		e.	Manure- Phosphorous quantity produced
		f.	Soil sealing
	2. Air	a.	Emission of CO_2
		b.	Emission of NOx
		c.	Emission of Particulate Matter ($PM_{2.5}$)
		d.	Emission of Volatile Organic Substances
		e.	Concentration of NOx
		f.	Concentration of Ozone
		g.	Concentration of $PM_{2.5}$
	3. Annoyance and Emergencies	a.	Noise annoyance
		b.	Light intensity during the night
		c.	Noise intensity
		d.	Annoyance by odours
		e.	Risk of road transport of dangerous chemicals
		f.	Land surface with a 10^{-6} risk contour
		g.	Earthquakes
		h.	Floods
	4. Water	a.	Chemical quality of surface water
		b.	Ecological quality of surface water
		c.	Nitrogen emissions to surface water
		d.	Phosphorous emissions to surface water
		e.	Drinking-water quality
	5. Nature and Landscape	a.	Share of forest and natural area
		b.	Distance to public green
		c.	Distance to inland recreational water
		d.	Biodiversity total
		e.	Biodiversity red list species
	6. Energy and Climate	a.	Wind energy
		b.	Solar energy
		c.	Average natural gas consumption households
		d.	Average electricity consumption households
		e.	Energy label houses
		f.	Average natural gas consumption businesses
		g.	Average electricity consumption businesses
	7. Resources and Waste	a.	Household waste
		b.	Residual waste
		c.	Organic waste
		d.	Paper and cardboard waste
		e.	Packaging glass
		f.	Plastics

Table 9: Stocks and indicators of the ecological capital.

Social-cultural (S)	1. Social Participation	a.	Cohesion
		b.	Volunteers
		c.	Turnout municipal elections
		d.	Turnout national elections
		e.	Informal care
	2. Economic Participation	a.	Financial assets household
		b.	Social assistance
		c.	Poor households
		d.	Long lasting unemployment
	3. Arts and Culture	a.	Distance to performing arts
		b.	National monuments
		c.	Municipal monuments
		d.	Distance to museum
		e.	Protected city/village views
	4. Health	a.	Insufficient exercise
		b.	Risky behaviour
		c.	Distance to GP practice
		d.	Quality of hospitals
		e.	Distance to hospital
		f.	Chronically sick people
		g.	Life expectancy
		h.	Confused people
		i.	Assessment of own health
	5. Safety	a.	Vandalism
		b.	Violent crimes
		c.	Crimes against property
		d.	Youth crime
		e.	Road safety
		f.	Feeling of insecurity
	6. Residential Environment	a.	Housing deficit
		b.	Distance to daily goods and services
		c.	Satisfaction with living environment
		d.	Mutations in number of residents
		e.	Satisfaction with shops
		f.	Satisfaction with dwelling
	7. Education	a.	Youth unemployment
		b.	Distance to elementary schools
		c.	Distance to secondary education schools
		d.	Dropouts
		e.	Real-time to diploma
		f.	Final examination mark
		g.	Education level population

Table 10: Stocks and indicators of the social-cultural capital.

Economic (E)	1. Labour	a.	Employment function
		b.	Human resources exploitation
		c.	Unemployment
		d.	Rejuvenation and ageing
		e.	Incapacity for work
	2. Spatial Local Conditions for Businesses	a.	Stock business parks
		b.	Net/gross area ratio business parks
		c.	Share out of date business parks
		d.	Vacant office space
		e.	Vacant retail space
	3. Competitive-ness	a.	Share starters
		b.	Bankruptcies
		c.	Share nationally promoted (top) sectors
		d.	Gross Regional Product per capita
		e.	Fast growing businesses
	4. Infrastructure and Mobility	a.	Access to public railway transport
		b.	Access to main roads
		c.	Number of charging stations for electric cars
		d.	Share of clean cars
	5. Knowledge	a.	Share highly educated people
		b.	Capacity university education/higher professional education
		c.	High- and medium tech employment
		d.	Creative industry employment

Table 11: Stocks and indicators of the economic capital.

Factors (F)	1. Income		
	2. Soil type	a.	Loam
		b.	Clay
		c.	Peat
		d.	Sand
	3. Sector structure	a.	Agriculture
		b.	Industry
		c.	Commercial services
		d.	Non-commercial services
	4. Religion		
	5. Population/Building density		
	6. Area type	a.	Residential area
		b.	Industrial area
		c.	Agricultural area
		d.	Forest and natural area
	7. Population age	a.	0 to 25
		b.	25 to 45
		c.	45 to 65
		d.	65 and above

Table 12: List and corresponding notation of the underlying factors.

A.2 Correlation tables

A.2.1 Ecological capital

	N1a	N1b	N1c	N1d	N1e	N1f	N2a	N2b	N2c
N1a	1.00	-	0.68***	-	-	0.30***	-	-	-
N1b		1.00	-	-	-	-	-	-	-
N1c			1.00	-	-	0.35***	-	-	-
N1d				1.00	0.96***	-	-	-	-
N1e					1.00	-	-	-	-
N1f						1.00	-	-	-
N2a							1.00	0.76***	0.58***
N2b								1.00	0.83***
N2c									1.00

	N2d	N2e	N2f	N2g	N3a	N3b	N3c	N3d	N3e
N1a	-	-	-	-	-	-	-	-	-
N1b	-	-	-	-	-	-	-	-	-
N1c	-	-	-	-	-	-	0.30***	-	-
N1d	-	-	-	-	-	-	-	-	-
N1e	-	-	-	-	-	-	-	-	-
N1f	-	0.62***	-0.34***	0.33***	0.43***	-	0.81***	-	-
N2a	0.63***	-	-	-	-	-	-	-	-
N2b	0.68***	-	-	-	-	-	-	-	-
N2c	0.58***	-	-	-	-	-	-	-	-
N2d	1.00	-	-	-	-	-	-	-	-
N2e		1.00	-0.80***	0.80***	0.34***	-	0.73***	-	-
N2f			1.00	-0.91***	-	-	-0.43***	-	-
N2g				1.00	-	-	0.42***	-	-
N3a					1.00	-	0.50***	0.35***	-
N3b						1.00	-	-	-
N3c							1.00	-	-
N3d								1.00	-
N3e									1.00

	N3f	N3g	N3h	N4a	N4b	N4c	N4d	N4e	N5a
N1a	0.34***	-	-	-	-	-	-	-	-
N1b	-	-	-	-	-	-	-	-	-
N1c	0.30***	-	-	-	-	-	-	-	-
N1d	-	-	-	-	-	-	-	-	-
N1e	-	-	-	-	-	-	-	-	-
N1f	-	-	0.34***	-	-	0.35***	0.35***	-	-
N2a	-	-	-	-	-	-	-	-	-
N2b	-	-	-	-	-	-	-	-	-
N2c	-	-	-	-	-	-	-	-	-
N2d	-	0.36***	-	-	-	-	-	-	-
N2e	-	-	-	-	-	0.35***	0.40***	-	-
N2f	-	-	-	-	-	-	-	-	-
N2g	-	-	-	-	-	-	-	-	-
N3a	-	-	-	-	-	-	-	-	-
N3b	-	-	-	-	-	-	-	-	-
N3c	-	-	-	-	-	0.37***	0.40***	-	-

N3d	-	-	-	-	-	-	-	-	-
N3e	0.33***	-	-	-	-	0.32***	-	-	-
N3f	1.00	-	-	-	-	0.40***	-	-	-
N3g		1.00	-	-	-	-	-	-	-
N3h			1.00	-	-	-	-	-	-
N4a				1.00	-	-	-	-	-
N4b					1.00	-	-	-	-
N4c						1.00	0.69***	-	-
N4d							1.00	0.43***	-0.31***
N4e								1.00	-
N5a									1.00

	N5b	N5c	N5d	N5e	N6a	N6b	N6c	N6d	N6e
N1a	-	-	-	-	-	-	-	-	-
N1b	-	-	-	-	-	-	-	-	-
N1c	-	-	-	-	-	-	-	-	-
N1d	-	-	-	-	-	-	-	-	-
N1e	-	-	-	-	-	-	-	-	-
N1f	-0.31***	-0.40***	0.30***	-	-	0.81***	-0.63***	-0.42***	-
N2a	-	-	-	-	0.31***	-	-	-	-
N2b	-	-	-	-	0.35***	-	-	-	-
N2c	-	-	-	-	-	-	-	-	-
N2d	-	-	-	-	-	-	-	-	-
N2e	-	-0.40***	0.32***	-	-	0.43***	-0.50***	-	-
N2f	-	-	-0.32***	-	-	-	-	-0.33***	-
N2g	-	-	0.34***	-	-	-	-	0.38***	-
N3a	-	-	-	-	-	0.36***	-0.43***	-0.33***	-
N3b	-	-	-	-	-	-	-	-	-
N3c	-0.30***	-0.41***	-	-	-	0.65***	-0.58***	-0.33***	-
N3d	-	-	-	-	-	-	-	-	-
N3e	-	-	-	-	-	-	-	-	-
N3f	-	-	-	-	-	-	-	-	-
N3g	-	-	-	-	-	-	-	-	-
N3h	-	-	-	-	-	0.33***	-0.38***	-	-
N4a	-	-	-	-	-	-	-	-	-
N4b	-	-	-	-	-	-	-	-	-
N4c	-	-	-	-	-	-	-	-	-
N4d	-	-	-	-	-	-	-0.37***	-	-
N4e	-	-	-	-	-	-	-	-	-
N5a	-	-	-	-	-	-	0.35***	-	-
N5b	1.00	0.36***	-0.31***	-	-	-	-	-	-
N5c		1.00	-	-	-	-	0.39***	-	-
N5d			1.00	0.65***	-	-	-	-	-
N5e				1.00	-	-	-	-	-
N6a					1.00	-	-	-	-
N6b						1.00	-0.51***	-	-
N6c							1.00	0.54***	-
N6d								1.00	-0.33***
N6e									1.00

	N6f	N6g	N7a	N7b	N7c	N7d	N7e	N7f
N1a	-	-	-	-	-	-	-	-
N1b	-	-	-	-	-	-	-	-
N1c	-	-	-	-	-	-	-	-
N1d	-	-	-	-	-	-	-	-
N1e	-	-	-	-	-	-	-	-
N1f	-	-	-	-	-0.47***	-0.46***	-	-
N2a	0.37***	0.53***	-	-	-	-	-	-
N2b	0.36***	0.51***	-	-	-	-	-	-
N2c	0.33***	0.67***	-	-	-	-	-	-
N2d	0.39***	0.45***	-	-	-	-	-	-
N2e	-	-	-	-0.34***	-0.42***	-0.46***	-	-0.38***
N2f	-	-	0.34***	0.40***	-	-	-	-
N2g	-	-	-0.33***	-0.41***	-	-	-	-
N3a	-	-	-	-	-	-0.40***	-	-
N3b	-	-	-	-	-	-	-	-
N3c	-	-	-	-	-0.44***	-0.49***	-	-
N3d	-	-	-	-	-	-	-	-
N3e	-	-	-	-	-	-	-	-
N3f	-	-	-	-	-	-	-	-
N3g	-	-	-	-	-	-	-	-
N3h	-	-	-	-	-	-	-	-
N4a	-	-	-	-	-	-	-	-
N4b	-	-	-	-	-	-	-	-
N4c	-	-	-	-	-0.30***	-	-	-
N4d	-	-	-	-	-	-0.33***	-	-
N4e	-	-	-	-	-	-	-	-
N5a	-	-	-	-	-	-	-	-
N5b	-	-	-	-	-	-	-	-
N5c	-	-	-	-	0.32***	-	-	-
N5d	-	-	-	-	-	-	-	-
N5e	-	-	-	-	-	-	0.31***	-
N6a	-	-	-	-	-	-	-	-
N6b	-	-	-	-	-0.35***	-0.31***	-	-
N6c	-	-	-	-	0.46***	0.43***	-	0.33***
N6d	-	-	-0.45***	-	-	-	-	-
N6e	-	-	-	-	-	-	-	-
N6f	1.00	0.31***	-	-	-	-	-	-
N6g		1.00	-	-	-	-	-	-
N7a			1.00	0.48***	-	-	-	-
N7b				1.00	-	0.53***	0.53***	-
N7c					1.00	-	-	-
N7d						1.00	0.62***	0.32***
N7e							1.00	-
N7f								1.00

$p < .001$***, $p < .01$**, $p < .05$*

Table 13: Correlation table of the ecological capital including only medium and strong correlations.

A.2.2 Social-cultural capital

	S1a	S1b	S1c	S1d	S1e	S2a	S2b	S2c	S2d
S1a	1.00	0.42***	-	-	-	0.30***	-	-	-
S1b		1.00	0.41***	0.37***	-	0.47***	-0.37***	-0.36***	-
S1c			1.00	0.67***	-	0.57***	-0.51***	-0.48***	-0.36***
S1d				1.00	-	0.50***	-0.50***	-0.49***	-0.42***
S1e					1.00	-	-	-	-
S2a						1.00	-0.86***	-0.81***	-0.56***
S2b							1.00	0.93***	0.67***
S2c								1.00	0.65***
S2d									1.00

	S3a	S3b	S3c	S3d	S3e	S4a	S4b	S4c	S4d
S1a	-	-	-	-	-	-0.33***	-	0.36***	-
S1b	0.33***	-	-	-	-	-	-	0.34***	-
S1c	0.35***	0.33***	-	-	-	-	-	-	-
S1d	0.34***	-	-	-	-	-	-	-	-
S1e	-	-	-	-	-	-	-	-	-
S2a	0.42***	-	-	-	-	-	-	0.41***	-
S2b	-0.30***	-	-	-	0.42***	-	-	-	-
S2c	-	-	-	-	0.44***	-	-	-	-
S2d	-	-	-	-	-	-	-	-	-
S3a	1.00	-	-	0.39***	-	-	-	0.34***	-
S3b		1.00	0.36***	-	-	-	-	-	-
S3c			1.00	-	-	-	-	-	-
S3d				1.00	-	-	-	-	-
S3e					1.00	-	-	-	-
S4a						1.00	-	-	-
S4b							1.00	-	-
S4c								1.00	-
S4d									1.00

	S4e	S4f	S4g	S4h	S4i	S5a	S5b	S5c	S5d
S1a	0.32***	-	-	-	-	-	-	-	-
S1b	0.40***	-0.32***	-	-	0.41***	-0.32***	-0.41***	-0.47***	-0.33***
S1c	0.33***	-	0.38***	-	0.39***	-0.44***	-0.55***	-0.58***	-
S1d	0.38***	-	0.40***	-	0.50***	-0.39***	-0.52***	-0.50***	-
S1e	-	-	-	-	-	-	-	-	-
S2a	0.33***	-	0.47***	-0.45***	0.44***	-0.69***	-0.79***	-0.86***	-0.66***
S2b	-	-	-0.51***	0.51***	-0.45***	0.66***	0.78***	0.80***	0.49***
S2c	-	-	-0.52***	0.50***	-0.47***	0.62***	0.74***	0.77***	0.45***
S2d	-	-	-0.38***	-	-0.44***	0.41***	0.52***	0.55***	0.31***
S3a	0.62***	-	-	-	-	-	-0.32***	-0.48***	-0.32***
S3b	0.38***	-	-	-	-	-	-	-	-
S3c	-	-	-	-	-	-	-	-	-
S3d	-	-	-	-	-	-	-	-	-
S3e	-	-	-	-	-	-	-	0.32***	-
S4a	-	-	-	-	-	-	-	-	-
S4b	-	-	-0.44***	-	-0.39***	-	-	-	-

S4c	-	-	-	-	-	-	-	-0.41***	-
S4d	-	-	-	-	-	-	-	-	-
S4e	1.00	-	-	-	-	-	-	-0.39***	-
S4f		1.00	-0.33***	-	-0.57***	-	-	-	-
S4g			1.00	-	0.47***	-0.36***	-0.47***	-0.40***	-
S4h				1.00	-	0.47***	0.52***	0.46***	0.37***
S4i					1.00	-	-0.45***	-0.40***	-
S5a						1.00	0.83***	0.79***	0.68***
S5b							1.00	0.87***	0.67***
S5c								1.00	0.72***
S5d									1.00

	S5e	S5f	S6a	S6b	S6c	S6d	S6e	S6f	S7a
S1a	-	-0.68***	-	0.30***	-	-	-	-	-
S1b	-	-0.38***	-	0.38***	0.38***	-	-	-	-
S1c	-	-	-	-	0.40***	-	-	-	-0.38***
S1d	-	-	-	-	0.35***	-	-	-	-0.49***
S1e	-	-	-	-	-	-	-	-	-
S2a	-	-	-	0.44***	0.61***	-	-	0.55***	-0.56***
S2b	-	-	-	-	-0.55***	-	-	-0.53***	0.70***
S2c	-	-	-	-	-0.50***	-	-	-0.51***	0.63***
S2d	-	-	-	-	-0.38***	-	-	-0.37***	0.58***
S3a	-	-0.31***	-	0.35***	-	-	-	-	-
S3b	-	-	-	-	-	-	-	-	-
S3c	-	-	-	-	-	-	-	-	-
S3d	-	-	-	-	-	-	-	-	-
S3e	-	-	-	-	-	-	-	-0.30***	-
S4a	-	0.40***	-	-	-	-	-	-	-
S4b	-	-	-	-	-	-	-	-	0.36***
S4c	-	-	-	0.79***	-	-	-	-	-
S4d	-	-	-	-	-	-	-	-	-
S4e	-	-0.34***	-	-	-	-	-	-	-
S4f	-	-	-	-	-	-	-	-	-
S4g	-	-	-	-	0.33***	-	-	-	-0.56***
S4h	-	-	-	-	-	-	-	-	0.36***
S4i	-	-	-	-	0.30***	-	-	-	-0.39***
S5a	-	-	-	-0.31***	-0.40***	-	-	-0.37***	0.49***
S5b	-	-	-	-0.32***	-0.47***	-	-	-0.45***	0.62***
S5c	-	-	-	-0.46***	-0.55***	-	-	-0.49***	0.52***
S5d	-	-	-	-	-0.39***	-	0.31***	-0.35***	0.40***
S5e	1.00	-	-	-	-	-	-	-	-
S5f		1.00	-	-	-	-	-	-	-
S6a			1.00	-	-	0.51***	-	-	-0.31***
S6b				1.00	0.31***	-	-0.31***	-	-
S6c					1.00	-	-	0.58***	-0.36***
S6d						1.00	-	-	-0.33***
S6e							1.00	-	-
S6f								1.00	-0.30***
S7a									1.00

	S7b	S7c	S7d	S7e	S7f	S7g
S1a	-	-	-0.35***	-	-	-
S1b	0.31***	-	-0.47***	-	-	-
S1c	-	-	-0.51***	-	-	-
S1d	-	-	-0.48***	-	-	-0.50***
S1e	-	-	-	-	-	-
S2a	0.43***	0.45***	-0.74***	0.37***	-	-
S2b	-	-0.34***	0.68***	-0.38***	-	-
S2c	-	-0.31***	0.68***	-0.36***	-	-
S2d	-	-	0.45***	-	-	-
S3a	0.32***	0.38***	-	-	-	-
S3b	-	-	-	-	-	-
S3c	-	-	-	-	-	-
S3d	-	0.45***	-	-	-	-
S3e	-	-	-	-	-	-
S4a	-	-	-	-	-	-
S4b	-	-	-	-	-	0.45***
S4c	0.67***	0.40***	-0.33***	-	-	-
S4d	-	-	-	-	-	-
S4e	-	-	-0.33***	-	-	-
S4f	-	-	-	-	-	-
S4g	-	-	-0.38***	-	-	-0.42***
S4h	-	-	0.35***	-	-	-
S4i	-	-	-0.48***	-	-	-0.40***
S5a	-	-	0.66***	-	-	-
S5b	-	-	0.73***	-0.35***	-	-
S5c	-0.41***	-0.44***	0.73***	-0.38***	-	-
S5d	-0.31***	-0.41***	0.42***	-	-	-
S5e	-	-	-	-	-	-
S5f	-	-	-	-	-	-
S6a	-	-	-	-	-	-
S6b	0.67***	0.52***	-0.35***	-	-	-
S6c	-	-	-0.44***	-	-	-
S6d	-	-	-	-	-	-0.37***
S6e	-	-0.45***	-	-	-	-
S6f	-	-	-0.44***	-	-	-
S7a	-	-	0.45***	-	-	0.34***
S7b	1.00	0.44***	-	-	-	-
S7c		1.00	-0.32***	-	-	-
S7d			1.00	-	-	-
S7e				1.00	0.35***	-
S7f					1.00	-
S7g						1.00

$p < .001$***, $p < .01$**, $p < .05$*

Table 14: Correlation table of the social-cultural capital including only medium and strong correlations.

A.2.3 Economic capital

	E1a	E1b	E1c	E1d	E1e	E2a	E2b	E2c	E2d
E1a	1.00	-	-	0.38***	-	-	-	-	0.37***
E1b		1.00	-0.66***	-	-0.53***	-	-	-	-
E1c			1.00	-	0.42***	-	-	-	0.31***
E1d				1.00	-	-	-	-	-
E1e					1.00	-	-	-	-
E2a						1.00	-	-	-
E2b							1.00	-	-
E2c								1.00	-
E2d									1.00

	E2e	E3a	E3b	E3c	E3d	E3a	E4a	E4b	E4c
E1a	-	-	-	-	-	-	-	-	0.36***
E1b	-	-	-0.34***	0.33***	-	-	-	-	-
E1c	-	0.55***	0.52***	-0.34***	-	-	-	-	-
E1d	-	-	-	-	-	-	-	-	-
E1e	-	0.30***	0.32***	-	-	-	-	-	-
E2a	-	-	-	-	-	-	-	-	-
E2b	-	-	-	-	-	-	-	-	-
E2c	-	-	-	-	-	-	-	-	-
E2d	-	0.30***	0.40***	-	-	-	-	-	-
E2e	1.00	-	-	-	-	-	-	-	-
E3a		1.00	0.65***	-0.40***	-	-	-0.37***	-	-
E3b			1.00	-0.47***	-	-	-0.35***	-	-
E3c				1.00	-	-	-	-	-
E3d					1.00	-	-	-	-
E3e						1.00	-	-	-
E4a							1.00	0.41***	-
E4b								1.00	0.48***
E4c									1.00

	E4d	E5a	E5b	E5c	E5d
E1a	0.33***	-	-	-	-
E1b	-	-	-	-	-
E1c	-	-	0.32***	-	-
E1d	-	-	0.56***	-	-
E1e	-	-	-	-	-
E2a	-	-	-	-	-
E2b	-	-	-	-	-
E2c	-	-	-	-	-
E2d	-	-	-	-	-
E2e	-	-	-	-	-
E3a	-	0.41***	0.44***	-	-
E3b	0.39***	0.36***	-	-	-
E3c	-	-0.31***	-	-	-
E3d	-	-	-	-	-
E3e	-	-	-	-	-
E4a	-	-0.38***	-	-	-

E4b	-	-	-	-	-
E4c	-	-	0.35***	-	-
E4d	1.00	0.34***	-	-	-
E5a		1.00	0.46***	-	-
E5b			1.00	0.48***	-
E5c				1.00	-
E5d					1.00
$p < .001$***, $p < .01$**, $p < .05$*					

Table 15: Correlation table of the economic capital including only medium and strong correlations.

A.2.4 Green Growth interface

	E1a	E1b	E1c	E1d	E1e	E2a	E2b	E2c	E2d
N1a	-	-	0.41***	-	-	-0.31***	-	-	-
N1b	-	-	-	-	-	-	-	-	-
N1c	0.31***	-	0.47***	0.35***	-	-	-	-	-
N1d	-	0.30***	-	-	-	-	-	-	-
N1e	-	-	-	-	-	-	-	-	-
N1f	-	-	0.41***	0.37***	-	-	-	-	0.31***
N2a	-	-	-	-	-	-	-	-	-
N2b	-	-	-	-	-	-	-	-	-
N2c	-	-	-	-	-	-	-	-	-
N2d	-	-	-	-	-	-	-	-	-
N2e	-	-	-	-	-	-	-	-	0.31***
N2f	-	-	-	-	-	-	-	-	-
N2g	-	-	-	-	-	-	-	-	-
N3a	-	-	0.35***	-	-	-	-	-	-
N3b	-	-	-	-	-	-	-	-	-
N3c	0.34***	-	0.31***	-	-	-	-	-	0.39***
N3d	-	-	-	-	-	-	-	-	-
N3e	-	-	-	-	-	-	-	-	-
N3f	-	-	-	-	-	-0.37***	-	-	-
N3g	-	-	-	-	-	-	-	-	-
N3h	-	-	-	-	-	-	-	-	-
N4a	-	-	-	-	-	-	-	-	-
N4b	-	-	-	-	-	-	-	-	-
N4c	-	-	-	-	-	-	-	-	-
N4d	-	-	-	-	-	-	-	-	-
N4e	-	-	-	-	-	-	-	-	-
N5a	-	-	-	-	-	-	-	-	-
N5b	-	-	-	-	-	-	-	-	-
N5c	-	-	-	-	-	-	-	-	-
N5d	-	-	-	-	-	-	-	-	-
N5e	-	-	-	-	-	-	-	-	-
N6a	-	-	-	-	-	-0.32***	-	-	-
N6b	-	-	-	0.33***	-	-	-	-	-
N6c	-	-	-0.37***	-0.49***	-	-	-	-	-0.35***
N6d	-	0.36***	-0.55***	-	-	-	-	-	-
N6e	-	-0.33***	-	-	-	-	-	-	-
N6f	-	-	-	-	-	-	-	-	-
N6g	-	-	-	-	-	-	-	-	-
N7a	-	-	-	-	-	-	-	-	-
N7b	-	-	-	-	-	-	-	-	-
N7c	-	-	-	-0.30***	-	-	-	-	-
N7d	-	-	-0.33***	-	-	-	-	-	-
N7e	-	-	-	-	-	-	-	-	-
N7f	-	-	-	-	-	-	-	-	-

	E2e	E3a	E3b	E3c	E3d	E3e	E4a	E4b	E4c
N1a	-	-	-	-	-	-	-	-	-
N1b	-	-	-	-	-	-	-	-	-
N1c	-	0.38***	0.33***	-	-	-	-	-	-
N1d	-	-	-	-	-	-	-	-	-
N1e	-	-	-	-	-	-	-	-	-
N1f	-	0.63***	0.57***	-	-	-	-0.34***	-	-
N2a	-	-	-	-	-	-	-	-	-
N2b	-	-	-	-	-	-	-	-	-
N2c	-	-	-	-	-	-	-	-	-
N2d	-	-	-	-	-	-	-	-	-
N2e	-	0.38***	0.43***	-	0.34***	-	-	-	-
N2f	-	-	-	-	-	-	-	-	-
N2g	-	-	-	-	-	-	-	-	-
N3a	-	0.54***	0.53***	-0.32***	-	-	-0.31***	-	-
N3b	-	-	-	-	-	-	-	-	-
N3c	-	0.59***	0.61***	-	-	-	-0.42***	-	-
N3d	-	-	-	-	-	-	-	-	-
N3e	-	-	-	-	-	-	-	-	-
N3f	-	-	-	-	-	-	-	-	-
N3g	-	-	-	-	-	-	-	-	-
N3h	-	0.36***	-	-	-	-	-	-	-
N4a	-	-	-	-	-	-	-	-	-
N4b	-	-	-	-	-	-	-	-	-
N4c	-	-	-	-	-	-	-	-	-
N4d	-	-	-	-	-	-	-	-	-
N4e	-	-	-	-	-	-	-	-	-
N5a	-	-	-	-	-	-	-	-	-
N5b	-	-0.34***	-0.41***	0.33***	-	-	-	-	-
N5c	-	-0.38***	-0.40***	-	-	-	-	-	-
N5d	-	-	-	-	-	-	-	-	-
N5e	-	-	-	-	-	-	-	-	-
N6a	-	-	-	-	-	-	-	-	-
N6b	-	0.56***	0.43***	-	-	-	-0.32***	-	-
N6c	-	-0.60***	-0.43***	-	-	-	-	-	-
N6d	-	-0.50***	-0.33***	-	-	-	-	-	-
N6e	-	-	-	-	-	-	-	-	-
N6f	-	-	-	-	-	-	-	-	-
N6g	-	-	-	-	-	-	-	-	-
N7a	-	-	-	-	-	-	-	0.38***	0.33***
N7b	-	-	-	-	-	-	0.46***	0.44***	-
N7c	-	-0.38***	-	-	-	-	-	-	-0.31***
N7d	-	-0.45***	-0.48***	-	-	-	0.32***	0.36***	-
N7e	-	-	-	-	-	-	0.38***	0.73***	-
N7f	-	-	-	-	-	-	-	-	-

	E4d	E5a	E5b	E5c	E5d
N1a	-	-	-	-	-
N1b	-	-	-	-	-

N1c	-	-	0.31***	-	-
N1d	-	-	-	-	-
N1e	-	-	-	-	-
N1f	0.36***	0.31***	0.35***	-	-
N2a	-	-	-	-	-
N2b	-	-	-	-	-
N2c	-	-	-	-	-
N2d	-	-	-	-	-
N2e	0.44***	0.43***	-	-	-
N2f	-0.30***	-	-	-	-
N2g	0.32***	0.33***	-	-	-
N3a	-	0.34***	0.34***	-	-
N3b	-	-	-	-	-
N3c	0.45***	0.42***	0.33***	-	-
N3d	-	-	-	-	-
N3e	-	-	-	-	-
N3f	-	-	-	-	-
N3g	-	-	-	-	-
N3h	-	-	-	-	-
N4a	-	-	-	-	-
N4b	-	-	-	-	-
N4c	-	-	-	-	-
N4d	-	-	-	-	-
N4e	-	-	-	-	-
N5a	-	-	-	-	-
N5b	-	-	-	-	-
N5c	-	-	-	-	-
N5d	-	-	0.31***	-	-
N5e	-	-	-	-	-
N6a	-	-	-	-	-
N6b	0.31***	-	0.34***	-	-
N6c	-0.37***	-	-0.34***	-	-
N6d	-	-	-	-	-
N6e	-	-	-	-	-
N6f	-	-	-	-	-
N6g	-	-	-	-	-
N7a	-	-	-	-	-
N7b	-	-0.37***	-	-	-
N7c	-	-	-	-	-
N7d	-	-0.39***	-	-	-
N7e	-	-	-	-	-
N7f	-	-	-	-	-

$p < .001^{***}$, $p < .01^{**}$, $p < .05^{*}$

Table 16: Correlation table of the Green Growth interface including only medium and strong correlations.

A.2.5 Social Growth interface

	E1a	E1b	E1c	E1d	E1e	E2a	E2b	E2c	E2d
S1a	-	-	-	-	-	-	-	-	-
S1b	-	-	-0.34***	-	-0.40***	-	-	-	-
S1c	-	-	-0.50***	-	-0.46***	-	-	-	-
S1d	-	0.37***	-0.48***	-	-0.56***	-	-	-	-
S1e	-	-	-	-	-	-	-	-	-
S2a	-	0.44***	-0.81***	-0.37***	-0.45***	-	-	-	-0.39***
S2b	-	-0.64***	0.88***	-	0.46***	-	-	-	-
S2c	-	-0.69***	0.85***	-	0.47***	-	-	-	-
S2d	-	-0.54***	0.71***	-	0.35***	-0.37***	-	-	-
S3a	-	-	-	-	-	-	-	-	-0.34***
S3b	-	-	-	-	-	-	-	-	-
S3c	-	-	-	-	-	-	-	-	-
S3d	-	-	-	-	-	-	-	-	-
S3e	-	-	0.33***	-	-	-	-	-	-
S4a	-	-	-	-	-	-	-	-	-
S4b	-	-	-	-	0.39***	-	-	-	-
S4c	-	-	-	-	-	-	-	-	-
S4d	-	-	-	-	-	-	-	-	-
S4e	-	-	-	-	-	-	-	-	-
S4f	-	-0.44***	-	-	0.49***	-	-	-	-
S4g	-	0.40***	-0.47***	-	-0.43***	-	-	-	-
S4h	-	-0.31***	0.41***	-	-	-	-	-	-
S4i	-	0.53***	-0.41***	-	-0.67***	-	-	-	-
S5a	0.31***	-	0.56***	0.34***	0.32***	-	-	-	-
S5b	-	-0.43***	0.69***	-	0.48***	-	-	-	-
S5c	0.36***	-0.38***	0.73***	0.33***	0.44***	-	-	-	0.39***
S5d	-	-	0.44***	-	-	-	-	-	0.33***
S5e	-	-	-	-	-	-	-	-	-
S5f	-	-	-	-	-	-	-	-	-
S6a	-	-	-	-	-	-	-	-	-
S6b	-	-	-	-	-	-	-	-	-
S6c	-	-	-0.48***	-	-0.32***	-	-	-	-
S6d	-	-	-	-	-	-	-	-	-
S6e	-	-	-	-	-	-	-	-	-
S6f	-	-	-0.47***	-	-	-	-	-	-
S7a	-	-0.59***	0.70***	-	0.50***	-	-	-	-
S7b	-	-	-	-0.31***	-	-	-	-	-
S7c	-	-	-0.36***	-	-	-	-	-	-
S7d	-	-0.42***	0.58***	0.31***	0.47***	-	-	-	-
S7e	-	-	-0.33***	-	-	-	-	-	-
S7f	-	-	-	-	-	-	-	-	-
S7g	-	-	-	-	0.37***	-	-	-	-

	E2e	E3a	E3b	E3c	E3d	E3e	E4a	E4b	E4c
S1a	-	-0.38***	-0.41***	-	-0.41***	-	-	-	-
S1b	-	-0.38***	-0.51***	-	-	-	-	-	-
S1c	-	-0.41***	-0.39***	-	-	-	-	-	-
S1d	-	-	-	-	-	-	-	0.30***	-
S1e	-	-	-	-	-	-	-	-	-
S2a	-	-0.71***	-0.69***	0.40***	-	-	0.32***	-	-
S2b	0.30***	0.57***	0.52***	-0.37***	-	-	-	-	-
S2c	-	0.53***	0.48***	-0.34***	-	-	-	-	-
S2d	-	0.38***	0.35***	-	-	-	-	-	-
S3a	-	-0.40***	-0.50***	-	-	-	0.56***	-	-
S3b	-	-	-	-	-	-	-	0.35***	-
S3c	-	-	-	-	-	-	-	-	-
S3d	-	-	-0.31***	-	-	-	-	-	-
S3e	-	-	-	-	-	-	-	-	-
S4a	-	-	-	-	-	-	-	-0.34***	-
S4b	-	-	-	-	-	-	-	-	-
S4c	-	-0.51***	-0.50***	-	-	-	-	-	-
S4d	-	-	-	-	-	-	-	-	-
S4e	-	-0.40***	-0.49***	-	-	-	0.50***	0.60***	-
S4f	-	-	-	-	-	-	-	-	-
S4g	-	-	-	-	-	-	-	-	-
S4h	-	-	-	-0.31***	-	-	-	-	-
S4i	-	-	-	-	-	-	-	-	-
S5a	-	0.46***	0.45***	-	-	-	-	-	-
S5b	-	0.55***	0.52***	-0.31***	-	-	-	-	-
S5c	-	0.70***	0.66***	-0.41***	-	-	-0.31***	-	-
S5d	-	0.43***	0.51***	-0.36***	-	-	-	-	-
S5e	-	-	-	-	-	-	-	-	0.31***
S5f	-	0.33***	0.36***	-	-	-	-	-	-
S6a	-	-	-	-	-	-	-	-	-
S6b	-	-0.50***	-0.51***	0.31***	-	-	-	-	-
S6c	-	-0.40***	-0.38***	-	-	-	-	-	-
S6d	-	-	-	-	-	-	-	-	-
S6e	-	-	-	-	-	-	-	-	-
S6f	-	-0.36***	-0.37***	-	-	-	-	-	-
S7a	-	-	-	-	-	-	-	-	-
S7b	-	-0.46***	-0.48***	-	-	-	-	-	-
S7c	-	-0.45***	-0.50***	0.39***	-	-	0.34***	-	-
S7d	-	0.54***	0.54***	-	-	-	-	-	-
S7e	-	-0.31***	-0.36***	-	-	-	-	-	-
S7f	-	-	-	-	-	-	-	-	-
S7g	-	-	-	-	-	-	-	-	-

	E4d	E5a	E5b	E5c	E5d
S1a	-	-0.31***	-	-	-
S1b	-	-	-	-	-
S1c	-	-	-	-	-
S1d	-	-	-	-	-
S1e	-	-	-	-	-
S2a	-	-	-0.33***	-	-
S2b	-	-	-	-	-
S2c	-	-	0.34***	-	-
S2d	-	-	-	-	-
S3a	-	-0.39***	-	-	-
S3b	-	-	-	-	-
S3c	-	-	-	-	-
S3d	-	-	-	-	-
S3e	-	-	-	-	-
S4a	-	-	-	-	-
S4b	-	-0.31***	-	-	-
S4c	-	-0.33***	-	-	-
S4d	-	-	-	-	-
S4e	-	-0.39***	-	-	-
S4f	-	-	-	-	-
S4g	-	-	-	-	-
S4h	-	-	-	-	-
S4i	-	-	-	-	-
S5a	-	-	-	-	-
S5b	-	-	-	-	-
S5c	-	-	0.31***	-	-
S5d	-	-	-	-	-
S5e	-	-	-	-	-
S5f	-	-	-	-	-
S6a	-	-	-	-	-
S6b	-	-	-	-	-
S6c	-	-	-	-	-
S6d	-	0.33***	-	-	-
S6e	-	-	-	-	-
S6f	-	-	-	-	-
S7a	-	-	-	-	-
S7b	-0.31***	-	-	-	-
S7c	-	-	-	-	-
S7d	-	-	-	-	-
S7e	-	-	-	-	-
S7f	-	-	-	-	-
S7g	-	-0.51***	-	-	-0.30***
$p < .001$***, $p < .01$**, $p < .05$*					

Table 17: Correlation table of the Social Growth interface including only medium and strong correlations.

A.2.6 Environmental Equity interface

	S1a	S1b	S1c	S1d	S1e	S2a	S2b	S2c	S2d
N1a	-	-	-	-	-	-0.33***	0.38***	0.40***	0.43***
N1b	-	-	-	-	-	-	-	-	-
N1c	-	-	-0.32***	-	-	-0.42***	0.46***	0.48***	0.41***
N1d	-	-	-	-	-	-	-	-	-
N1e	-	-	-	-	-	-	-	-	-
N1f	-0.42***	-0.41***	-0.38***	-	-	-0.63***	0.48***	0.47***	0.31***
N2a	-	-	-	-	-	-	-	-	-
N2b	-	-	-	-	-	-	-	-	-
N2c	-	-	-	-	-	-	-	-	-
N2d	-	-	-	-	-	-	-	-	-
N2e	-0.47***	-0.37***	-	-	-	-	-	-	-
N2f	-	-	-	-	-	-	-	-	-
N2g	-	-	-	-	-	-	-	-	-
N3a	-0.31***	-	-0.35***	-	-	-0.48***	0.37***	0.36***	-
N3b	-	-	-	-	-	-	-	-	-
N3c	-0.48***	-0.42***	-0.31***	-	-	-0.54***	0.35***	0.32***	-
N3d	-	-	-	-	-	-	-	-	-
N3e	-	-	-	-	-	-	-	-	0.33***
N3f	-	-	-	-	-	-	0.30***	-	0.46***
N3g	-	-	-	-	-	-	-	-	-
N3h	-	-	-	-	-	-	-	-	-
N4a	-	-	-	-	-	-	-	-	-
N4b	-	-	-	-	-	-	-	-	-
N4c	-0.30***	-	-	-	-	-	-	-	-
N4d	-0.34***	-	-	-	-	-	-	-	-
N4e	-	-	-	-	-	-	-	-	-
N5a	-	-	-	-	-	-	-	-	-
N5b	-	-	-	-	-	0.34***	-	-	-
N5c	-	-	-	-	-	0.34***	-	-	-
N5d	-	-	-	-	-	-	-	-	-
N5e	-	-	-	-	-	-	-	-	-
N6a	-	-	-	-	-	-	-	-	-
N6b	-	-	-	-	-	-0.48***	0.32***	0.31***	-
N6c	0.31***	0.40***	0.48***	-	-	0.68***	-0.42***	-0.38***	-
N6d	-	-	-	-	-	0.70***	-0.69***	-0.66***	-0.37***
N6e	-	-	-	-	-	-	-	-	-
N6f	-	-	-	-	-	-	-	-	-
N6g	-	-	-	-	-	-	-	-	-
N7a	-	-	-	-	-	-0.36***	-	-	-
N7b	-	-	-	0.38***	-	-	-	-	-
N7c	0.32***	-	0.30***	-	-	0.37***	-	-	-
N7d	0.42***	0.37***	0.36***	0.38***	-	0.50***	-0.35***	-0.32***	-
N7e	-	-	-	0.49***	-	0.33***	-	-	-
N7f	-	-	-	-	-	-	-	-	-

	S3a	S3b	S3c	S3d	S3e	S4a	S4b	S4c	S4d
N1a	-	-	-	-	0.33***	-	-	-	-
N1b	-	-	-	-	-	-	-	-	-
N1c	-	-	-	-	0.42***	-	-	-	-
N1d	-	-	-	-	-	-	-	-	-
N1e	-	-	-	-	-	-	-	-	-
N1f	-0.44***	-	-	-0.31***	-	-	-	-0.55***	-
N2a	-	-	-	-	-	-	-	-	-
N2b	-	-	-	-	-	-	-	-	-
N2c	-	-	-	-	-	-	-	-	-
N2d	-	-	-	-	-	-	-	-	-
N2e	-0.45***	-	-	-	-	0.37***	-	-0.51***	-
N2f	0.39***	0.34***	-	-	-	-0.43***	-	0.30***	-
N2g	-0.40***	-	-	-	-	0.40***	-	-0.33***	-
N3a	-0.44***	-	-	-	-	-	-	-0.43***	-
N3b	-	-	-	-	-	-	-	-	-
N3c	-0.50***	-	-	-	-	-	-	-0.57***	-
N3d	-	-	-	-	-	-	-	-	-
N3e	-	-	-	-	-	-	-	-	-
N3f	-	-	-	-	-	-	-	-	-
N3g	-	-	-	-	-	-	-	-	-
N3h	-	-	-	-	-	-	-	-	-
N4a	-	-	-	-	-	-	-	-	-
N4b	-	-	-	-	-	-	-	-	-
N4c	-	-	-	-	-	-	-	-	-
N4d	-	-	-	-	-	-	-	-	-
N4e	-	-	-	-	-	-	-	-	-
N5a	-	-	-	-	-	-	-	-	-
N5b	-	-	-	-	-	-	-	0.30***	-
N5c	0.33***	-	-	-	-	-	-	0.42***	-
N5d	-	-	-	-	-	-	-	-0.35***	-
N5e	-	-	-	-	-	-	-	-	-
N6a	-	-	-	-	-	-	-	-	-
N6b	-0.36***	-	-	-	-	-	-	-0.48***	-
N6c	0.33***	-	-	-	-	-	-	0.48***	-
N6d	-	-	-	-	-0.38***	-	-	-	-
N6e	-	-	-	-	-	-	-	-	-
N6f	-	-	-	-	-	-	-	-	-
N6g	-	-	-	-	-	-	-	-	-
N7a	-	-	-	-	-	-	-	-	-
N7b	0.49***	-	-	-	-	-	-	-	-
N7c	-	-	-	-	-	-	-	0.41***	-
N7d	0.45***	-	-	-	-	-	-	-	-
N7e	0.33***	0.34***	-	-	-	-0.41***	-	-	-
N7f	-	-	-	-	-	-	-	-	-

	S4e	S4f	S4g	S4h	S4i	S5a	S5b	S5c	S5d
N1a	-	-	-	-	-	-	0.33***	0.40***	-
N1b	-	-	-	-	-	-	-	-	-
N1c	-	-	-	-	-	0.38***	0.44***	0.52***	-
N1d	-	-	-	-	-	-	-	-	-
N1e	-	-	-	-	-	-	-	-	-
N1f	-0.40***	-	-	-	-	0.39***	0.46***	0.61***	0.39***
N2a	-	-	-	-	-	-	-	-	-
N2b	-	-	-	-	-	-	-	-	-
N2c	-	-	-	-	-	-	-	-	-
N2d	-	-	-	-	-	-	-	-	-
N2e	-0.49***	-	-	-	-	-	-	0.30***	-
N2f	0.44***	-	-	0.34***	-	-	-	-	-
N2g	-0.41***	-	-	-0.33***	-	-	-	-	-
N3a	-0.42***	-	-	-	-	0.33***	0.37***	0.48***	0.34***
N3b	-	-	-	-	-	-	-	-	-
N3c	-0.47***	-	-	-	-	0.32***	0.36***	0.53***	0.32***
N3d	-	-	-	-	-	-	-	-	-
N3e	-	-	-	-	-	-	-	-	-
N3f	-	-	-	-	-	-	-	-	-
N3g	-	-	-	-	-	-	-	-	-
N3h	-	-	-	-	-	-	-	-	-
N4a	-	-	-	-	-	-	-	-	-
N4b	-	-	-	-	-	-	-	-	-
N4c	-	-	-	-	-	-	-	-	-
N4d	-	-	-	-	-	-	-	-	-
N4e	-	-	-	-	-	-	-	-	-
N5a	-	-	-	-	-	-	-	-	-
N5b	-	-	-	-	-	-	-	-0.33***	-0.32***
N5c	-	-	-	-	-	-	-	-0.38***	-
N5d	-	-	-	-	-	-	-	-	-
N5e	-	-	-	-	-	-	-	-	-
N6a	-	-	-	-	-	-	-	-	-
N6b	-0.33***	-	-	-	-	-	-	0.44***	-
N6c	0.31***	-	-	-	-	-0.45***	-0.49***	-0.61***	-0.32***
N6d	-	-	0.34***	-0.57***	-	-0.51***	-0.58***	-0.57***	-0.39***
N6e	-	-	-	-	-	-	-	-	-
N6f	-	-	-	-	-	-	-	-	-
N6g	-	-	-	-	-	-	-	-	-
N7a	-	-	-	0.33***	-	0.32***	0.30***	0.31***	-
N7b	0.52***	-	-	-	-	-	-	-	-
N7c	-	-	-	-	-	-0.31***	-	-0.40***	-
N7d	0.50***	-	-	-	-	-0.41***	-0.38***	-0.48***	-0.33***
N7e	0.55***	-	-	-	-	-	-	-	-
N7f	-	-	-	-	-	-	-	-	-

	S5e	S5f	S6a	S6b	S6c	S6d	S6e	S6f	S7a
N1a	-	-	-	-	-	-	-	-	-
N1b	-	-	-	-	-	-	-	-	-
N1c	-	-	-	-	-	-	-	-	-
N1d	-	-	-	-	-	-	-	-	-
N1e	-	-	-	-	-	-	-	-	-
N1f	-	0.35***	-	-0.59***	-0.39***	-	-	-0.33***	-
N2a	-	-	-	-	-	-	-	-	-
N2b	-	-	-	-	-	-	-0.33***	-	-
N2c	-	-	-	-	-	-	-	-	-
N2d	-	-	-	-	-	-	-	-	-
N2e	-	0.49***	-	-0.54***	-	-	-	-	-
N2f	-	-0.47***	-	0.36***	-	-	-	-	-
N2g	-	0.51***	-	-0.40***	-	-	-	-	-0.38***
N3a	-	-	-	-0.40***	-0.35***	-	0.30***	-0.32***	-
N3b	-	-	-	-	-	-	-	-	-
N3c	-	0.39***	-	-0.59***	-0.33***	-	-	-0.32***	-
N3d	-	-	-	-	-0.31***	-	-	-	-
N3e	-	-	-	-	-	-	-	-	-
N3f	-	-	-	-	-	-	-	-	-
N3g	-	-	-	-	-	-	-	-	-
N3h	-	-	-	-	-	-	-	-	-
N4a	-	-	-	-	-	-	-	-	-
N4b	-	-	-	-	-	-	-	-	-
N4c	-	-	-	-	-	-	-	-	-
N4d	-	-	-	-	-	-	-	-	-
N4e	-	-	-	-	-	-	-	-	-
N5a	-	-	-	-	-	-	-	-	-
N5b	-	-	-	0.42***	-	-	-	-	-
N5c	-	-	-	0.47***	-	-	-	-	-
N5d	-	-	-	-0.44***	-	-	-	-	-
N5e	-	-	-	-0.32***	-	-	-	-	-
N6a	-	-	-	-	-	-	-	-	-
N6b	-	-	-	-0.50***	-	-	-	-	-
N6c	-	-	-	0.48***	0.43***	-	-	0.33***	-
N6d	-	-	-	-	0.42***	-	-	0.48***	-0.45***
N6e	-	-	-	-	-	-	-	-	-
N6f	-	-	-	-	-	-	-	-	-
N6g	-	-	-	-	-	-	-	-	-
N7a	-	-	-	-	-	-	-	-	-
N7b	-	-0.35***	-	-	-	-	-	-	-
N7c	-	-	-	0.43***	-	-	-	-	-
N7d	-	-0.31***	-	-	-	-	-	-	-
N7e	-	-	-	-	-	-	-	-	-
N7f	-	-	-	-	-	-	-	-	-

	S7b	S7c	S7d	S7e	S7f	S7g
N1a	-	-	-	-	-	-
N1b	-	-	-	-	-	-
N1c	-	-	0.35***	-	-	-
N1d	-	-	-	-	-	-
N1e	-	-	-	-	-	-
N1f	-0.53***	-0.51***	0.49***	-	-	-
N2a	-	-	-	-	-	-
N2b	-	-	-	-	-	-
N2c	-	-	-	-	-	-
N2d	-	-	-	-	-	-
N2e	-0.46***	-0.31***	-	-	-	-
N2f	-	-	-	-	-	-
N2g	-	-	-	-	-	-
N3a	-0.38***	-0.37***	0.38***	-	-	-
N3b	-	-	-	-	-	-
N3c	-0.53***	-0.47***	0.41***	-	-	-
N3d	-	-	-	-	-	-
N3e	-	-	-	-	-	-
N3f	-	-	-	-	-	-
N3g	-	-	-	-	-	-
N3h	-	-	-	-	-	-
N4a	-	-	-	-	-	-
N4b	-	-	-	-	-	-
N4c	-	-	-	-	-	-
N4d	-	-	-	-	-	-
N4e	-	-	-	-	-	-
N5a	-	-	-	-	-	-
N5b	-	0.35***	-	-	-	-
N5c	0.39***	0.40***	-	-	-	-
N5d	-0.31***	-0.31***	-	-	-	-
N5e	-	-	-	-	-	-
N6a	-	-	-	-	-	-
N6b	-0.45***	-0.45***	0.33***	-	-	-
N6c	0.45***	0.34***	-0.51***	-	-	-
N6d	-	-	-0.50***	-	-	-
N6e	-	-	-	-	-	-
N6f	-	-	-	-	-	-
N6g	-	-	-	-	-	-
N7a	-	-	-	-	-	-
N7b	-	-	-	-	-	-
N7c	0.33***	0.33***	-	-	-	-
N7d	-	-	-0.44***	0.30***	-	-
N7e	-	-	-	-	-	-
N7f	-	-	-	-	-	-

$p < .001$***, $p < .01$**, $p < .05$*

Table 18: Correlation table of the Environmental Equity interface including only medium and strong correlations.

A.2.7 Underlying factors

	Median income
N1a	-
N1b	-
N1c	-
N1d	-
N1e	-
N1f	-
N2a	-
N2b	-
N2c	-
N2d	-
N2e	-
N2f	-
N2g	-
N3a	-
N3b	-
N3c	-
N3d	-
N3e	-
N3f	-
N3g	-
N3h	-
N4a	-
N4b	-
N4c	-
N4d	-
N4e	-
N5a	-
N5b	-
N5c	-
N5d	-
N5e	-
N6a	-
N6b	-
N6c	-
N6d	0.58***
N6e	-
N6f	-
N6g	-
N7a	-
N7b	-
N7c	-
N7d	-
N7e	-
N7f	-

	Median income
S1a	-
S1b	-
S1c	0.35***
S1d	0.43***
S1e	-
S2a	0.63***
S2b	-0.71***
S2c	-0.73***
S2d	-0.44***
S3a	-
S3b	-
S3c	-
S3d	-
S3e	-
S4a	-
S4b	-0.47***
S4c	-
S4d	-
S4e	-
S4f	-
S4g	0.65***
S4h	-0.40***
S4i	0.47***
S5a	-0.47***
S5b	-0.58***
S5c	-0.49***
S5d	-
S5e	-
S5f	-
S6a	-
S6b	-
S6c	0.40***
S6d	0.42***
S6e	-
S6f	0.42***
S7a	-0.65***
S7b	-
S7c	-
S7d	-0.48***
S7e	-
S7f	-
S7g	-0.54***

	Median income
E1a	-
E1b	0.50***
E1c	-0.67***
E1d	-0.46***
E1e	-0.44***
E2a	-
E2b	-
E2c	-
E2d	-
E2e	-
E3a	-
E3b	-
E3c	-
E3d	-
E3e	-
E4a	-
E4b	-
E4c	-
E4d	-
E5a	-
E5b	-
E5c	-
E5d	-

Table 19: Correlation tables of the underlying factor *income* with each capital including only medium and strong correlations. ($p < .001$***, $p < .01$**, $p < .05$*)

	Loam	Clay	Peat	Sand
N1a	-	-	-	-
N1b	-	-	-	-
N1c	-	-	-	-
N1d	-	-	-	-
N1e	-	-	-	-
N1f	-	-0.32***	-	-
N2a	-	-	-	-
N2b	-	-	-	-
N2c	-	-	-	-
N2d	-	0.35***	-	-
N2e	-	-	0.37***	-
N2f	-	-	-	-
N2g	-	-	-	-
N3a	-	-0.31***	-	-
N3b	-	-	-	-
N3c	-0.32***	-0.32***	0.33***	-
N3d	-	-	-	-
N3e	-	-	-	-
N3f	-	-	-	-
N3g	-	-	-	-
N3h	-	-	-	-
N4a	-	-	-	-
N4b	-	-	-	-
N4c	-	-	-	-
N4d	-	-	-	-
N4e	-	-	-	-
N5a	-	-	-	-
N5b	0.35***	-	-	-
N5c	-	-	-	-
N5d	-	-	-	-
N5e	-	-0.30***	-	-
N6a	-	-	-	-
N6b	-	-	-	-
N6c	-	-	-0.34***	-
N6d	0.30***	-	-	-
N6e	-	-	-	-
N6f	-	-	-	-
N6g	-	-	-	-
N7a	-	-	-	-
N7b	-	-	-	-
N7c	-	-	-	-
N7d	-	-	-	-
N7e	-	-	-	-
N7f	-	-	-	-

	Loam	Clay	Peat	Sand
S1a	-	-	-	-
S1b	-	-	-	-
S1c	-	-	-	-
S1d	-	-	-	-
S1e	-	-	-	-
S2a	0.38***	0.31***	-	-
S2b	-0.35***	-	-	0.33***
S2c	-0.32***	-	-	0.31***
S2d	-	-	-	-
S3a	-	-	-	-
S3b	-	-	-	-
S3c	-	-	-	-
S3d	-	-	-	-
S3e	-	-	-	-
S4a	-	-	-	-
S4b	-	-	-	-
S4c	-	-	-	-
S4d	-	-	-	-
S4e	-	-	-	-
S4f	-	-	-	-
S4g	-	-	-	-
S4h	-	-	-	0.32***
S4i	-	-	-	-
S5a	-	-	-	-
S5b	-	-	-	-
S5c	-0.31***	-0.36***	-	-
S5d	-	-	-	0.36***
S5e	-	-	-	-
S5f	-	-	-	-
S6a	-	-	-	-
S6b	0.32***	-	-	-
S6c	-	-	-	-
S6d	-	-	-	-
S6e	-	-	-	-
S6f	-	-	-	-
S7a	-	-	-	0.32***
S7b	0.36***	-	-	-
S7c	0.35***	-	-	-
S7d	-	-	-	-
S7e	-	-	-	-
S7f	-	-	-	-
S7g	-	0.39***	-	-

	Loam	Clay	Peat	Sand
E1a	-	-	-	-
E1b	0.31***	-	-	-0.38***
E1c	-0.34***	-	-	-
E1d	-	-	-	-
E1e	-	-	-	-
E2a	-	-	-	-
E2b	-	-	-	-
E2c	-	-	-	-
E2d	-	-	-	-
E2e	-	-	-	-
E3a	-	-0.42***	-	-
E3b	-0.44***	-0.38***	-	-
E3c	0.48***	0.38***	-	-0.55***
E3d	-	-	-	-
E3e	-	-	-	-
E4a	-	-	-	-
E4b	-	-	-	-
E4c	-	-	-	-
E4d	-	-	0.30***	-
E5a	-	-0.33***	-	-
E5b	-	-	-	-
E5c	-	-	-	-
E5d	-	-	-	-

Table 20: Correlation tables of the underlying factor *soil type* with each capital including only medium and strong correlations. ($p < .001$***, $p < .01$**, $p < .05$*)

	Agriculture	Industry	Commercial services	Non-commercial services
N1a	-	-	-	-
N1b	-	-	-	-
N1c	-	-	-	-
N1d	-	-	-	-
N1e	-	-	-	-
N1f	-	-	-	-
N2a	-	-	-	-
N2b	-	-	-	-
N2c	-	0.30***	-	-
N2d	-	0.41***	-	-
N2e	-	-	0.39***	-
N2f	-	-	-	-
N2g	-	-	0.31***	-
N3a	-	-0.37***	-	-
N3b	0.33***	-	-	-
N3c	-0.31***	-	0.32***	-
N3d	-	-	-	-
N3e	-	-	-	-
N3f	-	-	-	-
N3g	-	-	-	-
N3h	-	-	-	-
N4a	-	-	-	-
N4b	-	-	-	-
N4c	-	-	-	-
N4d	-	-	-	-
N4e	-	-	-	-
N5a	-	-	-	0.31***
N5b	0.32***	-	-	-
N5c	-	-	-	-
N5d	-	-	-	-
N5e	-	-	-	-
N6a	-	-	-	-
N6b	-	-	-	-
N6c	-	-	-0.32***	-
N6d	0.30***	-	-	-
N6e	-	-	-	-
N6f	-	-	-	-
N6g	-	-	-	-
N7a	-	-	-	-
N7b	-	-	-	-
N7c	-	-	-	-
N7d	-	-	-	-
N7e	-	-	-	-
N7f	-	-	-	-

	Agriculture	Industry	Commercial services	Non-commercial services
S1a	-	-	-0.30***	-
S1b	-	-	-	-
S1c	-	-	-	-
S1d	-	-	-	-
S1e	-	-	-	-
S2a	0.37***	-	-	-
S2b	-0.35***	-	-	0.33***
S2c	-0.32***	-	-	0.32***
S2d	-	-	-	-
S3a	0.34***	-	-	-
S3b	-	-	-	-
S3c	-	-	-	-
S3d	-	-	-	-
S3e	-	-	-	-
S4a	-	-	-	-
S4b	-	-	-	-
S4c	-	-	-	-
S4d	-	-	-	-
S4e	-	-	-	-
S4f	-	-	-	-
S4g	-	-	-	-
S4h	-	-	-	0.33***
S4i	-	-	-	-
S5a	-	-	-	-
S5b	-	-	-	-
S5c	-0.30***	-0.33***	-	-
S5d	-	-	-	0.35***
S5e	-	-	-	-
S5f	-	-	-	-
S6a	-	-	-	-
S6b	0.31***	-	-	-
S6c	-	-	-	-
S6d	-	-	-	-
S6e	-	-	-	-
S6f	-	-	-	-
S7a	-	-	-	0.34***
S7b	0.34***	-	-	-
S7c	0.35***	-	-	-
S7d	-	-	-	-
S7e	-	-	-	-
S7f	-	-	-	-
S7g	-	0.44***	-	-

	Agriculture	Industry	Commercial services	Non-commercial services
E1a	-	-	-	-
E1b	0.31***	-	-	-0.40***
E1c	-0.34***	-	-	0.30***
E1d	-	-	-	-
E1e	-	-	-	-
E2a	-	-	-	-
E2b	-	-	-	-
E2c	-	-	-	-
E2d	-	-	-	-
E2e	-	-	-	-
E3a	-	-0.44***	-	-
E3b	-0.45***	-0.37***	-	-
E3c	0.50***	0.38***	-	-0.56***
E3d	-	-	-	-
E3e	-	-	-	-
E4a	-	-	-	-
E4b	-	-	-	-
E4c	-	-	0.32***	-
E4d	-	-	0.33***	-
E5a	-	-0.44***	-	-
E5b	-	-	-	-
E5c	-	-	-	-
E5d	-	-0.32***	-	-

Table 21: Correlation tables of the underlying factor *sector structure* with each capital including only medium and strong correlations. ($p < .001$***, $p < .01$**, $p < .05$*)

	Catholics (Registered)
N1a	-
N1b	-
N1c	-
N1d	-
N1e	-
N1f	-
N2a	-
N2b	-
N2c	-
N2d	-
N2e	-
N2f	-0.39***
N2g	0.47***
N3a	-
N3b	-
N3c	-
N3d	-
N3e	-
N3f	-
N3g	-
N3h	-
N4a	0.37***
N4b	-
N4c	-
N4d	-
N4e	-
N5a	-
N5b	-
N5c	-
N5d	-
N5e	-
N6a	-
N6b	-
N6c	-
N6d	0.51***
N6e	-
N6f	-
N6g	-
N7a	-0.46***
N7b	-
N7c	-
N7d	-
N7e	0.39***
N7f	-

	Catholics (Registered)
S1a	-
S1b	-
S1c	-
S1d	-
S1e	-
S2a	-
S2b	-
S2c	-
S2d	-
S3a	-
S3b	-
S3c	-
S3d	-
S3e	-
S4a	-
S4b	-
S4c	-
S4d	-
S4e	-
S4f	-
S4g	-
S4h	-
S4i	-
S5a	-
S5b	-
S5c	-
S5d	-
S5e	-
S5f	0.36***
S6a	-
S6b	-
S6c	-
S6d	-
S6e	-
S6f	-
S7a	-
S7b	-
S7c	-
S7d	-
S7e	-
S7f	-
S7g	-

	Catholics (Registered)
E1a	-
E1b	-
E1c	-
E1d	-
E1e	-
E2a	-
E2b	-
E2c	0.32***
E2d	-
E2e	-
E3a	-
E3b	-
E3c	-
E3d	-
E3e	-
E4a	-
E4b	-
E4c	-
E4d	-
E5a	-
E5b	-
E5c	-
E5d	-

Table 22: Correlation tables of the underlying factor *religion* with each capital including only medium and strong correlations. ($p < .001$***, $p < .01$**, $p < .05$*)

	Density
N1a	0.38***
N1b	-
N1c	0.53***
N1d	-
N1e	-
N1f	0.78***
N2a	-
N2b	-
N2c	-
N2d	-
N2e	0.59***
N2f	-0.30***
N2g	0.31***
N3a	0.56***
N3b	-
N3c	0.72***
N3d	-
N3e	-
N3f	-
N3g	-
N3h	0.34***
N4a	-
N4b	-
N4c	0.35***
N4d	0.35***
N4e	-
N5a	-
N5b	-0.38***
N5c	-0.45***
N5d	0.34***
N5e	-
N6a	-
N6b	0.60***
N6c	-0.67***
N6d	-0.55***
N6e	-
N6f	-
N6g	-
N7a	-
N7b	-
N7c	-0.52***
N7d	-0.56***
N7e	-
N7f	-0.31***

	Density
S1a	-0.42***
S1b	-0.43***
S1c	-0.41***
S1d	-
S1e	-
S2a	-0.72***
S2b	0.59***
S2c	0.60***
S2d	0.38***
S3a	-0.51***
S3b	-
S3c	-
S3d	-0.36***
S3e	-
S4a	-
S4b	-
S4c	-0.58***
S4d	-
S4e	-0.46***
S4f	-
S4g	-
S4h	-
S4i	-
S5a	0.50***
S5b	0.56***
S5c	0.74***
S5d	0.51***
S5e	-
S5f	0.36***
S6a	-
S6b	-0.62***
S6c	-0.43***
S6d	-
S6e	0.37***
S6f	-0.45***
S7a	-
S7b	-0.58***
S7c	-0.57***
S7d	0.58***
S7e	-0.31***
S7f	-
S7g	-

	Density
E1a	0.38***
E1b	-
E1c	0.54***
E1d	0.44***
E1e	-
E2a	-
E2b	-
E2c	-
E2d	0.39***
E2e	-
E3a	0.75***
E3b	0.65***
E3c	-0.42***
E3d	-
E3e	-
E4a	-0.37***
E4b	-
E4c	0.31***
E4d	0.39***
E5a	0.47***
E5b	0.51***
E5c	0.31***
E5d	-

Table 23: Correlation tables of the underlying factor *population/building density* with each capital including only medium and strong correlations. ($p < .001$***, $p < .01$**, $p < .05$*)

	Residential area	Industrial area	Agricultural area	Forest and natural area
N1a	-	0.35***	-	-
N1b	-	-	-	-
N1c	-	0.34***	-0.32***	-
N1d	-	-	-	-
N1e	-	-	-	-
N1f	0.90***	0.84***	-0.69***	-
N2a	-	-	-	-
N2b	-0.32***	-	-	-
N2c	-	-	-	-
N2d	-0.31***	-	-	-
N2e	0.67***	0.68***	-0.49***	-0.33***
N2f	-0.40***	-0.45***	-	-
N2g	0.37***	0.32***	-	-
N3a	0.43***	0.37***	-0.44***	-
N3b	-	-	-	-
N3c	0.83***	0.79***	-0.65***	-
N3d	-	-	-	-
N3e	-	-	-	-
N3f	-	0.31***	-	-
N3g	-	-	-	-
N3h	0.30***	-	-	-
N4a	-	-	-	-
N4b	-	-	-	-
N4c	-	0.38***	-	-
N4d	-	0.32***	-	-0.38***
N4e	-	-	-	-
N5a	-	-0.32***	-0.30***	1.00***
N5b	-0.45***	-0.38***	0.50***	-
N5c	-0.40***	-0.39***	0.34***	-
N5d	0.34***	-	-0.31***	-
N5e	-	-	-	-
N6a	-	-	-	-
N6b	0.81***	0.65***	-0.51***	-0.31***
N6c	-0.60***	-0.65***	0.43***	0.45***
N6d	-0.53***	-0.50***	0.52***	-
N6e	0.33***	-	-0.35***	-
N6f	-	-	-	-
N6g	-	-	-	-
N7a	0.33***	0.32***	-0.40***	-
N7b	-	-	-	-
N7c	-0.43***	-0.43***	0.35***	-
N7d	-0.46***	-0.48***	0.43***	-
N7e	-	-0.35***	-	-
N7f	-	-	-	-

	Residential area	Industrial area	Agricultural area	Forest and natural area
S1a	-0.46***	-0.38***	0.37***	-
S1b	-0.39***	-0.41***	0.37***	-
S1c	-0.32***	-0.39***	-	-
S1d	-	-0.31***	-	-
S1e	-	-	-	-
S2a	-0.67***	-0.66***	0.65***	-
S2b	0.57***	0.57***	-0.59***	-
S2c	0.53***	0.52***	-0.53***	-
S2d	0.35***	0.45***	-0.36***	-
S3a	-0.50***	-0.44***	0.42***	-
S3b	-	-	-	-
S3c	-	-	-	-
S3d	-0.33***	-	0.32***	-
S3e	-	-	-	-
S4a	-	-	-	-
S4b	-	-	-	-
S4c	-0.54***	-0.46***	0.48***	-
S4d	-	-	-	-
S4e	-0.46***	-0.40***	0.36***	-
S4f	-	-	-	-
S4g	-	-	-	-
S4h	0.33***	0.32***	-0.44***	-
S4i	-	-	-	-
S5a	0.38***	0.43***	-0.43***	-
S5b	0.45***	0.49***	-0.52***	-
S5c	0.60***	0.58***	-0.64***	-
S5d	0.35***	0.37***	-0.51***	-
S5e	-	-	-	-
S5f	0.36***	-	-	-
S6a	-	-	-	-
S6b	-0.61***	-0.55***	0.57***	-
S6c	-0.39***	-0.41***	0.38***	-
S6d	-	-	-	-
S6e	-	-	-0.32***	-
S6f	-0.40***	-0.39***	0.43***	-
S7a	0.36***	0.36***	-0.37***	-
S7b	-0.53***	-0.52***	0.54***	-
S7c	-0.50***	-0.43***	0.37***	-
S7d	0.52***	0.51***	-0.55***	-
S7e	-	-	-	-
S7f	-	-	-	-
S7g	-	-	-	-

	Residential area	Industrial area	Agricultural area	Forest and natural area
E1a	-	0.42***	-	-
E1b	-	-	0.35***	-
E1c	0.52***	0.52***	-0.49***	-
E1d	-	0.37***	-	-
E1e	-	-	-	-
E2a	-	-	-	-
E2b	-	-	-	-
E2c	-	-	-	-
E2d	-	0.33***	-	-
E2e	-	-	-	-
E3a	0.68***	0.48***	-0.61***	-
E3b	0.61***	0.53***	-0.65***	-
E3c	-0.39***	-	0.46***	-
E3d	-	-	-	-
E3e	-	-	-	-
E4a	-0.35***	-	-	-
E4b	-	-	-	-
E4c	-	0.31***	-0.32***	-
E4d	0.31***	0.35***	-	-
E5a	0.41***	-	-	-
E5b	0.38***	-	-0.30***	-
E5c	-	-	-	-
E5d	-	-	-	-

Table 24: Correlation tables of the underlying factor *area type* with each capital including only medium and strong correlations. ($p < .001$***, $p < .01$**, $p < .05$*)

	0 to 25	25 to 45	45 to 65	65 and above
N1a	-	0.36***	-	-
N1b	-	-	-	-
N1c	-	0.51***	-0.36***	-
N1d	0.30***	-	-	-
N1e	0.33***	-	-	-
N1f	-	0.59***	-0.42***	-0.32***
N2a	-	-	-	-
N2b	-	-	-	-
N2c	-	-	-	-
N2d	-	-	-	-
N2e	-	0.41***	-	-0.31***
N2f	-	-	-	-
N2g	-	-	-	-
N3a	-	0.35***	-	-
N3b	-	-	-	-
N3c	-	0.53***	-0.37***	-0.32***
N3d	-	-	-	-
N3e	-	-	-	-
N3f	-	-	-	-
N3g	-	-	-	-
N3h	-	-	-	-
N4a	-	-	-	-
N4b	-	-	-	-
N4c	-	-	-	-
N4d	-	-	-	-
N4e	-	-	-	-
N5a	-	-	-	0.31***
N5b	-	-	-	-
N5c	-	-0.34***	-	-
N5d	-	-	-	-
N5e	-	-	-	-
N6a	-	-	-	-
N6b	-	0.50***	-0.36***	-0.30***
N6c	-	-0.70***	0.39***	0.56***
N6d	-	-0.46***	0.39***	-
N6e	-	-	-	-
N6f	-	-	-	-
N6g	-	-	-	-
N7a	-	-	-	-
N7b	-	-	-	-
N7c	-	-0.43***	-	-
N7d	-	-0.39***	0.34***	-
N7e	-	-	-	-
N7f	-	-	-	-

	0 to 25	25 to 45	45 to 65	65 and above
S1a	-	-	-	-
S1b	-	-	-	-
S1c	-	-0.36***	-	-
S1d	-	-	-	-
S1e	-	-	-	-
S2a	-	-0.65***	0.37***	0.33***
S2b	-	0.47***	-	-
S2c	-	0.45***	-	-
S2d	-	-	-	-
S3a	-	-	-	-
S3b	-	-	-	-
S3c	-	-	-	-
S3d	-	-	-	-
S3e	-	-	-	-
S4a	-	-	-	-
S4b	-	-	-	-
S4c	-	-0.39***	0.31***	-
S4d	-	-	-	-
S4e	-	-	-	-
S4f	-0.40***	-	-	0.32***
S4g	-	-	-	-
S4h	-	-	-	-
S4i	0.37***	-	-	-
S5a	-	0.51***	-0.32***	-
S5b	-	0.53***	-	-
S5c	-	0.64***	-0.33***	-
S5d	-	0.34***	-	-
S5e	-	-	-	-
S5f	-	-	-	-
S6a	-	-	-	-
S6b	-	-0.43***	0.35***	-
S6c	-	-0.41***	-	-
S6d	-	-	-	-
S6e	-	-	-0.30***	-
S6f	-	-0.39***	-	-
S7a	-	-	-	-
S7b	-	-0.44***	0.42***	-
S7c	-	-0.36***	0.32***	-
S7d	-	0.52***	-	-
S7e	-	-	-	-
S7f	-	-	-	-
S7g	-	-	-	-

	0 to 25	25 to 45	45 to 65	65 and above
E1a	-	0.44***	-0.42***	-
E1b	0.55***	-	-	-0.51***
E1c	-	0.43***	-	-
E1d	0.77***	0.82***	-0.84***	-0.78***
E1e	-0.44***	-	-	-
E2a	-	-	-	-
E2b	-	-	-	-
E2c	-	-	-	-
E2d	-	0.34***	-	-
E2e	-	-	-	-
E3a	-	0.54***	-0.32***	-
E3b	-	0.32***	-	-
E3c	-	-	-	-
E3d	-	-	-	-
E3e	-	-	-	-
E4a	-	-	-	-
E4b	-	-	-	-
E4c	-	-	-	-
E4d	-	0.36***	-0.30***	-0.32***
E5a	-	-	-	-
E5b	0.35***	0.47***	-0.48***	-0.37***
E5c	-	-	-	-
E5d	-	-	-	-

Table 26: Correlation tables of the underlying factor *population age* with each capital including only medium and strong correlations. ($p < .001$***, $p < .01$**, $p < .05$*)

	F1	F2a	F2b	F2c	F2d	F3a	F3b	F3c
F1	1.00	-	-	-	-	-	-	-
F2a		1.00	-	-	-	-	-	-
F2b			1.00	-	-0.79***	-	-	-
F2c				1.00	-	-	-	-
F2d					1.00	-	-	-
F3a						1.00	-	-
F3b							1.00	-0.35***
F3c								1.00

	F3d	F4	F5	F6a	F6b	F6c	F6d	F7a
F1	-	-	-	-	-0.38***	-	-	-
F2a	-	0.42***	-	-	-	-	-	-0.37***
F2b	-	-0.30***	-	-	-	-	-0.53***	-
F2c	-	-	-	-	-	-	-	-
F2d	-	-	-	-	-	-	0.64***	-
F3a	-	-	-0.34***	-0.39***	-	0.32***	-	-
F3b	-0.45***	-	-0.39***	-0.33***	-	0.37***	-	-
F3c	-0.60***	-	-	-	-	-	-	-
F3d	1.00	-	-	-	-	-0.40***	0.38***	-
F4		1.00	-	-	-	-	-	-0.43***
F5			1.00	0.77***	0.69***	-0.70***	-	-
F6a				1.00	0.75***	-0.72***	-	-
F6b					1.00	-0.57***	-0.32***	-
F6c						1.00	-	-
F6d							1.00	-
F7a								1.00

	F7b	F7c	F7d
F1	-0.46***	-	-
F2a	-	-	-
F2b	-	-	-
F2c	-	-	-
F2d	-	-	-
F3a	-	-	-
F3b	-	-	-
F3c	-	-	-
F3d	-	-	-
F4	-	0.45***	-
F5	0.71***	-0.54***	-0.38***
F6a	0.48***	-0.33***	-
F6b	0.57***	-0.41***	-0.31***
F6c	-0.38***	0.33***	-
F6d	-	-	-
F7a	0.51***	-0.72***	-0.81***
F7b	1.00	-0.73***	-0.79***
F7c		1.00	0.55***
F7d			1.00

$p < .001$***, $p < .01$**, $p < .05$*

Table 25: Correlation tables of the underlying factors including only medium and strong correlations.

A.2.8 Cluster correlations

	F1	F3a	F3b	F3c	F3d	F5	F6a
Cluster 1	0.61***	0.35***	-	-	-0.35***	-0.48***	-0.50***
Cluster 2	0.39***	-	-0.43***	-	-	0.53***	0.43***
Cluster 3	-	-	-	-	-	-0.45***	-0.42***
Cluster 4	-	-	-	-	-	-	-
Cluster 5	-	-	-0.36***	-	-	0.37***	0.45***
Cluster 6	-	0.31***	-	-	-	-0.51***	-0.40***
Cluster 7	-	-0.41***	-0.36***	-	-	0.75***	0.73***
Cluster 8	-	-	-	-	-	-	-
Cluster 9	-	-	-	-	-	-	-
Cluster 10	-	-	-	-	-	-	-
Cluster 11	-0.52***	-	-	-	-	0.47***	0.45***
Cluster 12	0.56***	-	-	-	-	-0.36***	-0.40***
Cluster 13	-	-	-	-	-	-	-
Cluster 14	-	-	-	-	-	-	-
Cluster 15	-	-	-	-	-	-	-
Cluster 16	0.53***	-	-	-	-	-	-

	F6b	F6c	F6d	F7a	F7b	F7c	F7d
Cluster 1	-0.48***	0.53***	-	-	-0.35***	-	-
Cluster 2	-	-0.34***	-	-	-	-	-
Cluster 3	-0.44***	0.39***	-	-	-0.36***	-	-
Cluster 4	-	-	-	-	-	-	-
Cluster 5	-	-	-	-	-	-	-
Cluster 6	-0.49***	0.36***	-	-	-0.40***	-	-
Cluster 7	0.64***	-0.66***	-	-	0.45***	-0.35***	-
Cluster 8	-0.34***	0.33***	-	-	-	-	-
Cluster 9	-	-	-	0.35***	0.37***	-0.47***	-
Cluster 10	-	-	0.52***	-	-	-	-
Cluster 11	0.44***	-0.44***	-	-	0.43***	-0.37***	-
Cluster 12	-0.43***	0.36***	-	0.35***	-	-	-
Cluster 13	-	-	-	-	-	-	-
Cluster 14	-	-0.33***	-	-	-	-	-
Cluster 15	-0.33***	-	-	-	-	-	-
Cluster 16	-	-	-	0.36***	-	-	-

$p < .001$***, $p < .01$**, $p < .05$*

Table 27: Correlation tables of the underlying factors with each cluster found by ALGORITHM 1, ALGORITHM 2 and ALGORITHM 3 including only medium and strong correlations.

A.3 Clusters

1	*Living conditions*
S2a	Financial assets household
E1b	Human resources exploitation
E1c	Unemployment
E1d	Rejuvenation and ageing
E1e	Incapacity for work
E3b	Bankruptcies
F1	Income
F5	Density
F7b	Age: 25 to 45
F7c	Age: 45 to 65
F7d	Age: 65 and above
N3c	Noise intensity
N6b	Solar energy
N6c	Average natural gas consumption households
N7c	Organic waste
S2b	Social assistance
S2c	Poor households
S2d	Long lasting unemployment
S3a	Distance to performing arts
S4g	Life expectancy
S4i	Assessment of own health
S5a	Vandalism
S5b	Violent crimes
S5c	Crimes against property
S5d	Youth crime
S6b	Distance to daily goods and services
S6c	Satisfaction with living environment
S6f	Satisfaction with dwelling
S7a	Youth unemployment
S7b	Distance to elementary schools
S7c	Distance to secondary education schools
S7e	Real-time to diploma

2	*Income and capabilities*
E5a	Share highly educated people
E3a	Share starters
E3c	Share nationally promoted (top) sectors
E5b	Capacity university education/higher professional education
F3b	Industry
F5	Density
S3a	Distance to performing arts
S4b	Risky behaviour
S6d	Mutations in number of residents
S7g	Education level population

3	*Living environment*
N3a	Noise annoyance
E4a	Access to public railway transport
F3b	Industry
F5	Density
F6b	Industrial area
N3c	Noise intensity
N3d	Annoyance by odours
S1a	Cohesion
S6c	Satisfaction with living environment
S6e	Satisfaction with shops
S6f	Satisfaction with dwelling

4	*Air quality*
E4d	Share of clean cars
F3c	Commercial services
F5	Density
F7b	Age: 25 to 45
F7c	Age: 45 to 65
F7d	Age: 65 and above
N2e	Concentration of NOx
N2f	Concentration of Ozone
N2g	Concentration of $PM_{2.5}$

5	*Emissions*
N2a	Emission of CO_2
N2b	Emission of NOx
N2c	Emission of Particulate Matter ($PM_{2.5}$)
N2d	Emission of Volatile Organic Substances
N6f	Average natural gas consumption businesses

6	*Industrial soil use*
N3f	Land surface with a 10^{-6} risk contour
E2a	Stock business parks
F6b	Industrial area
N1a	Contaminated sites with unacceptable human risks
N1c	Contaminated sites with high distribution risks
N3e	Risk of road transport of dangerous chemicals

7	*Accessibility*
N5b	Distance to public green
F5	Density
F6a	Residential area
F6b	Industrial area
N5c	Distance to inland recreational water
N5d	Biodiversity total
S4c	Distance to GP practice
S6b	Distance to daily goods and services
S7c	Distance to secondary education schools

8	*Waste*
N7b	Residual waste
N7a	Household waste
N7d	Paper and cardboard waste
N7e	Packaging glass

9	*Labour market*
E1a	Employment function
E1d	Rejuvenation and ageing
E2d	Vacant office space
E4c	Number of charging stations for electric cars
F7b	Age: 25 to 45
F7c	Age: 45 to 65

10	*Water quality*
N4d	Phosphorous emissions to surface water
F5	Density
N4c	Nitrogen emissions to surface water
N4e	Drinking-water quality

11	*Residential energy use*
N6e	Energy label houses
F6a	Residential area
F6c	Agricultural area
N6d	Average electricity consumption households

12	*Social involvement*
S1b	Volunteers
E1c	Unemployment
E1e	Incapacity for work
F5	Density
S1a	Cohesion
S1c	Turnout municipal elections
S1d	Turnout national elections
S2b	Social assistance
S3a	Distance to performing arts
S4i	Assessment of own health

13	*Infrastructure*
E4b	Access to main roads
E4a	Access to public railway transport
S4a	Insufficient exercise

14	*Manure*
N1d	Manure- Nitrogen quantity produced
N1e	Manure- Phosphorous quantity produced

15	*Cultural heritage*
S3b	National monuments
S3c	Municipal monuments

16	*Health*
S4f	Chronically sick people
F7a	Age: 0 to 25
F7d	Age: 65 and above
S4g	Life expectancy
S4i	Assessment of own health

Table 28: Overview of all clusters found by ALGORITHM 1, ALGORITHM 2 and ALGORITHM 3 with their corresponding indicator and underlying factor names.

A.3.1 Requirements per cluster

Cluster 1

- There is no poverty or exclusion.
- Everybody is able to afford essential requirements for life such as food, clothing and housing.
- There is a wide diversity of culture on offer.
- The population is and perceives itself to be physically and spiritually healthy.
- The population considers itself healthy.
- The risk of becoming a victim of crime or accident is negligible.
- Public facilities and everyday necessities are accessible and within easy reach for everyone.
- Citizens are satisfied with their living environment; it is safe, comfortable and healthy.
- Citizens are satisfied with their own home; it is safe and comfortable.
- Education meets the needs of society.
- Education is of high quality.
- Education is easily accessible to all.
- There is no unacceptable nuisance from odour, noise and dust caused by humanity.
- Residents consume less energy and cause less pollutants.
- All energy used for consumption comes from a sustainable source.
- Residents work towards a zero-waste society.
- The potential of the total potential labour force is being used.
- There is balance on the labour market (in both qualitative and quantitative terms).
- Work is healthy.
- The economic structure has a good mix of driving industries and service industries. They are constantly regenerated by the arrival of new enterprises (starter companies and enterprises newly locating to the area).

Cluster 2

- There is a wide diversity of culture on offer.
- Citizens have a responsibility for a healthy lifestyle.
- Citizens are satisfied with their living environment; it is safe, comfortable and healthy.
- Citizens have a responsibility to keep their competences connected to the needs of the society.

- The economic structure has a good mix of driving industries and service industries. They are constantly regenerated by the arrival of new enterprises (starter companies and enterprises newly locating to the area).
- The economy is competitive.
- The knowledge institutions play an active, supportive role in this.

Cluster 3

- There is social cohesion.
- Public facilities and everyday necessities are accessible and within easy reach for everyone.
- Citizens are satisfied with their living environment; it is safe, comfortable and healthy.
- Citizens are satisfied with their own home; it is safe and comfortable.
- There is no unacceptable nuisance from odour, noise and dust caused by humanity.
- The accessibility (via road, water, rail, air, and ICT) of companies, facilities and economic centres is good.

Cluster 4

- The air is clean (for humans and wildlife).
- The accessibility (via road, water, rail, air, and ICT) of companies, facilities and economic centres is good.

Cluster 5

- The air is clean (for humans and wildlife).
- The municipality is climate-neutral.
- Business investments are focused on reducing the use of non-renewable resources.

Cluster 6

- The soil is clean (for humans and wildlife).
- The municipality restricts the number of contaminated sites
- There is no unacceptable risk of calamities.
- There is enough space (areas, commercial properties) available for industrial activities.

Cluster 7

- Healthcare of good quality is accessible to everyone.
- Public facilities and everyday necessities are accessible and within easy reach for everyone.
- Education is easily accessible to all.
- Preservation of biodiversity.
- Area covered by linked nature reserves.
- Nature is accessible.

Cluster 8

- Residents work towards a zero-waste society.

Cluster 9

- There is balance on the labour market (in both qualitative and quantitative terms).
- The available space for industrial activities is managed in an optimal way.
- The accessibility (via road, water, rail, air, and ICT) of companies, facilities and economic centres is good.

Cluster 10

- The surface water is clean (for humans and wildlife).

Cluster 11

- Residents consume less energy and cause less pollutants.

Cluster 12

- There is social cohesion.
- Citizens are involved in society.
- Citizens are involved in politics (both passively and actively) and have access to the necessary information.
- Everybody is able to afford essential requirements for life such as food, clothing and housing.
- There is a wide diversity of culture on offer.
- The population considers itself healthy.

- There is balance on the labour market (in both qualitative and quantitative terms).
- Work is healthy.

Cluster 13

- Citizens have a responsibility for a healthy lifestyle.
- The accessibility (via road, water, rail, air, and ICT) of companies, facilities and economic centres is good.

Cluster 14

- The soil is clean (for humans and wildlife).

Cluster 15

- The cultural heritage is protected and strengthened.

Cluster 16

- The population is and perceives itself to be physically and spiritually healthy.
- The population considers itself healthy.

A.4 Algorithm

Algorithm 1 Adaptation of algorithm ROUND (Demaine et al., 2005)

```
procedure FIND CLUSTERS(n.f.less,n,e,g)
    e ← adj.edge.weight(e,g)                          ▷ Changes the edge value.
    N = nrow(n)              ▷ Computes the numbers of nodes at the start of the algorithm.
    n.red ← n                        ▷ Creates a list which will keep track of deleted nodes.
    e.red ← e                        ▷ Creates a list which will keep track of deleted edges.
    E = nrow(e)              ▷ Computes the numbers of edges at the start of the algorithm.
    t ← triang.ineq(n,e)                  ▷ Determines the triangle inequality constraints.
    lp ← lin.progr(e,t)                                    ▷ Solves the linear program.
    sol ← change.neg(lp[2],e)
    clusterindex = 1
    cluster ← list( )            ▷ Creates a list which will keep track of the obtained clusters.
    while N ! = 0 & E ! = 0 do        ▷ The algorithm ends when no nodes or edges are left.
        u = node.highest(n.f.less,n.red,e.red)        ▷ Picks the node with the highest degree.
        nodeindex2 ← node.number(u[ ,1],n)   ▷ Determines the index of the node within the
                                               graph.
        nodeindex ← node.number(u[ ,1],n.red)    ▷ Determines the index of the node
                                                   within the graph.
        u ← n[nodeindex2, ]
        n.red ← n.red[−nodeindex, ]       ▷ Removes the node from the list of starting points.
        r = 0                                              ▷ Initialises the radius to zero.
        B ← ball(u,r,n,e,sol)                  ▷ Determines a ball of radius r around node u.
        nodesB ← unlist(B[1])
        cutB ← cut(nodesB,n,e)                            ▷ Computes the cut of ball B(u, r).
        volB ← vol(u,r,nodesB,n.red,n,e,sol)           ▷ Computes the volume of ball B(u, r).
        while cutB > 3 log(N + 1)volB do     ▷ Increases the radius of the ball B(u, r) until the
                                               boundary condition is met.
            r = r + grow.r(u,r,e,n,B)               ▷ Grows r by the smallest positive edge.
            B ← ball(u,r,n,e,sol)       ▷ Determines a ball around node u with the new radius r.
            nodesB ← unlist(B[1])
            cutB ← cut(nodesB,n,e)                    ▷ Computes the new cut of ball B(u, r).
            volB ← vol(u,r,nodesB,n.red,n,e,sol)   ▷ Computes the new volume of ball B(u, r).
        end while
        cluster[clusterindex] ← list(nodesB)      ▷ Saves the nodes of B(u, r) as cluster number i.
        clusterindex = clusterindex + 1
        e.red ← delete.edges(nodesB,n,e.red)  ▷ Deletes the edges containing a node which is part
                                                of the obtained cluster.
        N = nrow(n.red)                             ▷ Determines the new number of nodes.
        E = nrow(e.red)                             ▷ Determines the new number of edges.
    end while
    return(cluster)                              ▷ Returns a list of all obtained clusters.
end procedure
```

Functions and additional explanations regarding the algorithm above will be provided by Telos on request. For this algorithm, we have used the packages Hmisc, igraph, lpSolve, shiny, visNetwork and xtable (Almende B.V., Thieurmel, & Robert, 2018; Chang, Cheng, Allaire, Xie, & McPherson, 2018; Harrell Jr, Dupont, & Al., 2018; Dahl, 2016; Berkelaar & Al., 2015; Csardi & Nepusz, 2006).

A.5 Graph of the National Monitor of Sustainable Municipalities

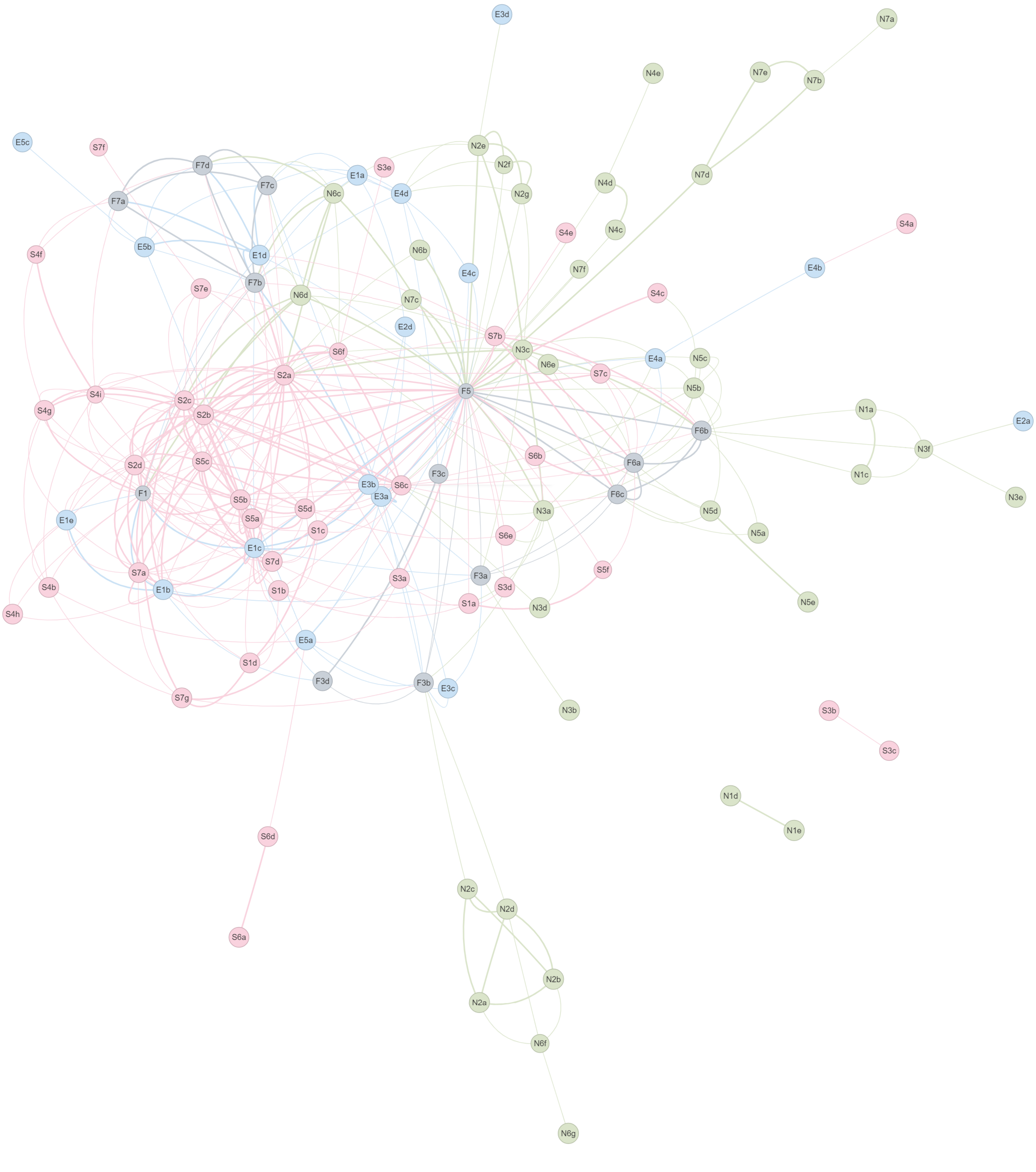

Figure 12: Undirected graph of the National Monitor of Sustainable Municipalities consisting of indicators and underlying factors as nodes and direct correlations as edges.