
# Building balance to build resilience

## An empirical study on the neighbourhood balance policy of Rotterdam's resilience strategy

Guillermo Prieto Viertel

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## An empirical study on the neighbourhood balance policy of Rotterdam's resilience strategy

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# Executive Summary

The rise in urban stresses has prompted the need for preparedness of urban areas to face precarious circumstances. Consequently, the concept of urban resilience has grown in popularity not only to tackle sudden shocks but also to face long-lasting socio-economic tensions. To implement the arrangements for resilience policy, literature suggests that social factors govern the resilience of urban areas. Communities in which the residents work together and have common goals have a stronger willingness to cooperate. To this end, social cohesion has been proven to be significant for subsistence in the event of a catastrophe. Cohesive communities protect residents against threats, care of others during hardships, and ultimately promote community resilience.

Balanced neighbourhood policies aim to strengthen the cohesion between citizens, communities, and social institutions departing from the assumption that social mix fosters social cohesion. Their goal is to increase the social mix of specific areas to avoid the clustering and segregation of disadvantaged households to, as a result, promote resilient actions. There is, however, literature that suggests that the anticipated effects are rather inconclusive and usually not achieved. Instead, balanced neighbourhood policies would promote segregation by forcing the displacement of groups of residents.

The issue arises whether balanced neighbourhoods trigger resilient actions that are pivotal in resilient communities. In other words, **does neighbourhood balance increase resilient action of neighbourhood residents?** We took a cross-sectional confirmatory approach to understand the social mechanism that triggers resilient action in balanced neighbourhoods based on Partial Least Squares—Structural Equation Modelling (PLS-SEM) and spatial econometrics. To this end, the research tests the assumptions on which the municipality of Rotterdam grounds their Resilience Strategy's balanced neighbourhood policy, the Woonvisie, using a 2019 public survey on social development. Rotterdam's definition of a balanced neighbourhood is defined from a set of conditions for the amount of houses in different house price segments. Therefore, the tested model is based on the grounds that geographically connected people become affected by their neighbourhood's balance to promote resilient action. As such, we use the willingness to help friends and neighbours to characterise informal support as resilient action. Here we show that balanced neighbourhoods are associated with less informal support: the higher the balance, the fewer residents are willing to help their friends and neighbours.

The results indicate that social cohesion is the social mechanism that triggers help between friends and relatives and fully acts as the mechanism for resilient actions triggered by the balance in a neighbourhood. From the multiple combinations of houses in different house price segments that the definition of balanced neighbourhoods allows, we distinguish two associations. On one hand, house price distributions which foment a reduction in polarisation (more middle-priced houses) are negatively associated with social cohesion. On the other hand, balanced neighbourhoods which foment polarisation (more low- and high-priced houses) are positively associated with social cohesion.

This indicates that our results are in line with Putnam's homophily principle, i.e. 'birds of a feather flock together'. This outcome is opposite to the policy discourse of governments in favour of balanced neighbourhoods, including the municipality of Rotterdam, that mixed neighbourhoods foster social cohesion and therefore resilient action.

The testing of the theory is complemented in two ways. First, we show that social cohesion and informal support are not constrained by administrative boundaries, so the social perceptions and actions in nearby neighbourhoods affects the level of the other neighbourhoods. Second, we found no moderating effect of factors related to the demographics and the built environment that can promote or deter social interactions, and thus are aspects of what can be considered a resilient neighbourhood.

The analysis also shows that Rotterdam's definition of balance allows multiple and dispersed combinations of the amount of houses in each price segment, which can result in counterintuitive conceptions of balance. In addition, the results show apparently contradicting results of the relationship between balance and social cohesion depending on whether the distribution foments house price polarisation. As a result, we argue that the definition is under-specified and can be misleading.

Finally, only 2.1% of the possible balance distributions yielded an acceptable goodness-of-fit of our model. This could be indicative that the model needs to be reevaluated. We found that neighbourhood ethnic heterogeneity and house type heterogeneity are directly associated to social cohesion and informal support, respectively. Future research should elaborate on the theory on which the model is grounded and create coherence to the empirical relationships identified. In contrast, the few fitting distributions could otherwise indicate that that social cohesion and informal support cannot be explained by the balance in a neighbourhood and that the policy should be reevaluated. Under this second interpretation, the study has uncovered which are the balance distributions for the city that can actually show the alleged effects of balance.

Based on these findings, a policy advice is formulated. If the objective is to increase social cohesion and resilient actions, we discourage the municipality of Rotterdam to approach this by building balanced neighbourhoods. Nevertheless, we have seen that building social cohesion is a way to build social resilience, so recently developed city programs focused on the development of neighbourhood organisations, which not only provide a space for social cohesion but also to collect and share resources directly, are a step forward from the Woonvisie.

# Preface

Love your neighbour!

Not too long ago, our neighbour alerted my family of a possible robbery. Friday night, they detected suspicious behaviour from a security camera and motion sensor they had set up after a previous robbery in their flat. The camera recorded a person placing a paper on their front door hinge, and then walking towards our house, to do the same. In summer, many families spend the weekends in their second residences, so if the paper is still there on Saturday, the family is probably away for the whole weekend. Coincidentally, our neighbour was away, but we were in town, so we coordinated to face the situation. Saturday night at 3am, the motion sensor activated, and our neighbour notified us. My family called the police and let them in the building for inspection. Nobody was to be found. Still, the police decided to stay in the block, and later that night, they arrested people coming out of the building's main entrance. They cross-checked the arrested with the security camera recordings and found a match. That night, none of the building houses were broken into.

The trust between neighbours galvanised them into resilient action. They were willing to help each other and to protect their neighbourhood. To understand what generated that willingness is essential. This motivated me to contribute to the field of resilience and write this study. Hopefully, this will cease to be an ideal behaviour and will become the norm in neighbourhoods.

*Guillermo Prieto Viertel*
*Barcelona, August 2022*

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# ABBREVIATIONS

| **Abbreviation** | **Concept** |
|---|---|
| 100RC | 100 Resilient Cities |
| AIC | Akaike information criterion |
| AVE | Average variance extracted |
| BAG | Addresses and Buildings Key Registry |
| BFPI | Best fitting proper indices |
| BRP | Personal Records Database |
| CBS | Statistics Netherlands |
| CB-SEM | Covariance based Structural equation modelling |
| CI | Confidence interval |
| ESDA | Exploratory Spatial Data Analysis |
| $f^2$ | Cohen's effect size |
| GDP | Gross Domestic Product |
| H | Hypothesis |
| HH | High-High |
| HHI | Herfindahl-Hirschman Index |
| HL | High-Low |
| IPCC | Intergovernmental Panel on Climate Change |
| IS | Informal support |
| KL | Kullback-Leibler |
| KMO | Kaiser-Meyer-Olkin |
| LISA | Local Indicators of Spatial Association |
| LH | Low-High |
| LL | Low-Low |
| MAE | Mean absolute error |
| NA | Not Available |
| NB | Neighbourhood balance |
| NHG | National Mortgage Guarantee |
| NPRZ | National Programme Rotterdam South |
| ns | non-significant |
| OBI | Research and Business Intelligence |
| OSM | OpenStreetMap |
| PLS-SEM | Partial least squares structural equation modelling |
| $Q^2$ | Predictive relevance |
| $R^2$ | Coefficient of determination |
| $r^2$ | Pearson's correlation coefficient |
| RMSE | Root mean squared error |
| s.d. | standard deviation |
| SDG | Sustainable Development Goal |
| SC | Social cohesion |
| SQ | Sub-question |

| Abbreviation | Concept |
|---|---|
| SRMR | Standardized root mean squared residual |
| SSE | Sum-squared error |
| VIF | Variance inflation factor |
| WHO | World Health Organization |
| WOZ | Valuation of Immovable Property Act |

# Acknowledgements

This thesis represents the end of my two-year period as a master's degree student in Engineering and Policy Analysis at the TU Delft. Having experienced the lack of vitamin D due to the long hours in the library and to the Dutch weather, I want to take a moment to thank all the people that have been next to my side.

First, thank you, yaya, for being like a second mom to Sandra and me. We all know you would have loved to come to the Netherlands and keep travelling like you always did. I am glad I was able to show you around in your last moments, and that you could see the place that has been my home for the last two years. We all take you in our hearts like the charming person you always were.

Thank you mama and papa for always investing in my education without hesitation. Thank you for bringing me up with ambition to learn and explore, but always being appreciative and not forgetting where we come from. Especial thanks to my dad for designing the amazing front page of the report.

Thank you, Sandra, for being an annoying sister, but being there when necessary. The last two years were tough for the family, but you took care of everyone better than anyone could ask for. I will always insist to you that you are more than capable to pursue your master's at the TU Delft.

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# 1

# INTRODUCTION

## 1.1. BACKGROUND

### 1.1.1. GLOBAL CHALLENGE

At present, more than half of the world's population lives in urban areas, and it is expected that this amount will increase to 68% by 2050 (United Nations et al., 2018). The high concentration of people living in urban spaces gives room for innovation and learning but also results in an increase in vulnerability to threats like climate change, resource scarcity, and social exclusion (Meerow et al., 2016; Wolf et al., 2015). This conspicuously complicates the objective of attaining the Sustainable Development Goal (SDG) 11 'sustainable cities and communities' and has cross-cutting impact on other SDGs, especially SDG 9 'industry, innovation and infrastructure', and SDG 13 'climate action'. As a result, policy-makers have prioritised the interest of urban areas in their agenda (UN-Habitat, 2016).

Cities are of special relevance due to their large number of vulnerable people. An accelerating trend in adverse effects of living in major urban areas has been increasingly observed around the globe. Income inequality has exacerbated in cities across the United States (Heinrich Mora et al., 2021), female citizens have seen an increase in inactivity and unemployment across East and South-East Asian urban regions (ILO, 2020), and a greater shortage of housing threatens major European municipalities (OECD, 2021). What is more, the COVID-19 pandemic has clearly shown how globally connected cities are more exposed to global emergencies and require appropriate urban policy planning (UN-Habitat, 2020).

Even though urbanisation comes with several challenges, sustainable and inclusive growth can also be achieved if properly managed (European Commission, 2010). The potential of urban areas is clear, given that they contribute to 80% of the global GDP (UN-Habitat, 2016). Consequently, the concept of urban resilience has grown in popularity to tackle these challenges that abrupt urbanisation and a lack of proper planning have put in place (Saja et al., 2019).

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### 1.1.2. CALL FOR LOCAL ACTION

While the definition of urban resilience subsumes multiple dimensions and is still debated among scholars and policy-makers, it is widely shared that social elements shape the level of resilience of urban areas. This can be seen, for instance, in Barcelona's neighbourhood L'Eixample, that ranked first place in 2020 TimeOut's Coolest neighbourhoods in the world index. With COVID-19 wreaking lock-downs over the world, the community spirit and solidarity kept the neighbourhood as a hub of mutual aid during the pandemic (Walker-Arnott, 2020).

Social cohesion has been proven to be significant for subsistence in the event of a catastrophe (Elliott et al., 2010; Larimian et al., 2020). Cohesive communities are more willing to take resilient actions like protecting residents against threats, caring of others during hardships, and ultimately promote community resilience (Center for American Progress, n.d.; Forrest & Kearns, 2001; Larimian et al., 2020). Therefore, governments are looking to strengthen the relationships between citizens, communities, and social institutions to boost social cohesion.

The fundamental reason for the growing interest in neighbourhoods in today's policy debate is their context effects. Negative neighbourhood effects have often been associated with the segregation of poor communities or ethnic minorities. Large concentrations of these groups in specific areas are believed to reinforce and perpetuate poverty and exclusion, and consequently reduce social cohesion (Bolt et al., 2010; Colomb, 2011). Major world cities have observed a gradual decrease in social cohesion since the late 20th century (Schiefer & van der Noll, 2017), so this relation was embraced by policy-makers, as it implies that eliminating such concentrations would address negative neighbourhood effects (Méreiné-Berki et al., 2021). As a consequence, neighbourhoods have been targeted by policy-makers and urban planners to design solutions to create more resilient cities.

A policy that aims to halt the deterioration of social cohesion is the establishment of balanced neighbourhoods. Balanced neighbourhood policies aim to increase the social mix of specific areas to avoid the clustering and segregation of disadvantaged households (Hananel et al., 2022). They aim to increase the social cohesion of cities as they allegedly counter antisocial behaviours as well as criminal activity to, as a result, increase the resilience to distress and tackle long-lasting systemic issues (Jordan, 2018; Ministry for Housing and the Civil Service of the Netherlands, 2017). Creating neighbourhoods with a balanced social composition is a commonly accepted technique by policy-makers and scholars for addressing perceived negative neighbourhood effects (Bolt et al., 2010; Chaskin & Joseph, 2011; Kearns & Mason, 2007; Manley et al., 2011; van Ham & Manley, 2012). There is, however, literature that challenges this believed abstraction and suggests that the anticipated effects are rather inconclusive and usually not achieved (Custers, 2021; van Ham & Manley, 2012). In addition, balanced neighbourhoods are also widely criticised for promoting exclusion and having counterproductive effects on social cohesion and resilience (van Eijk, 2010).

Given the dearth of consensus on the impacts of balanced neighbourhoods, it is remarkable that governments have embraced these policies with such zeal. To elucidate the extent to which governments should implement balanced neighbourhoods, this study aims to contribute to the field of urban resilience studies by analysing the effect of balanced neighbourhoods as a policy instrument to improve the resilience of cities by increasing social cohesion. The research will use the city of Rotterdam, Netherlands, as a case study.

## 1.2. Case study: Rotterdam

As the second-largest city in the Netherlands, Rotterdam is critical in the development of the country. Today, Rotterdam is considered an attractive place to live, as can be seen, reflected in the inflation of housing prices brought by its increasing popularity (Custers, 2021). Therefore, the government has a dire need to 'fight for a sustainable, safe, united and healthy future' for the city and its residents (Municipality of Rotterdam, 2016a, p. 13).

The complex geographical nature of the city, which is entirely situated below sea level, has historically called for policies that fight against the adverse effects of climate (Spaans & Waterhout, 2017). To address these growing challenges, the municipality has been actively involved in working toward a climate-proof city by developing and participating in local, regional, national, and international initiatives. In 2014, the city joined Rockefeller Foundation's 100 Resilient Cities program (100RC) and the efforts of fighting against the force of nature culminated in 2016, when Rotterdam presented its Resilience Strategy as a member of the 100RC (Municipality of Rotterdam, 2016a).

Rotterdam already has a reputation for designing and engineering robust systems, but the municipality acknowledges that future risks might call for a different response (Municipality of Rotterdam, 2016a). As such, the Resilience Strategy has not only been motivated by the response to sudden shocks (e.g. earthquakes, fires, floods), but also to face systemic socio-economic tensions. To address the different vulnerabilities, the Resilience Strategy is divided into seven Resilience Goals and six Challenges. Of particular interest to this study is Goal 1 'Rotterdam: A balanced society' which aims to address Challenge 1 'Social cohesion and education'. The Strategy advocates for a more socially cohesive Rotterdam as a way to increase social resilience.

As part of the efforts to achieve Goal 1, in 2012 the municipality developed the National Programme Rotterdam South (NPRZ) (Municipality of Rotterdam, 2016a, p. 109), and in 2016 the Woonvisie (Housing Vision of Rotterdam) (Municipality of Rotterdam, 2016a, p. 65), which aim to create a balance in the groups of residents by demolishing and renewing old cheap housing to make way for higher-income groups. A physical change in the housing structure mutates the composition of a neighbourhood and is presumed to foster social cohesion to achieve the resilience Goal 1 and increase social resilience (see Figure 1.1).

The resilience view of Rotterdam is endorsed by a balanced society that in practice is linked to the housing policy. The housing policy of Rotterdam has, however, been criticised for its apparent motivation to disperse and exclude social groups. Scholars and activists claim that low and middle-income families, the homeless, young people, and ethnic minorities are excluded due to their limited purchasing power (Right to the City, 2021a; Versluis, 2017). Although the municipality claims that advocating for more balanced neighbourhoods will have a positive effect in Rotterdam, some scholars attribute these claims to a misleading use of indicators and statistics (Schinkel & van den Berg, 2011; Uitermark et al., 2017). They argue that political decision-makers frame data to fit their storyline of a balanced society while obscuring controversial motives and negative

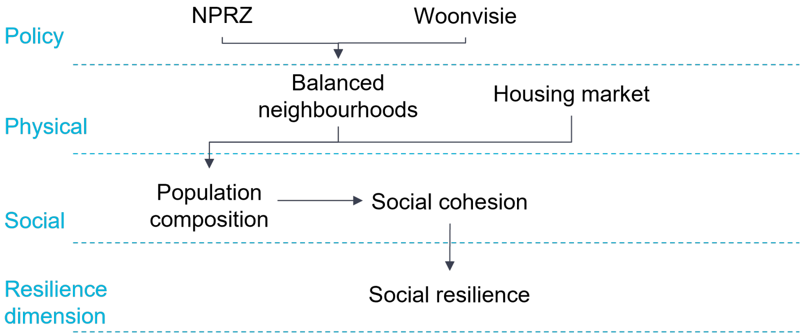



**Figure 1.1:** Balance as a remedy: Rotterdam strategy to increase the municipal resilience. Rotterdam's resilience office divides resilience into six dimensions: Social, Energy, Cyber, Climate, Critical infra, and Governance (Molenaar, 2016). Beating the Challenge 1 'Social cohesion and education' contributes to the Social resilience dimension. Source: Author.

outcomes (de Bruijn, 2019). Other studies suggest that the storyline does not even hold, given the lack of demonstrable promised improvements (Hochstenbach et al., 2015). In that sense, some scholars and organisations regard these measures as a transgression of freedom and justice (Uitermark et al., 2017; van Eijk, 2010; van Gent et al., 2018). This sentiment has also reached the public. Detractors of the Woonvisie have organised protests under the movement Recht op de Stad (Right to the City) that rejects the city in balance and champion a city for everyone (Right to the City, 2022). Remarkably, in 2021 the United Nations filed a report that denounced these policies as racist and classist (UN-OHCHR, 2021). As a consequence, it requested an investigation to assess how the policy relates to human rights and called for the application of measures if these are not guaranteed (Right to the City, 2021b).

Taking into account the heavy load of dispute that Rotterdam's balanced neighbourhood policies carry, and in order to elucidate their impact on urban resilience, it is vital to study whether the assumptions on which the municipality grounds their policies are valid.

## 1.3. KNOWLEDGE GAP

This study aims to address the existing literature gap from the urban resilience angle. In general, academic and governmental publications agree that in cohesive societies, local communities protect residents against threats, care of others during hardships, and ultimately promote community resilience (Arup, 2015; Pelling, 2003; Quigley et al., 2018; Saja et al., 2019). Nonetheless, there are few ex-post empirical studies that confirm this relation. Therefore, we aim to understand if balanced neighbourhoods trigger resilient actions that are pivotal in resilient communities (Doff, 2017; Fay-Ramirez et al., 2015). To this end, this study contributes to the existing literature in three ways: (i) determining if social cohesion acts as the mechanism for resilient actions triggered by the balance in a neighbourhood, (ii) measuring the level of neighbourhood balance in terms of the housing stock value, and (iii) use a multidimensional conceptualisation of social cohesion.

The relationship between balanced neighbourhoods and urban resilience has been scarcely explored. Custers (2021) evaluated the association between balance and willingness to help — which, as we will argue, can be used as a proxy to measure resilient actions —, and the relationship between balance and social capital. Our research elaborates on these results in the three above-mentioned ways: (i), Custers (2021) analysed the relationships between balance, social cohesion, and willingness to help independently, lacking the capability to understand the mechanism between balance and resilient actions; (ii), it considered balance in terms of ethnicity, socio-economic status, or tenure, whereas we go down to the physical level considering house prices; and (iii), by measuring social cohesion as a unidimensional variable. From the existing studies, to our knowledge, only Wang and Kemeny (2022) have empirically studied the relationship between balanced neighbourhoods in terms of the housing stock value and social cohesion. Nevertheless, their study does not address points (i) and (iii). Therefore, little is known about the empirical relationship between balanced neighbourhoods, social cohesion, and resilient action.

## 1.4. RESEARCH QUESTIONS

This thesis aims to contribute to the literature by measuring and studying the implications of the value of houses as indicators of balance, and performing an empirical analysis of the relationship between balanced neighbourhoods, social cohesion, and resilient action. Taking into account the gaps detected in the literature, the research aims to answer the following main question:

***Does neighbourhood balance increase resilient action of neighbourhood residents?***

The following sub-questions are considered in order to address this main question:

SQ1: *What are the underlying mechanisms that drive balanced neighbourhoods to act more resiliently?*

SQ2: *How can the indicators of the mechanisms that drive balanced neighbourhoods to act more resiliently be operationalised?*

SQ3: *What is the empirical relationship between the indicators that drive balanced neighbourhoods to act more resiliently?*

## 1.5. RESEARCH APPROACH

A **deductive (confirmatory) approach** is suitable as the objective is to empirically test the mechanism that triggers resilient action in balanced neighbourhoods (Hair et al., 2016; Henseler, 2020). To this end, the research aims to test the assumptions on which the municipality of Rotterdam grounds their balanced neighbourhood policies. Following the deductive approach (Dudovskiy, 2016), first a theory is deduced from the literature; second, hypotheses on the relationship between the variables are formulated; third, the hypotheses are tested using quantitative methods; fourth, the theory is accepted or rejected, and recommendations to policymakers to adapt their resilience governance if necessary are provided. Furthermore, by virtue of the vastly detailed data available in the Netherlands, a comprehensive geo-spatial investigation can be carried out. We combine resident and neighbourhood census tract data to unravel the effect of contextual and individual factors. More specifically, the deductive approach is based on Partial Least Squares—Structural Equation Modelling (PLS-SEM) and spatial econometrics, two statistical modelling techniques which provide empirical evidence for the research hypotheses.

A deductive approach is advantageous as it starts with a clear hypothesis (Schwab & Held, 2020; Shih & Chai, 2016). This avoids stating a hypothesis after using a data-driven approach to fit the data. In addition, it also prevents selectively reporting what works and ignoring what does not. For instance, previous neighbourhood effects studies use a data-driven approach (e.g. Abada et al. (2007), Custers (2021), and Wang and Kemeny (2022)) which can test various covariates until the model fit is good enough to consider satisfactory results. On the other hand, the limitation of a deductive approach is its reliance on the theory on which the hypotheses are grounded (Hair et al., 2016; Henseler, 2020). A strong theoretical foundation based on the literature review can help mitigate this limitation (Manley et al., 2011; van Ham & Manley, 2010). In addition, expert interviews were performed to increase the confirmatory power of the results (Barth et al., 2011).

## 1.6. RESEARCH STRUCTURE

The report consists of six chapters. Figure 1.2 graphically depicts the structure of the thesis. Chapter 2 is dedicated to a literature review that provides the theoretical foundations for the research. The chapter concludes with the formulation of the hypotheses to test, grounded on the literature review, and answers SQ1.

Chapter 3 describes the data and methods used in the development of the study. The chapter concludes with the computational framework to be applied to the case study, i.e. the way of how the data and methods are used to test the research hypotheses and respond to the research questions.

Chapter 4 presents the outcomes of applying the research methods to the Rotterdam case. This chapter provides empirical evidence of the acceptance or rejection of the research hypotheses, and answers SQ2 and SQ3.

Chapter 5 provides an interpretation of the obtained results based on the theoretical concepts grounded in literature and the input of interviews to experts.

Finally, Chapter 6 gives an answer to the posed research questions and formulates policy advice. It also discusses the limitations of the study and suggests directions of future research.

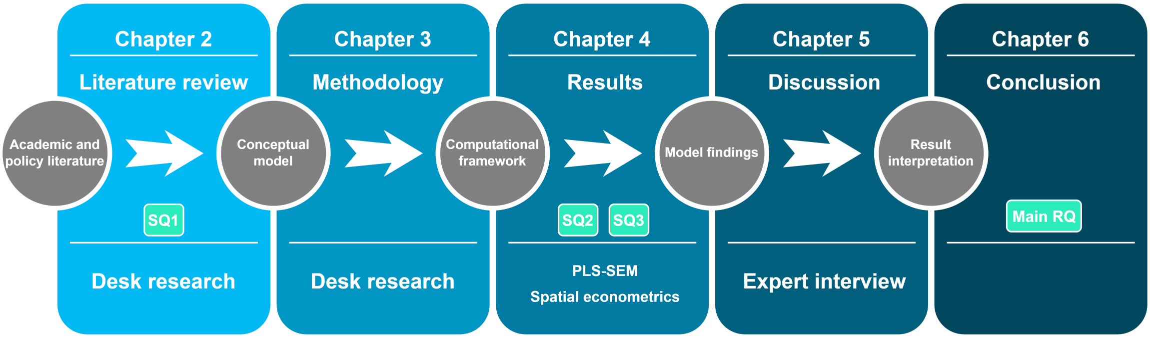



**Figure 1.2:** Research flow diagram.

# 2

# Literature review

A literature review was necessary to break down, conceptualise, and operationalise balanced neighbourhoods, social cohesion, and resilient actions. For this, we relied on academic literature as well as government documents. On one hand, the concepts are very debated in the academic world, with contrasting views and ideas. Desk research is useful in creating an understanding of concepts. On the other hand, government documentation that defines or discusses the concepts is critical in order to “speak” the language of the politicians.

The first section of this chapter is concerned with the reconciliation between social cohesion and resilience. The chapter follows with the current understanding of housing policies as a way to increase social cohesion by achieving a social mix of the population. Next, the state of the policies in Rotterdam is discussed and their understanding of a balanced neighbourhood explained. Finally, the chapter concludes with the formulation of the hypotheses to test, grounded on the literature review.

## 2.1. Urban resilience

This section first introduces the concept of urban resilience and explains the characteristics of a resilient city. Next, it exhibits how social factors govern the resilience of a community to argue that informal support is a voluntary action characteristic of resilient cities.

### 2.1.1. The resilient city

The rise in urban stresses throughout the world, coupled with the consequences of climate change, such as extreme weather and natural catastrophes, has prompted the need for preparedness of urban areas to face precarious circumstances (UNISDR, 2015). Consequently, the concept of urban resilience has grown in popularity to tackle these challenges that abrupt urbanisation and a lack of proper planning have put in place.

**Urban resilience** is ill-defined, and the variety of conceptualisations make it hard to put it into practice (Larimian et al., 2020; Meerow et al., 2016). Here, we understand urban resilience as ‘the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity’ (Meerow et al., 2016, p. 39). This definition subsumes a continuum of actions that consider different timescales of the system. First, a resilient urban system should be able “to maintain ... desired functions” during a shock. This means they should have the coping capability to absorb and withstand an adverse event. Next, the city should be able “to adapt” to the new conditions by learning from their experience and later on “to transform” if required (see Figure 2.1). Shocks are regarded as opportunities to address long-lasting inequity problems such as poverty concentration, however, persistence may still be desirable for certain components such as infrastructure. Therefore, a resilient city is a city that can sustain, adapt, and develop under a variety of unexpected shocks and stresses.

time ↓

| Phase of resilience | Characteristic |
|---|---|
| Before an event | Preparedness |
| During an event | Absorption |
| After an event | Recovery |
| | Adaptability |
| | Transformability |

**Figure 2.1:** Phases and characteristics of urban resilience. The downward time arrow indicates the order of phases. Source: Tong (2021)

### 2.1.2. INFORMAL SUPPORT AS RESILIENT ACTION

It has been generally agreed upon that **social factors govern the resilience of urban areas** (Copeland et al., 2020). Aldrich (2017) goes as far as to state that resilience comes from responses built on communities’ social networks rather than on complicated engineering. Within this idea, social resilience ‘concerns the extent to which a local community is able to respond to or anticipate changes’ (Doff, 2017, p. 4). At this level, resilience is shaped by the structure of social networks, the access to resources, and the social institutions (Adger et al., 2002). Resilience can only be present if the members in a community are capable of collective action. Only in this way, they can collect enough resources and have the capacity to mobilise them in the event of a disaster or to address a chronic stress (Veld Academie, 2021).

Communities’ everyday resilience to unanticipated adversities are therefore fostered by pro-community behaviours. Communities in which the residents work together and have common goals find it easier to understand the needs of others and share necessary resources. In the event of a disaster, the existence of shared norms and trust result in a stronger willingness to cooperate and in a better cooperation (Aldrich, 2017; Baldwin & King, 2017).

How do we then know how resilient a community is? Unfortunately, **resilience cannot be measured directly**. Therefore, studies employ proxy indicators to construct resilience variables or, otherwise, measure phenomena that are indirectly related to resilient capabilities (Copeland et al., 2020). In line with Aldrich (2017), we argue that the end mechanism through which social resilience is achieved is mutual aid. A resilient community is one that can collaborate and is caring. Therefore, **informal support** (or informal help) is a suitable proxy to measure the resilient action of a neighbourhood.



Informal support is essential before and after disasters, as local care systems cannot work without the support of the local community. It contributes to desaturate local care systems, as well as to be a *locum tenens* when these normal providers of assistance are shut after a disaster (Aldrich, 2017; Naganuma et al., 2018). Informal support is characterised by emotional and instrumental support (Noguchi, 1991). Forms of emotional support are for example listening to the worries of someone else, giving a hug, or saying encouraging words. On the other hand, forms of instrumental support are for example lending money, watching someone else's child, or helping with moving.

Residents with strong connections before a disaster are more likely to ask and receive informal support than those who are not in a cohesive community. After a disaster, it is too hard to form connections and trust in such a compressed and tense time (Aldrich, 2017). Therefore, Doff (2017) distinguishes between **effective and potential resilient actions**. Effective actions are those which happen only after a stressor has occurred. Potential action refer to the 'potential' to act resiliently. If only effective action is considered, potential resilience is missed. If only potential action is considered, obstacles to actual action are not taken into account. As such, it is important to consider both effective and potential informal support.

Informal support can come from the hand of **strong ties** like friends and family, from **weak ties** like neighbours and acquaintances, or **invisible or non-existent ties** like strangers (Felder, 2020). The CBS argues that the accessibility to informal support is greater with strong ties, but that most Dutch citizens still have access to informal support from weak ties (CBS, 2012, 2015). In this sense, **social cohesion is posited to be the mechanism underlying informal support from weak, invisible, or non-existent ties**. However, the National Academies of Sciences, Engineering, and Medicine (2020) alerts of the decrease in weak ties relationships and of the possible consequences in informal support. As such, urban planning policies are concerned about strategies to promote weak ties in the community.

Previous empirical studies have related informal support to the resilience after a disaster. For example, Aldrich (2017) shows how neighbourhoods in New Orleans had to rely on the support from other locals to recover, especially because shops and grocery stores lacked resources for more than a year after hurricane Katrina. Another study by L. Cheshire (2015) analysed the extent to which weak ties helped each other in the 2011 floods in Queensland, Australia. Finally, Klinenberg (2015) studied how the capacity of response and recovery of those more vulnerable to heat waves in Chicago was raised by the care provided by those around them.

## 2.2. HOW CAN SOCIAL COHESION IMPROVE RESILIENCE?

The starting point of this section is the justification in resilience thinking of social cohesion as the mechanism that triggers informal support. The section follows with a clarification on what we understand by social cohesion. This is especially necessary because of the cross-disciplinary use of the concept between social sciences and policymaking. To this end, we identified the key characteristics of social cohesion that have been explored in the academic literature and policy discourse. The section finalises with the review of urban elements that have been recognised to have an impact on social cohesion and informal support.

### 2.2.1. From social cohesion to resilient actions

Social cohesion has been acknowledged to contribute to the general well-being of society. Cohesive societies are characterised by their political stability and their economic and business growth (OECD, 2011). Exclusion and marginalisation are reduced by minimising the disparities among social groups, and members of society are offered the opportunity of upward mobility.

Resilience thinking defines as **resilient city, the city with social cohesion** (Center for American Progress, n.d.; Forrest & Kearns, 2001; Larimian et al., 2020). Literature suggests that in cohesive societies, local communities protect residents against threats, care of others during hardships, and ultimately promote community resilience. Social bonding not only provides for daily activities, but also facilitates access to resources and information through social connections (Forrest & Kearns, 2001). Strong social cohesion is associated with the ability of members to be able to cooperate and take actions to support each other in the presence of adverse events (Baldwin & King, 2017; Elliott et al., 2010; Larimian et al., 2020). As such, voluntary action in terms of **informal support** is deemed an important factor of a so-called resilient city (G. Huang, 2020). Therefore, governments are looking to strengthen the relationships between citizens, communities, and social institutions to boost social cohesion.

Past studies have found a positive relationship between social cohesion and community resilience. For example, Berkman et al. (2000) developed a conceptual framework that explains how social networks enhance informal support like having someone to talk to or to ask for a ride. An empirical study by Kawachi et al. (1997), found out that higher social cohesion was related to lower mortality, partially explained by the increase in income inequality with the reduction of social cohesion. Research by Sampson et al. (1997) also showed empirical evidence that socially cohesive communities influence behaviour through social norms and as a result have better access to medical care, healthy food, and exercise facilities. This effect of social contagion is especially relevant in this study due to the **geographically bounded conceptualisation** within neighbourhoods. Finally, in a study of heat waves in Chicago, Klinenberg (2015) concluded that during natural disasters like heat waves, elder citizens in poorly cohesive neighbourhoods lack social support from caring neighbours who will check on them, as well as they know of fewer safe common locations where they may seek help and shelter.

### 2.2.2. Origin and definitions of social cohesion

Resilience thinking associates a cohesive society with a resilient society. But, what is social cohesion? Several authors attribute the beginning of the discussion on social cohesion to Durkheim's (1897) *Étude de sociologie* (Fonseca et al., 2019; Hulse & Stone, 2007). Since that starting point, sociologists and social psychologists have been working on the definition and development of social cohesion as a construct.

A century after the term was coined, since the 1990s, policymakers in developed countries have utilised social cohesion to justify public spending on social policies and economic growth (Hulse & Stone, 2007; Klein, 2013). Despite its long-lasting presence in the literature and government policies, social cohesion remains an ill-defined concept whose definition varies between authors and institutions (Chan et al., 2006). Bernard (1999) already emphasises this difficulty when he considers social cohesion as 'a quasi-concept, that is, one of those hybrid mental constructions that politics proposes to us more often in order to simultaneously detect possible consensuses on a reading of reality, and to forge them.' (as cited in Chan et al., 2006; Klein, 2013).

In order to have an overview of the different conceptualisations of social cohesion, Table A.1 and Table A.2 show definitions coined by scholars and political institutions, respectively. These definitions have been collected from previous literature reviews on social cohesion (i.e. Fonseca et al. (2019), Hulse and Stone (2007), Klein (2013), Langer et al. (2017), and Schiefer and van der Noll (2017)) and from the core research papers of the study.

From the evaluation of the literature, we can see in Table A.1 and Table A.2 that there is no single definition of social cohesion. Nevertheless, some similarities can be identified from the multiple definitions. For instance, most authors believe that social cohesion is a positive feature of a social entity, and therefore it is not an individual quality (Schiefer & van der Noll, 2017). These definitions are mostly related to the economic components of society such as well-being, trust, and equitable opportunities (Fonseca et al., 2019). Furthermore, Table A.1 exhibits how social cohesion is a characteristic of a social entity that emerges from the individuals. Finally, Table A.2 also shows that social cohesion does not encompass a single policy concept. This strengthens the idea that social cohesion is viewed as a multidimensional construct.

### 2.2.3. SOCIAL COHESION CONCEPTUAL FRAMEWORKS

Beyond the definitions of social cohesion, policymakers have been especially interested in monitoring the social cohesion of citizens. Several conceptualisations can be found in the literature that indicate the lack of agreement on how to approach this issue.

In general, the authors have embraced the above-mentioned consideration of a multidimensional construct. For example, Forrest and Kearns (2001) understands social cohesion as being composed of Common values, Social order, Social solidarity, Social capital, and Identity. Later, Chan et al. (2006) developed a two-by-two framework that considers a Horizontal dimension (cohesion with society) and a Vertical dimension (state-citizen cohesion) divided between a Subjective component (state of mind) and an Objective component (behavioural manifestations). Finally, Langer et al. (2017) goes on to simplify that social cohesion can be characterised by the dimensions of Inequalities, Trust, and Identity.

The discrepancy within the construct of social cohesion is clear. Nevertheless, Schiefer and van der Noll (2017) indicate that there is far more overlap than is assumed. In an effort to reduce the concept to its essential dimensions by analysing previous conceptualizations, they argue that many elements identified in the literature are outcomes of social cohesion rather than constituting elements. In this way, shared values, inequality, and quality of life are not inherent in the concept, but are consequences of social cohesion. For instance, they argue that a society is not cohesive because individuals feel well, but individuals feel well because there is a strong social cohesion. The direction of causality frames social cohesion as an antecedent to well-being. As a result, they characterise social cohesion as a construct of Social relations, Attachment/Belonging, and Orientation towards the common good.

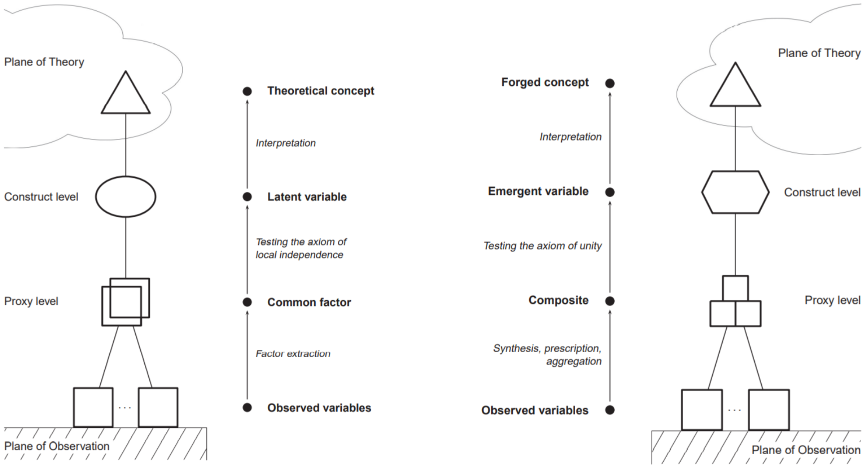
Taking into account the multiple ways to interpret and put together the multiple dimensions of social cohesion, three important considerations were identified in the literature to define an operationalisable conceptualisation for social cohesion: (i) type of construct, (ii) variables, and (iii) geographic level of analysis.

Beginning with (i), the literature agrees that social cohesion is composed of several distinct characteristics, thus it should be treated as a construct (Langer et al., 2017; van Beuningen & Schmeets, 2013). To operationalise such a multidimensional concept, we can distinguish between two main approaches: measurement theory and synthesis theory (see Figure 2.2). **Measurement theory** aims at revealing the structure of empirical data by analysing the common factors among the data that conform to the construct (Henseler, 2020). In this sense, the theoretical concept is first developed and then connected to the empirical data, usually for confirmation purposes. In measurement theory, the construct is regarded as a **latent variable** from the underlying common factors, where the unobserved latent concept causes the observed data and their relationships (Henseler, 2020). This direction of causality is known as **reflective** (Skrondal & Rabe-Hesketh, 2004, p. 77). On the other hand, **synthesis theory** is a pragmatic strategy that conceives these unobservable variables in terms of what is already familiar and well known (Henseler, 2020). Instead of finding the common factors within the data, synthesis theory creates **emergent variables** by forging the different components as a whole, instead of being an assembly of parts. While measurement theory is usually used for confirmatory purposes, synthesis theory is an instrumental approach to solve and analyse problems. For this reason, emergent variables rely as much as possible on the results from previous measurement theory studies (Henseler, 2020). This direction of causality is known as **formative** (Skrondal & Rabe-Hesketh, 2004, p. 77).

The distinction between these perspectives demands a comprehensive examination of the grounds for determining the approach. Although synthesis theory is mostly used for social constructs (widely seen in the conceptualisation of socioeconomic status) (Diamantopoulos & Winklhofer, 2001), some examples of measurement theory can be found, such as Dragolov et al. (2013).

In the Dutch context, we can find the social cohesion construct of Netherlands Statistics (CBS, 2015). Based on the work of van Beuningen and Schmeets (2013), CBS (2015) constitutes one of the two official Dutch social cohesion frameworks. By means of measurement theory, it includes the following three dimensions: Participation, Trust; and Integration. In their framework, Participation and Trust are subdivided within social, organisational, and political. Integration is not subdivided (see Figure 2.4). Studies like Schiefer and van der Noll (2017) and Dragolov et al. (2013) take a similar approach.

Within the Dutch context, we can also identify the study of Schnabel et al. (2008), that uses synthesis theory to conceptualise social cohesion for the Dutch Office of Social and Cultural Planning. Instead of defining all the different factors that give place to the latent subdimensions, the study makes use of the previously validated results of measurement




**(a)** Diagram of measurement theory.

**(b)** Diagram of synthesis theory.

**Figure 2.2:** Diagrams of the two theories for the development of constructs discussed in this study. Source: Henseler (2020).

theory to forge an emergent variable for social cohesion. They devised social cohesion as an emergent variable composed of the elements in Figure 2.3. These elements have previously been validated as the pieces that forge social cohesion from measurement theory. Other studies that take the same approach from similar components are Baldwin and King (2017), Miao et al. (2019), and Stuij (2020).

| Social cohesion in Schnabel et al. (2008). Each item ranked on a Likert scale as:<br>(1) Totally disagree, (2) Disagree, (3) Nor agree or disagree (4) Agree and (5) Totally agree. |
|---|
| i. I have a lot of contact with my immediate neighbors |
| ii. In this neighborhood, people treat each other in a pleasant way |
| iii. We live in a cozy neighborhood with a lot of togetherness |
| iv. People hardly know each other in this neighborhood |
| v. I am satisfied with the population composition in this neighbourhood |

**Figure 2.3:** Social cohesion indicators in Schnabel et al. (2008) for the Dutch Office of Social and Cultural Planning.

Finally, it is also important to mention that many other studies do not use a construct to determine social cohesion (see Chan et al. (2006), Sluiter et al. (2015), or Tolsma et al. (2009)). These investigations analyse several individual variables, which can be used as proxies to define social cohesion. Generally, these studies are concerned with correlational analyses that do not just want to measure social cohesion, but want to use the measurement in further analyses. These studies acknowledge the limitation of such an approach.

Once the dimensions and the type of construct have been conceptualised, it is also

| Indicators | Variables | Subdimensions | Dimensions |
|---|---|---|---|
| Frequency of contacts | Family contacts | Social participation | Participation |
| Social life satisfaction | | | |
| Superficiality of contacts | | | |
| Feeling of being understood | | | |
| Frequency of contacts | Friend contacts | | |
| Social life satisfaction | | | |
| Superficiality of contacts | | | |
| Feeling of being understood | | | |
| Frequency of contacts | Neighbor contacts | | |
| Social life satisfaction | | | |
| Superficiality of contacts | | | |
| Feeling of being understood | | | |
| Given unpaid help | Informal help | | |
| Type of association | Participation associations | Organizational participation | |
| Frequency of participation | | | |
| Type of volunteering | Volunteering | | |
| Voting turnout | Voting | Political participation | |
| Radio, TV, or newspaper follower | Political activities | | |
| Engaged in a political party or organization | | | |
| Attended consultation meeting or hearing | | | |
| Contacted a politician or official | | | |
| Participated in activism | | | |
| Participated in a demonstration | | | |
| Participated in a signature campaign | | | |
| Participated in a political action via Internet or email | | | |
| Has done something to raise political issue | | | |
| Generalized trust on people | General trust | Social trust | Trust |
| How much trust on army | Army trust | Organizational trust | |
| How much trust on police | Police trust | | |
| How much trust on judges | Judges trust | | |
| How much trust on civil servants | Civil servants trust | | |
| How much trust on press | Press trust | | |
| How much trust on large companies | Large companies trust | | |
| How much trust on the Parliament | Parliament trust | Political trust | |
| N/A | N/A | N/A | Integration |

**Figure 2.4:** Dimensions and indicators used in CBS (2015) to determine social cohesion. Indicators for Integration are not available because in the study, Integration is inferred by indirectly comparing the scores of Participation and Trust of the various population groups. Adapted from CBS (2015).

relevant to determine (ii), the **variables** which define social cohesion. On the premise that indicators need to be based in both qualitative data and a theoretical model (Townshend et al., 2015), a wide range of indicators for social cohesion can be found in literature. To give two relevant examples, we show the indicators used in the two social cohesion frameworks used by the Dutch government. First, Figure 2.4 compiles the indicators used in CBS (2015). Given that the study bases their definition of social cohesion on measurement theory, the framework consists of both behavioural and attitudinal indicators for each dimension. It can be seen, however, that there are no indicators for the Integration dimension. This is because their framework infers Integration by indirectly comparing the scores of Participation and Trust of the various population groups. On the other hand, Figure 2.3 shows the indicators used in Schnabel et al. (2008) based on synthesis theory. The various dimensions of social cohesion as conceptualised in measurement theory are reduced to single indicators for each of the dimensions. They express the behaviour, perception, and participation of individuals as members of society.

Finally, consideration (iii) the **geographic level** of the analysis, is also of relevance when conceptualising social cohesion. Sociologists do not agree at which geographical level social cohesion is properly defined and measured (Harell & Stolle, 2010). While some believe social cohesion is a small community phenomenon, others argue that it can be best understood at a national level. This entails that sources and outcomes of social cohesion will vary accordingly. Consequently, this had led to the study of a variety of geographical levels in social cohesion research spanning from countries (CBS, 2015; Langer et al., 2017), going through municipalities (Islam et al., 2008) and neighbourhoods (Custers, 2021; Wang & Kemeny, 2022), all the way down to postcodes (Tolsma et al., 2009). What is more, several authors indicate that social cohesion crosses the physical boundaries of country, municipality, or neighbourhood, and more important are the form and content of social networks (Forrest & Kearns, 2001; Takagi & Shimada, 2019). Given that in Rotterdam's policy context policies are targeted at a neighbourhood level, this study will consider social cohesion a characteristic at a neighbourhood level.

In this research, social cohesion is treated as a multi-dimensional construct. Both measurement theory and synthesis theory are explored to find out which conceptualisation fits better the available data. In addition, neighbourhoods are considered the focal points for shaping and strengthening the social cohesion of cities insofar we are focusing on a spatial-bounded problem (Forrest & Kearns, 2001).

### 2.2.4. Urban elements that shape social cohesion and informal support

As a final consideration, both social cohesion and informal support have been associated to **characteristics of the built environment and the demographics**. This is based on the idea that urban elements can promote or deter social interactions, and thus are aspects of what can be considered a resilient neighbourhood (Mouratidis & Poortinga, 2020; Wood et al., 2010) (see Figure 2.5). However, results of these studies show mixed results.

To begin with, social demographic factors have been previously accounted for variance in neighbourhood social cohesion. **Ethnic heterogeneity** has been identified as positively associated with social cohesion (Tunstall & Lupton, 2010), negatively associated (Coffé & Geys, 2006), and with non-significant effect (Abada et al., 2007; Musterd & Andersson, 2005). The effects of ethnic heterogeneity on social cohesion and support can be explained by the contact hypothesis and the homophily principle developed later in Section 2.3.2. A second relevant type of mix is **house type heterogeneity**. House type heterogeneity has been less explored empirically, but qualitative studies and policy documents argue that a more heterogeneous range of house types allows residents to stay in the neighbourhood as they move in life stages, thus increasing the cohesion to the community (Bolt et al., 2010; Galster et al., 2015). Finally, most literature agrees that long-term residence is strongly associated to social aspects like integration, capital, and cohesion (Rogers & Sukolratanametee, 2009; Wood et al., 2010), but there is also evidence of studies like Small (2007) which contradict the status-quo.

The land use has been regarded as another relevant factor. First, higher **population density** increases the chances of social interaction, and as Rogers and Sukolratanametee (2009) concluded, density had a positive effect on local support. However, in the study by Koohsari et al. (2021) these characteristics were all associated with a negative score. Next,

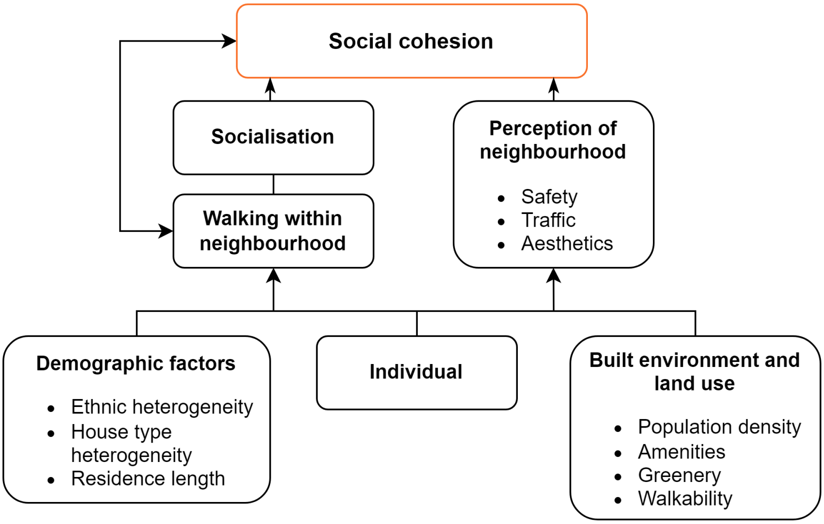



**Figure 2.5:** Conceptual model of the association between urban elements and social cohesion. Adapted from: Wood et al. (2010)

the amount of **amenities** has also been argued to affect social cohesion as they provide a space for encounter and interaction (Mouratidis & Poortinga, 2020; Veld Academie, 2021).

Finally, the built environment has also been considered in previous studies as a relevant factor (Mazumdar et al., 2018; Mouratidis & Poortinga, 2020). According to previous research, **greenery** may also promote social interaction and hence build social cohesion (Hartig et al., 2014). Second, Cabrera (2013) argued that street encounters can increase local social interaction and strengthen ties within the community. Therefore, the **walkability** of a neighbourhood has also been considered as a relevant built environment factor.

Urbanism literature, notices that demographic, built environment and land use elements are not sufficient to understand their effect on the social cohesion of neighbourhood residents (Kim & Kaplan, 2004; Rogers & Sukolratanametee, 2009; Wood et al., 2010). Individual characteristics such as intentions and preferences regulate the perception and experience of urban elements. In addition, urban design elements that encourage interaction (e.g. street width, the interconnectedness of streets, the presence of porches and balconies, or physical aesthetics) have been associated with a higher sense of community.

## 2.3. BALANCED NEIGHBOURHOODS

In the last section, we saw how socially cohesive areas have a stronger willingness to cooperate in the event of a disaster. But, how do we achieve a socially cohesive community? In this section, we develop the idea of balanced neighbourhoods as a policy instrument to achieve a more resilient city by improving its social cohesion.

Balanced neighbourhoods are ill-defined and context dependent, but generally aim for a mix of local demographics with the objective of promoting inclusion, liveability, and the economy (Tunstall & Lupton, 2010). In this section, we start by explaining the roots of balanced neighbourhoods from the concept of social mix. Then, we relate social mix to social cohesion by showing relevant studies that connect both concepts. We finally follow up by taking social mix to the housing policy realm.

### 2.3.1. SOCIAL MIXING

Governments and scholars generally agree that residing in a deprived neighbourhood has a detrimental impact on people's life opportunities. Previous research has identified a relation between deprived neighbourhoods and a variety of negative outcomes such as higher school dropout rates, lower childhood achievement, lack of social mobility, deviant behaviour, and social exclusion (Manley et al., 2011). These so-called **neighbourhood effects** have been explained by deprived neighbourhood characteristics such as social and physical disconnection, poor culture, discrimination, limited public accessibility, and high exposure to criminal activity (van Ham & Manley, 2010).

Negative neighbourhood effects have often been associated with the segregation of poor communities or ethnic minorities. Large concentrations of these groups in specific areas are believed to reinforce and perpetuate poverty and exclusion (Bolt et al., 2010; Colomb, 2011). This relation was embraced by policy-makers, as it implies that eliminating such concentrations would address negative neighbourhood effects. This accessible and actionable solution has led to the development of area-based policies to create socially mixed neighbourhoods (Méreiné-Berki et al., 2021).

**Social mixing** aims to prevent stigmatised groups from congregating in one location and subsequently provide better conditions for generating social capital to restore or create conditions of integration, cohesion, workability, and sustainability (Musterd & Andersson, 2005; Tunstall & Lupton, 2010). Figure 2.6 summarises the alleged positive effects of social mix. First, the local economy and employment would be boosted as a result of improved local public and private services. Second, the behaviour and aspirations of segregated communities should improve. Third, an improvement in community bonding would increase neighbourhood stability. Fourth and final, we would see an improvement in bridging with other communities as a result of the loss of stigma. This objective can be achieved in different ways: through the mixing of household types and tenures (Bolt et al., 2010; van Gent et al., 2018); occupation and income levels (Galster et al., 2015; van Ham & Manley, 2012); ethnicities and birthplaces (Jordan, 2018); and languages and cultural backgrounds (Wang & Kemeny, 2022).

A key problem for those who have consistently advocated for social mixing is that this point of view has relied on a **theoretical rather than empirical evidence** base. Despite its theoretical foundation and broad adoption in urban policy, several scholars have questioned the goal of socially mixed neighbourhoods on conceptual and practical grounds (Galster et al., 2015; Graham et al., 2009). Opposing scholars suggest that there is a paucity of evidence that social mix is the answer to neighbourhood effects, and most empirical studies point in the opposite direction. Findings by Kearns and Mason (2007) suggest that mixed-tenure neighbourhoods do not guarantee that neighbourhood problems such as vandalism, graffiti, crime or littering will be reduced. Also, Graham et

| Economic and service impacts | Community-level effects |
|---|---|
| Better quality public services | Increased social interaction |
| Improved quality & quantity of private services | Enhanced sense of community and place attachment |
| Enhanced local economy | Reduction in mobility |
| Increased rates of employment | Greater residential stability |
| **Social & behavioural effects** | **Overcoming social exclusion** |
| Reduction in anti-social behaviour | Reduction in area stigma |
| Better upkeep of properties and gardens | Increased connectivity with other places |
| Raised aspirations | Enhanced social networks |
| Enhanced educational outcomes | |

**Figure 2.6:** Alleged benefits of social mix. Source: Kearns and Mason (2007)

al. (2009) find little support for mixed-tenure neighbourhoods as good for social well-being. A study by Bricocoli and Cucca (2016) argues that strategies to achieve mixed-income neighbourhoods foster exclusion from social housing. Similarly, Custers (2021) concludes that balanced neighbourhoods in Rotterdam do not positively relate to employment for the less well-educated. Finally, Musterd and Andersson (2005) indicate that the housing mix did not lead to a considerable social and ethnic mix, even after almost forty years of policy implementation in Sweden.

The success of social mix in the political discourse has also been attributed to the neoliberal strategy that aims to perpetuate capitalism in cities (van Eijk, 2010). By means of these policies, governments try to ensure that stigmatised groups do not congregate in one location with the objective of luring middle-class households and keeping lower-class households away (Uitermark et al., 2017). A mixed neighbourhood is therefore an “upgraded” neighbourhood where affluent people live (Versluis, 2017). The end objective is not a just city, but real estate development. This has led to the belief that the pursuit of social mix may be a waste of public funds and resources that diverts attention away from or even worsens structural inequalities (Colomb, 2011; van Gent et al., 2018).

### 2.3.2. FROM SOCIAL MIX TO SOCIAL COHESION

Departing from the **assumption that social mix fosters social cohesion**, urban policy-makers strive to create socially heterogeneous neighbourhoods (Méreiné-Berki et al., 2021). Social mix policies have been marketed as solutions to encourage class, racial, ethnic or religious cohesion to prevent increasing segregation (Tunstall & Lupton, 2010). However, several studies that focus on the relationship between social mix and social cohesion also gainsay the claims of the status quo.

Research with a qualitative approach, such as Curley (2009), shows that the social capital of women did not benefit from relocation to mixed-income Boston neighbourhoods. Similarly, Chaskin and Joseph (2011) indicate that mixed-income communities resulted in more division and isolation in Chicago. Furthermore, Bolt et al. (2010) conclude that mixed-tenure neighbourhoods do not meet the expectations of the policy on social cohesion.

There is a paucity of studies on the relationship between socially mixed neighbourhoods and social cohesion at a quantitative level. Notably, most of these studies challenge the positive relationship advocated by the status quo. For example, Abada et al. (2007) did not find significant effects on the social cohesion of youth living in ethnically balanced neighbourhoods in Canada. Furthermore, Coffé and Geys (2006) did not find a correlation between income-mix and social capital in Flemish neighbourhoods and even indicates that ethnic balance had a negative effect on social capital. Finally, Wang and Kemeny (2022) explored the impact of different balance indicators in China to obtain contrasting results, although they found that mixed tenure or educational backgrounds are associated with higher social cohesion, a mix in income or birthplace indicates the opposite.



The concept of **social capital** can help understand both contradicting stances. The first efforts to define social capital can be traced back to the work of Bourdieu (1986). However, it was Putnam (2000) who laid the ground for the contemporary policy approach of social capital (Forrest & Kearns, 2001). According to Putnam, 'social capital refers to connections among individuals—social networks and the norms of reciprocity and trustworthiness that arise from them.' (Putnam, 2000, p. 19). In his work, he conceptualised social capital as being composed of **bonding** social capital (inward looking, promoting homogeneity) and **bridging** social capital (outward looking, promoting heterogeneity). Later, Woolcock (2001) included a third component, **linking** social capital, which refers to the ties across the individual and an authority in society to gain access to valuable resources (Claridge, 2018).[1] The bonding, bridging, and linking properties of social capital can help understand the contradicting stances of the effects of social mix. First, the **contact hypothesis** argues that mixing communities can increase the bridging and linking of marginalised groups, such that ties between heterogeneous groups lead to overcoming social differences (Allport et al., 1954). In socially mixed areas, different groups meet and interact with each other, and eventually this reduces hostility toward out-groups. On the other hand, according to the **homophily principle** (Putnam, 2000), even though segregation of stigmatised communities can decrease the bridging and linking of marginalised groups with other communities, homogeneity can create bonding within the community (Méreiné-Berki et al., 2021). In this second view, people prefer to be surrounded by those who resemble them, thus social cohesion in mixed neighbour-

[1] Even if social capital and social cohesion appear similar at first glance, the examination of their definitions reveals a contrast between these concepts. One fundamental difference present in most definitions of social capital is that social capital is created by collective and individual actors in order to provide future returns that, like any other form of capital, are individually appropriated (Klein, 2013). This capital is generated by investing in social networks, norms, and trust. In this way, the accumulation of social capital refers to the accumulation of resources available to individuals which can yield, for instance, health returns from the help and support from others when being sick (CBS, 2015; Klein, 2013). While social capital is regarded as a voluntary bottom-up approach, social cohesion is on the other hand seen as an involuntary top-down product of the form and quality of shared values, trust, and the relationships among the individuals of a society (Forrest & Kearns, 2001; Klein, 2013). Social cohesion does not aim to accumulate; instead, it refers to the reduction of gaps between individuals within a community and between communities. Therefore, social cohesion is more than the sum of its parts, i.e. more than the sum of social capital and gap reduction (Hulse & Stone, 2007). The ambiguous interpretation and arbitrary application of the terms have consequently led to their overuse and vagueness in the policy arena (Forrest & Kearns, 2001). This can be seen, for example, in the interchangeable use by The World Bank of the terms social capital and social cohesion (Schiefer & van der Noll, 2017). The CBS (2015) Dutch social cohesion framework takes another approach and considers the dimensions of Participation and Trust as the building blocks of social capital which, together with Integration, compose social cohesion (see Figure 2.4).

hoods is affected by one's aversion to the alien (Wang & Kemeny, 2022). In other words, birds of a feather flock together.

Finally, an even smaller body of literature has studied the relationship between socially mixed neighbourhoods and informal support. A relevant example comes from the Rotterdam context in which Custers (2021) found that socio-economically mixed neighbourhoods do not foment bridging between social groups, and that even if there exist mixed social networks in a neighbourhood, these are not strong enough to understand the needs of others and share necessary resources in the event of need. As a result, more evidence is necessary to unravel the relationship between the policy and the observed effects.

### 2.3.3. Balanced housing

Governments have developed a variety of policies to increase the social mix of specific areas. Interventions through the housing mix are among the most widely employed to avoid the clustering and segregation of disadvantaged households because of their ability to diversify households that reside next to each other (Hananel et al., 2022). These mix policies have been labelled with multiple terms that have been used interchangeably like social mix, housing mix, balanced community, social balance or balanced neighbourhood (Manley et al., 2011; Ruiz-Tagle, 2019). We will refer to these mixing strategies as **balanced neighbourhood** policies, because that is the term in the political discourse of the municipality of Rotterdam (Municipality of Rotterdam, 2016b).

Western governments have explicitly adopted balanced housing policies as part of their agenda, including those in the Netherlands, the United Kingdom, the United States, Germany, France, Finland, and Sweden (Bolt et al., 2010; Chaskin & Joseph, 2011; Kearns & Mason, 2007; Manley et al., 2011; van Ham & Manley, 2012). Figure 2.7 shows the conceptual framework that current urban policy-makers explain for the link between balanced neighbourhood policies as the alleged means to achieve a complete community, social equity, diversity and social mix. A physical change in the housing structure mutates the composition of a neighbourhood and is presumed to foster social contact and interaction to achieve the alleged beneficial goals.

A wide range of balanced neighbourhood policies have been developed. A popular strategy is to promote heterogeneity in housing tenure, i.e. a mix between different types of housing such as private rental, public rental, or private ownership. Examples of such policies are social housing management and tenant-based housing allowances (Galster et al., 2015). The theory is that combining homeowners and social tenants in a neighbourhood will generate a more diversified social mix that reduces the negative neighbourhood effects (Musterd & Andersson, 2005).

In line with the previous strategy, some governments have also opted to apply tenant allocation reforms. By means of new legislation, households can be banned the choice to move to certain housing types or neighbourhoods (Galster et al., 2015). A good example of such policy is the Act on Extraordinary Measures for Urban Problems implemented in problematic neighbourhoods in the city of Rotterdam.

Another popular, but very contested, balanced neighbourhood policy is urban renewal. These strategies aim to deconcentrate stigmatised groups while attracting inhabitants with greater status and better incomes by selling, refurbishing, or demolishing

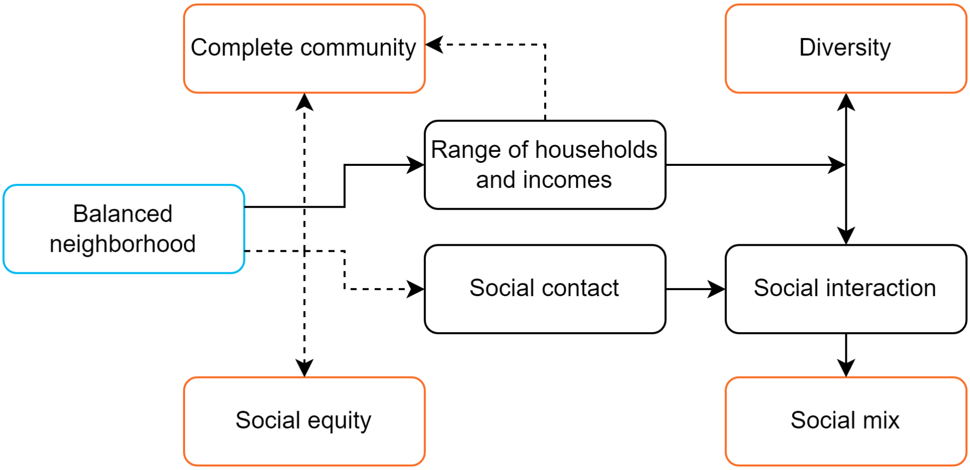



**Figure 2.7:** Conceptual model of balanced neighbourhood policies as the alleged means to the ends in the orange boxes. Solid lines represent direct evidence, whereas dashed lines circumstantial evidence. Adapted from: Perrin and Grant (2014)

public housing and installing more affluent houses (Doff, 2017; van Gent et al., 2018). In addition to the benefits mentioned above that balanced housing can provide through social mixing, proponents of these policies also argue that increasing the number of high-quality homes in a neighbourhood gives housing career prospects for the socially mobile, thus promoting intergenerational cohesion (Custers, 2021).

Studies that analyse the link between housing and social cohesion have come to both positive and negative relationships (Bolt et al., 2010; Kearns & Mason, 2007). As a consequence, most authors have concluded that balanced housing does not result in tangible benefits (P. Cheshire, 2009; Colomb, 2011; Galster et al., 2015; Klein, 2013). Moreover, some authors point out how these regulations might contribute to discriminatory housing market dynamics and emphasise the prevalence of discrimination in limiting minority groups' housing options. For example, Bolt et al. (2010) explains that in Sweden and Belgium minorities are denied to move in ethnically dense areas or that urban redevelopment plans in the Netherlands and the United States result in a loss of cheap housing, further limiting housing options.

## 2.4. Resilient Rotterdam

Following the Western trend, Rotterdam also jumped on the balanced neighbourhood bandwagon. Although the municipality today has a more balanced class structure than previously, recent evidence suggests that the city may become a victim of its own success. Rotterdam is on the verge of becoming inaccessible to both the middle and lower classes (Custers, 2021).

To understand the assumptions underlying the housing policies in Rotterdam as well as their development, this chapter starts by introducing the strategy of the municipality to improve the resilience of the city. This leads to the explanation of the programs that the municipality has implemented to transform the city to a balanced city, and their definition of a balanced neighbourhood is introduced. Finally, the section closes with a reflection of the controversy of their policies that motivate this study.



### 2.4.1. RESILIENCE STRATEGY

The complex geographical nature of the city, which is entirely situated below sea level, has historically called for policies that fight against the adverse effects of climate (Spaans & Waterhout, 2017). To address these growing challenges, the municipality has been actively involved in working toward a climate-proof city by developing and participating in local, regional, national, and international initiatives such as the Rotterdam Climate Initiative (2007), the Rotterdam Climate Change Adaptation Strategy (2013), or the C40 Cities Climate Leadership Group (2013) (Spaans & Waterhout, 2017). In 2014, the city joined Rockefeller Foundation's 100 Resilient Cities program (100RC) and the efforts of fighting against the force of nature culminated in 2016, when Rotterdam presented its Resilience Strategy as a member of the 100RC (Municipality of Rotterdam, 2016a).

Rotterdam already has a reputation for designing and engineering robust systems, but the municipality acknowledges that future risks might call for a different response (Municipality of Rotterdam, 2016a). As such, the Resilience Strategy has not only been motivated by the response to sudden shocks (e.g. earthquakes, fires, floods, or heat waves), but also to face systemic socio-economic tensions. To address the different vulnerabilities, the Resilience Strategy defined six focus areas that represent the main resilience challenges:

1. Social cohesion and education,
2. Energy transition,
3. Climate adaptation,
4. Cyber use and security,
5. Critical infrastructure,
6. Changing urban governance (Municipality of Rotterdam, 2016a, p. 23).

To address them, the Resilience Strategy has been divided into seven goals (Figure 2.8). With the purpose of monitoring the tensions in social cohesion and improving social resilience, the Goal 1 'Rotterdam: a balanced society' was set in scope. Municipality of Rotterdam (2019b) indicates that a balanced population demographic in Rotterdam strengthens resilience at the individual and the societal level. The expansion of the resilience view from climate change adaptation to include social urban issues intends to develop community involvement and awareness to build urban resilience (G. Huang, 2020; Spaans & Waterhout, 2017).

As part of the efforts to achieve Goal 1, in 2012 the municipality developed the National Programme Rotterdam South (NPRZ) (Municipality of Rotterdam, 2016a, p. 109), and in 2016 the Woonvisie (Housing Vision) of Rotterdam (Municipality of Rotterdam, 2016a, p. 65), which aim to create a balance in the groups of residents by demolishing and renewing cheap old housing to make way for higher-income groups. Later, in 2022, the municipality updated their Resilience Strategy and adopted a new policy, the

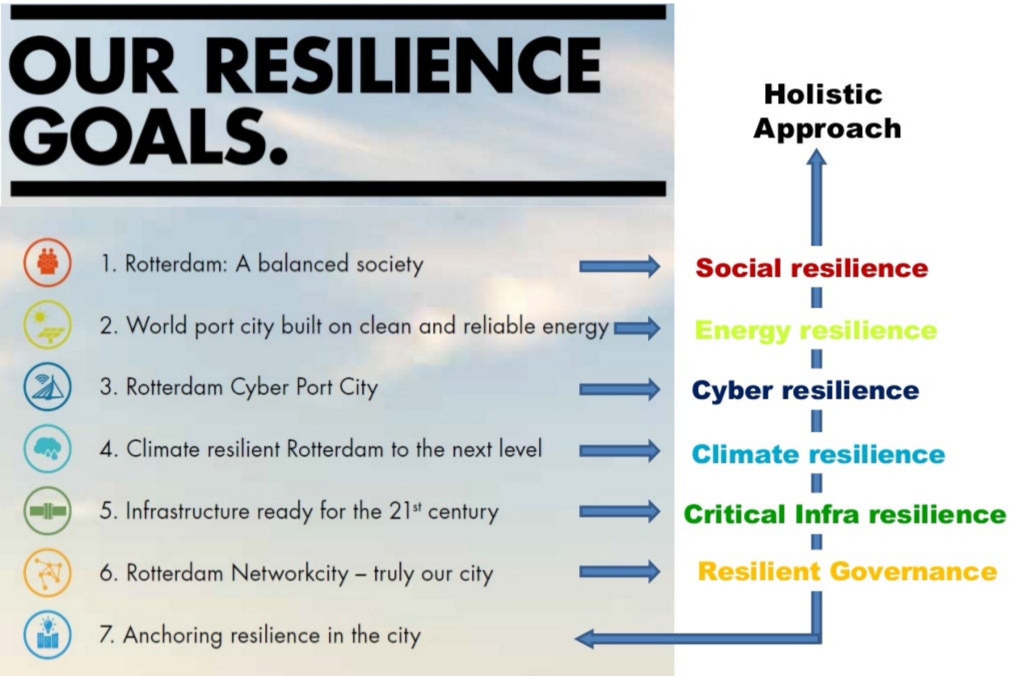



**Figure 2.8:** Rotterdam's Resilience Strategy goals. Source: Molenaar (2016)

Resilient BoTu programme, which is in line with the previous policies (Municipality of Rotterdam, 2022a, p. 25).

The policy mix of Rotterdam has not only been motivated the resilience view. The social balance of Rotterdam can be traced back to 2005 when the Rotterdam Act was approved. By means of a tenant allocation reform, the Rotterdam Act can exclude newcomers who have not lived in Rotterdam for the last six years and who rely on unemployment benefits or social assistance from moving to specific city neighbourhoods (Uitermark et al., 2017; van Eijk, 2010). The objective of the Rotterdam Act is to prevent the influx of disadvantaged households to improve the liveability of the targeted neighbourhoods. Still, in 2016, an amendment to the Rotterdam Act was approved that allows towns to exclude households accused of extremism, crime, or disturbance (Uitermark et al., 2017). The Rotterdam Act has been in force in the neighbourhoods of Carnisse, Hillesluis, Oud-Charlois, Tarwewijk, Bloemhof, and a number of streets in the Delfshaven area since 2006 and no other city in the Netherlands has adopted the policy.

During the development and implementation of the housing policies, some politicians referred to ethnic mixing, while others spoke of socially mixed areas. Whatever the label, the policies grounded on the assumption that a concentration of residents relying on unemployment benefits leads to a lower quality of life in the neighbourhood, so dispersing the concentration will increase the overall well-being (Uitermark et al., 2017). This discussion was tied to a larger, contentious debate on integration (Musterd & Andersson, 2005). However, the result was the clear preference of the municipality for higher socioeconomic groups over lower socioeconomic ones, usually associated to immigrants. Thus, the spark for controversy was ignited.



### 2.4.2. A BALANCED SOCIETY

This section elaborates on the housing policies within the Resilience Strategy that the municipality of Rotterdam has developed to achieve balanced neighbourhoods. Furthermore, it explains the definition that the municipality has adopted for the idea of balanced neighbourhood.

Beginning with the NPRZ, this initiative had started before the Resilience Strategy was put in place. Still, it was included as part of it. The aim of the NPRZ is to reach average national levels in education, participation in labour, and quality of life in Rotterdam South by 2030 (Municipality of Rotterdam, 2019b). Furthermore, the municipality explicitly states that the NPRZ is key for the strengthening of social resilience and social cohesion in Rotterdam South.

The programme focuses on the discourse on urban renewal in Rotterdam, and therefore has mainly looked at the housing and spatial aspects of this plan. They aim for a decrease of thousands of low-cost housing in exchange for more costly in the neighbourhoods of Feijenoord, Afrikaanderwijk, Hillesluis, Bloemhof, Tarwewijk, Carnisse, and Oud-Charlois in the South of Rotterdam (Municipality of Rotterdam, 2019a). This has attracted the attention of researchers, activists and international organisations such as the United Nations given the exclusion of low-income households from these neighbourhoods (UN-OHCHR, 2021).

Following with the Woonvisie, the end goal of the programme is to achieve a balance in the housing stock of Rotterdam neighbourhoods for 2030. A balance in the housing stock will result in a balanced society. Nonetheless, the initial document did not explicitly state what the municipality understands by a balanced neighbourhood. It was not until three years later that balance was defined in the Gebiedsatlas, an atlas which monitors the evolution of the housing programme in the city (Municipality of Rotterdam, 2020). Figure 2.9 shows the conditions that the housing stock needs to meet for the municipality of Rotterdam to consider the neighbourhood balanced (Municipality of Rotterdam, 2020, p. 14). Social, Middle, Higher, and Top are the names the municipality gives to the different housing price segments. This is measured by means of the WOZ-value (Valuation of Immovable Property Act value). The WOZ-value is the value of a property for tax purposes in the Netherlands. They are based on market values of the characteristics of the building, official valuations, and the selling price of nearby properties (Ministry of General Affairs, 2016). Table 2.1 shows the WOZ-values that define the housing segments in 2018. The addendum notes that the prices need to be adjusted per year according to the NHG (National Mortgage Guarantee) limit.

The definition in Figure 2.9 suggests that there is not a unique distribution of balance, but that it can be achieved in multiple ways. This is because the Woonvisie targets the whole city of Rotterdam, but has tailored strategies for the different areas of the city. The municipality states that the aim is not to have a homogenous structure, but that each neighbourhood can retain its own character and, within certain bandwidths, each neighbourhood's quality of life comes into its own (Municipality of Rotterdam, 2020). In turn, this complicates the understanding of balance and can result in ambiguous inter-

**>=45% Social and Middle,**
**=<60% Social, and**
**>=40% Middle, Higher, and Top.**

**Figure 2.9:** Balanced neighbourhood objective of the municipality of Rotterdam. The conditions indicate the percentage of houses that they aim to have in that price segment in each neighbourhood.

**Table 2.1:** WOZ-value housing segments in Rotterdam in 2018.

| | Social | Middle | Higher | Top |
|---|---|---|---|---|
| **WOZ-value 2018 (in thousand €)** | <220 | 220-265 | 265-400 | >400 |

pretations of the concept.

To achieve this goal, the municipality of Rotterdam plans to reduce the housing stock by 13,500 homes, of which 10,900 homes in the cheapest (Social) segment are planned to be demolished. At the same time, the municipality wants to increase the number of houses in the Middle, Higher, and Top price segments by 46,600 new housing units (Municipality of Rotterdam, 2019c). The programme aims to intervene on a city-wide and neighbourhood level where necessary and in a targeted manner. The guideline for new housing throughout the city — in the short and long term — is to build the following composition: 20% Social segment, 30% Middle segment, 30% Higher segment and 20% Top segment (Municipality of Rotterdam, 2019c). [2]

### 2.4.3. Controversy of balance

As a result of the housing policy-mix, the municipality of Rotterdam has seen a decrease in the social housing stock. Consequently, low-income individuals, mostly persons of immigrant heritage, are being pushed to leave the city (UN-OHCHR, 2021). The decision to reduce cheap housing stock is based on the assumption that the amount of cheap housing is greater than the amount of households that belong to the cheap (Social) price segment. To have a reference, Figure 2.10 shows how, in 2019, the amount of Social housing predominated in the city. Nevertheless, this assumption is debated and some even estimate that by the year 2030 there will be a shortage of nine thousand social homes in Rotterdam (Staalduine, 2019). In addition, the UN alerts that the housing policies do not take into account the impact that reallocating households has in social networks, as breaking social ties increases the vulnerability of low-income families (UN-OHCHR,

[2] In 2019, the Resilient BoTu 2028 programme was also launched. This initiative was not included in the first Resilience Strategy, but in the updated version of 2022. Resilient BoTu 2028 targets the neighbourhoods of Bespolder and Tussendijken to raise their Wijkprofiel Social Index score to that of Rotterdam's average within 10 years (Veld Academie, 2021). This programme encompasses a wider range of proposals than the Woonvisie, and is similar to the NPRZ in scope and magnitude. In the Resilient BoTu 2028 programme, the municipality is in line with the previously implemented housing policies. They aim to upgrade the current houses and to build new constructions to 'rebalance' the neighbourhood (Municipality of Rotterdam, 2019b, p. 20). So far, they have relied on the Woonvisie, nonetheless, the official document suggests that additional efforts should be put in place for the BoTu neighbourhoods. Even so, they do not provide specific details of these additional housing policies.

2021).

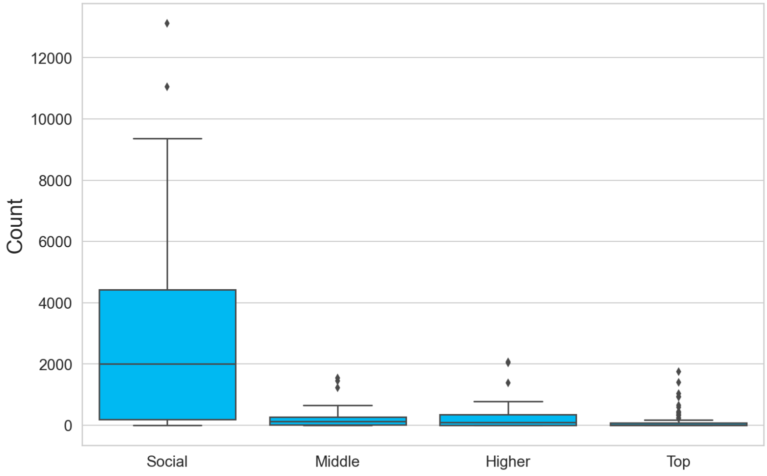



**Figure 2.10:** Boxplot of the number of houses that belong to the Social, Middle, Higher, and Top segment in each neighbourhood in Rotterdam in 2019.

Even though the municipality claims that advocating for more balanced neighbourhoods will have a positive effect in Rotterdam, some studies suggest that the storyline does not hold given the lack of demonstrable promised improvements (Hochstenbach et al., 2015). Supporting this claim, academics and social activists attribute these assumptions to a misleading use of indicators and statistics (Schinkel & van den Berg, 2011; Uitermark et al., 2017). For example, Lubberink et al. (2018) alerts that the WOZ-value on which the level of balance is based is not a valid and reliable market value indicator because it does not include enough housing characteristics. Furthermore, the idea of balance has been posited as a necessity on the basis of common sense, without regard for the problems that the co-living of different social groups may bring (Bricocoli & Cucca, 2016).

Finally, this sentiment of forced displacement has also reached the public. Detractors of the Woonvisie have mobilised under the movement Recht op de Stad (Right to the City) that rejects the city in balance and champion a city for everyone. In their efforts, they debate with politicians and councillors about a new better plan for housing policy and also created an electoral guide to inform voters in the elections of Rotterdam in March 2022 about the housing plans of each candidate. They also defend participatory policymaking by organising events at which they expose and ask about the current and future of Rotterdam's housing. Finally, in their efforts to come forward, they organised a public demonstration in October 17th, 2021 (Right to the City, 2022).

In sum, the urban policy mix of Rotterdam has become institutionalised over time, and become part of the policy tool kit. Therefore, it is vital to study whether the assumptions on which the municipality grounds the policies are valid.

## 2.5. HYPOTHESIS DEVELOPMENT

Following the discourse of the municipality of Rotterdam coupled with the results of the literature review, the chapter concludes that the theoretical conceptualisation foundation of this research can be illustrated in Figure 2.11. With this, the following hypotheses are formulated:

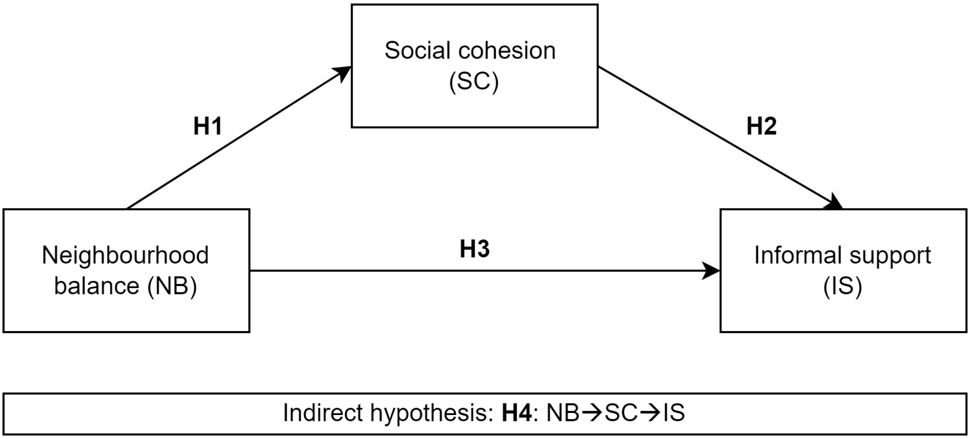



**Figure 2.11:** Illustration of the concepts and the relationships that are the analysis objective of this research. Social cohesion is supposed to mediate the relationship between having balanced neighbourhoods and more informal support in the city.

**H1: Social cohesion positively affects Informal support.** In cohesive societies, local communities protect residents against threats, care of others during hardships, and ultimately promote community resilience (Larimian et al., 2020; Municipality of Rotterdam, 2019b).

**H2: Neighbourhood balance positively affects Social cohesion.** In socially mixed areas, different groups meet and interact with each other, and eventually this reduces hostility toward out-groups (Allport et al., 1954). Balanced neighbourhoods mix the population composition in a neighbourhood to improve the social cohesion of its residents (Municipality of Rotterdam, 2016b, 2019b).

**H3: Neighbourhood balance positively affects Informal support.** Balanced neighbourhoods are considered a policy instrument that promote resilient actions by means of social mix (Allport et al., 1954; Municipality of Rotterdam, 2019b).

**H4: The relationship between Neighbourhood balance and Informal support is mediated by Social cohesion.** The previous hypotheses build the grounds for the mediation hypothesis between the concepts. Social cohesion acts as the mechanism for resilient actions triggered by the balance in a neighbourhood (Méreiné-Berki et al., 2021; Municipality of Rotterdam, 2016b, 2019b).

The study of these hypotheses is complemented in two ways. First, by taking into account the implications of spatial distribution. Social cohesion and informal support are not constrained by administrative boundaries, so the social perceptions and actions in nearby neighbourhoods affects the level of the other neighbourhoods (Forrest & Kearns, 2001; Sampson et al., 1997). This formulates the following hypotheses:
**H5a: Spatial spillover effects are significant on the relationship between Neighbourhood balance and Social cohesion.**
**H5b: Spatial spillover effects are significant on the relationship between Neighbourhood balance and Informal support.**

Second, the study of the relationships is complemented by considering the moderating effect of demographic and built environment elements identified in the literature review. Moderating effects overcome the supposition that the relationships between neighbourhood balance, social cohesion, and informal support are exactly the same for all neighbourhoods and identify instances in which the moderating variables change the strength or direction of the relationship between the concepts (Henseler, 2020). This formulates the following hypotheses:
**H6a: Ethnic heterogeneity moderates the relationship between Neighbourhood balance and Social cohesion.**
**H6b: Ethnic heterogeneity moderates the relationship between Neighbourhood balance and Informal support.**

**H7a: Residence length moderates the relationship between Neighbourhood balance and Social cohesion.**
**H7b: Residence length moderates the relationship between Neighbourhood balance and Informal support.**

**H8a: Population density moderates the relationship between Neighbourhood balance and Social cohesion.**
**H8b: Population density moderates the relationship between Neighbourhood balance and Informal support.**

**H9a: House type heterogeneity moderates the relationship between Neighbourhood balance and Social cohesion.**
**H9b: House type heterogeneity moderates the relationship between Neighbourhood balance and Informal support.**

**H10a: The amount of greenery moderates the relationship between Neighbourhood balance and Social cohesion.**
**H10b: The amount of greenery moderates the relationship between Neighbourhood balance and Informal support.**

**H11a: Walkability moderates the relationship between Neighbourhood balance and Social cohesion.**

**H11b: Walkability moderates the relationship between Neighbourhood balance and Informal support.**

**H12a: The number of amenities moderates the relationship between Neighbourhood balance and Social cohesion.**
**H12b: The number of amenities moderates the relationship between Neighbourhood balance and Informal support.**



## 2.6. CONCLUSION

This chapter reviewed previous literature to get a deeper understanding and extract the necessary concepts, to operationalise balanced neighbourhoods, social cohesion, resilient action, and the relationship between them. Concluding with the research hypotheses, this chapter answers SQ1: *What are the underlying mechanisms that drive balanced neighbourhoods to act more resiliently?*.

Literature suggests that social factors govern the resilience of urban areas. Communities in which the residents work together and have common goals have a stronger willingness to cooperate. Given that resilience is not directly measurable, we argue that informal support is a suitable proxy to measure the potential resilience of a neighbourhood, as the end mechanism through which social resilience is achieved is mutual aid.

Social cohesion is an involuntary product of the form and quality of shared values, trust, and the relationships among the individuals of a society. As a result, in cohesive societies, local communities protect residents against threats, care of others during hardships, and ultimately promote community resilience. The municipality of Rotterdam also maintains this claim, and regards social cohesion as a challenge to address to reach the goal of a resilient city. We then consider social cohesion as a multidimensional concept that is a geographically bounded property that characterises neighbourhoods.

Finally, balanced neighbourhoods are considered a policy instrument to achieve a more resilient city by means of social mix. Balanced neighbourhoods mix the population composition in a neighbourhood to allegedly improve the social cohesion of its residents. The effectiveness of this strategy has been very contested in literature, as empirical studies have mostly conflicting results. Furthermore, the exclusionary nature of such policies increase the controversy of their implementation. We have seen the strategies that the municipality of Rotterdam has taken so far to promote balanced neighbourhoods, and conclude that it is imperative to study whether the assumptions on which the municipality grounds the policies are legitimate.

# 3

# METHODOLOGY

This chapter has three main objectives. First, to identify the data that can transfer the conceptual model to a set of measurable indicators. Second, the chapter then introduces the measurement model which will be used for the study. Finally, it identifies and explains the research methods that can satisfy the main requirements for the analysis of the proposed model. Putting all together, a computational framework that will be applied to the case study is presented.

## 3.1. DATA

This thesis strongly depends on the availability of open data due to the public nature of the research. The operationalisation of individually measured characteristics, such as social cohesion or informal support, is best captured by the use of microdata. Microdata are administrative data on the individual level that are derived from various registers such as income, age, sex, or, very important for this study, spatial data. Such an infrastructure with detailed and extensive microdata is present in few countries, but the Netherlands is superb in the collection and accessibility to microdata (Custers, 2021). Due to the nature of the research at a *buurt* level (the neighbourhood level from here on), the aggregate data at this level will be used. Microdata provides the capabilities of identifying the neighbourhood to which the respondents belong. In addition, due to data privacy concerns, other data such as the WOZ-value is not available at a micro level, so we are forced to use aggregated data sets.

In this section, the data used in the research is presented together with its characteristics and sources. The **data from the year 2019 was selected** for the cross-sectional analysis, as it has the most recent survey data before the impact of COVID-19. We argue that the pandemic will have an impact on the social cohesion and willingness to help of residents, and therefore analyse the situation before it to avoid possible biases. First, the indicators for social cohesion and informal support are shown as collected by a survey conducted in Rotterdam. Second, the collection and aggregation of WOZ-values for the houses in each neighbourhood is explained. Then, the data collection and pre-

**Table 3.1:** Characteristics of the indicators for *Social cohesion* and *Informal support* in the Wijkprofiel in 2019. **N** indicates the number of neighbourhoods included in the Wijkprofiel. Source: OBI.

| Constructs and indicators | | N | Min/Max | Mean | s.d. |
|---|---|---|---|---|---|
| *Social cohesion* | | | | | |
| SC1 | % of residents who say that local residents know each other | 70 | 2/72 | 37 | 16 |
| SC2 | % of residents who say that local residents spend a lot of time with each other | 70 | 2/60 | 29 | 12 |
| SC3 | % of residents who say that local residents share each other's views | 70 | 16/64 | 32 | 11 |
| SC4 | % of residents who say that local residents help each other | 70 | 25/56 | 41 | 6 |
| SC5 | % of residents who say they feel at home with local residents | 70 | 28/81 | 55 | 11 |
| *Informal support* | | | | | |
| IS1 | % of residents who say they are willing to care for neighbors or friends who need help | 70 | 45/71 | 57 | 6 |



processing for the moderating factors are presented. Finally, the section explains how the data had to be adapted to the survey collection areas.

### 3.1.1. SOCIAL COHESION AND INFORMAL SUPPORT

The **Wijkprofiel** (Neighbourhood profile) provides the data to assess the operationalisation of social cohesion and informal support. The profile was developed by the Research and Business Intelligence (OBI) department in Rotterdam over two decades ago and serves as an instrument to monitor social development and inform local policies (Municipality of Rotterdam, 2022b).

The Wijkprofiel is based on registrations and survey data collected biannually to determine the scores for three domains: physical, safety, and social. A stratified sample approach is utilised since the Wijkprofiel seeks to be representative at a neighbourhood level. As a result, random sampling is done at the neighbourhood scale. The sample system is based on a municipal address list from which possible respondents are selected at random. The response rates vary between 20% and 25% per wave (Custers, 2021). Due to the nature of the research at a neighbourhood level, the **aggregate data** at this level will be used. Appendix B.1 provides information of the aggregation procedure used by the municipality of Rotterdam, as well as information of the survey questions.

To identify the set of indicators which fit the conceptual model, this study follows the Wijkprofiel survey design. The survey is composed of sets of indicators that correspond to established psychometric scales. To begin with, the Wijkprofiel uses the same indicators as the Dutch Office of Social and Cultural Planning for the conceptualisation of *Social cohesion* (Schnabel et al., 2008). This conceptualisation is based on synthesis theory and its indicators can be seen in the first panel of Table 3.1. These elements have previously been validated as the pieces that forge social cohesion.

Second, the survey also contains an independent section for care giving. The second panel of Table 3.1 shows the indicator from the Wijkprofiel to quantify the willingness of citizens to provide care to friends and neighbours who need help. We argue that this indicator is a good representation of informal support in Rotterdam and can act as a proxy for potential resilient actions. As we have seen in Chapter 2, the end mechanism through which social resilience is achieved is mutual aid, therefore, the willingness of citizens to help can capture the potential resilience of a neighbourhood (Doff, 2017). The indicator captures the willingness to help others in the strong (friends) and weak (neighbours) relationship ties.

**Table 3.2:** WOZ-value segments from 2018 and 2019. "Real" shows the value used by the municipality of Rotterdam. "Approximated" shows the segments that can be used from the OBI data. The values in bold for 2018 "Real" are the official values, the 2019 values have been adjusted following the % increase NHG limit, rounded to multiples of five thousand. Source: Municipality of Rotterdam (2019c)

| | | WOZ-value Social (in thousand €) | WOZ-value Middle (in thousand €) | WOZ-value Higher (in thousand €) | WOZ-value Top (in thousand €) |
|---|---|---|---|---|---|
| **2018** | **Real** | **<220** | **220-265** | **265-400** | **>400** |
| | **Approximated** | <225 | 225-275 | 275-400 | >400 |
| **2019** | **Real** | <240 | 240-290 | 290-440 | >440 |
| | **Approximated** | <250 | 250-300 | 300-450 | >450 |

**Table 3.3:** Characteristics of the WOZ-value segments used to measure the level of balance for the year 2019. **N** indicates the number of neighbourhoods included in the Wijkprofiel. Source: BAG.

| WOZ-value segments | N | Min/Max | Mean | s.d. |
|---|---|---|---|---|
| <250k (Social) | 70 | 80/13,113 | 3,498 | 2,639 |
| 250-300k (Middle) | 70 | 0/1,545 | 265 | 289 |
| 300-450k (Higher) | 70 | 0/2,066 | 306 | 395 |
| >450k (Top) | 70 | 0/1,757 | 175 | 336 |

### 3.1.2. BALANCED NEIGHBOURHOODS

To measure the level of balance of neighbourhoods, the **distribution of WOZ-values** per neighbourhood was used. The Addresses and Buildings Key Registry (BAG) is an automated system that stores information on local addresses and buildings. They collect the WOZ-values of every house in The Netherlands and make them available to governments, companies, institutions, and private citizens (Netherlands Enterprise Agency, 2022). In the case of Rotterdam, this data is stored by the OBI and made publicly accessible in their data portal (Research and Business Intelligence, 2022).

The Woonvisie addendum points out that the Social, Middle, Higher, and Top segments are **adjusted** following the percentage increase National Mortgage Guarantee (NHG) limit, rounded to multiples of five thousand (Municipality of Rotterdam, 2019c, p. 2). In the Netherlands, the mortgage is specified by the NHG to guarantee that the risk and the interest rate are lower for buyers. The limit for a mortgage backed by the NHG is adjusted every year based on the average price of a home in the Netherlands (ABN-AMRO, 2022). Adjusting the brackets in Table 2.1 to this limit allows defining the balance to the yearly market situation. In Municipality of Rotterdam (2019c, p. 10), the municipality only includes the value for the 2018 balance, so segments for the other years had to be manually adjusted. In addition, the WOZ-values data is presented in the data portal as the count of houses that fall within a set of predefined price brackets per neighbourhood. Therefore, to fit the definition of the brackets from the municipality of Rotterdam, the WOZ-values were aggregated to the **best approximation** as can be seen in Table 3.2. Finally, Table 3.3 shows the characteristics of the data used to measure the level of balance for the year 2019.

### 3.1.3. MODERATING FACTORS

To determine the moderating effect of exogenous factors, Table 3.4 shows the selection and the characteristics of items that the literature review has identified as relevant.

To begin with, *Ethnic heterogeneity* has been measured as one minus the Herfindahl-Hirschman Index (HHI), a very commonly used method to calculate the degree of ethnic diversity per neighbourhood (Chakraborty & McMillan, 2018).[1] This index was calculated using data collected by the Dutch Personal Records Database (BRP), which includes each share of nine ethnic groups per neighbourhood: Dutch, Turks, Moroccans, Surinamese, Cape Verdeans, Antilleans, other EU, other Western, and others. A value of 0 means all residents are from the same ethnicity. Values that approach 1 show that residents at that neighbourhood are from multiple ethnicities. Another factor modelled using one minus the HHI is *House type heterogeneity*. This calculates the degree of house type diversity per neighbourhood. This index was also calculated using data collected by the BAG, which includes each share of four house type groups per neighbourhood: single-family house, multi-family house with elevator, multi-family house without elevator, and other multi-family house.

The other demographic factor considered was *Residence length*. The data was provided by the Wijkprofiel survey conducted by the OBI and includes the percentage of citizens in a neighbourhood that have resided in that same neighbourhood for ten years or more.

The land use has been regarded as another relevant factor. First, *Population density* was obtained from the data collected by the BRP and is given in citizens per neighbourhood hectare. In the same context of land use, *Amenities* represents the total number of cafés, restaurants, community centres, bars, and pubs in each neighbourhood. Data was obtained from OpenStreetMap (OSM) using Overpass (OpenStreetMap contributors, 2017).

Finally, the built environment has also been considered in previous studies as a relevant factor (Mazumdar et al., 2018; Mouratidis & Poortinga, 2020). First, *Greenery* represents the percentage of green area in a neighbourhood which serves that specific function. For example, a green lane split, or a green riverbank do not count as green area, but as road infrastructure or water, respectively. This value was obtained from the 'Functional urban land use at ground level' data set from the OBI. Second, *Walkability* represents the percentage of walkable area in a neighbourhood which serves that specific function. This value was obtained from the same data set as *Greenery*.

### 3.1.4. NEIGHBOURHOOD SHAPE

Finally, the Wijkprofiel does not contain information on all neighbourhoods, plus it does not strictly follow the official neighbourhood division of Rotterdam. Consequently, the analysis, especially in the spatial context, has to be adapted accordingly.

[1] Consider $k$ groups with each having a share of the total composition, $\pi$, then the heterogeneity was calculated as:

$$\text{Heterogeneity} = 1 - \text{HHI} = 1 - \left(\sum_{i=1}^{k} \pi_i^2\right).$$

This value varies between 0 and 1. A value of 0 means no diversity at all in the neighbourhood. Values that approach 1 show a high degree of diversity.

**Table 3.4:** Characteristics of the exogenous factors.

| Exogenous factors | Description | N | Min/Max | Mean | s.d. |
|---|---|---|---|---|---|
| *Ethnic heterogeneity* | One minus the Herfindahl-Hirschman Index of the ethnic groups | 70 | 0.2/0.86 | 0.67 | 0.16 |
| *Residence length* | % of residents who have lived for a long time in the neighbourhood | 70 | 0.06/0.62 | 0.42 | 0.10 |
| *Population density* | Number of residents per hectare | 70 | 2.86/209.47 | 78.73 | 57.10 |
| *House type heterogeneity* | One minus the Herfindahl-Hirschman Index of the house type groups | 70 | 0/0.74 | 0.56 | 0.16 |
| *Greenery* | % of green space | 70 | 2.8/76.5 | 20.33 | 13.03 |
| *Walkability* | % of walkable infrastructure | 70 | 0.6/31.6 | 13.98 | 6.43 |
| *Amenities* | Number of amenities | 70 | 0/76 | 6.73 | 11.86 |

**Table 3.5:** Differences in the Wijkprofiel survey structure compared to the official CBS neighbourhood division. "Not included" column shows all those neighbourhoods that are not in the Wijkprofiel survey. "Combined" column shows the neighbourhoods that were combined into one same collection area for the Wijkprofiel survey. "Divided" shows the neighbourhoods that were split into two different survey data collection areas.



| Not included | Combined | Divided |
|---|---|---|
| Landzicht | Oud Mathenesse + Witte Dorp | Groot IJsselmonde |
| Spaanse Polder | Blijdorp + Blijdorpsepolder | |
| Nieuw Mathenesse | Kralingen Oost + Kralingse Bos | |
| Waalhaven | Zuiderpark + Zuidrand | |
| Eemhaven | Dorp + Rijnpoort | |
| Waalhaven Zuid | Noord Kethel + Schieveen + Zestienhoven | |
| Vondelingenplaat | | |
| Botlek | | |
| Europoort | | |
| Maasvlakte | | |
| Bedrijvenpark Noord West | | |
| Rivium | | |
| Bedrijventerrein Schieveen | | |
| Noordzeeweg | | |

Table 3.5 summarises the differences between the Wijkprofiel survey structure and the official CBS neighbourhood division. To begin with, a list of neighbourhoods was not included in the survey. Most of these neighbourhoods belong to the port area or to neighbourhoods with few residents. Second, the survey groups certain neighbourhoods into larger areas to reduce the reliability margin. Finally, in the survey, the neighbourhood of Groot Ijsselmonde was divided into North and South Groot Ijsselmonde due to its large size.

For this study, the Rotterdam shapefiles and the data associated to them had to be adapted to take into consideration these changes in the administrative boundaries for the survey. First, the neighbourhoods **not included** in the survey were also not included in the subsequent research. Second, the **combined** neighbourhoods in the survey had their shapefiles combined as well as the data values associated to them. In this aggregation process, values that do not belong to the Wijkprofiel survey were aggregated by means of a weighted average. For example, *Residence length* used as weights the number of citizens in each neighbourhood. Finally, the neighbourhood of Groot Ijsselmonde was **divided** into North and South. Given that the housing data is collected at the official administrative boundaries' division, the Wijkprofiel values for Groot Ijsselmonde North and South had to be aggregated by means of a weighted average using as weights the number of Wijkprofiel respondents in each of them.

## 3.2. MEASUREMENT MODEL

The combination of the available data and the theoretical foundations conceptualise the measurement model in Figure 3.1, which shows the indicators that make up the constructs and the relationships that this study aims to model and analyse. The constructs of the model are defined as follows[2]:

- ***Neighbourhood balance***: How far a neighbourhood is from achieving balance as defined by a target house WOZ-value distribution. It is modelled as a single-indicator emergent construct, i.e. using synthesis theory, as there is no systematic error associated to the measurement.
- ***Social cohesion***[3]: 'The extent to which people express in behaviour and perception their involvement in social connections in their personal lives, as citizens in society and as members of society.'(Schnabel et al., 2008, p. 13). It is modelled as an emergent construct, i.e. using synthesis theory, as it is not reducible to the several dimensions expressed in behaviour, perception, and involvement of individuals as members of a social entity.
- ***Informal support***: 'Help you give to your neighbours or friends, if that person is sick, dependent or disabled for a long time. It is not paid, a volunteer from a volunteer centre is not an informal caregiver, it is not about professional care, and it is not about the normal care of parents to their children.' (Municipality of Rotterdam, 2022b, p. 12)[4]. It is modelled as a latent construct, i.e. using measurement theory, as it is a unique behavioural aspect of individuals.

In Figure 3.1 the indicators that make up the measurement model of each construct are shown. Unlike the dichotomous definition of the municipality of Rotterdam (see Figure 2.9), we are interested in quantifying the possible outcomes that can result from the feasible ranges of the definition of balanced neighbourhood. Several techniques have been developed to measure diversity and segregation, but in the following section we argue why the **Kullback-Leibler (KL) divergence** is the most suitable measurement for *Neighbourhood balance* in this study (Kullback, 1987).

## 3.3. RESEARCH METHODS

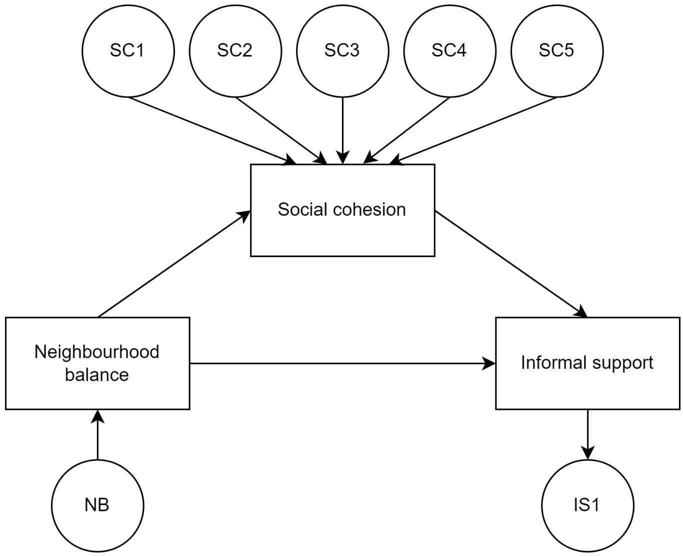
Having the measurement model, this section provides motivation for the chosen research methods and, finally, explains the necessary fundamentals for each of them.

Five major aspects were taken into consideration: (i) the constructs are composed of multiple indicators, so the method had to be able to aggregate them into one construct.

[2]From this point all constructs in the model will be in italics for disambiguation.

[3]This definition of *Social cohesion* is adopted given that it is an emergent construct, given the indicators with which it is modelled. This research also tried to model *Social cohesion* as a latent variable following the other definition of the Dutch government (CBS, 2015) by means of Exploratory Factor Analysis (EFA). The results indicate that no clear factors could be identified, so we conclude that from the data available, *Social cohesion* is best modelled formatively. Appendix B.2 shows the methodology and the obtained results.

[4]The presented model conceptualises *Informal support* as willingness to help friends or neighbours. Appendix C shows the results of adding indicators of the willingness to help relatives, and of the willingness to help others in the surroundings. The discussion section elaborates on the implications of the findings using the different indicators.




| **Constructs and indicators** | |
|---|---|
| *Neighbourhood balance* | |
| NB | Negative of the Kullback-Leibler divergence of the WOZ-value distribution in a neighbourhood with respect to the objective balance distribution |
| *Social cohesion* | |
| SC1 | % of residents who say that local residents know each other |
| SC2 | % of residents who say that local residents spend a lot of time with each other |
| SC3 | % of residents who say that local residents share each other's views |
| SC4 | % of residents who say that local residents help each other |
| SC5 | % of residents who say they feel at home with local residents |
| *Informal support* | |
| IS1 | % of residents who say they are willing to care for neighbours or friends who need help |

**Figure 3.1:** Structural and measurement model. Incoming arrows to a construct mean that is modelled formatively, so it is an emergent construct. When arrows point away from the construct, it means that it is modelled reflectively, so it is a latent construct.

Furthermore, *Social cohesion* is an emergent variable, while *Informal support* is a latent variable, which added another layer of complexity in the identification of a methodology that could estimate both constructs. Next, it is necessary to study three types of associations: (ii) direct effects between the constructs, (iii) the mediating effect of *Social cohesion* as a way to increase *Informal support* by means of *Neighbourhood balance*, and (iv) the moderating effect of exogenous factors on the strength of the relationships between the constructs. Consideration (v) and finally, the dependence of the results on the spatial distribution of the neighbourhoods in the city had to be taken into account.



To fulfil these requisites, **Partial Least Squares Structural Equation Modelling** is a modelling technique that enables us to simultaneously examine considerations (i), (ii), (iii), and (iv). On one hand, it allows estimating the measurement of emergent and latent constructs that arise from other observable indicators. On the other hand, it can estimate the direct, indirect and total effects between *Neighbourhood balance*, *Social cohesion*, and *Informal support* as well as the moderating effect of exogenous variables (Hair et al., 2016; Henseler, 2020; Lauro et al., 2018).

Finally, given that the theory of the model is based on the grounds that geographically connected people become affected by the balance in their neighbourhood to promote informal support, **spatial econometric** techniques will be used to address the spatial interaction and effects among observations in the model in consideration (v). Within the many available techniques, we will make use of **Local Indicators of Spatial Association** and the **Durbin spatial model** (Anselin, 1988, 1995). Using spatial econometrics techniques to consider spatial autocorrelation is a prime concern, as previous research by the municipality of Rotterdam has obviated it in their analyses (Uitermark et al., 2017).

Together, the combination of these methods provide a strong analysis framework. As a result, better assumptions regarding neighbourhood effects may be developed and subsequently evaluated in different neighbourhood contexts.

### 3.3.1. KULLBACK-LEIBLER DIVERGENCE

The measurement of inequality, segregation, and diversity is critical for the understanding of complex social phenomena. The measurements are relevant to policy-makers as they provide insights into how to plan urban areas. As a result, several measures have been developed. This section will start by exploring different indicators and explaining why the Kullback-Leibler (KL) divergence is the most suitable measurement for the balance of neighbourhoods in this study.

To begin with, the most popular measure of residential segregation is the Dissimilarity index (Duncan & Duncan, 1955). The index score indicates the proportion of one of two groups used in the calculation that would have to relocate to another subarea to match the distribution of the wider area. The success of this index lies in its simplicity; however, it is limited to the segregation of two groups. Another main drawback of the index is that it is not additively decomposable, so total segregation cannot be decomposed into segregation occurring within and between areas.

Another popular segregation measure is the Simpson Diversity index. It overcomes the limitation of the Dissimilarity index, as it is used to measure the degree of concentration when elements are classified into several types. The measure equals the probability that two entities taken at random from the dataset of interest represent the same type

(Simpson, 1949). The Simpson Diversity index has been widely used in several fields and has been coined with different names in the different fields: Herfindahl–Hirschman index in economics, Hunter–Gaston index in microbiology, or Housing Diversity Index in real estate (Chakraborty & McMillan, 2018). Nevertheless, as with the Dissimilarity index, it is not additively decomposable. Furthermore, in the research context, while the Simpson Diversity index (or the Housing Diversity index, to be more precise) serves to capture a mix of the existing housing stock, it does not allow capturing the mix relative to a target housing stock.

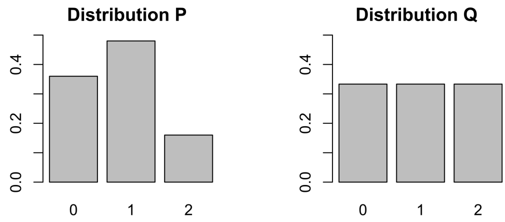
To address the issue of additive decomposition, a popular measure of inequality and segregation is the Theil index. It measures the probability of an outcome occurring weighted by its probability of occurrence. It is based on the concept of entropy, where entropy is a measure of randomness in a given set of information (Roberto, 2015). The World Bank has defined Theil's entropy as the 'best-known entropy measure ... to decompose inequality into the part that is due to inequality within areas (e.g. urban, rural) and the part that is due to differences between areas (e.g., the rural-urban income gap).' (Haughton & Khandker, 2009, p. 101). However, some inconveniences are present in the use of Theil's index. First, the entropy can only be calculated for discrete distributions, so the inequality of continuous distributions like income cannot be measured. Second, and of importance to this research, is the limitation that it measures the difference between a set of distributions and a summary statistic of those distributions, e.g., the mean. Therefore, it is limited to measure whether a neighbourhood is balanced according to the definition by the municipality of Rotterdam.

Theil also developed the Information Theory Index, which is another entropy-based measure. The index measures the extent to which the entropy of a subarea is below or above the entropy of the entire area. Even if the measurement has become the standard for segregation studies, the Information Theory Index measures relative homogeneity, and it is misleading to interpret it as a measure of diversity (Roberto, 2015). In addition, it has the same limitations as the Theil index.

The **Kullback-Leibler divergence** offers the opportunity to overcome the mentioned issue of the previous indices to develop a measurement of the level of balance of a neighbourhood. Unlike Theil's indices, which are entropy-based, the KL divergence is based on relative entropy, a measure of the difference between two probability distributions (Kullback, 1987). Formally, given an empirical probability distribution, $P$, and a theoretical reference probability distribution, $Q$, defined in the same probability space, $\mathscr{X}$, the KL divergence from $Q$ to $P$ is defined as

$$D_{\mathrm{KL}}(P \parallel Q) = \sum_{x \in \mathscr{X}} P(x) \log\left(\frac{P(x)}{Q(x)}\right) \tag{3.1}$$

Similar to the entropy measures, the KL divergence measures the amount of information lost when $Q$ is used to approximate $P$. Consequently, the minimum value is 0, indicating that there is no difference between P and Q, and the maximum value can be greater than 1. The logarithms in Equation (3.1) are taken to base $e$ and information is measured in nats (Roberto, 2015). One nat is the information content of an event when the probability of that event occurring is 1/e. This means that large values of the KL divergence suggest a larger deviation from the balance.




| $x$ | **Distribution** $P(x)$ | **Distribution** $Q(x)$ |
|---|---|---|
| 0 | 9/25 | 1/3 |
| 1 | 12/25 | 1/3 |
| 2 | 4/25 | 1/3 |

**Figure 3.2:** Example of the Kullback-Leibler divergence. Top: the graphical representation of the real data distribution, $P$, and the objective distribution, $Q$. Bottom: Values of the distributions. Source: Kullback (1959) as cited on Wikipedia.

Kullback gives an example in Kullback (1959). Let $P$ be the real data distribution and $Q$ the objective uniform distribution (see Figure 3.2). Then, the KL divergence from $Q$ to $P$ is calculated as:

$$
\begin{aligned}
D_{\mathrm{KL}}(P \parallel Q) &= \sum_{x \in \mathcal{X}} P(x) \ln\left(\frac{P(x)}{Q(x)}\right) \\
&= \frac{9}{25} \ln\left(\frac{9/25}{1/3}\right) + \frac{12}{25} \ln\left(\frac{12/25}{1/3}\right) + \frac{4}{25} \ln\left(\frac{4/25}{1/3}\right) \\
&\approx 0.0852996\,\text{nats}
\end{aligned}
$$

For interpretability, **we define the measurement of *Neighbourhood balance*, $NB$, as the negative KL divergence** between the WOZ-value distribution of a neighbourhood, $P$, and an assumed distribution of balance for that year (from Figure 2.9), $Q$,

$$NB = -D_{\mathrm{KL}}(P \parallel Q). \tag{3.2}$$

The more negative the $NB$, the less likely it is that the WOZ-value distribution of a neighbourhood is the assumed distribution, thus the further way to achieve balance.

As the conditions in Figure 2.9 show, there are multiple combinations of Social, Middle, Higher, and Top house brackets that are considered as balanced. By applying the KL divergence to the set of combinations, the technique allows us to explore the implications of the definition by the municipality of Rotterdam. If the different possibilities of balance are very dispersed, the KL divergence will capture the increase in divergence from one another.

### 3.3.2. K-MEANS CLUSTERING

The KL divergence allows us to find the level of *Neighbourhood balance* for any objective housing stock value distribution. To find relevant insights of the results that different distributions may yield, it is relevant that we select instances which are representative of the possible situations. To this end, clustering allows us to group the possible distributions that define balance into a number of representative sets.

Clustering is an unsupervised machine learning technique and there are several existing clustering algorithms. In this study, we will use the k-means clustering algorithm because it is simpler, faster and has fewer parameters to set than other algorithms like DBSCAN or Expectation–Maximization (Pedregosa et al., 2011). In k-means, an initial number, $k$, of clusters is specified, and then, the algorithm places $k$ centroids at random. Then, it calculates the euclidean distance from each point in the dataset to the centroids. With this, it assigns each data point to the closest centroid using the distance in the previous step. The new centroids are calculated by taking the averages of the distances in each cluster and the algorithm is rerun, until the centroids do not change or for a specified number of iterations (Pedregosa et al., 2011).

3

### 3.3.3. PARTIAL LEAST SQUARES STRUCTURAL EQUATION MODELLING

Structural equation modelling (SEM) has been labelled as one of the most useful advanced statistical analysis techniques for the social sciences in the recent decades (Hair et al., 2016). SEM is a multivariate technique enables the simultaneous examination of observed variables and constructs, as well as between constructs (Hair et al., 2016). Observed variables are those for which we have concrete values for the individual observations (we will refer to them as indicators). In contrast, the constructs do not have a concrete measure and have to be estimated from the indicators. In addition, SEM is capable of performing **mediation analysis**. As we concluded from the literature review, the mechanism studied in the present thesis is of *Social cohesion* mediating the relationship between *Neighbourhood balance* and *Informal support*. Mediation analysis explains how the change between an independent variable and a dependent variable occurs by means of the mediating variable (Henseler, 2020). Whereas the study of direct effects gives an answer on whether a change in an independent variable evokes a change in a dependent variable, mediation analysis tells how this change occurs.

The partial least squares approach to SEM (PLS-SEM) consists of an iterative algorithm that estimates the constructs measured by a set of indicators and the relationships between them, by means of an interdependent system of equations based on multiple and simple regression (Lauro et al., 2018). We can differentiate between the inner and the outer models. The **outer model** consists of the equations that make up the different constructs from their corresponding indicators, while the **inner model** captures the effects between the constructs themselves. Within the inner model, we can also distinguish between exogenous and endogenous variables. **Exogenous variables** are those that do not depend on any other variable within the inner model, whereas **endogenous variables** have at least one other construct causing them (Henseler, 2020).

The derivations and equations below are cited and summarized from Lauro et al. (2018). In the estimation of the constructs, two relevant types can be identified: latent variables and emergent variables. Latent variables are estimated by what is known as

Mode A (reflective). Consider $k$ constructs, $\xi_j$ with $j$ from 1 to $k$, which are latent variables of $q$ indicators, $x_{ij}$ with $i$ from 1 to $q$. Then, Mode A related the indicators to the latent variables by

$$x_{ij} = \lambda_{ij}\xi_j + \epsilon_{ij} \tag{3.3}$$

where $\lambda$ is the **loading** of the indicator on the latent variable (i.e. the bivariate correlation between the indicator and its construct) and $\epsilon$ is the error term associated to each indicator. On the other hand, emergent variables are estimated using what is known as Mode B (formative), which relates the indicators to the emergent constructs by

$$\xi_j = \sum_j \pi_{ij} x_{ij} + \delta_j \tag{3.4}$$

where $\pi$ is the **weight** of the indicator on the emergent variable (i.e. the regression between the indicators and the construct) and $\delta$ is the error term associated to each emergent variable. The distinction between Mode A and Mode B is the different mathematical specification between loadings and weights. While the latter takes into account the collinearity between indicators, the former ignores collinearity (Rigdon, 2012). Conceptually, calculating the correlation in Mode A is equivalent to identifying the common factor between the indicators while in Mode B, the regression corresponds to forging the construct by linearly combining the indicators.

Finally, the constructs are related to each other in the inner model. Here, $\eta$ plays the role of a construct when it is an endogenous variable and $\xi$ when it is an exogenous variable. This relationship is estimated by

$$\eta_j = \sum_{j'} \beta_{jj'}\eta_{j'} + \sum_h \gamma_{jh}\xi_h + \zeta_j. \tag{3.5}$$

where $\eta_j$ is an endogenous dependent construct (*Informal support* in our case), and $\eta'_j$ is an endogenous construct that is both a dependent and an independent variable (*Social cohesion* in our case). $\beta$ and $\gamma$ are known as the path coefficients. Path coefficients are the partial correlation coefficients, adjusted for other independent variables, that express the strength of the dependence relationships between constructs. $\zeta$ represents the error term (Lauro et al., 2018).

Besides Mode B, emergent variables can also be constructed by what is known as Mode BNNLS which uses an algorithm known as best fitting proper indices (BFPI) to estimate the constructs. In short, BFPI restricts the signs of the weights of each observable variable to guarantee that it contributes to its own construct in a predefined way. For more information on the underlying mechanism, see Dijkstra and Henseler (2011).

Covariance-based structural equation modelling (CB-SEM) is an alternative approach to SEM estimation. The difference between PLS and CB approaches will not be discussed here. For a more detailed overview of the mechanisms and the differences between PLS-SEM and CB-SEM readers are referred to Hair et al. (2016), Henseler (2020), and Lauro et al. (2018). The underlying mechanisms of both approaches lead to different motivations to use them. PLS-SEM is considered the best approach for this research, given that:

- the research objective is to understand implications of established theories;

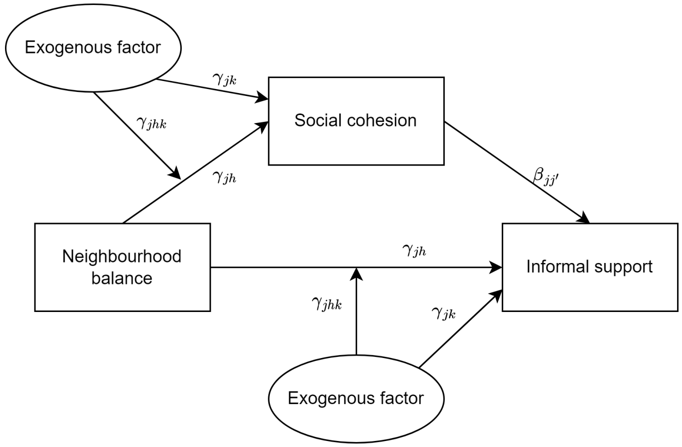



**Figure 3.3:** Exogenous factors as moderators of the effect of *Neighbourhood balance* on *Social cohesion* and on *Informal support.*

- the path model includes formatively measured constructs;
- the path model includes single-indicator constructs;
- the research is based on secondary data;
- the research requires construct scores for follow-up analyses (Hair et al., 2019).

In addition, PLS-SEM has several benefits compared to its counterpart CB-SEM:

- obtains the best prediction of the constructs;
- can estimate the model in the presence of multicollinearity;
- can estimate the model with fewer observations;
- does not require assumptions in the data distribution such as univariate or multivariate normality (Lauro et al., 2018).

The research objective combined with the benefits of PLS-SEM makes it the chosen research approach.

Along with the estimation of the constructs and the relationships between them, PLS-SEM can also estimate more complex relationships such as interaction effects. Interaction effects are brought by the so-called **moderators**. The study of interaction effects, **moderation analysis**, shows the dependency of the relationship between the constructs on the strength of the moderators, indicating instances in which the moderating variables change the strength or direction of the relationship between the constructs in the model (Henseler, 2020) (see Figure 3.3). Put simply and in words of Molin (2018), eating nuts is good; drinking beer is great; but drinking beer while eating nuts is even greater!

The interaction effect of exogenous moderators is of special interest, as they help improve the capability of the model to capture underlying mechanisms between the associations. Including exogenous moderators transforms Equation (3.5) into

$$\eta_j = \sum_{j'} \beta_{jj'}\eta_{j'} + \sum_h \gamma_{jh}\xi_h + \sum_k \gamma_{jk}\mu_k + \sum_h \sum_k \gamma_{jhk}\xi_h\mu_k + \zeta_j. \tag{3.6}$$

where $\gamma_{jk}$ is the simple effect of the exogenous moderator $\mu_k$, and $\gamma_{jhk}$ is the interaction path coefficient of the moderation of $\mu_k$ on the relationship between $\xi_h$ and $\eta_j$. The interpretation of the path coefficient of the model construct, $\gamma_{jh}$, also changes to a simple effect. In the interaction model, these effects now quantify the increase in the dependent variable if the independent variable is increased by one unit and the moderator is kept at zero (Henseler, 2020).



### 3.3.4. SPATIAL ECONOMETRICS

The interest in spatial models has been growing in recent years. The spatial dependence between phenomena in different areas is key to analyse models that consider multiple regions. Furthermore, the concern of understanding the role of heterogeneity across spatial locations motivates the need for spatially explicit techniques. To tackle this, spatial econometrics is a statistical approach developed to consider interaction and effects among observations in models with a known spatial structure (Ewing & Park, 2020).

Overman (2009) points out the main reasons to consider spatial effects. First, the assumption of non-spatial dependence invalidates the results of other statistical techniques. To unravel the true nature of relationships, spatial effects need to be considered. Modelling spatial effects improves the prediction of models, even when the underlying effect is not well understood. Second, space is a source of information. The interpretation of results is improved by exploring the spatial distribution and dependence.

When it comes to neighbourhood level policies, spatial effects may show up in a variety of ways. Effects are not restricted to act within the borders of administrative boundaries. Rather, the behaviour and characteristics of contiguous areas may be expected to spill over between neighbourhood boundaries. To analyse these effects, in this subsection, we first introduce Local Indicators of Spatial Association as a technique to identify sources of spatial autocorrelation by studying the clustering of neighbourhoods. Then, we describe spatial regression as a way to account for the effects that the spatial structure can have in the relationship between neighbourhood characteristics.

#### LOCAL INDICATORS OF SPATIAL ASSOCIATION

Exploratory spatial data analysis (ESDA) is the process by which data and research results are analysed taking into account their spatial structure to identify spatial outliers, and discover spatial patterns, clusters or hot spots (Dall'erba, 2009). Within this context, local measures of spatial autocorrelation focus on the relationships between each observation and the observations in their surroundings to obtain insight into the spatial structure of our data.

Local Indicators of Spatial Association (LISA) is part of the set of techniques that belong to the field of ESDA. LISA **classifies the observations** into four groups: high values surrounded by high values (HH), low values surrounded by low values (LL), high values surrounded by low values (HL), and vice-versa (LH). The key principle is to find events in which the value of an observation and the average of its neighbours are either more

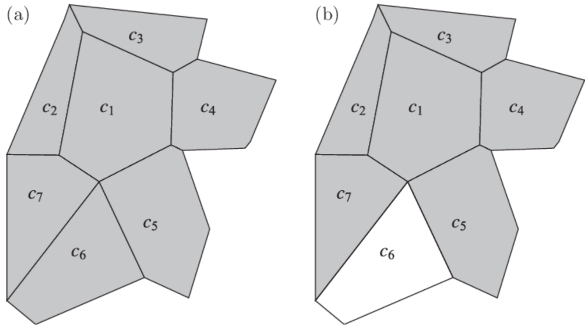



**Figure 3.4:** Example of polygon neighbourhoods. (a) Moore neighbourhood. Polygons are neighbours if they share at least an edge or a vertex. (b) Von Neumann neighbourhood. Polygons are neighbours only if they share at least an edge. Source: Baetens and De Baets (2012).

similar (HH, LL) or dissimilar (HL, LH) than we would expect from pure chance (Arribas-Bel, 2015). Based on the paper from Anselin (1995), consider a neighbourhood $i$ with an observation value $x$, then the Local Moran statistic, $I$, of that neighbourhood can be calculated as:

$$I_i = \frac{x_i}{m_2} \sum_j w_{ij} x_j \quad | \quad m_2 = \frac{\sum_i x_i^2}{N} \tag{3.7}$$

where $w_{ij}$ is the spatial weights matrix that represents the spatial structure of the data, and $N$ the total number of observations. Once the Local Moran, $I$, values have been determined, their p-values are estimated to test for local spatial clusters in the absence of global spatial autocorrelation. For that, we assume that the underlying distribution for generating the observations is normal. In other words, we test the hypothesis that no local spatial association is present. The significance is then combined with the location of each observation to classify the significant locations as spatial clusters of HH and LL, and spatial outliers of HL and LH. This classification is relative to the mean of the variable (Leung et al., 2003).

For simplicity, in this research $w_{ij}$ is equivalent to a binary matrix with ones in position $ij$ whenever observation $i$ is in the Moore neighbourhood of observation $j$, and zero otherwise (see Figure 3.4):

$$w_{ij} = \begin{cases} 1 & \text{if } j \text{ is a Moore neighbour of } i \\ 0 & \text{otherwise} \end{cases} \tag{3.8}$$

LISA is a useful technique that can easily show areas in which values are clustered and provide suggestive evidence about the processes that might be at work (Arribas-Bel, 2015).

### SPATIAL REGRESSION—DURBIN SPATIAL MODEL

Spatial regression models allow modelling variables in the presence of spatial autocorrelation. Spatial autoregressive models extend classical regression models by including spatial autocorrelation as a coefficient. Spatial regression models range from the simpler SLX model, which only includes the spatial lag of the covariates, all the way up to more complex models which account for temporal and spatially lagged dependent and independent variables and error terms (Ewing & Park, 2020).

In the present study, we used the **Durbin spatial model**. Considering a neighbourhood $i$ with a dependent variable $y$, then the Durbin model is defined as

$$y_i = \rho_i \sum_j w_{ij} y_j + \beta_i x_i + \gamma_i \sum_j w_{ij} x_j + \epsilon_i \tag{3.9}$$

where $w$ is the spatial weight matrix and $\epsilon$ is the normally distributed error term (Anselin, 1988). In the Durbin model, $\rho$ is the spatial autoregressive coefficient, $\beta$ is the general linear model coefficient, and $\gamma$ is the coefficient of spatially lagged covariates. The **spatial lag** of a variable is the weighted average of neighbouring values, defined by $w$.

Models that include spatial lag, like Durbin's, consider that autocorrelation arises from a diffusive process between locations. This process could be in the form of **spillovers**, where effects at one location influence neighbouring locations; or could indicate **contagion**, where effects at one location causally influence other locations (Ewing & Park, 2020; Rey et al., 2020). For instance, if social cohesion is high in a certain neighbourhood, this may spill over into near neighbourhoods, as social cohesion is not constrained by imaginary administrative boundaries. The Durbin model includes lagged dependent and independent variables to include the diffusive effect of both. For example, social cohesion in a neighbourhood might be affected by the level of balance of the surrounding neighbourhoods.

## 3.4. COMPUTATIONAL FRAMEWORK AND SOFTWARE IMPLEMENTATION

The gathered data and research methods come together in the computational framework (see Figure 3.5). It provides a clear, graphic way of how the data and methods are used to test the research hypotheses and respond to the research questions in this study. The framework is complemented with Table 3.6, which shows the used packages in the research flow to apply the selected methodologies.

First, data is collected and then pre-processed. For every possible distribution that the definition of balance from the municipality of Rotterdam can yield (see Figure 2.9), the *Neighbourhood balance* of each neighbourhood is calculated. Having this, all the possible measurements of *Neighbourhood balance* are fed into the PLS-SEM model. The instances where the model does not show appropriate fit are filtered out. In the next step, the models that fit were clustered using the k-means algorithm and the model that had the best fit in each cluster is selected to study the hypotheses. This ensures that we have a representative samples of the possible combinations of balance. We begin by analysing the mediation mechanism between *Neighbourhood balance*, *Social cohesion*, and *Informal support* to respond to the hypotheses **H1**, **H2**, **H3**, and **H4**. This is followed by a spatial exploratory analysis using LISA to then respond to **H5** and **H6** using the Durbin model. Finally, **H7** to **H12** are assessed in the moderation analysis using again

PLS-SEM.

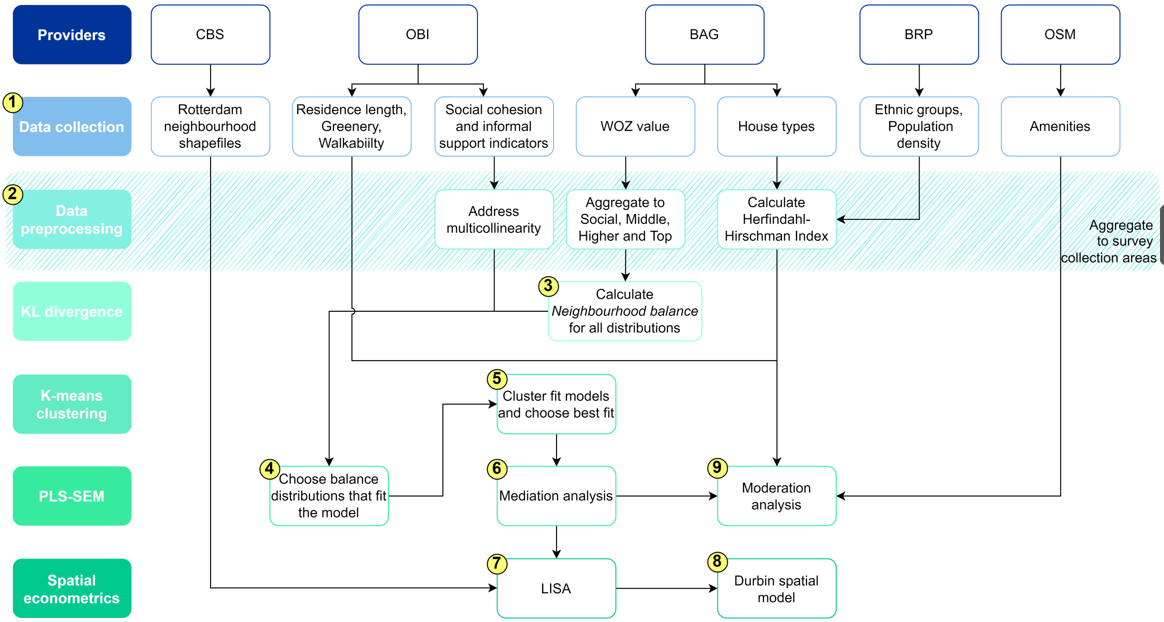



**Figure 3.5:** Computational framework. This diagram is meant to be read from top to bottom, each number indicates the step of analysis, and each arrow is the flow between an output and input. The “Providers” row shows the data owners of the data used in this research. “Data collection” shows the output data from each provider. “Data preprocessing” describes the specific data wrangling steps for each type of data. The whole row is highlighted because all the raw data had to be aggregated to the survey areas of the Wijkprofiel as explained in Section 3.1.4. The “KL divergence” row shows the use of that technique to measure *Neighbourhood balance*. The “K-means clustering” row shows the application of clustering to the models that fit. The “PLS-SEM” row presents the analysis done using the methodology of the same name. Finally, “Spatial econometrics” shows the techniques used for spatial analysis.

## 3.5. CONCLUSION

The aim of this section was to identify the data that could transfer the conceptual model to a set of measurable indicators, show the proposed research model, and to identify the research methods that can satisfy all the requirements for the analysis.

The measurement of the level of balance of a neighbourhood comes from the hand of a single-indicator, being *Neighbourhood balance*. This is obtained by calculating the Kullback-Leibler divergence between the WOZ-value distribution of a neighbourhood and the possible distributions that imply balance. Given the ambiguity due to the range of possible house stock distributions that can achieve balance, we are interested in quantifying the possible outcomes that can result from the feasible ranges of the definition of balanced neighbourhood. The KL divergence permits the identification and comparison of how far each neighbourhood is to achieve the defined balance for each combination. Furthermore, it is a versatile technique which is transferable between contexts as the target distribution can be adapted accordingly.

**Table 3.6:** Software implementation of the research methods.

| Research method | Language | Package name | Reference |
|---|---|---|---|
| KL Divergence | Python | SciPy | Virtanen et al. (2020) |
| K-means | Python | SciPy | Virtanen et al. (2020) |
| PLS-SEM | R | cSEM | Rademaker and Schuberth (2020) |
| LISA | Python | PySAL | Rey and Anselin (2007) |
| Durbin model | Python | PySAL | Rey and Anselin (2007) |



*Social cohesion* and *Informal support* can be operationalised using the data collected by the Wijkprofiel survey in Rotterdam. The survey is already structured into validated psychometric scales, which easily allow us to identify the relevant indicators to measure the constructs. Furthermore, the Wijkprofiel is a tool used by the municipality for the analysis and development of local policies, which strengthens the translation of the model to real application.

The chapter also describes the sources and the pre-processing of the following exogenous factors identified in the literature: *Ethnic heterogeneity*, *Residence length*, *Population density*, *House type heterogeneity*, *Greenery*, *Walkability*, and *Amenities*. These variables will be used in moderation analysis to overcome the supposition that the relationships are exactly the same for all neighbourhoods and identify instances in which the moderating variables change the strength or direction of the relationship between the concepts

To analyse the relationships, two main research methods are proposed. PLS-SEM allows estimating constructs made up from multiple indicators modelled either formatively or reflectively. In addition, it can estimate the direct effects, and mediating effects of the constructs as well as the moderating effects of the exogenous variables. As a second method, spatial econometrics provides insights on the dependence of the results on the spatial distribution of the neighbourhoods, and of the possible spillover or contagion effects by means of LISA and the Durbin model. Putting all together creates a computational framework which is the foundations of the analysis of this research.

# 4

# RESULTS

This chapter presents the results of the case study analysis. The developed computational framework is applied to the city of Rotterdam to understand the relationship between the level of balance of neighbourhoods, their social cohesion, and their informal support.[1,2]

The chapter starts with an analysis of the definition of balance from the municipality of Rotterdam. Then, the house WOZ-value balance distributions that best fit the model are selected for further analysis. The following section presents the results of the PLS-SEM mediation analysis and shows the relationships between the model constructs in the year 2019. The results of spatial econometrics are then showed to quantify the relevance of spatial effects in the role between the model constructs. Finally, the outcomes of the external factors moderation analysis are exhibited.

## 4.1. BALANCE OF ROTTERDAM

The first step of the research process was to analyse the level of balance of Rotterdam's neighbourhoods. The definition provided by the municipality of Rotterdam (see Figure 2.9), is formulated in such a way that balance is a dichotomous variable. If the neighbourhood complies with the conditions it is in balance, otherwise it is not. These conditions can be translated to the following set of inequalities:

[1] There was an attempt to operationalise *Social cohesion* by means of measurement theory using Exploratory Factor Analysis. The results indicate that no clear factors could be identified, so we conclude that from the data available, *Social cohesion* is best modelled formatively. Appendix B.2 shows the methodology and the obtained results.

[2] The presented model conceptualised *Informal support* as willingness to help friends or neighbours. Appendix C shows the results of adding indicators of the willingness to help relatives, and of the willingness to help others in the surroundings. We saw that the willingness to help others does not correlate with the willingness to help relatives, friends, and neighbours, so a common factor could not be found. In addition, informal support as willingness to help others does not show an acceptable model fit. Finally, a common factor was found between willingness to help relatives and willingness to help friends and neighbours, which yielded an acceptable model fit. Appendix C and the discussion chapter provide further details on these results.

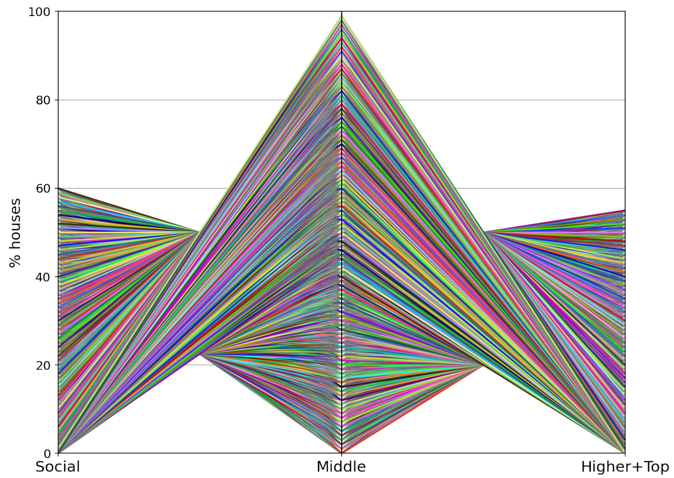



**Figure 4.1:** Full solution space for the definition of balance according to the municipality of Rotterdam. Only integer solutions are shown.

$$\begin{cases} 0\% \leq \text{Social} \leq 60\% \\ 45\% \leq \text{Social} + \text{Middle} \leq 100\% \\ 40\% \leq \text{Middle} + \text{Higher} + \text{Top} \leq 100\% \\ 0\% \leq \text{Middle} \leq 100\% \\ 0\% \leq \text{Higher} \leq 100\% \\ 0\% \leq \text{Top} \leq 100\% \\ \text{Social} + \text{Middle} + \text{Higher} + \text{Top} = 100\% \end{cases}.$$

Figure 4.1 shows the full solution space that satisfies the inequalities established by the conditions of the municipality to have balance. Any combination within that space that adds up to 100% is an acceptable solution, and thus the municipality will argue that the neighbourhood is in balance. We can see that even though the municipality distinguishes Higher and Top as two different brackets, they do not specify a difference in their definition of balance, thus they can be combined.

Given that the definition of balance from the municipality is not a unique distribution, but a whole solution space, it is of interest to analyse (i) the dispersion of the definition, and (ii) the effect that this might have in the analysis of the relationship between a balanced neighbourhood and its social cohesion and informal support.

As explained in Section 3.3, the KL divergence is a suitable technique to operationalise the measurement of the level of balance of a neighbourhood, i.e. the *Neighbourhood balance*. For that, we need an objective distribution from which to measure the distance of the actual WOZ-value distribution in the neighbourhood. Therefore, as a next step in the exploration of the definition from the municipality, *Neighbourhood balance* was calculated for every neighbourhood for all the possible integer configurations that add up to 100%.

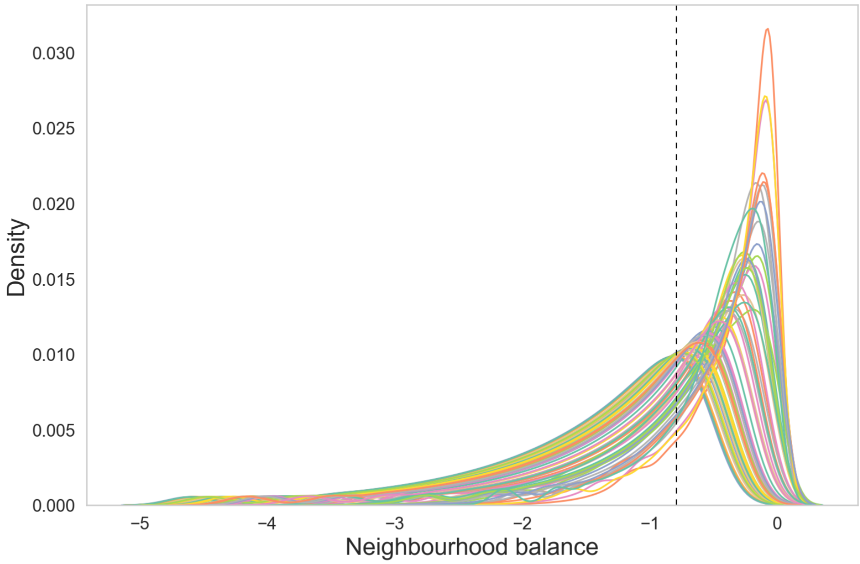



**Figure 4.2:** Each line shows the density estimation plot for each of the neighbourhoods in the Wijkprofiel of the measurement of *Neighbourhood balance* for every possible combination of Social, Middle, and Higher+Top that satisfy balance according to the municipality of Rotterdam. Density plots are a smoothed version of the histogram and are used to study the distribution of data (the smoothening shows possible values above zero, even though we have seen that the measurement of *Neighbourhood balance* does not allow that, but density estimation is better for visual comparison of the multiple neighbourhoods). The vertical dotted line shows the average median value of -0.79 nats.

Starting with (i) the dispersion, each line in Figure 4.2 shows the density plot of the measurement of *Neighbourhood balance* for each neighbourhood for every possible integer distribution that satisfies the conditions for balance in Figure 2.9. We can see how the *Neighbourhood balance* calculated from the KL divergence is distributed for each neighbourhood for all the integer configurations in the solution space exhibited in Figure 4.1. Given that the data is skewed, we use the range, interquartile range and outliers to interpret the dispersion, as the standard deviation and mean are sensitive to outliers (Manikandan, 2011).[3] The figure shows the large range of the measurement of *Neighbourhood balance*, with an average range of -3.63 nats. The neighbourhood with the largest range is Beverwaard, for which the minimum measurement of *Neighbourhood balance* is -0.51 nats, and the largest -4.61 nats. The average interquartile range is -0.86 nats, which indicates that 50% of the data is distributed within 23% of the average total range. Having the interquartile range, we found that the average percentage of outliers per neighbourhood is 5%. Making an analogy with a perfectly normal distribution which has 0.3% of outliers (Ruan, 2005), our results suggest that the definition of balance from the municipality has a considerable variability and is susceptible to outliers.

[3] The range is the difference between the highest and the lowest values in a distribution (Manikandan, 2011). The interquartile range measures the spread 50% of the data. Outliers are defined as values which are 1.5 interquartile ranges above and below the 25% and 75% quartiles.

4

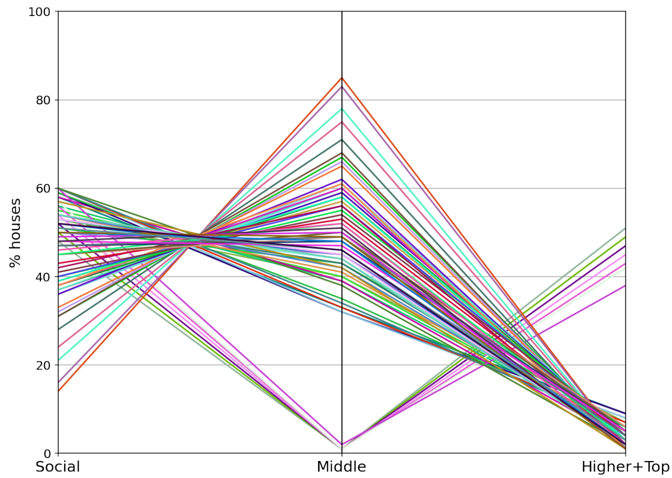



**Figure 4.3:** House stock distributions within the balance definition of Rotterdam that have an acceptable goodness-of-fit (≈ 2.1%) in the PLS-SEM model.

4

Continuing with (ii), to obtain further insights about the implications of the possible distributions of balance, the PLS-SEM model presented in Figure 3.1 was evaluated for all the *Neighbourhood balance* measures for each of the possible integer configurations that add up to 100% in Figure 4.1. Only the models which reported an acceptable standardised root mean squared residual (SRMR) measure were considered. The SRMR is a goodness-of-fit measure that quantifies how strongly the empirical correlation matrix differs from the model-implied correlation matrix (Henseler, 2020). A value of 0 for the SRMR would indicate a perfect fit and the generally accepted threshold is of 0.08 established by Hu and Bentler (1999). Therefore, models with an SRMR below this threshold and which meet the 95% confidence interval (CI) quantile criteria for the estimated models were considered. Out of 3,162 models — the total number of possible integer configurations for the distribution of balance—, only 66 (≈ 2.1%) met these criteria (see Figure 4.3)

From Figure 4.3, we can infer that the models that fitted are separated into different groups with similar attributes. To unravel the structure of these groups, the results were clustered using the k-means algorithm. To begin, k-means requires the specification of the number of clusters. The elbow method is a common way of choosing the optimal number of clusters. The method assumes that the optimal number of clusters is that for which adding another cluster doesn't give much better representation of the data (Pedregosa et al., 2011). First, we calculate the sum-squared error (SSE) of the k-means algorithm for an arbitrary range of 1 to 10 clusters. Then, the number of clusters that minimises the SEE without overfitting is the recommended number of clusters. This corresponds to the elbow of the plot, as can be seen in Figure 4.4. In this case, the elbow method recommended 3 different clusters (Figure 4.5).

Figure 4.6 shows the values of the significant path coefficients (95% CI) for each model within each cluster. While the relationship between *Social cohesion* and *Infor-*

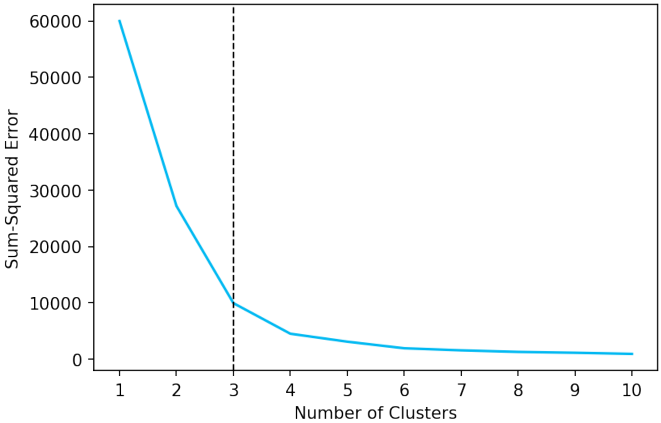



**Figure 4.4:** Elbow method for the optimal number of clusters. The vertical dotted line indicates the position of the elbow at 3 clusters.

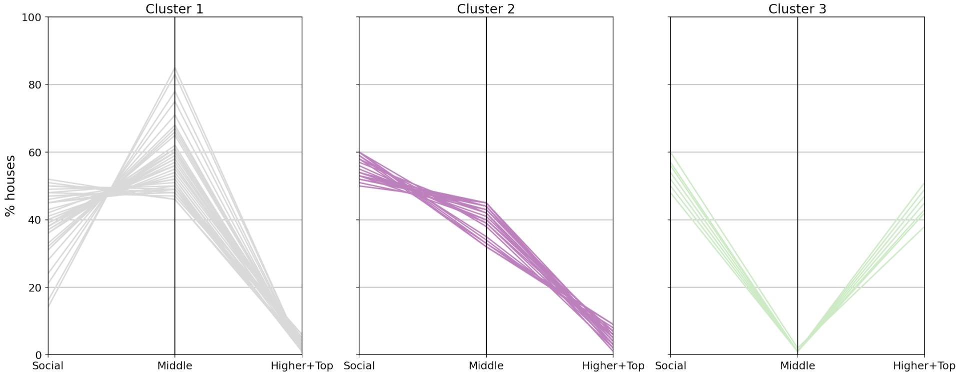



**Figure 4.5:** Clusters of the house stock distributions that meet the definition of balance from the municipality and that have an acceptable goodness-of-fit. Clusters 1, and 2 exhibit concave shapes, while Cluster 3 has a convex shape.

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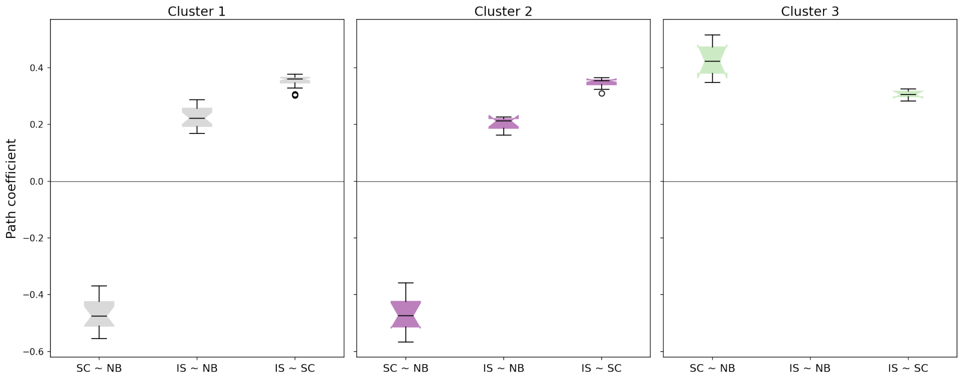





**Figure 4.6:** Boxplot of the path coefficients for each cluster. SC~NB: path coefficient of the relationship between *Neighbourhood balance* and *Social cohesion*. IS~NB: Path coefficient of the relationship between *Neighbourhood balance* and *Informal support*. IS~SC: Path coefficient of the relationship between *Social cohesion* and *Neighbourhood balance*. Only the path coefficients significant to the 95% CI are shown.

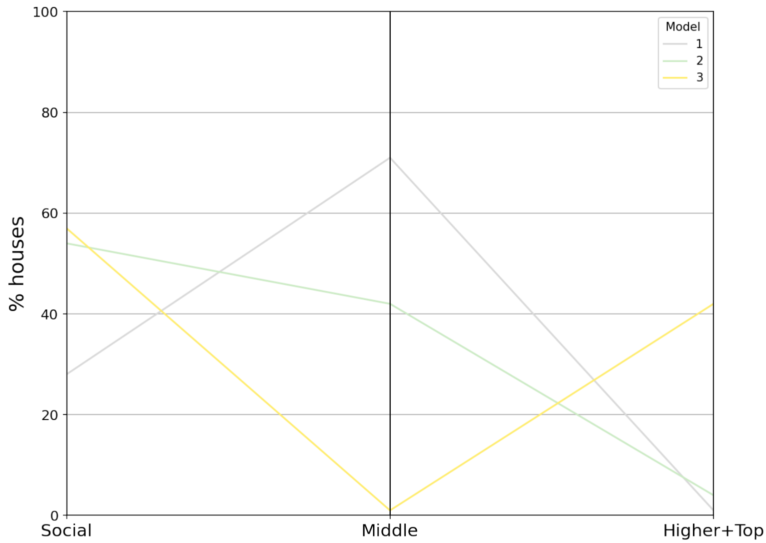
*mal support* is similar throughout all clusters, we can see that the relationship between *Neighbourhood balance* and *Social cohesion*, and the relationship between *Neighbourhood balance* and *Informal support* change direction in Cluster 3 compared to the others. In addition, Cluster 3 does not have any fit model with a significant relationship between *Neighbourhood balance* and *Informal support*. To provide further insights about the relationships and the effect of the different distributions in the model, we selected the model from each cluster that had the best goodness-of-fit, i.e. the lowest SRMR value (Figure 4.7).

## 4.2. PLS-SEM MODEL RESULTS

Before presenting the outcomes of the selected models, we first show the values for the model fit tests. After goodness-of-fit is guaranteed, the measurement models are evaluated to determine which items better form the model constructs. We begin with the assessment of the reflective measurement models, i.e. *Informal support*, and we follow with the assessment of the formative measurement models, i.e. *Social cohesion* and *Neighbourhood balance*. Finally, the reliability and validity of the inner structural model is assessed and the relationships between the constructs are presented.

### 4.2.1. MODEL GOODNESS-OF-FIT

We start by reporting the estimated model misfit using non-parametric model fit tests (i.e. dG, dM, and dML) and a model fit index (i.e. SRMR) (Table 4.1). The different non-parametric tests calculate the difference between the empirical and the model-implied indicator variance-covariance matrix using different distance measures (Rademaker & Schuberth, 2020). The lower the value of the distance, the better the model fit. On the other hand, the standardised root mean squared residual (SRMR) quantifies how strongly the empirical correlation matrix differs from the model-implied correlation matrix (Henseler, 2020). A value of 0 for the SRMR would indicate a perfect fit. As seen




| | Social (%) | Middle (%) | Higher+Top (%) |
|---|---|---|---|
| **Model 1** | 28 | 71 | 1 |
| **Model 2** | 54 | 42 | 4 |
| **Model 3** | 57 | 1 | 42 |

**Figure 4.7:** Housing stock distributions of the models with best goodness-of-fit for each identified cluster.

**Table 4.1:** Goodness-of-fit of the estimated models.

| | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | **Value** | **95% CI** | **Value** | **95% CI** | **Value** | **95% CI** |
| dG | 0.044 | 0.057 | 0.040 | 0.056 | 0.050 | 0.055 |
| SRMR | 0.042 | 0.067 | 0.043 | 0.069 | 0.050 | 0.060 |
| dL | 0.049 | 0.125 | 0.053 | 0.132 | 0.069 | 0.102 |
| dML | 0.218 | 0.278 | 0.202 | 0.272 | 0.247 | 0.267 |



earlier, the selected models scored below the generally accepted threshold of 0.08 established by Hu and Bentler (1999), which indicates an acceptable fit. Furthermore, they meet the 95% confidence interval (CI) quantile criteria for all the goodness-of-fit measures.

### 4.2.2. REFLECTIVE MEASUREMENT MODEL

Examining the internal consistency reliability is the first step in evaluating a reflective measurement model. For that, Dijkstra-Henseler's rho, $\rho_A$, should lie between 0.70 and 0.95 to guarantee a good level of internal consistency that avoids indicator redundancy (Dijkstra & Henseler, 2015). Given that only one indicator was used, the value of $\rho_A$ equals one, which suggests that it is not possible to determine the amount of random measurement error in the indicator based on the available data (Henseler, 2020). Literature recommends that, in these cases, an additional error is imposed from the modeller (Brown, 2015), however, the package cSEM does not have that feature yet. Therefore, we acknowledge this limitation in the measurement of *Informal support*.

The following step of the reflective measurement model assessment addresses the convergent validity of each construct. Convergent validity is the extent to which the construct converges to explain the variance of its items (Henseler, 2020). To this end, the average variance extracted (AVE) for all items on each construct is used. The AVE, is the mean-squared loading of each indicator. The AVE of *Informal support* equals 1, which indicates that the construct explains 100% of the variance of its item (Henseler, 2020).

The third step is the assessment of indicator loadings. Although loading values of 0.7 or higher are regarded as highly satisfactory, value loadings of 0.5 or higher are considered acceptable (Chin, 1998; Hair, 2009). As *IS1* explains the whole variance of the extracted latent variable *Informal support*, it has a loading equal to 1.

A final step in the assessment of the reflective constructs is discriminant validity. This determines to what extent a construct is empirically distinct from other constructs in the model. Since we only have one concept modelled as a latent variable from common factors, discriminant validity does not need to be assessed.

### 4.2.3. FORMATIVE MEASUREMENT MODEL

Assessing the convergent validity is the first step in the evaluation of a formative measurement model. The model goodness-of-fit with an SRMR below 0.08 within the 95% CI (see Table 4.1) indicates the confirmatory power of our emergent construct and is

**Table 4.2:** Formative construct assessment.

| | Item | Models 1, and 2 | | Model 3 | |
|---|---|---|---|---|---|
| | | Weight | 95% CI | Weight | 95% CI |
| Social Cohesion | SC1: % of residents who say that local residents know each other | NA[a] | NA[a] | NA[a] | NA[a] |
| | SC2: % of residents who say that local residents spend a lot of time with each other | NA[b] | NA[b] | NA[b] | NA[b] |
| | SC3: % of residents who say that local residents share each other's views | 1.00 | [1.00, 1.00] | NA[b] | NA[b] |
| | SC4: % of residents who say that local residents help each other | NA[b] | NA[b] | NA[b] | NA[b] |
| | SC5: % of residents who say they feel at home with local residents | NA[b] | NA[b] | 1.00 | [1.00, 1.00] |
| Neighbourhood Balance | NB: Negative of the Kullback-Leibler divergence of the WOZ-value distribution in a neighbourhood with respect to the objective balance distribution | 1.00 | [1.00, 1.00] | 1.00 | [1.00, 1.00] |

*a*: Item dropped due to high multicollinearity
*b*: Item dropped due to insignificant weight.

suggestive of its reliability and validity (Henseler, 2020).

Next, the statistical significance and size of the indicators weights were assessed. *Neighbourhood balance* is a single-indicator construct, which is to say that its value is inferred from only one observed variable. This means that the item is a perfect ingredient of the emergent variable. On the other hand, *Social cohesion* is a multiple indicator formative construct. When estimating the weights using Mode B as described in Section 3.3.3, the results showed negative signs for the weights corresponding to *SC1* and *SC3*. Negative weights can be indicative of a negative contribution of the items to the construct. However, according to the qualitative theory expectations, all the items should contribute positively to *Social cohesion*. This suggests that negative weights are caused by multicollinearity between the items (Diamantopoulos & Winklhofer, 2001). The variance inflation factor (VIF) is often used to evaluate multicollinearity. VIF values of 5 or above indicate critical multicollinearity issues among the indicators of formatively measured constructs. Ideally, the VIF values should be close to 3 and lower. The VIF showed that the items of *Social cohesion* were above 5. Mode BNNLS is recommended in these situations, as explained in Section 3.3.3.

When applying Mode BNNLS to Models 1, and 2, PLS-SEM reduced *Social cohesion* to the *% of residents who say that local residents share each other's views* (*SC3*). On the other hand, when applied to Model 3, *Social cohesion* was reduced to the *% of residents who say they feel at home with local residents* (*SC5*) (see Table 4.2).

### 4.2.4. Structural model

After guaranteeing that the measurement model is satisfactory, the structural model results were assessed. First, the Models showed acceptable explanatory power, but low predictive accuracy (details can be found in Appendix D.1). Given that the research approach is deductive and not predictive, this outcome is not considered inadequate as we are mainly concerned about the goodness-of-fit and the values of the path coefficients (Henseler, 2020).

The final step is to assess the statistical significance and relevance of the path coefficients. Table 4.3 presents the total, direct, and indirect effects of the path analysis ($\beta$). In mediation analysis, the direct path coefficient represents the effect of exposure on the outcome in the absence of the mediator. On the other hand, the indirect path coefficient shows the effect that acts through the mediator. The total effect is the sum of direct and indirect path coefficients. Another consideration to take into account is that the path coefficients are standardized. This means that, for example, in Model 1 with a path coefficient between *Neighbourhood balance* and *Social cohesion* of -0.467, a 10% increase in the *Neighbourhood balance* would report a decrease of 0.0467 standard deviations in the *Social cohesion* of the target neighbourhood.

The results of the effects can be summarised as follows. First, in Models 1, and 2, *Neighbourhood balance* has a significant negative association with *Social cohesion* (**H2** Neighbourhood balance positively affects Social cohesion: Not supported). Second, we see a positive association between *Social cohesion* and *Informal support* (**H1** Social cohesion positively affects Informal support: Supported). Finally, the direct relationship between *Neighbourhood balance* and *Informal support* is non-significant (**H3**: Neighbourhood balance positively affects Informal support: Not supported), so we can talk about full mediation (Henseler, 2020), the effects of balance on willingness to help are due to social cohesion. (**H4**: The relationship between Neighbourhood balance and Informal support is mediated by Social cohesion: Supported).



We can see different results for Model 3. Here, *Neighbourhood balance* is positively associated with *Social cohesion*, but non-significantly (**H2** Neighbourhood balance positively affects Social cohesion: Not supported). Second, the association between *Social cohesion* and *Informal support* is again positive (**H1** Social cohesion positively affects Informal support: Supported). Finally, as in the previous models, the relationship between *Neighbourhood balance* and *Informal support* is non-significant (**H3**: Neighbourhood balance positively affects Informal support: Not supported). Therefore, Model 3 does not show mediation effects (**H4**: The relationship between Neighbourhood balance and Informal support is mediated by Social cohesion: Not supported).

Even though the relationship between *Neighbourhood balance* and *Social cohesion* in Model 3 is non-significant, the change of sign between Models 1, and 2, and Model 3 is of interest. Especially because, as we saw in Figure 4.6, other models in the same cluster showed significant relationships. This could be explained by two reasons. First, the different specification of *Social cohesion* could change the direction of the relationship if *% of residents who say that local residents share each other's views* (*SC3*; Models 1, and 2) and *% of residents who say they feel at home with local residents* (*SC5*; Model 3) are negatively related. Second, the distribution of balance in Model 3, yields a *Neighbourhood balance* measurement which is negatively related to the measure from the other distributions. After examination, we saw that *SC3* and *SC5* are positively related and highly collinear ($r^2$=0.8, VIF>3), which suggests that the second argument is the reason for the results. This can be explained by the fact that the distribution in Model 3 is convex, whereas the distributions for the other models are concave (see Figure 4.5). Chapter 5 discusses the reasons and implications of these results.

The results show that the PLS-SEM successfully estimated the model constructs and yielded acceptable explanatory power, although low predictive accuracy. Model 1 had the best overall goodness-of-fit, but Model 3 captured the relationship between *Social cohesion* and *Informal support* with better explanatory power. Overall, the latent construct *Informal support* expressed as the *% of residents who say they are willing to care for neighbours or friends who need help* (*IS1*) had a low explanatory power. The emergent construct *Social cohesion* was reduced to the *% of residents who say that local residents share each other's view* (*SC3*) when the objective balance distribution is concave (Models 1, and 2), or to the *% of residents who say they feel at home with local residents* (*SC5*)

**Table 4.3:** Structural model total, direct, and indirect path coefficients.

| Dependent variable | Independent variable | Model 1 | | | Model 2 | | | Model 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $\beta$ Total | $\beta$ Direct | $\beta$ Indirect | $\beta$ Total | $\beta$ Direct | $\beta$ Indirect | $\beta$ Total | $\beta$ Direct | $\beta$ Indirect |
| Informal Support | | | | | | | | | | |
| | Social Cohesion | 0.352** | 0.352** | | 0.351** | 0.351** | | 0.325** | 0.325** | |
| | Neighbourhood Balance | -0.067 | 0.097 | -0.164 | -0.037 | 0.108 | -0.145 | 0.141 | 0.037 | 0.104 |
| Social Cohesion | | | | | | | | | | |
| | Neighbourhood Balance | -0.467*** | -0.467*** | | -0.412*** | -0.412*** | | 0.321 | 0.321 | |

Significance levels: *p<0.001 **p<0.01 ***p<0.05
Note: No superscript indicates statistically non-significant values.



when the balance distribution is convex (Model 3). This yields two different possible results. On one hand, concave balance distributions to measure *Neighbourhood balance* are negatively associated to *Social cohesion* and only related to *Informal support* by full mediation. On the other hand, convex balance distributions to measure *Neighbourhood balance* are positively associated to *Social cohesion* and again related to *Informal support* by full mediation. Finally, *Social cohesion* and *Informal support* are positively related in all instances.

## 4.3. SPATIAL ECONOMETRICS RESULTS

This section elevates the results from the PLS-SEM model to the geographical level. First, the impact of the different distributions of balance in the measurement of *Neighbourhood balance* are analysed. Then the spatial effects in *Social cohesion* are assessed, followed by the effects in *Informal support.*[4]

### 4.3.1. SPATIAL DISTRIBUTION OF NEIGHBOURHOOD BALANCE

To introduce this section, Figure 4.8 shows the different outcomes in *Neighbourhood balance* that result from the chosen distribution in each model. Overall, we can see that *Neighbourhood balance* increases from the South of the city towards the North.

When comparing the different models, we can however see a considerable difference in the measurement of *Neighbourhood balance*. Models 1, and 2 present very similar outcomes, showing this increase in balance towards the North, but with less extreme values. On the other hand, Model 3 assigns stronger levels of imbalance to the South of Rotterdam and stronger levels of balance towards the North. Not only that, but we can also see how some neighbourhoods which in the first three models were considered with a very low *Neighbourhood balance*, Model 3 assigns them a high level of *Neighbourhood balance*. The same happens in the opposite way. Neighbourhoods like Blijdorp which presented high levels of *Neighbourhood balance* in Models 1, and 2, in Model 3 decrease their level. This can be explained by the earlier mentioned change in balance distribution shape. While Models 1, and 2 measure *Neighbourhood* balance from con-

[4] The main results do not take into account the river that divides Rotterdam. Appendix E shows the results considering that the river cancels any type of spillover effect from both sides. The results are talk about in the discussion chapter.


**Figure 4.8:** Choropleth of the standardised measure of *Neighbourhood balance* in 2019 for every model. The neighbourhoods of Noord Kethel, Strand en Duin, and Nesselande are outliers and are removed from the figure for clarity (Appendix D.2 shows the values for each neighbourhood in each Model).

cave distributions, Model 3 does from a convex distribution (see Figure 4.5). As a result, some measurements are flipped.

### 4.3.2. Spatial effects in Social cohesion

The PLS-SEM model reduced *Social cohesion* to the *% of residents who say that local residents share each other's view* (*SC3*) for Models 1, and 2; and to the *% of residents who say they feel at home with local residents* (*SC5*) for Model 3. This section begins with a spatial exploration of these results and continues with the use of spatial econometrics to quantify the implications of the spatial arrangement.

Figure 4.9 shows a vertical gradient in *Social cohesion* from North to South in Rotterdam. The neighbourhoods in the South suffer from a lower level of *Social cohesion*, as well as those in the centre of the city. We can also see how neighbourhoods to the West, which are not in the periphery of Rotterdam's centre, also express higher levels of *Social cohesion*. While *Social cohesion* expressed as the *% of residents who say that local residents share each other's view* (Models 1, and 2; *SC3*) yields higher values towards the positive end, *% of residents who say they feel at home with local residents* (Model 3; *SC5*) does the opposite. Even so, we can see that the spatial structure has a similar pattern for all models.

To visually explore the relationship between *Social cohesion* and *Neighbourhood balance*, Figure 4.10 shows the distribution of both measurements in Rotterdam. We can observe two different associations. Foremost, we can observe the similarity between the choropleths for Models 1, and 2 given that they measure *Social cohesion* the same way. They show how the balance tends to increase towards the North of Rotterdam, but that the increase in *Social cohesion* towards the North is less progressive, given the low *Social cohesion* in the city centre. While a few neighbourhoods with higher *Neighbourhood balance* and *Social cohesion* can be spotted towards the North, in these models they

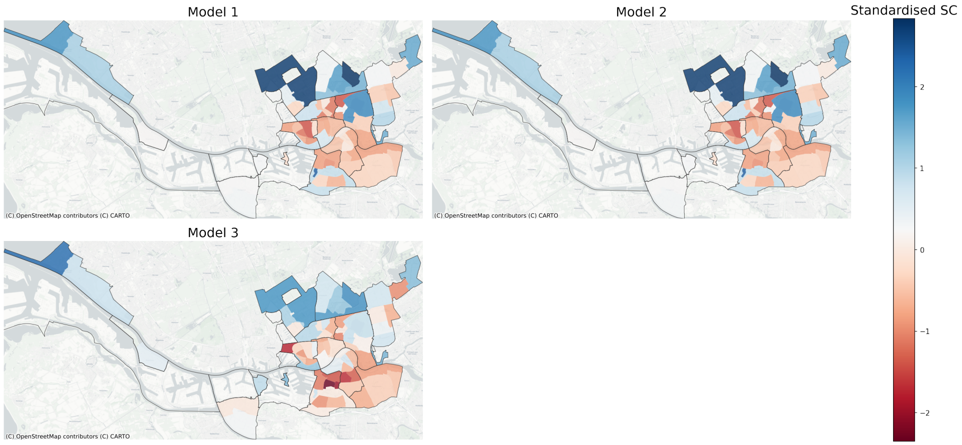



**Figure 4.9:** Choropleth of the standardised measure of *Social cohesion* in 2019 for every model.

are negatively associated, given the large spread of lower *Social cohesion* throughout the city. The choropleth for Model 3 shows a different story. We can see a progression from neighbourhoods with low *Social cohesion* and low *Neighbourhood balance* in the South, to high in the North, due to the change of the distribution for balance in Model 3 from concave to convex. Nevertheless, the reader is reminded that in the case of Model 3 the relationship between these variables was not significant to the 95% CI, but to the 90%. To further explore the spatial distribution of *Social cohesion*, Appendix D.3 shows its LISA classification.


**Figure 4.10:** Choropleth of the distribution of *Social cohesion* and *Neighbourhood balance* in 2019. Grey shades represent neighbourhoods in which *Social cohesion* and *Neighbourhood balance* are low. Shades of blue represent neighbourhoods in which the level of *Neighbourhood balance* is high. Shades of red represent counties in which *Social cohesion* is high. The values in the shades were determined by Jenks natural breaks optimization.

**Table 4.4:** Results of the Durbin spatial model with *Social cohesion* as dependent variable. Lagged variables are the weighted averages of neighbouring values. Significant values of the lagged variables indicate spillover or contagion effects. In brackets, the standard deviations.

| Variable | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Intercept | -0.025 | -0.027 | -0.063 |
| | (0.099) | (0.102) | (0.103) |
| Neighbourhood Balance | -0.458* | -0.403* | 0.227*** |
| | (0.102) | (0.104) | (0.104) |
| Lagged Neighbourhood Balance | -0.242 | -0.174 | 0.219 |
| | (0.173) | (0.168) | (0.163) |
| Lagged Social Cohesion | 0.329*** | 0.375** | 0.404** |
| | (0.138) | (0.133) | (0.130) |
| Log-likelihood | -81.818 | -84.046 | -84.648 |
| Akaike information criterion | 171.635 | 176.092 | 177.297 |
| $R^2$ (pseudo) | 0.365 | 0.330 | 0.293 |

Significance levels: *p<0.001 **p<0.01 ***p<0.05
Note: No superscript indicates statistically non-significant values.

To quantify the strength of the possible spillover or contagion effects, Table 4.4 shows the results of Durbin's spatial autoregressive model with *Social cohesion* as dependent variable and *Neighbourhood balance* as the independent variable. From the results, we can see that *Social cohesion* demonstrates such effects in all models (**H5a** Spatial spillover effects are significant on the relationship between Neighbourhood balance and Social cohesion: Supported). For example, in Model 1, a 10% increase in the average surrounding *Social cohesion* would report an increase of 0.0329 standard deviations in the *Social cohesion* of the target neighbourhood. This effect is of the same order as the direct effect of *Balance neighbourhood* on *Social cohesion*, however, *Balance neighbourhood* did not report significant spillover or contagion effects. This suggests that the PLS-SEM model results are limited, as they do not account for these spatial effects.

### 4.3.3. Spatial effects in Informal support

This section studies the relationship between *Social cohesion* and *Informal support*. The relationship between *Neighbourhood balance* and *Informal support* was not further analysed because the PLS-SEM results pointed out no significant relationship between the latter in any of the Models.

Figure 4.11 shows how, in comparison to *Social cohesion*, the division in *Informal support* between North and South is less accentuated, although a gradient can still be observed. The choropleths for each model are the same, as they all specified *Informal support* using the same single-indicator.

To visually explore the association of *Informal support* with *Social cohesion*, Figure 4.12 shows the distribution of both constructs in the city. We can see that neighbourhoods in the South of the city are mostly associated with low *Social cohesion* and

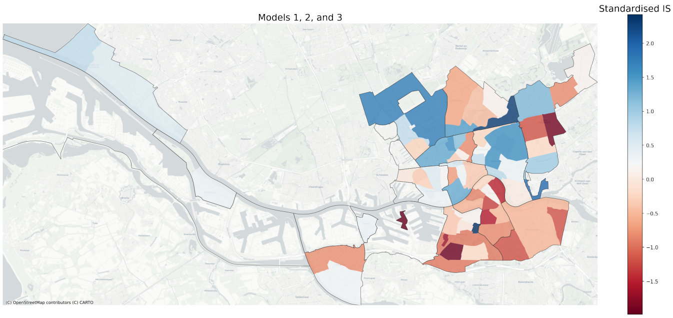



**Figure 4.11:** Choropleth of the standardised measure of *Informal support* in 2019 for all Models.




**Figure 4.12:** Choropleth of the distribution of *Informal support* and *Social cohesion* in 2019. Grey shades represent neighbourhoods in which *Informal support* and *Social cohesion* are low. Shades of blue represent neighbourhoods in which the level of *Social cohesion* is high. Shades of red represent counties in which *Informal support* is high. The values in the shades were determined by Jenks natural breaks optimization.

low *Informal support*. As we move towards the North, these two variables tend to increase. Most differences between Model 3 and the rest can be identified in the central and to the East and West of it. This shows that the polarisation is consistent and only fuzzier in the border zone between North and South. A more nuanced exploration of the relevance of the geographical distribution can be found in Appendix D.3, which shows the LISA clusters for *Informal support*.

The presence of clusters is suggestive of possible spillover or contagion effects. Table 4.5 shows the results of Durbin's spatial autoregressive model with *Informal support* as dependent variable and *Neighbourhood balance* and *Social cohesion* as independent variables. The results from Models 1 and 2 suggest that *Informal support* of other neighbourhoods spill over (**H5b** Spatial spillover effects are significant on the relationship between Neighbourhood balance and Informal support: Supported). The spillover or con-

**Table 4.5:** Results of the Durbin spatial model with *Informal support* as dependent variable. Lagged variables are the weighted averages of neighbouring values. Significant values of the lagged variables indicate spillover or contagion effects. In brackets, the standard deviations.

| Variable | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Intercept | -0.010 | -0.010 | 0.002 |
| | (0.110) | (0.110) | (0.108) |
| Neighbourhood Balance | 0.094 | 0.096 | -0.027 |
| | (0.128) | (0.123) | (0.114) |
| Lagged Neighbourhood Balance | 0.156 | 0.162 | 0.097 |
| | (0.210) | (0.191) | (0.166) |
| Social Cohesion | 0.371** | 0.366** | 0.385** |
| | (0.136) | (0.133) | (0.130) |
| Lagged Social Cohesion | -0.105 | -0.106 | -0.125 |
| | (0.228) | (0.220) | (0.187) |
| Lagged Informal Support | 0.301*** | 0.293*** | 0.261 |
| | (0.143) | (0.144) | (0.147) |
| Log-likelihood | -88.072 | -87.971 | -86.945 |
| Akaike information criterion | 188.145 | 187.941 | 185.889 |
| $R^2$ (pseudo) | 0.185 | 0.186 | 0.205 |

Significance levels: *p<0.001 **p<0.01 ***p<0.05
Note: No superscript indicates statistically non-significant values.

tagion of *Social cohesion* is not significant enough to have an effect in this process. In Model 3, no significant spillover or contagion effects can be seen (**H5b** Spatial spillover effects are significant on the relationship between Neighbourhood balance and Informal support: Not supported).

## 4.4. RESULTS OF MODERATION ANALYSIS

In this section, moderation analysis is conducted to overcome the supposition that the relationships between neighbourhood balance, social cohesion, and informal support are exactly the same for all neighbourhoods and identify instances in which the moderating variables change the strength or direction of the relationship between the concepts (Henseler, 2020).

The results of moderation analysis can be summarised as follows (see Table 4.6). *Social cohesion* is negatively associated with the *Ethnic heterogeneity* of the neighbourhoods in all models. No other exogenous factors were directly related to *Social cohesion* or moderated the relationship between *Neighbourhood balance* and *Social cohesion* (**H6a**, **H7a**, **H8a**, **H9a**, **H10a**, and **H11a**: Not supported). Next, Table 4.6 shows that *Informal support* is only directly related to *House type heterogeneity* in Model 3, with no significant moderation effects. No other exogenous factors were directly related to *Informal support* or moderated the relationship between *Neighbourhood balance* and *Informal*

**Table 4.6:** Results of moderation analysis. In bold the effects which are significant up to 95% CI.

| | | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|---|
| **Dependent variable** | **Independent variable** | $\gamma$ | **95% CI** | $\gamma$ | **95% CI** | $\gamma$ | **95% CI** |
| Social Cohesion | | | | | | | |
| | Neighbourhood balance (NB) | -0.326 | [-0.578, 0.122] | -0.234 | [-0.479, 0.189] | 0.471 | [0.238, 0.684] |
| | Ethnic heterogeneity | **-0.705*** | **[-0.910, -0.307]** | **-0.711*** | **[-0.926, -0.344]** | **-0.585*** | **[-0.861, -0.344]** |
| | Residence length | 0.118 | [-0.147, 0.336] | 0.121 | [-0.141, 0.330] | 0.093 | [-0.097, 0.288] |
| | Population density | -0.225 | [-0.523, 0.067] | -0.205 | [-0.498, 0.076] | -0.004 | [-0.254, 0.273] |
| | House type heterogeneity | 0.050 | [-0.287, 0.306] | 0.046 | [-0.314, 0.337] | -0.089 | [-0.300, 0.126] |
| | Greenery | -0.197 | [-0.404, 0.043] | -0.208 | [-0.401, 0.059] | 0.088 | [-0.171, 0.350] |
| | Walkability | 0.099 | [-0.293, 0.417] | 0.082 | [-0.281, 0.433] | 0.082 | [-0.227, 0.419] |
| | Amenities | -0.088 | [-0.447, 0.206] | -0.107 | [-0.452, 0.168] | -0.099 | [-0.379, 0.167] |
| | NB × Ethnic heterogeneity | -0.139 | [-0.677, 0.528] | -0.172 | [-0.784, 0.441] | 0.215 | [-0.238, 0.604] |
| | NB × Residence length | -0.102 | [-0.282, 0.395] | -0.042 | [-0.235, 0.426] | -0.015 | [-0.324, 0.282] |
| | NB × Population density | 0.251 | [-0.509, 0.821] | 0.109 | [-0.548, 0.604] | 0.054 | [-0.328, 0.453] |
| | NB × House type heterogeneity | -0.112 | [-0.456, 0.466] | -0.080 | [-0.463, 0.551] | -0.047 | [-0.326, 0.346] |
| | NB × Greenery | -0.035 | [-0.356, 0.460] | -0.038 | [-0.377, 0.446] | -0.047 | [-0.35, 0.205] |
| | NB × Walkability | 0.124 | [-0.727, 0.922] | 0.262 | [-0.381, 1.003] | -0.006 | [-0.341, 0.370] |
| | NB × Amenities | -0.166 | [-1.001, 0.771] | -0.096 | [-0.815, 0.749] | -0.063 | [-0.392, 0.347] |
| Informal Support | | | | | | | |
| | Neighbourhood balance (NB) | 0.195 | [-0.380, 0.747] | 0.146 | [-0.408, 0.672] | 0.255 | [-0.188, 0.580] |
| | Social cohesion | -0.001 | [-0.544, 0.692] | 0.011 | [-0.509, 0.699] | 0.023 | [-0.455, 0.586] |
| | Ethnic heterogeneity | -0.437 | [-0.898, 0.289] | -0.451 | [-0.974, 0.290] | -0.303 | [-0.787, 0.137] |
| | Residence length | -0.083 | [-0.441, 0.220] | -0.079 | [-0.394, 0.204] | -0.070 | [-0.392, 0.209] |
| | Population density | -0.019 | [-0.394, 0.506] | 0.053 | [-0.466, 0.604] | 0.203 | [-0.146, 0.683] |
| | House type heterogeneity | -0.296 | [-0.783, 0.194] | -0.310 | [-0.837, 0.152] | **-0.470**** | **[-0.752, -0.144]** |
| | Greenery | -0.245 | [-0.516, 0.060] | -0.226 | [-0.470, 0.147] | 0.129 | [-0.247, 0.458] |
| | Walkability | 0.092 | [-0.596, 0.454] | 0.118 | [-0.505, 0.578] | 0.127 | [-0.481, 0.622] |
| | Amenities | 0.000 | [-0.283, 0.708] | 0.085 | [-0.248, 0.734] | 0.109 | [-0.362, 0.779] |
| | NB × Ethnic heterogeneity | -0.415 | [-1.200, 0.378] | -0.413 | [-1.151, 0.248] | 0.154 | [-0.565, 0.712] |
| | NB × Residence length | -0.200 | [-0.547, 0.298] | -0.134 | [-0.482, 0.245] | 0.071 | [-0.446, 0.519] |
| | NB × Population density | 0.844 | [-0.025, 1.638] | 0.532 | [-0.427, 1.416] | -0.055 | [-0.647, 0.597] |
| | NB × House type heterogeneity | 0.054 | [-0.658, 0.728] | 0.111 | [-0.651, 0.747] | -0.158 | [-0.782, 0.426] |
| | NB × Greenery | -0.101 | [-0.407, 0.533] | -0.130 | [-0.531, 0.278] | -0.058 | [-0.537, 0.346] |
| | NB × Walkability | 0.163 | [-0.641, 1.431] | 0.319 | [-0.677, 1.449] | 0.013 | [-1.023, 0.639] |
| | NB × Amenities | -0.606 | [-1.972, 0.109] | -0.746 | [-2.122, -0.029] | -0.268 | [-1.157, 0.416] |

Significance levels: *p<0.001 **p<0.01
Note: No superscript indicates statistically non-significant values.

*support* in any model (**H6b**, **H7b**, **H8b**, **H9b**, **H10b**, and **H11b**: Not supported).

## 4.5. CONCLUSION

This chapter presented the results of applying the developed computational framework to the case study of the city of Rotterdam. It provided evidence for the research hypotheses and answered SQ2: *How can the indicators of the mechanisms that drive balanced neighbourhoods to act more resiliently be operationalised?*; and SQ3: *What is the empirical relationship between the indicators that drive balanced neighbourhoods to act more resiliently?*

First, we observed that the conditions that define a balanced neighbourhood for the municipality of Rotterdam subsume a set of different possible distributions. The application of the KL divergence showed a considerable variance and susceptibility to outliers in the measurement of *Neighbourhood balance*. From all the possible configurations, roughly 2.1% fit the proposed PLS-SEM model. From the fit models, we identified three different clusters, and we selected the best fitting distribution in each to obtain further insights.

The results of the PLS-SEM assessment to the three chosen models show that they successfully estimated the constructs and yielded an acceptable explanatory power, but low predictive accuracy. The indicator *% of residents who say they are willing to care for neighbours or friends who need help* (*IS1*) makes up the total variance of the latent construct *Informal support*. The emergent construct *Social cohesion* was reduced to the *% of residents who say that local residents share each other's views* (Models 1, and 2; *SC3*) or to the *% of residents who say they feel at home with local residents* (Model 3; *SC5*).

Table 4.7 summarises the findings for the formulated hypotheses. The results of PLS-SEM showed that *Neighbourhood balance* is associated to *Social cohesion* but not to *Informal support*. This indicates that the relationship is fully mediated by *Social cohesion*. Models 1, and 2 present a concave distribution for balance and a negative relationship between *Neighbourhood balance* and *Social cohesion*. Model 3 presents a convex distribution for balance and a non-significant relationship between *Neighbourhood balance* and *Social cohesion*. Other models with convex distribution shows a significant positive relationship between *Neighbourhood balance* and *Social cohesion*, in opposition to the results of the concave distributions. All models indicate there is a positive association between *Social cohesion* and *Informal support*.

In the spatial analysis of *Social cohesion* and *Informal support*, we have seen the presence of spatial clusters. These clusters show a clear geographical division between the North, South, and centre of Rotterdam. In general, the North has a higher level of *Social cohesion* and *Informal support* than the South. Clusters of low *Neighbourhood balance* and high *Neighbourhood balance* can be found throughout the city, with prominent clusters in the South and North, respectively. The centre shows low levels of *Social cohesion* and *Informal support* while having a high level of *Neighbourhood balance*. The results of the spatial regression indicate, that the results of the PLS-SEM model are biased given the presence of autoregression from the spatial distribution. The outcome of the Durbin spatial model shows that there is presence of spillover or contagion effect in *Social cohesion* and *Informal support* between neighbouring neighbourhoods.

To overcome the supposition that the relationships between neighbourhood balance, social cohesion, and informal support are exactly the same for all neighbourhoods, moderation analysis was conducted from a list of previously identified relevant demographic and built environment factors. The results show that *Social cohesion* is negatively associated with the *Ethnic heterogeneity*. No moderation effects are significant between *Neighbourhood balance* and *Social cohesion*. On the other hand, we can also see that *Informal support* is negatively associated with the *House type heterogeneity*, only in Model 3. No moderation effects are significant between *Neighbourhood balance* and *Informal support*.

**Table 4.7:** Status of the formulated hypotheses for every Model.

| Hypothesis | Model 1, and 2 status | Model 3 status |
|---|---|---|
| H1: Social cohesion positively affects Informal support | Supported | Supported |
| H2: Neighbourhood balance positively affects Social cohesion | Not supported | Not supported |
| H3: Neighbourhood balance positively affects Informal support | Not supported | Not supported |
| H4: The relationship between Neighbourhood balance and Informal support is mediated by Social cohesion | Supported | Not supported |
| H5a: Spatial spillover effects are significant on the relationship between Neighbourhood balance and Social cohesion | Supported | Supported |
| H5b: Spatial spillover effects are significant on the relationship between Neighbourhood balance and Informal support | Supported | Not supported |
| H6a: Ethnic heterogeneity moderates the relationship between Neighbourhood balance and Informal support | Not supported | Not supported |
| H6b: Ethnic heterogeneity moderates the relationship between Neighbourhood balance and Social cohesion | Not supported | Not supported |
| H7a: Residence length moderates the relationship between Neighbourhood balance and Informal support | Not supported | Not supported |
| H7b: Residence length moderates the relationship between Neighbourhood balance and Social cohesion | Not supported | Not supported |
| H8a: Population density moderates the relationship between Neighbourhood balance and Informal support | Not supported | Not supported |
| H8b: Population density moderates the relationship between Neighbourhood balance and Social cohesion | Not supported | Not supported |
| H9a: House type heterogeneity moderates the relationship between Neighbourhood balance and Informal support | Not supported | Not supported |
| H9b: House type heterogeneity moderates the relationship between Neighbourhood balance and Social cohesion | Not supported | Not supported |
| H10a: The amount of greenery moderates the relationship between Neighbourhood balance and Informal support | Not supported | Not supported |
| H10b: The amount of greenery moderates the relationship between Neighbourhood balance and Social cohesion | Not supported | Not supported |
| H11a: Walkability moderates the relationship between Neighbourhood balance and Informal support | Not supported | Not supported |
| H11b: Walkability moderates the relationship between Neighbourhood balance and Social cohesion | Not supported | Not supported |
| H12a: The number of amenities moderates the relationship between Neighbourhood balance and Informal support | Not supported | Not supported |
| H12b: The number of amenities moderates the relationship between Neighbourhood balance and Social cohesion | Not supported | Not supported |

# 5

# Discussion

This chapter discusses the results presented in Chapter 4 embedded within the political controversy of balanced neighbourhood policies. The discussion starts with a section dedicated to the implications of the definition of a balanced neighbourhood from the municipality of Rotterdam. Second, we discuss the results obtained for the constructs based on social indicators. Finally, the relationships between the constructs in the model are examined, and we reflect upon balanced neighbourhood policies.[1]

## 5.1. The dichotomy of balance

The first part of this section is dedicated to a discussion about the definition of a balanced neighbourhood by the municipality of Rotterdam. As explained in Section 2.4.2, the municipality of Rotterdam aims to demolish cheaper housing in favour of middle- and higher-income groups. To measure the progress and set a goal for the housing programme, the municipality defined the set of conditions in Figure 2.9.

**The definition of balance can result in counterintuitive conceptions of balance.** As we saw in the exploration of the conditions for balance, the municipality defined a broad combination of housing WOZ-value stock distributions (see Figure 4.1) that results in a dispersed measurement of *Neighbourhood balance* (see Figure 4.2). This shows the discrepancy in the multiple possible combinations that the definition of the municipality allows.

To get a better grasp of the differences, Figure 5.1, shows an example for the neighbourhood of Zuiderpark and Zuidrand. This extreme example aims to show the implications of the broadness of the definition of balance by the municipality. As we can see,

[1]Two interviews were conducted to two experts for consultation. Interviewee 1 was Dr.ir. André Ouwehand, researcher at the Delft University of Technology. Interviewee 2 was Dr. Wenda Doff, independent researcher in Rotterdam. The interviews have been cited as Ouwehand (2022, personal communication) and Doff (2022, personal communication), respectively. While the first interviewee is a resident in the North of Rotterdam, the second lives in the South. The variety in views contributes to avoiding biased results.

this neighbourhood is not in balance according to the definition of the municipality of Rotterdam: it has more than 60% of the houses in the Social segment and less than 40% of Middle, Higher, and Top combined. What is the house stock distribution that would achieve balance with the least change? That corresponds to Balance:60-9-31 as can be seen in Figure 5.1. This is the distribution from the solution space that yields the lowest *Neighbourhood balance*, i.e. that is closer to the actual housing stock. From a pragmatic policy perspective, this facilitates the implementation of a building program that aims towards this to fit the political discourse of a city in balance. The municipality would "only" have to transform around 20% of the Social housing in the neighbourhood to 5% Middle and 15% Higher or Top to check a box. What if, on the other hand, we took a look at the distribution that is the furthest away from the housing stock in the neighbourhood? Balance:1-98-1 would fit that description. This means that the municipality could get rid of all Social housing and the box would still be checked.

This is, of course, an extreme example, but it shows how the lack of specificity of the definition of balance of the municipality can result in counterintuitive conceptions of balance. The amount of Social housing could be reduced to the minimum, and we would have balance in the neighbourhood, as both the distributions of Balance:60-9-31 and Balance:1-98-1 are both within the conditions of the municipality of Rotterdam.



**The dichotomy of balance limits quantification and can be misleading.** Another concern with the definition of a balanced neighbourhood by the municipality is its dichotomous specification. If the neighbourhood complies with the conditions in Figure 2.9 it is in balance, otherwise it is not. The consequence in the approach of this study was that the quantitative analysis between balance and other concepts was made more difficult. Of course, a binary variable could be used to determine balance (0 = No balance, 1 = Balance). Nevertheless, this has two fundamental limitations. First, the use of ordinal variables in statistical modelling techniques (like the ones used in this study) is limited. An ordinal variable is in the end a qualitative measure that has been numerically coded; to be treated as quantitative by models, specific assumptions and techniques need to be taken (Schuberth et al., 2018). The second limitation is the interpretation of a binary ordinal variable. A neighbourhood is in balance, so what? How much in balance is it? On what side of the balance? Ordinal variables have the disadvantage that the information they provide is often so narrow that they can easily mislead conclusions. On the other hand, ordinal variables present two advantages which make them attractive, especially in the political discourse. First, they are easy to measure and categorise. By setting a number of straightforward conditions, the municipality can easily identify which neighbourhoods require more attention. The second advantage is the ease of communication. As variables get too complex and obscure, it is harder to explain them to laypeople. Within the social policy context, it is important to keep things as simple as possible (de Bruijn, 2019).

**The definition of balance is under-specified in the expensive housing segments.** Another point of attention in the definition of balance from the municipality is the aggregation of Higher and Top segments into the same segment. The goal of the municipality of Rotterdam is to build the following composition: 20% Social segment, 30% Middle segment, 30% Higher segment and 20% Top segment, in the long run. Nevertheless, this cannot be directly measured by their definition of balance. The Higher and Top segments get confounded and leave room for a hidden increase in polarisation, as the measurement for balance would capture an increase in 50% of Top segment in the same way. In the official documentation, they are open about the exact building programme for each segment, so transparency is guaranteed to a certain extent. However, an extension of this definition to other less monitored contexts could incite malpractices.

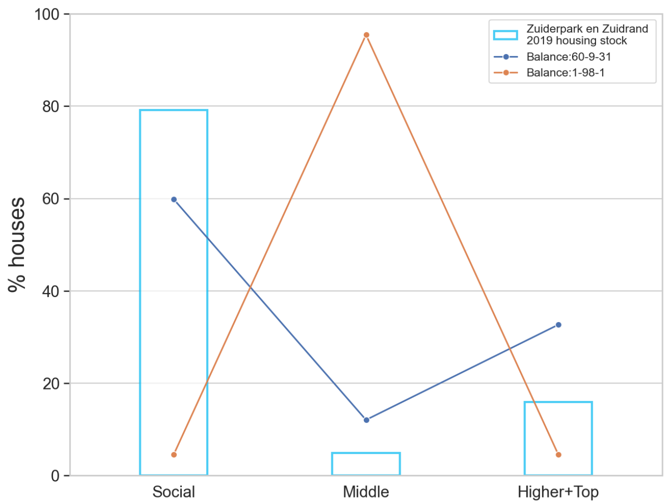



**Figure 5.1:** Example of the implication of the definition of balanced neighbourhood of the municipality of Rotterdam. Bars: Distribution of the housing stock of Zuiderpark en Zuidrand in 2019. Blue line: Possible distribution of 60% Social, 9% Middle, and 31% Higher+Top which would yield the best *Neighbourhood balance* for Zuiderpark en Zuidrand in 2019 with NB = -0.08 nats. Orange line: Possible distribution of 1% Social, 98% Middle, and 1% Higher+Top which would yield the worst *Neighbourhood balance* for Zuiderpark en Zuidrand in 2019 with NB = -3.76 nats. For the municipality of Rotterdam, both cases are considered as balanced. Remember that nat is the information loss from one distribution to the other that the KL divergence calculates. To make sense of these results, the measure of Balance:60-9-31 is 1.13 standard deviations above the overall mean, while the measure of Balance:1-98-1 is -3.33 standard deviations below the overall mean. This shows the lack of specificity of the definition provided by the municipality.

**Only a few distributions within the definition of balance can explain the alleged effects of the municipality.** Structural equation modelling provides us with the ability to test theories between complex social constructs as sets of linear equations (Hair et al., 2016). To determine how likely it is that that our conceptual model matches the real world (or better put, the data collected from the real world), it is important to assess how well the relationships coincide with empirical data. In other words, we need to test the model's goodness-of-fit. Our results showed that from all the possible integer configurations that satisfy the conditions of balance, roughly 2.1% fit the model. Why did only a few fit? To understand this in a more sensible way, let's suppose you have to make a drawing of a hat. To know if your drawing is good, you can compare the distances between pairs of points on the drawing with the corresponding measured distances on a real hat. The closer the match, the more certain you are that your drawing is faithful to reality. The same can be applied in SEM by comparing the strength of relationships as implied by the model and the empirically observed strength of the relationships. This was quantified by the SRMR, a measure that indicates how strongly the empirical correlation matrix differs from the model-implied correlation matrix (Henseler, 2020). In that sense, the integer configurations that fit our model were the ones which could explain the relationships between *Neighbourhood balance*, *Social cohesion*, and *Informal support* better. However, we have to pay attention when drawing the hat, as we may really be drawing a boa constrictor digesting an elephant! (see Figure 5.2). Our model fit not only depends on the inner workings of PLS-SEM, but also on the different distributions to obtain *Neighbourhood balance*. Therefore, in every model, we kept changing the target balance distribution the same way we kept changing what the boa is digesting. This can contribute to explain why a low number of the different integer configurations that satisfy the conditions of balance fit. While PLS-SEM works with linear equations, the KL divergence to calculate *Neighbourhood balance* from the distributions set by the municipality is a logarithmic transformation.



With the understanding of the fit of the different models, we can give a meaning to the integer configurations that satisfy the conditions of balance that did fit the model. The balance distributions that we have found in this study are the ones which can explain the relationships in the model; all the others, did not manage to capture the relationship. A first interpretation of this result can mean that the model isn't complex enough to match the available data. As we have seen in the analysis of exogenous factors, *Ethnic heterogeneity* and *House type heterogeneity* play a significant role in the inner model. It could possibly be that by incorporating those (and other) factors in the model, it would capture reality with more detail and more estimations would fit. In addition, variables may also be affected by systematic measurement error or assumptions like uncorrelated measurement errors may not hold.

This interpretation opens a reflection of possible malpractices in using statistics for policymaking. A model's goodness-of-fit can be increased by increasing its complexity, i.e. if we add more parameters, the model will be able to explain the data with more accuracy. However, if we overfit the model, it will **only** be able to explain the data to which it is fitted and will obscure the theoretical foundations. Decision-makers run the risk of accepting the model with the best goodness-of-fit, but with ineligible relationships. This reflection supports the logic of using a deductive approach rather than a data-driven approach (Schwab & Held, 2020; Shih & Chai, 2016). In the deductive approach, the theory is first developed and then checked against available data, so the theory is central and clear. Instead, in the data-driven approach, the theory is reasoned from the data, so complexity (and, therefore, goodness-of-fit) can be increased until the theory fits the modeller's interests.

Another interpretation of the few fitting distributions is that the study has uncovered which are the balance distributions for the city that can actually show the alleged effects of balance. This would mean that the distributions of the models that did not fit do not provide empirical evidence of the policy discourse of the municipality of Rotterdam. In this sense, if the municipality wants to keep developing the housing programme to achieve balance, the found distributions would be more specific objectives which actu-

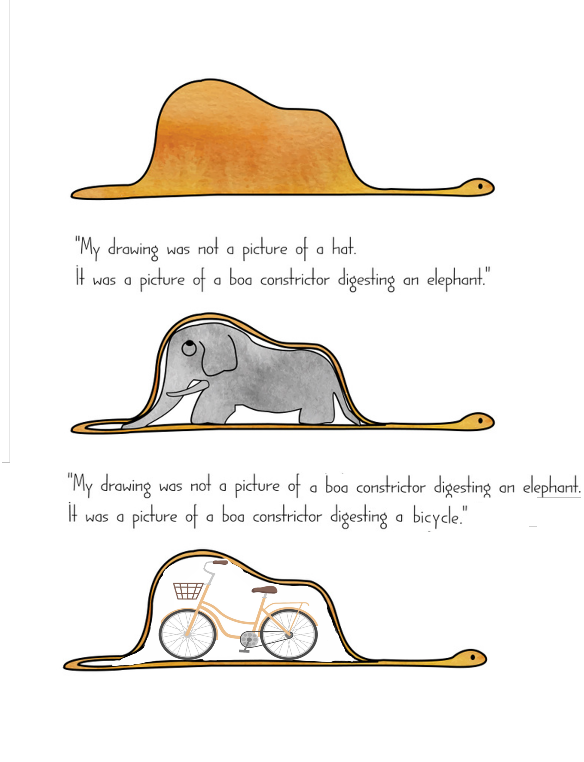



**Figure 5.2:** Analogy of model fit. In PLS-SEM we estimate the model fit by comparing the strength of relationships as implied by the model (hat drawing) and the empirically observed strength of the relationships (real hat). Nevertheless, in our model we also varied the construct of *Neighbourhood balance*, showing that we were not just drawing a hat, but a boa digesting different things. Adapted from: de Saint-Exupéry (1943).

ally show the intended outcomes.

**Each neighbourhood should aim at a balance according to its characteristics, but the definition of balance is the same for all.** While in this study the same target WOZ-value distribution was used for every neighbourhood in each model run, the Woonvisie programme aims to intervene on a city-wide and neighbourhood level where necessary and in a targeted manner (Municipality of Rotterdam, 2019c). This means that balance should not be measured as a unique city-wide distribution, but that each neighbourhood could have a different goal that achieves balance in relation to the population in the neighbourhood. Nonetheless, the definition of balance from the municipality of Rotterdam inherently posits the same ideal for all neighbourhoods. The indicator can identify which neighbourhood requires attention, but it fails to capture the distinctive features of every community. Therefore, the results of this study can be of use to the urban planners of the municipality. The computational framework could be adapted to calculate all the combinations of every balance distribution for each neighbourhood to select which balance explains better the relationships in each neighbourhood. This would provide specific insights for the building programme for each neighbourhood, as well as a more concrete measure for each. This suggestion was not performed in this research and should be optimised due to the time constraints and computational power limitations. If we were to calculate all possible combinations, that would result in $\binom{k}{n} = 4 \times 10^{144}$ estimations with $k = 3,164$ integer configurations that satisfy the conditions of balance and $n = 70$ neighbourhoods. At an average time of 13 seconds per estimation,[2] we can clearly see the limitation. And this is just considering integer combinations...

**Balance as physical indicator for social resilience carries normative and political load.** The assumption of balance is grounded in the presumed superiority of the newcomers that will transform the neighbourhood. As such, "Balance" is associated with a resilient and inclusive city, and makes neighbourhoods not in balance undesirable. The concept in itself is politically powerful: If you are against balance, you favour vulnerability and segregation. The policy has an indirect political implication for the citizens dwelling in those designated areas.

Instead of being a victim of the political discourse, the detractors of the Woonvisie in the movement Recht op de Stad have reframed the paradigm (Right to the City, 2022). If you are in favour of balance you support the cold technocratic city, if you are against it, you champion a city for the people. In their frame, a resilient and cohesive city requires to go beyond an indicator and embrace the social characteristics of a neighbourhood.

The measurement of a physical indicator like the WOZ-value fails to recognise the importance of social factors, while it points towards social resilience capabilities of a community. This is partially due to how challenging it is to assess traits like the ability for community members to develop resilience via their agency (Copeland et al., 2020). Social resilience indicators like informal support can factor in that agency, but as we will see in the next section, they also carry their own limitations.

## 5.2. SOCIAL INDICATORS FOR RESILIENCE

Before jumping into the discussion of the relationship between the constructs, this section first elaborates on the obtained results for the measurement of *Social cohesion* and *Informal support* and then critically assesses their implications.

**Measurement theory could not identify the common factors of social cohesion.** To begin with, it is relevant to mention how approaching the conceptualisation of *Social cohesion* using measurement theory failed to provide positive results. Appendix B.2 elaborates on the procedure and the possible reasons, but we concluded that no clear factors could be extracted to treat *Social cohesion* as a latent variable. Thereupon, the construct was conceptualised from synthesis theory using PLS-SEM.

**The (lack of) reliability of social cohesion as a single-indicator construct.** In PLS-SEM, Models 1, and 2 reduced *Social cohesion* to *SC3* (% of residents who say that local residents share each other's views) when the objective balance distribution was concave. On the other hand, Model 3 estimated that it can be reduced to *SC5* (% of residents who

[2]Estimations were conducted on a quad-core Intel Core i7-6700HQ @ 2.60GHz with 16GB RAM.

say they feel at home with local residents) when the objective balance distribution was convex. The other indicators were either non-significant or highly collinear with the final measures. The reduction to single-indicator measurements for *Social cohesion* could stem from the fact that aggregate data was used. The use of aggregate data has been widely acknowledged to result in **ecological fallacy**, where relationships that are concluded as true at a level of aggregation, must be true at another level (G. King, 2013). In this case, the fact that aggregate data of the Wijkprofiel survey suggest that *Social cohesion* can be reduced to a single-indicator, does not mean that at an individual level response *Social cohesion* would be characterised in the same way. Assuming that our measure of *Social cohesion* is not a victim of the ecological fallacy, the results may cast doubts on the utility of the scale employed by the Dutch government, or on the data collection process from the Wijkprofiel. Previous research emphasises the multidimensional nature of social cohesion. Tolsma et al. (2009) even states that 'it is imperative that social cohesion is not reduced to one single indicator, let alone that different dimensions are simply aggregated. The overarching concept of social cohesion is not easily reduced to one or two indicators.' (p. 303). Taking this into account, and knowing that other research from Benitez-Avila et al. (2022) also showed that the scale from the Dutch government could be reduced to two indicators using microdata, put into question the validity of the indicators.

5

**Social cohesion in urban settings is mostly based on forms of personal relations governed by relatedness.** *Informal support* was defined as the *% of residents who say they are willing to care for neighbours or friends who need help* (*IS1*). *Informal support* is therefore characterised by strong relationship ties with friends and weak relationship ties with neighbours, without invisible or non-existent ties. Appendix C explored other conceptualisations of *Informal support* to obtain different results.

First, we assessed whether balanced neighbourhoods foster *Informal support* conceptualised as a latent construct from the *% of residents who say they are willing to care for*: (i) *relatives*, (ii) *neighbours or friends*, and (iii) *others in the area*. Results showed that a common factor could only be found between the two first indicators, thus reducing *Informal support* to the strong and weak relationship ties. This is aligned with the research from CBS on help and support, in which they state that the order of family, friends, and finally acquaintances has always been maintained because of the assumption that the relationship with family is stronger than the relationship with friends and the relationship with friends is then stronger than that with acquaintances. The resources are expected to be most accessible through family members, followed by those from friends. Because of the less close ties with acquaintances, resources are the least accessible via this group (CBS, 2012).

To further explore the relationship of balanced neighbourhoods with resilient actions to others, we then conceptualised *Informal support* as a latent construct from the *% of residents who say they are willing to care for*: (i) *neighbours or friends*, and (ii) *others in the area who need help*. Again, a common factor could not be identified, due to the low collinearity between indicators. Following the CBS study on help and support, the tight relationship of Dutch people with strong and weak relationship ties inhibits the relationship with others and thus results in a lower willingness to help them (CBS, 2012).

As a final exploration, *Informal support* was conceptualised as only consisting of *% of residents who say they are willing to care for others in the area who need help.* We found that none of the estimations yielded an acceptable goodness-of-fit. This suggests that invisible and non-existent ties are not a guarantee of resilient action, and that social cohesion in urban settings is mostly based on forms of personal relations governed by relatedness (Felder, 2020).

**Strong and weak ties constitute informal support, but stated choice might not represent revealed preference.** The expert interviews concurred in a caveat of the measurement of informal support. The data provided by the Wijkprofiel measured the willingness to help, i.e. the stated choice of the respondent. Nevertheless, during the COVID-19 pandemic, the revealed support was actually higher than the stated. In the vocabulary of resilience, the measurement of potential action underestimated the measurement of the effective action (Doff, 2017). Veld Academie (2021) shows how in the neighbourhoods of the BoTU programme (Bospolder/Tussendijken), low-income ethnically mixed areas exhibited more helping and caring than the previously stated. On one hand, this shows that it is after the stressor (COVID-19 in this case) when the actual level of informal support can be measured so if only potential action is considered, obstacles to actual action are not taken into account.



Additionally, both interviewees also pointed out that from their experience, qualitative research does not show the same as quantitative, especially in the South. Interviewing residents shows that the level of informal support is higher than the recorded because people are not interested in filling out questionnaires. This is also observed in the research from the CBS on help and support, which also indicated that non-Western immigrants have access to resources somewhat less often through their social network than native Dutch and Western immigrants. Our results are aligned as they show how in the South of Rotterdam, where there is a higher percentage of non-Dutch residents, the willingness to help is generally lower. This outcome is aligned with the idea in resilience literature that that social resilience must see social positions (Copeland et al., 2020).

**Social indicators towards a technocratic city.** The results of the PLS-SEM models showed that the indicators used to measure *Social cohesion* and *Informal support* have a low explanatory power. Even though this is not a problem for our confirmatory deductive approach, it limits the possibility to obtain consistent estimates of relationships between constructs (Henseler, 2020). Consequently, quantitative research that aims to employ these indicators is limited in essence.

Taking a closer look at *Social cohesion*, significant indicators portrayed the feeling of belonging and the mutual tolerance between groups. Neighbourhoods in the South of Rotterdam showed low levels of *Social cohesion*, while they are acknowledged to have more social contacts (Doff, 2022, personal communication). We can also see that measuring *Social cohesion* as the *% of residents who say that local residents share each other's views* yields less negative outcomes in the South than measuring it as the *% of residents who say they feel at home with local residents.* This shows a difference in the consequences of how to measure social cohesion. In the South, people might not feel at home in the neighbourhood, but they feel more connected to the people than to the place.

Second, *Informal support* to friends and family was used as a proxy for resilient actions based on the literature search. Other formulations of social resilience could have been formulated to check the consistency of results. For example, using indicators that reflect effective resilient action instead of potential action. On the other hand, the willingness to help is liable to conflict of multiple interpretations. People have different beliefs, values, and understanding of what is helping someone. As such, policies that rely on the indicator are subjectively loaded given its normative quality.

Indicators for social cohesion and social resilience hardly capture the actions and perceptions within the community. Furthermore, the selection, measurement, and use of indicators are accompanied by a normative leverage (Copeland et al., 2020). In this study, we tried to overcome this issue by contextualising the social indicators within the spatial location and other exogenous factors. Even so, social indicators are subjective to interpretations of individual values, their change over time, and the comparison across places. Therefore, the establishment of predefined indicators, together with the increasing norm of quantitative-based political decision-making due to the vast amount of data available in recent years, show an approach towards the technocratic city.



## 5.3. BALANCED NEIGHBOURHOODS AS AN INSTRUMENT TO ACHIEVE SOCIAL RESILIENCE BY MEANS OF SOCIAL COHESION

The effects of balance on the social cohesion and the resilience of a neighbourhood are widely disputed. While the policy discourse and ample qualitative literature indicate that balanced neighbourhoods improve neighbourhood effects, most quantitative studies show that these claims are unfounded. This research aimed to throw light on the debate by providing additional empirical evidence.

**Balanced neighbourhoods are not in line with the discourse from the municipality. Results show that they are associated with a lower social cohesion and satisfy the homophily principle.** Models 1, and 2 suggested a negative relationship between the level of balance and social cohesion, while Model 3 suggested the opposite.[3] Models 1, and 2 are directly aligned with the homophily principle of Putnam (2000) by which people share the same views when surrounded by those who resemble them, thus social cohesion in mixed neighbourhoods is affected by one's aversion to the alien (Méreiné-Berki et al., 2021). Instead, Model 3 shows a positive relationship between the level of balance and the feeling of being at home with local residents, **apparently** in correspondence with contact hypothesis, by which ties between heterogeneous groups lead to overcoming social differences.

Both interviewees stated that from their field experience, the homophily principle is predominant in Rotterdam. Ouwehand (2022, personal communication) indicated that restructuring neighbourhoods does not contribute to better and integrated relationships between different groups in the neighbourhood. From the beginning of the housing restructuring policy in the Netherlands, urban planners have known that if part

[3]Note that the relationship in Model 3 was non-significant, however, Figure 4.5 shows that other results from the same cluster did have a significant relationship. Therefore, we discuss the implication of such relationship.

of a neighbourhood is demolished and expensive units are built, the high-income newcomers do not mix much with the previous residents. The newcomers visit different amenities, sporting facilities, and schools, thus not contributing to the social cohesion in the neighbourhood. This perspective was corroborated by Doff (2022, personal communication), who stated that demolishing housing destroys social networks and social cohesion. Our cross-sectional study cannot capture these effects that can only be observed with a longitudinal analysis that gathers data on the evolution of the neighbourhood after the incorporation of newcomers.

What about Model 3 in which *Neighbourhood balance* and *Social cohesion* were positively correlated? As mentioned earlier, this result **apparently** contradicts the other models and suggests that a balanced neighbourhood leads to higher social cohesion. This can be explained from the shape of the balance distribution of Model 3. While the other models had a concave shape, Model 3 presented a convex distribution. This means that Models 1, and 2 aimed towards a higher percentage of Low or Middle than Top, while balance in Model 3 minimises the number of Middle housing. This distribution for a balanced neighbourhood — which is considered balanced according to the municipality —, actually aims for a stronger segregation by polarising the housing value. The outcome of the model can then be interpreted as neighbourhoods which are more polarised show a stronger relationship with *Social cohesion* (see Figure 5.3). We can therefore see how Model 3, even though it would seem that it is in line with the contact hypothesis, it actually follows the same logic as the other models. These results are of extreme relevance, as they show how the ambiguity of the definition of balance by the municipality could actually mislead the interpretation of results.

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This study is innovative as it measures balance from the house market value level, and thus cannot be directly compared to results from previous literature. Nevertheless, balance in terms of house value is an intermediate for income, as acknowledged in the Woonvisie (Municipality of Rotterdam, 2016b). Therefore, this perspective can also be identified in previous empirical research that relates income mix to social cohesion. For example, Coffé and Geys (2006) did not find a correlation between income mix and social capital in Flemish neighbourhoods and even indicates that ethnic balance had a negative effect on social capital. Also, Wang and Kemeny (2022) found that mixed income neighbourhoods in China were associated with lower social cohesion.

Fostering housing balance strengthens the average real estate value and socioeconomic status of a neighbourhood, but it does not necessarily improve the situation of the worst off that live or lived in that neighbourhood. As mentioned by Ouwehand (2022, personal communication), the indicators of a neighbourhood improve when attracting higher income families. The amount of residents that are associated with high levels of vulnerability like migrants, the young, the old, and the poor are reduced (D. King & MacGregor, 2000), but they do not obtain the benefits of living with newcomer high income residents. These conclusions can be seen in studies like Tolsma et al. (2009) who suggest social cohesion in Dutch neighbourhoods can be improved by increasing the average income of the neighbourhood. This does not necessarily imply that the social cohesion between income groups improves, but that the measured social cohesion is higher because of the introduction of a new group in a neighbourhood. We can then see how quantitative indicators of social phenomena cannot be fully tested with quantitative re-

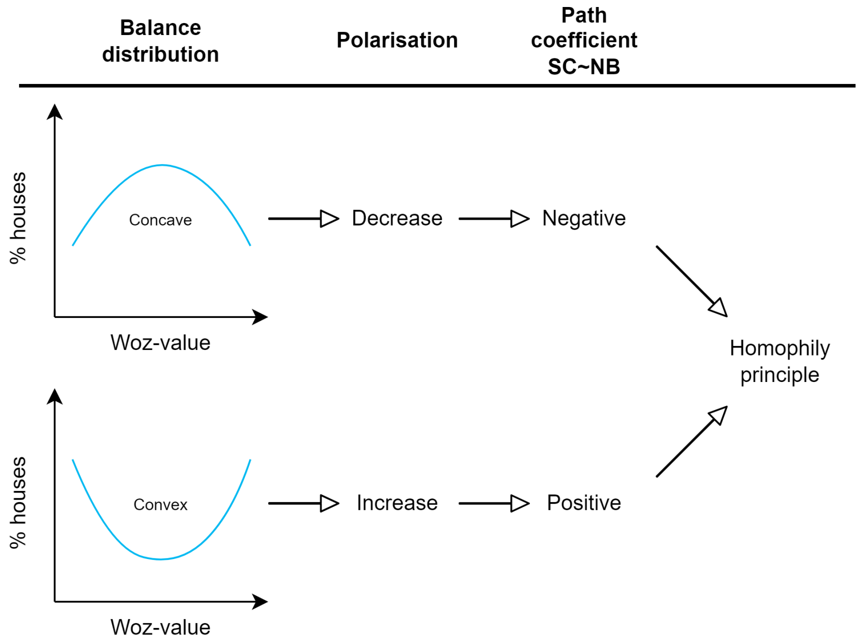


**Figure 5.3:** Concave and convex distributions of balance follow the homophily principle. Concave WOZ-value distributions reduce the polarisation between income groups and have a negative path coefficient between *Neighbourhood balance* and *Social cohesion*. This shows how aiming for a decrease in polarisation decreases social cohesion, thus follows the homophily principle. Convex WOZ-value distributions increase the polarisation between income groups and have positive path coefficients between *Neighbourhood balance* and *Social cohesion*. This shows how aiming for an increase in polarisation increases social cohesion, thus follows the homophily principle.

search designs.

**Social cohesion fully mediates the relationship between balance and informal support.** Moving on to the interpretation of the relationship between *Social cohesion* and *Informal support*, we can see that our results are in line with the expected outcomes. In more cohesive neighbourhoods, residents are more willing to help friends, and neighbours in moments of hardship. Both interviewees also agreed with this outcome. Taking this into account, the relationship between *Neighbourhood balance* and *Informal support* is fully mediated by *Social cohesion*. The inclusion of *Social cohesion* as a mediator variable moves the focus away from whether a physical indicator like the WOZ-value affects the resilient actions and instead toward how the variables are related. This result is interesting as it shows that changing the level of balance of the neighbourhood will not have any direct effects in the willingness to help friends and neighbours. Potential resilience can be increased by other means that increase social cohesion other than the WOZ-value distribution. For example, Doff (2022, personal communication) suggested that within the BoTu programme, positive results in social cohesion and community support have been observed by the development of neighbourhood organisations which provide a space for bonding and bridging (Veld Academie, 2021).

Overall, the results from mediation analysis indicate that balanced neighbourhoods are associated with lower levels of *Social cohesion*, and therefore of *Informal support*. A physical mix in the housing stock value discourages resilient action.[4] These results are in line with previous research in Rotterdam using the Wijkprofiel survey results. Custers (2021) found that mixed neighbourhoods do not foment bridging between social groups, and that even if there exist mixed social networks in a neighbourhood, these are not strong enough to understand the needs of others and share necessary resources in the event of need.

Balanced neighbourhoods have been criticised for reducing the amount of affordable housing in cities and consequently displacing low-income families (UN-OHCHR, 2021). The negative effects are allegedly countered by the benefits that balanced neighbourhoods bring on the social cohesion and the resilience of Rotterdam. Our results show, however, that balanced neighbourhoods are less cohesive and are less willing to help their friends and neighbours. Therefore, the legitimacy of the discourse of the municipality of Rotterdam is contested by our results. Rotterdam wants to create a city for everyone, however, together with the claims of the UN and the movement Right to the City, our results indicate that the housing policies could serve as a gentrification instrument that works towards the polarisation in the city by which the social class is gradually replaced by high-income newcomers to increase the average real state value of neighbourhoods (Custers, 2021; Versluis, 2017).



**The use of Wijkprofiel survey data can lead to biased results if spatial effects are not taken into consideration.** The spatial analysis helped unravel other relevant implications of the study. First, in the analysis each neighbourhood contributes equally to understanding the relationship between the concepts, however, this can result in biased results because this is not proportional to the amount of people that live in the city. For example, Noord Kethel and Schiebroek are industrial neighbourhoods with few residents compared to other locations. Nevertheless, these neighbourhoods are included in the Wijkprofiel and used in the evaluation of urban policies. We saw how these neighbourhoods obtained high scores for *Social cohesion* and *Informal support*. Similarly, the outlying characteristics of the centre of the city also call for caution. The city presents a high level of balance due to the recent building of middle, higher, and top level units (Custers, 2021). In line with the results, *Social cohesion* levels are low in the centre. This is not necessarily attributed to the level of balance, but is specially influenced by the characteristics of the groups that live in the city centre, so results are biased by Type I error. While people in residential areas are usually more attached to the neighbourhood,

[4]The theory of the model is based on the grounds that geographically connected people become affected by the social mix in the area to promote solidarity. As such, it uses the willingness of friends and neighbours to characterise resilient action. Appendix C shows similar results when conceptualising *Informal support* as the common factor of the *% of residents who say they are willing to care for relatives who need help* (*IS3*), and the *% of residents who say they are willing to care for neighbours or friends who need help* (*IS1*). When incorporating relatives, the geographical boundaries are broken and arguably the change at a physical level might not have an effect in the resilient action. We see, however, that the path coefficients have higher absolute values when incorporating strong relationship ties from relatives. The results show an intrinsic capacity of people to be willing to help relatives if the balance is low. This preliminary results motivate future research on the effect of changes at a physical level that could have an impact on the behaviour of the private deterritorialized domain.

residents in the centre are more cosmopolitan and footloose. Therefore, it is relevant to acknowledge the influence of other neighbourhood characteristics in the results and how can that affect the development of policies.

Second, spatial analysis shows the presence of spillover or contagion effects. We observed that the relationship between *Neighbourhood balance* and *Social cohesion* is significantly dependent on the average value of *Social cohesion* of surrounding neighbourhoods. Similarly, the dependence of *Informal support* on *Neighbourhood balance* and *Social cohesion* is also affected by the average *Informal support* value of surrounding neighbourhoods. This confirms that *Social cohesion* and *Informal support* are not administratively bounded, so the interaction between residents of adjacent neighbourhoods can influence the perception and actions of others.[5] As a result, the outcomes of the PLS-SEM model are again biased by Type I error. These results are very context dependent, however, too little research on social cohesion has taken this into consideration (Uitermark et al., 2017). The spatial capabilities in SEM are still very limited, but this research shows the relevance of incorporating spatial dependence to avoid biased results.

Finally, spatial autocorrelation is relevant in this case study due to the geography of Rotterdam. Provided that the city is divided by the Nieuwe Maas river, the difference in interaction between and within river beds is expected to considerably impact social cohesion. Furthermore, the larger concentration of reported problems and supply of low-cost housing is greatest in Rotterdam South (Municipality of Rotterdam, 2016b, 2019b). For that reason, the NPRZ and Woonvisie demolition plans are primarily concentrated on the South side, despite the fact that this is not expressly stated (Versluis, 2017). The main findings reported spatial effects without taking into consideration the river effects, i.e. by assuming that neighbourhoods face to face across the river were direct neighbours. Appendix E shows the same results by considering that neighbourhoods on both sides of the river are not neighbouring and there is no spillover between them. The LISA results show the clear presence of polarisation between both sides of the river in Rotterdam. These results are relevant because if reality corresponds to a strong separation caused by the river (i) improving areas in the centre or North of the city will not have a beneficial spillover effect on the South, and (ii) negative neighbourhood effects in the South do not impact other areas, reinforcing the marginalisation of the South. Future research should deepen into the structure and strength of the interactions across the river.

**Ethnic heterogeneity, and house type heterogeneity are relevant urban factors that require additional examination.** The moderation analysis showed the absence of moderation effects from the identified exogenous factors. However, we found that *Ethnic heterogeneity* and *House type heterogeneity* are the two factors which directly affect the constructs in our model.

The effects of *Ethnic mix* are very disputed in the literature, with proponents of both the contact hypothesis and the homophily principle. In our results, we can see that a

[5] Additionally, we observed no spillover effects of *Informal support* when studying the common factor that included the willingness to help relatives. We argue that this is because the construct is forged by strong ties, therefore informal support is a characteristic that stays within the closest network and does not spill over it.

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high *Ethnic heterogeneity* is associated with lower *Social cohesion*, thus agreeing with the homophily principle. Although *Ethnic heterogeneity* was treated as an exogenous factor as it is not the same as balance in terms of income, they could be confounded as wealthiest neighbourhoods correspond to those of Dutch majority. *House type heterogeneity* was also significant in Model 3, showing a negative direct relationship with *Informal support*. This variable can be interpreted in a very similar way to ethnic or income mix. In neighbourhoods with a high mix of housing types, spatial segregation occurs and therefore follows the homophily principle. Consequently, we argue that future research should elaborate on the theory on which the model is grounded and create coherence to the empirical relationships identified with *Ethnic heterogeneity* and *House type heterogeneity*.



Both direct relationships and moderation effects were found as non-significant for the other built environment factors. For instance, regarding *Greenery*, previous research using the Wijkprofiel data showed how a green living environment offers opportunities for recreation and relaxation and contributes to a sustainable neighbourhood, indirectly contributing to a more resilient neighbourhood (Veld Academie, 2021). The fact that our results were non-significant in contrast to the study from Veld Academie (2021) could be explained by the difference in the indicators. Veld Academie (2021) used personal perceptions like ‘Sufficient use of green space’ to understand its relationship to social cohesion, while we used a physical variable that measures the % of green areas in the neighbourhood. The use of subjective indicators carries the same normative weight previously explained. Survey respondents answer from their perception of what is “sufficient” for a green space. In addition, this relates to the individual characteristics such as intentions and preferences that regulate the perception and experience of urban elements (Kim & Kaplan, 2004; Rogers & Sukolratanametee, 2009; Wood et al., 2010) (see Figure 2.5). As such, not only the % of greenery or % of walkable area are important, but also their urban design and how residents experience it. Appendix F qualitatively explores urban design elements of the North and South of Rotterdam which could have an influence in the social cohesion of the residents. It does not intend to be a rigorous qualitative analysis, but an opening door to neighbourhood specific research to uncover the underlying consequences of these results.

Finally, the interviewees provided two points of attention to the results of the exogenous factors. Ouwehand (2022, personal communication) expected the *Length of residence* to be a significant factor. Previous studies on the liveability in Rotterdam pointed out that liveability is strongly affected by this variable. It is possible that the relationship with liveability is not extended to social cohesion. Studies like Rogers and Sukolratanametee (2009) did not find significant effects between sense of community and length of residence. Further research should study these relationships more in depth. Next, Doff (2022, personal communication) also pointed out that *Amenities* had been observed as significant in previous research in Rotterdam by Veld Academie (2021). After examination of their study, we saw that they define amenities as cultural facilities and religious centres, differing from our conceptualisation of cafés, restaurants, community centres, bars, and pubs. This semantic confusion calls attention to additional issues that arise in the utilisation of resilience indicators. Using the same label for different indicators can be a result of lack of semantic accuracy, i.e. the conformity to its real value, or a lack of mapping consistency, i.e. the uniformity in the keys of values (Y. Huang, 2013). The former puts into question the essence of what are considered amenities, again showing the normative quality of indicator practises. On the other hand, the second would suggest an error in the key used to define the values considered as “amenities”. In any case, this shows potential misleading interpretations of research studies.

# 6

# CONCLUSION

In this final chapter, we present the conclusions that can be drawn from this study. To this end, we first discuss the findings of this study that give an answer to each research sub-question. Next, we translated the insights gained from the study into policy recommendations for municipal governments. Finally, we explicitly state the limitations of the study coupled with future work that could address these limitations. This chapter thereby answers the main research question ***Does neighbourhood balance increase resilient action of neighbourhood residents?***

## 6.1. RESEARCH QUESTIONS

Taking into account the core concepts and gaps detected in the literature, the research was formulated to answer the following sub-questions:

SQ1: *What are the underlying mechanisms that drive balanced neighbourhoods to act more resiliently?*

Literature suggests that social factors govern the resilience of urban areas. Communities in which the residents work together and have common goals have a stronger willingness to cooperate. Scholars generally agree that resilience can only be present if the members in a community are capable of collective action to collect enough resources and have the capacity to mobilise them in the event of a disaster. Given that resilience is not directly measurable, we argue that informal support is a suitable proxy to measure the potential resilience of a neighbourhood, as the end mechanism through which social resilience is achieved is mutual aid.

Mutual aid depends on the level of social cohesion of the community. In cohesive societies, local communities protect residents against threats, care of others during hardships, and ultimately promote community resilience. This is because social cohesion is an involuntary product of the form and quality of shared values, trust, and the relationships among the individuals of a society. The municipality of Rotterdam also maintains this claim, and regards social cohesion as a challenge to address to reach the goal of a resilient city.

Balanced neighbourhoods are considered a policy instrument to achieve a more resilient city by means of social mix. Balanced neighbourhoods mix the population composition in a neighbourhood to allegedly improve the social cohesion of its residents. Large concentrations of segregated groups in specific areas are believed to reinforce and perpetuate poverty and exclusion, and consequently reduce social cohesion. Based on the contact hypothesis, in socially mixed areas, different groups meet and interact with each other, and eventually this reduces hostility toward out-groups. As a result, residents of balanced areas are more cohesive and thus more willing to take resilient actions for subsistence in the event of a catastrophe or to tackle long-lasting problems.

Putting all elements together, the resilience mechanism that we studied is that of social cohesion mediating the relationship between neighbourhood balance and informal support. Social cohesion acts as the mechanism for resilient actions triggered by the balance in a neighbourhood, and mediation analysis explains how the change in balance and resident support occurs by means of social cohesion.

In addition, social cohesion and informal support have been associated to characteristics of the built environment and the demographics. This is based on the idea that urban elements can promote or deter social interactions, and thus are aspects of what can be considered a resilient neighbourhood. As such, the moderating effects of ethnic heterogeneity, residence length, population density, house type heterogeneity, amount of greenery, walkability, and the number of amenities were determined to overcome the supposition that the relationships between neighbourhood balance, social cohesion, and informal support are exactly the same for all neighbourhoods and to identify instances in which the moderating variables change the strength or direction of the relationship between the concepts.



SQ2: *How can the indicators of the mechanisms that drive balanced neighbourhoods to act more resiliently be operationalised?*

From the underlying mechanism, we distinguish three main indicators: the level of balance, the level of social cohesion, and the resilient action.

First, we have seen that, in the case of Rotterdam, balanced neighbourhoods are defined from a set of conditions for the amount of houses in different house price segments. Only specific combinations satisfy the definition of balance. A first analysis pointed out the under-specification of the definition of balance from the municipality of Rotterdam. The possible combinations of housing price segments is broad, and can result in combinations which are counterintuitive to the idea of balance, such as having all middle-class housing or none at all. As a result, the indicator can be misleading. The question arises as to how balanced is a neighbourhood with respect to the possible distributions. The negative of the Kullback-Leibler divergence has been found to be an adequate tool to measure the level of balance of a neighbourhood. Given a target house price distribution, it can determine how far off a neighbourhood is to achieve it. It is a versatile technique which is transferable between contexts, as the target distribution can be adapted accordingly. This provides a two-fold advantage. First, the level of balance can be adjusted to the evolution of housing prices in the same area. Second, it can be adjusted to different aggregation levels or even different areas, as it does not depend on intrinsic characteristics of the measured distributions.

Second, the abstraction and the cross-disciplinary use of social cohesion between social sciences and policymaking have made the measurement of the concept challenging. However, the interest in monitoring the social cohesion of communities has driven scholars to the development of several approaches. In this study, we have discussed and measured social cohesion from the grounds of measurement theory and from the grounds of synthesis theory. Taking the measurement theory approach, we conceptualised social cohesion as a latent construct that causes a number of observed variables and their relationships. Social cohesion as a latent construct emanates from and reveals the structure of empirical data. The results of such approach suggested that no clear factors could be extracted, thus social cohesion could not be treated as latent from the available data. Next, taking the synthesis approach, social cohesion was treated as en emergent variable which acts as a whole instead of being an assembly of parts. As emergent constructs rely as far as possible on the revealed principles of measurement theory, social cohesion was conceptualised using an existing set of five indicators used by Dutch Office of Social and Cultural Planning. The results reduced the set of indicators to a single indicator being the *% of residents who say they feel at home with local residents* or *% of residents who say that local residents share each other's view*. Literature suggests that the overarching concept of social cohesion is not easily reduced to one or two indicators, which raised doubts on the utility and validity of the measurement scale.

Finally, informal support is based on the grounds that geographically connected people become affected by the social mix in the area to promote solidary actions. As such, it was conceptualised as a latent construct of the *% of residents who say they are willing to care for neighbours or friends who need help*. The indicator represented informal support from strong ties with friends and weak ties with neighbours. This indicator can measure potential resilience action, however, actual action is not taken into account and the revealed support can differ from what residents state.

SQ3: *What is the empirical relationship between the indicators that drive balanced neighbourhoods to act more resiliently?*

To begin with, only 2.1% of the possible balance distributions yielded an acceptable goodness-of-fit of our model. This could be indicative that the model needs to be reevaluated, but, in contrast, it could otherwise mean that that social cohesion and informal support cannot be explained by the balance in a neighbourhood and that the policy should be reevaluated. Under this second interpretation, the study has uncovered which are the balance distributions for the city that can actually show the alleged effects of balance.

The possible distributions of a balanced neighbourhood can, on one hand, aim for a polarised neighbourhood with houses on both ends of the low- and high-priced segments, or, on the other hand, gap the bridge and increase the amount of middle-priced housing. The results of the study suggest that balanced neighbourhoods which foment a reduction in polarisation are negatively associated with social cohesion, and that balanced neighbourhoods which foment polarisation are positively associated with social cohesion. This indicates that our results are in line with Putnam's homophily principle, i.e. 'birds of a feather flock together'. This outcome is opposite to the policy discourse of governments in favour of balanced neighbourhoods, including the municipality of Rotterdam, that mixed neighbourhoods foster social cohesion.

Next, the results of the study suggest that the association of social cohesion to informal support is positive. This outcome agrees with the existing literature which points out that socially cohesive communities are more resilient given their willingness to protect residents against threats and care of others during hardships. In this sense, this result is in line with Resilience challenge 1 of the municipality 'Social cohesion and education', by which the resilience of the city can be positively influenced by the social cohesion. Taking this into account, the results of the study suggest that balanced neighbourhoods are not directly associated with informal support, but indirectly related, fully mediated by social cohesion. Our results therefore indicate that mixed neighbourhoods are less cohesive and less willing to help each other. This outcome is in opposition with the policy discourse of the municipality of Rotterdam, that state that a city in balance is a more resilient city.



To increase the explanatory power, the model outcomes were followed by an exploratory spatial analysis. The inspection identified clusters of social cohesion and informal support within the city, visibly geographically divided between North, South, and city centre. This pointed out the relevance of tailored neighbourhood analyses to come up with strong inference. The history, development, and composition of each neighbourhood should be considered. In addition, another potential source of the clusters is the presence of spillover or contagion effects, as identified by spatial regression. This confirms that social cohesion and informal support are not administratively bounded, so the interaction between residents of adjacent neighbourhoods can influence the perception and actions of others.

Finally, the moderating effect of exogenous factors related to the demographics and the built environment of the neighbourhoods was assessed. None of the factors showed moderating effects. However, ethnic heterogeneity and house type heterogeneity were negatively associated to social cohesion and informal support, respectively. Future research should elaborate on the theory on which the model is grounded and create coherence to the empirical relationships identified if actionable policy wants to be developed and implemented.

## 6.2. POLICY ADVICE

The confirmatory analysis conducted in this thesis represents a first step in understanding the mechanism that drives resilient action in balanced neighbourhoods. Hence, the policy advice provided in this section does not feature specific, quantified metrics, but rather point towards a general policy direction given the conclusions drawn.

We found that balanced neighbourhoods are not associated with higher levels of social cohesion, and therefore of resilient action. In fact, the higher the balance, the fewer residents are willing to help their friends and neighbours. Consequently, if the objective is to increase social cohesion and resilient actions, we would discourage the municipality of Rotterdam to approach this by building balanced neighbourhoods. Even so, we have seen the relevance of tailored neighbourhood analyses to come up with strong inference. The history, development, and composition of each neighbourhood should be considered. This has an impact in the characteristics of the population as well as the built environment. As a result, although the research outcomes show that balanced neighbourhoods are not positively associated to their alleged effects, it is hard to attribute the results to the housing policies.

Moving residents around in space to achieve balance may not address many of the underlying reasons for the pathology of deprived areas. Balancing a neighbourhood is a very indirect and lengthy way of getting the resources to residents in the need of help, therefore, the municipality should focus on alternatives to foster resilient actions between residents. In this study, we have seen that building social cohesion is a way to build social resilience, but the question arises whether the excluded (vulnerable) residents really want to be mixed. The movement Recht op de Stad shows that in Rotterdam this mix is imposed, rather than requested (Right to the City, 2022). The movement highlights that the end goal is to have a city for the residents that live there, and not a technocratic city governed by indicators of balance. In light of this, the municipality could favour a bottom-up participatory approach, in which they ask residents what is wrong with the neighbourhood and provide resources directly. In this sense, the BoTu programme is a step forward from the Woonvisie in this regard with the development of neighbourhood organisations which not only provide a space for social cohesion but also to collect and share resources (Municipality of Rotterdam, 2022a). Instead of balancing the neighbourhoods and letting the free market supply the resources to families, the programme provides resources directly.

On a separate note, we also encourage the municipality of Rotterdam to develop a more specific and transparent definition of neighbourhood balance if they were to continue with the policy. The ranges of the conditions could be neighbourhood specific to openly show what is the target that the municipality wants to achieve in each neighbourhood. This would allow for a more detailed analysis on the effects of the policy on the resilience of the city as well as prevent possible misinterpretations.

## 6.3. LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

The research approach showed the strong capabilities of the computational framework to perform this study. It specified multidimensional constructs; direct, mediating, and moderating effects between variables; and considered spatial phenomena. Even so, we acknowledge a series of limitations and show how we mitigated them or how future research could approach them.

1. **Validity of results:** Testing cause and effect relationships requires an assessment of the validity of the outcomes to conclude we have evidence of causality (Barth et al., 2011). Validity can be divided into the following categories (Hox, 2017): internal

validity, external validity, and construct validity.

(a) **Internal validity:** refers to the 'degree to which a study or experiment is free from flaws in its internal structure and its results can therefore be taken to represent the true nature of the phenomenon' (Guha, 2017). Internal validity was guaranteed at a theory level and at a statistical level (Marczyk et al., 2005). First, a literature review which combined academic and policy literature laid the grounds for the theory to test to provide a theoretical validity support. The internal validity of the results was also validated in the discussion of principal findings by comparing the results to alternative methods in the field and to previous studies (Barth et al., 2011). In addition, two interviews were conducted to two experts for additional consultation (Barth et al., 2011). Second, statistical validity was guaranteed by the PLS-SEM goodness-of-fit indicators. Internal validity is threatened by the omitted variable bias or the spatial autocorrelation bias, explained below in the 'PLS-SEM' item.

(b) **External validity:** refers to 'the extent to which the results of research or testing can be generalized beyond the sample that generated the results to other individuals or situations' (Guha, 2017). This is concerned with how generalizable the findings are. For instance, do the findings apply to other cities? Replication would be the best way of guaranteeing external validity, however, due to time constraints, the framework was not applied to other contexts (Marczyk et al., 2005). According to Doff (2022, personal communication), the concepts studied here are very general sociological patterns, so they should not be context dependent on the city itself and can be generalised. Nevertheless, future research may address this limitation by replicating the computational framework to other areas.

(c) **Construct validity:** refers to 'the degree to which a test or instrument is capable of measuring a theoretical construct, trait, or ability' (Guha, 2017). In our research, *Social cohesion* and *Informal support* were measured using previously validated psychometric scales used by the Dutch government (Schnabel et al., 2008). The PLS-SEM statistical tests also guaranteed the convergence validity, explanatory power, and predictive accuracy of the constructs. Even so, we recommend that future research re-validates the psychometric scales in the Wijkprofiel, as our results cast doubts on their validity.

2. **Data**: This research heavily relied on the availability of public data. On this account, the following assumptions and limitations were identified:

(a) **Willingness to help friends is confounded with willingness to help neighbours:** The theory of the model is based on the grounds that geographically connected people become affected by the social mix in the area to promote solidarity. Nevertheless, to measure informal support, it uses the indicator *% of residents who say they are willing to care for neighbours or friends who need help* (*IS1*). This indicator combines neighbours, who are geographically connected to the survey respondent, and friends, who are not necessarily geographically connected. Therefore, the assumption that social mix is the mechanism that triggers neighbours to cooperate does not need to be the same as the one that triggers friends to help each other, as friendly relationships are driven by mutual affection (Felder, 2020). We recommend the Wijkprofiel researchers to separate willingness to help friends and neighbours into two questions in future surveys.

(b) **Neighbourhood aggregation:** The Wijkprofiel data for the neighbourhood of Groot IJsselmonde had to be aggregated from Groot IJsselmonde North and Groot IJsselmonde South. For this, the weighted average using the number of respondents was used. Nevertheless, some respondents may have not answered, biasing the estimation. Future research should correct for the actual number of respondents if microdata is available.

(c) **WOZ-value aggregation:** The Social, Middle, Higher, and Top WOZ-value brackets had to be adapted to the available data by OBI. Given the narrow width of the Middle segment (just €50,000), this could bias the estimation results. Future research should procure more precise WOZ-value segments.

(d) **Ecological fallacy:** Relationships that are regarded as true at a level of aggregation, may not be true at another level (G. King, 2013). The fact that aggregate data of the Wijkprofiel survey yields the present results does not mean that at an individual level the relationships would follow the same way. Thus, the aggregate relationship could go in the opposite direction to the individual relationship. Future research should consider multilevel regression to combine different levels of aggregation to increase the validity of the results. So far, the multilevel capabilities of structural equation modelling are limited, so developments on the methodological level are limiting (Rabe-Hesketh et al., 2007). Furthermore, we also suggest that the relationships are not just studied at administrative levels of aggregation. Social cohesion and social resilience are phenomena that cross administrative boundaries, so future research could incorporate network analysis as a different aggregation mechanism.

(e) **Selection bias:** This study relies on the validity of the Wijkprofiel survey. Nevertheless, Doff (2022, personal communication) suggested that residents from the South of Rotterdam are less keen than residents in the North to fill in surveys. Consequently, the possibility that failure to accomplish correct randomization that is representative of the population arises. We rely on the expertise of the researchers in OBI that conducted the Wijkprofiel survey to guarantee the mitigation of this bias.

3. **PLS-SEM**: The principal relationships for this study were obtained by means of PLS-SEM. Even though it proved to be a complete methodology to satisfy the many requirements of the analysis, some limitations were present.

(a) **Spatial autocorrelation bias:** PLS-SEM does not consider the spatial characteristics of the data. From the results of the spatial analysis, we have seen that there is presence of spatial spillover, so the outcomes of the structural model are biased. This involves the calculation of the relationships between constructs as well as the measurement of the constructs themselves. Effort has already been put into incorporating spatial autoregression within SEM, however, it is at its early stages and not available in popular packages.

(b) **Omitted variable bias:** Our model showed a good fit, which guarantees internal validity and the existence of the studied relationships. Nevertheless, the results from moderation analysis showed that *Ethnic heterogeneity*, and *House type heterogeneity* have significant direct effects on *Social cohesion* and *Informal support*, respectively. Consequently, future research should elaborate on the theory on which the model is grounded and create coherence to the empirical relationships identified with *Ethnic heterogeneity* and *House type heterogeneity*.

(c) **Single-indicator latent variable:** Given that only one indicator was used for the measurement of *Informal support*, it is not possible to determine the amount of random measurement error in the indicator based on the available data (Henseler, 2020). Literature recommends that, in these cases, an additional error is imposed from the modeller (Brown, 2015), however, the package cSEM does not have that feature yet. We recommend that the study is replicated when the capability is incorporated.

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4. **Spatial analysis:** The main purpose of the spatial analysis in this research was to search for the presence of local or spillover effects that could increase the explanatory power of the outcomes. First, the outcomes of the analysis are limited given the proposed weight matrix (see Equation (3.8)). Future research could change the structure of the weight matrix to incorporate a decay effect as distance increases. Furthermore, the effects of the river that divides Rotterdam were considered superficially. Future research should deepen into the structure and strength of the social interactions between both sides of the river by means of space syntax or network theory (van Nes & Yamu, 2021). Social processes arise from social interaction, and space syntax and network theory would allow quantifying and describing the places of interaction. Second, spatial spillover or contagion effects can be further tested with more complex spatial models that can capture non-stationarity. Future research could, for instance, use geographically weighted regression to increase the accuracy of the results (Ewing & Park, 2020).

5. **Computational power:** In this study, the models were estimated using the same objective WOZ-value distribution for each neighbourhood due to the computational power limitation. The computational framework could be adapted to calculate all the combinations of every balance distribution for each neighbourhood to select which balance explains better the relationships in each neighbourhood. This would provide specific insights for the building programme for each neighbourhood, as well as a more concrete measure for each.

6. **High abstraction:** The research has analysed the relationships of moderating factors at a high level of abstraction, i.e. low level of detail. As we have seen in the literature review, urban factors like walkability and greenery have been found to be significant in previous research. However, our study has only considered these

indicators at a high level of abstraction to capture the effect of these variables on the social cohesion and the willingness to help (e.g. greenery as percentage of green area in the neighbourhood and walkability as percentage of walkable area). Future research should take into account the design elements of the urban environment that could play a role in the actions and perceptions of residents (Rogers & Sukolratanametee, 2009; Wood et al., 2010). A first step has been shown in Appendix F which hopefully opens the door to future research. In addition, we have seen that each neighbourhood could have a different goal that achieves balance in relation to the population and history in the neighbourhood. Consequently, future research should tailor the analysis to the characteristics of every neighbourhood. The BoTu programme is a good start from the hand of the municipality of Rotterdam.

7. **Deductive approach for causal inference:** Following the deductive research approach, we first elaborated a theory based on the literature, and then we tested whether the theory holds according to the data. The model represents the causal assumptions stated by the researcher, and the credibility of these assumptions depends on their theoretical foundations. The robustness of the causal inference is based on the validity of the theory. Finally, what the results show is whether the data rejects the null hypothesis. To increase the validity, this thesis developed a literature-grounded conceptualisation, validated the results with previous research, and with expert interviews. To increase the reliability of the causal inference, future research should perform a longitudinal study of the modelled relationships (Spector, 2019). Longitudinal studies are preferred to determine the direction of causal relationships due to their ability to detect changes in the population. Furthermore, future research could conduct an impact evaluation to infer causality to a larger extent. Parallel trends is an example of impact evaluation analysis that could be useful (Angrist & Pischke, 2014). It can compare neighbourhoods in which the balance has not been changed, to assess if treated neighbourhoods have seen an improvement in resilience in comparison.

   In addition, cross-sectional studies limit causal inferences because of the possibility of residual confounding and the inability to take into account the neighbourhood self-selection (Cobb et al., 2015). This brings to the next well known causal inference problem in neighbourhood studies: **Self-selection bias** (not to confuse with the previously mentioned selection bias). This bias suggests that the statistical model outcomes cannot determine whether the neighbourhood characteristics are the cause or the effect, i.e. if the characteristics are caused by a certain effect or if a certain effect is caused by the characteristics of the neighbourhood (Custers, 2021; Manley et al., 2011; van Ham & Manley, 2012). In the case of resilience, the problem is whether the neighbourhood favours resilient responses to problems, or people who have resilient capabilities are often able to concentrate in some areas of the city (usually brought by their income). Put simply, people self-select themselves into neighbourhoods and the selection mechanism explains the associations on the neighbourhood level (Manley et al., 2011). The same recommendations of longitudinal studies or impact evaluation can reduce this bias.

In conclusion, using Rotterdam as a case study, we have seen that balanced neighbourhoods do not foster resilient action between friends and neighbours. Consequently, we discourage the municipality to employ balanced neighbourhoods as policies to increase the social resilience of the city. However, we have also listed a series of limitations of the study which future research should overcome to provide finer conclusions and recommendations.

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# A

# Appendix A

## A.1. Definitions of social cohesion

**Table A.1:** Definitions of social cohesion in the academic literature.

| Source | Definition of social cohesion |
|---|---|
| Chan et al. (2006) | Social cohesion is a state of affairs concerning both the vertical and the horizontal interactions among members of society as characterized by a set of attitudes and norms that includes trust, a sense of belonging and the willingness to participate and help, as well as their behavioural manifestations. |
| Maxwell (1996) | Social cohesion involves building shared values and communities of interpretation, reducing disparities in wealth and income, and generally enabling people to have a sense that they are engaged in a common enterprise, facing shared challenges, and that they are members of the same community |
| Kearns and Forrest (2000) | A society in which the members share common values which enable them to identify common aims and objectives, and share a common set of moral principles and codes of behaviour through which to conduct their relations with one another |

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A

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| Source | Definition of social cohesion |
|---|---|
| Beauvais and Jenson (2002) (as cited in Fonseca et al., 2019) | On-going process, with known group structures, levels of solidarity and shared values between individuals, and with mechanisms to solve conflict, while arguing that it is comprised of five different dimensions (belonging, inclusion, participation, recognition, and legitimacy). |
| Fonseca et al. (2019) | The ongoing process of developing well-being, sense of belonging, and voluntary social participation of the members of society, while developing communities that tolerate and promote a multiplicity of values and cultures, and granting at the same time equal rights and opportunities in society. |
| Schiefer and van der Noll (2017) | A descriptive, multifaceted and gradual phenomenon attributed to a collective, indicating the quality of collective togetherness. |
| Schmeets (2012) | Cooperative relations among individuals and groups of individuals that are based on mutual recognition, equality and norms of reciprocity. |

**Table A.2:** Definitions of social cohesion in the policy discourse.

| Source | Definition of social cohesion |
|---|---|
| OECD (2011) | A cohesive society works towards the well-being of all its members, fights exclusion and marginalization, creates a sense of belonging, promotes trust, and offers its members the opportunity of upward mobility. |
| Council of Europe (2010) | The capacity of a society to ensure the well-being of all its members – minimising disparities and avoiding marginalisation – to manage differences and divisions and ensure the means of achieving welfare for all members. |

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| **Source** | **Definition of social cohesion** |
|---|---|
| European Commission (2001) | The degree to which individuals and groups within a particular society are bound by common feelings of consensus, share common values and goals and relate to one another on a co-operative basis. |
| Australian Institute of Health and Welfare (2021) | People's perception of whether most people can be trusted, are fair and most of the time try to be helpful. |
| Statistics Netherlands (CBS, 2015) | The extent to which people: establish ties or networks with each other and provide each other with help and support; participate in social organizations, such as being a member of associations and organizations and work as a volunteer; and participate in political activities. |
| Dutch Office of Social and Cultural Planning (Schnabel et al., 2008) | The extent to which people express in behaviour and perception their involvement in social connections in their personal lives, as citizens in society and as members of society. |
| International and Ibero-American Foundation for Administration and Public Policies (2011) | An attribute of societies which implies equality of opportunity so that people can exercise their fundamental rights and ensure their welfare, without discrimination of any kind and in response to diversity. From an individual perspective, it assumes the existence of people who feel part of a community, participate in decision-making areas and can exercise active citizenship. It also involves the development of public policies and mechanisms of solidarity between individuals, groups, territories and generations. |

# B

# Appendix B

## B.1. Wijkprofiel data

The municipality of Rotterdam makes publicly available the aggregated responses of the Wijkprofiel survey. In this appendix, we will explain the methodology of the Wijkprofiel to aggregate the individual responses into the indicators used in this study (described in Table 3.1).

First, respondents are asked to respond to 5-point Likert scales in the Wijkprofiel survey. Table B.1 shows the questions for the corresponding indicators used in this study. Then, the Wijkprofiel researchers use the percentage that answered the statement positively for the aggregation. Let's take one indicator from *Social cohesion* and another from *Informal support* as examples. Starting with *People in this neighbourhood hardly know each other* (*SC1*), the percentage that answered positively are indexed as follows:

1. if range(1, 6) | $SC1 = 0 \rightarrow$ all respondents that answered get 0.
2. if range(4, 5) | $SC1 = 1 \rightarrow$ respondents who (totally) disagree get 1.

If the question is formulated in the opposite direction like it is the case of *I live in a nice neighbourhood, where people socialise a lot* (*SC2*), then the indexing is done in the opposite direction:

1. if range(1, 6) | $SC2 = 0 \rightarrow$ all respondents that answered get 0.
2. if range(1, 2) | $SC2 = 1 \rightarrow$ respondents who (totally) agree get 1.

In the case of the indicators for *Informal support*, like *To what extent are you willing to take care of neighbours or friends who need help?* (*IS1*), the indexing is done as follows:

1. if range(1, 6) | $IS1 = 0 \rightarrow$ all respondents that answered get 0.
2. if range(1, 2) | $IS1 = 1 \rightarrow$ respondents who (already) do get 1.

The (weighted) percentage of respondents with value 1 is then the value presented on the aggregated data set.

B

**Table B.1:** Questions in the Wijkprofiel survey associated to the indicators used in the study for each construct.

| | |
|---|---|
| **Social cohesion (SC)** | |
| Each item ranked as (1.) Totally disagree, (2.) Disagree, (3.) Nor agree or disagree, (4.) Agree, (5.) Totally agree, and (6.) Don't know / no opinion. | |
| SC1 | People in this neighbourhood hardly know each other. |
| SC2 | I live in a nice neighbourhood, where people socialise a lot. |
| SC3 | The residents in this neighbourhood have the same opinions about what can and cannot be done in the neighbourhood. |
| SC4 | People in this neighbourhood help each other when needed. |
| SC5 | I feel at home with the people who live in this neighbourhood. |
| **Informal support ((IS))** | |
| Each item ranked as (1.) I already do, (2.) Definitely do, (3.) Maybe, (4.) Maybe not, (5.) Not applicable, and (6.) Don't know / no opinion. | |
| IS1 | To what extent are you willing to take care of neighbours or friends who need help? |
| IS2 | To what extent are you willing to take care of others in your environment you do not know very well and who need help? |
| IS3 | To what extent are you willing to take care of relatives in need of help who do not live with you? |

## B.2. EXPLORATORY FACTOR ANALYSIS

The results of the literature review pointed out that social cohesion is a multi-dimensional concept that can be formed either by means of measurement theory or by synthesis theory. In the study, we conceptualise *Social cohesion* as an emergent variable grounded in synthesis theory. This is because we take a pragmatic strategy of conceiving of these unobservable variables in terms of what is already familiar and well understood. The indicators employed are forged concepts that rely on the revealed principles of measurement theory. Nevertheless, we also explored the possibility of conceptualising social cohesion from measurement theory.

In the measurement theory approach, the theoretical concept comes first, and then it is connected to empirical data. The theoretical concept causes a number of observed variables and their relationships, and the aim is revealing the structure of empirical data. This means that we need to use specific methodologies that can capture the common factor of the underlying dimensions. Exploratory Factor Analysis (EFA), is a technique based on the concept that unobserved constructs underlie the **variation** of observed variables. This technique has been previously used to measure social cohesion as it is the case in Schiefer et al. (2012) and Dragolov et al. (2013), or social resilience as in Larimian et al. (2020).

EFA assumes that the correlation between observed variables is due to latent variables. This correlation is explained by the covariance between the observed variables. In this sense, EFA is a multivariate statistical method that captures the covariance between variables to account for the correlations among observed measurements. For further details on the mechanism of EFA we refer the readers to the extensive literature on the topic (see, for example, Watkins (2021)).

In our intent to use EFA to measure social cohesion, we based the indicators on CBS (2015), the Dutch framework that uses measurement theory using the indicators in Figure 2.4. We combined this with the insights from Schiefer and van der Noll (2017), especially because they differentiate between factors of social cohesion and consequences of it. Table B.2 shows the selected indicators from the Wijkprofiel next to their corresponding dimension, which represents the associated latent construct.

In the following paragraphs, we will explain the steps taken to guarantee the validity of the EFA results, as explained in Watkins (2021). First, EFA assumes that a **linear relationship** exists between the variables. This relationship was explored by means of scatter plots. Variables which did not follow a linear relationship were excluded. Next, B

**Table B.2:** Indicators and their corresponding dimensions for EFA.

| Dimension | Indicator |
|---|---|
| Social networks | % of residents who often take the initiative to contact people |
| | % of residents who say they do not feel abandoned |
| | % of residents who say that local residents know each other[a] |
| | % of residents with weekly family contacts |
| | % of residents with weekly friends contacts |
| | % of residents with weekly neighbor contacts |
| | % of residents with weekly contacts with other neighbours |
| Socio-cultural participation | % of residents who say they are satisfied with their own participation |
| | % of residents who visit ideological or religious gatherings every month |
| | % of residents who visit cultural facilities every month |
| | % of residents who visit a hobby club or association every month |
| | % of households that do not use social facilities (WMO, Participation Act, Youth Act) |
| | % of residents who are actively involved in the neighbourhood |
| | % of residents who have been involved in making plans for a neighborhood or city |
| Trust | % of residents who say they trust government organizations |
| | % of residents who say they have confidence in authorities and care providers |
| | % of residents who say they have confidence in area government |
| | % of residents who say they expect progress from the city |
| | % of residents who say they have confidence in municipal authorities |
| | % of residents who say they have confidence in the future of the city |
| Mutual tolerance | % of residents who say that local residents share each other's views |
| | % of residents who say that young and old get along well in the neighbourhood |
| | % of residents who say they do not experience discrimination in and outside their own neighbourhood |
| | % of residents who say that interaction between ethnic groups in the neighborhood is good[b] |
| Attachment | % of residents who say they feel at home with local residents[a] |
| | % of residents who say they are proud of the neighbourhood[a] |
| | % of residents that say they like the neighborhood[a] |
| | % of residents who say they feel connected to the city[c] |
| Responsibility for common good | % of residents who say they feel responsible for their neighbourhood |
| | % of residents who are active as volunteers |
| | % of residents who have been involved in making plans for a neighbourhood or city |
| | % of residents that are active in a residents' initiatives |
| Compliance of order | Score for perceived victim probability in own neighbourhood |
| | Score for perceived chance of victimization in the neighborhood of someone else in the household[a] |
| | Score for avoidance behavior[a] |

[a] Item dropped due to correlation larger than 0.8
[b] Item dropped due to non-linearity
[c] Item dropped due to deviation from normality

**multicollinearity** should be avoided between indicators. Variables with a correlation above 0.8 not acceptable and were excluded. The removal of one item from the highly correlated pairs is based on a qualitative analysis of the items. The likelihood of a multicollinearity problem can be checked by calculating the determinant of the correlation matrix. Multicollinearity is not a problem if the determinant is greater than 0.00001. In our case, the determinant yielded a value of 1.72E-13, which could potentially result in a non-invertible correlation matrix. However, the high correlation between indicators might be due to a strong general factor between all the variables (Gorsuch, 1990), which would be social cohesion in our case. The KMO measure is another way of determining if the correlation matrix is invertible. The KMO value of our data was above the recommended 0.7 threshold, so we increase our confidence that multicollinearity might not be that much of an issue. A second appraisal of the suitability of the correlation matrix is Bartlett's test of sphericity, which 'tests the null hypothesis that the original correlation matrix is an identity matrix.' (Field, 2013). The test was significant, which strengthens the idea that there are no strong correlations between variables.

The next step in EFA is to analyse **outliers** and deviation from **normality**. EFA assumes that there is an underlying normal distribution within and between variables. Moderately skewed distributions are acceptable, and as a rule of thumb, skewness above 2 and kurtosis above 7 indicate deviation from normality. Variables which had skewness and kurtosis above the stated values were excluded. In the case of normality between variables, i.e. multivariate normality, the same rule of thumb applies. By means of Mardia's multivariate normality test, we found out that our data had a kurtosis of 786 with $p<0.001$ and a skewness of 382 with the same p-value. Data in the social sciences are rarely multivariate normally distributed, but this suggests that in our data there is a strong deviation which can affect the results of EFA. The effects of normality deviation strongly depend on the estimation technique used. For example, Maximum Likelihood is strongly affected. Literature suggests that Principal Axis Factoring is the least affected estimation method, so in light of the results of Mardia's test, we will use it in the estimation of our EFA model.

The next step in EFA, is to determine the **number of underlying factors** in our data. We used three different techniques to validate the appropriate number. First, parallel analysis revealed 4 factors as appropriate. Second, the minimum average partial method suggested 5 or 4 factors. The third method is the subjective analysis of the scree plot, which suggested that 4 was the right number of factors.

Before extracting the common factors, the **rotation method** has to be selected. The rotation determines how the variance across factors is distributed. This is analogous to taking a picture from different angles; the object does not change, but the quality of the picture does. On one hand, Ministry for Housing and the Civil Service of the Netherlands (2017) indicates that oblique rotation recognises the high correlation between variables in the social sciences. On the other hand, Schmeets (2012) indicates that orthogonal rotation that has the restriction that the factors cannot be correlated captures better social science variables. For example, people who have frequent contact with family members do not necessarily interact a lot with friends. Consequently, we explored the varimax rotation within the orthogonal rotations and the promax rotation within the oblique rotations, as recommended by Watkins (2021).

**Table B.3:** EFA results using varimax rotation.

| Factor | Indicator | Loading | Corresponding dimension |
|---|---|---|---|
| 1 | % of residents who say they do not feel abandoned | 0.809 | Social networks |
| | % of households that do not use social facilities (WMO, Participation Act, Youth Act) | 0.809 | Socio-cultural participation |
| | Score for perceived victim probability in own neighbourhood | 0.770 | Compliance of order |
| | % of residents who visit ideological or religious gatherings every month | 0.763 | Socio-cultural participation |
| | % residents who say they do not experience discrimination in and outside their own neighbourhood | 0.740 | Mutual tolerance |
| 2 | % of residents who say they have confidence in municipal authorities | 0.754 | Trust |
| | % of residents who say they are satisfied with their own participation | 0.704 | Socio-cultural participation |
| | % of residents who say they trust government organizations | 0.657 | Trust |
| | % of residents who say they have confidence in area government | 0.639 | Trust |
| 3 | % of residents who often take the initiative to contact people | 0.831 | Social networks |
| | % of residents with weekly neighbor contacts | 0.814 | Social networks |
| | % of residents who say they expect progress from the city | 0.731 | Trust |
| | % of residents with weekly contacts with other neighbours | 0.703 | Social networks |
| 4 | % of residents who are actively involved in the neighbourhood | 0.786 | Socio-cultural participation |
| | % of residents that are active in a residents' initiative | 0.776 | Socio-cultural participation |
| | % of residents who are active as volunteers | 0.731 | Responsibility for common good |

**Table B.4:** EFA results using promax rotation.

| Factor | Indicator | Loading | Corresponding dimension |
|---|---|---|---|
| 1 | % of households that do not use social facilities (WMO, Participation Act, Youth Act) | 0.928 | Socio-cultural participation |
| | % of residents who visit ideological or religious gatherings every month | 0.916 | Socio-cultural participation |
| | % of residents who say they do not feel abandoned | 0.833 | Social networks |
| | % of residents who visit cultural facilities every month | 0.775 | Socio-cultural participation |
| | % residents who say they do not experience discrimination in and outside their own neighbourhood | 0.769 | Mutual tolerance |
| | Score for perceived victim probability in own neighbourhood | 0.762 | Compliance of order |
| 2 | % of residents who say they are satisfied with their own participation | 0.871 | Socio-cultural participation |
| | % of residents who say they have confidence in municipal authorities | 0.823 | Trust |
| | % of residents who say they have confidence in area government | 0.725 | Trust |
| | % of residents who say they trust government organizations | 0.646 | Trust |
| 3 | % of residents who often take the initiative to contact people | 0.902 | Social networks |
| | % of residents with weekly neighbor contacts | 0.833 | Social networks |
| | % of residents who say they expect progress from the city | 0.709 | Trust |
| | % of residents with weekly contacts with other neighbours | 0.644 | Social networks |
| 4 | % of residents that are active in a residents' initiative | 0.851 | Socio-cultural participation |
| | % of residents who are actively involved in the neighbourhood | 0.824 | Socio-cultural participation |
| | % of residents who have been involved in making plans for a neighborhood or city | 0.730 | Responsibility for common good |
| | % of residents who are active as volunteers | 0.726 | Responsibility for common good |

Finally, the **factor loading threshold** should be chosen before extraction. After exploring our data, we have seen that multivariate normality is not met, and that there is still presence of multicollinearity between variables. Therefore, we decided to pick a more strict threshold that satisfies significance to 99% CI, such that

$$\text{Threshold} = \frac{5.152}{\sqrt{N-2}}$$

with 70 neighbourhoods in the Wijkprofiel, this yields a threshold for the factor loadings of 0.62.

With all this, the extraction results for varimax rotation can be seen in Table B.3 and results for promax rotation in Table B.4. The extraction was done using the software SPSS by IBM (IBM Corp., 2020). The end goal in EFA is to find the common factors between a set of variables. We can see that the **factors are entangled and are not clearly identifiable**. This means that EFA was not successful in extracting clear common factors for any of the rotations. This can be the result of different reasons. First, the presence of high multicollinearity even after the screening of variables can confound the meaning of the extracted factors. Most trust indicators were highly collinear with the other indicators. This suggests the possibility that trust is also a consequence of the other factors. Second, the little amount of data also plays a large role in the final outcome. We have 70 data points, and the minimum recommended is of 10 points per factor indicator. Third, after the screening, some dimensions had missing indicators, which can confound the meaning of the factors. Finally, defining social cohesion from measurement theory is tricky as it is a catch-all concept hard to translate.

Overall, the results from EFA were not satisfactory as no clearly identifiable factors were extracted. Consequently, we argue that for this study, synthesis theory is a better way to conceptualise social cohesion.

# C

# APPENDIX C

The aim of the study was to assess the capabilities of balanced neighbourhoods to promote resilient actions between neighbourhood residents. As such, *Informal support* was defined as the willingness to help of friends and neighbours. In addition to this indicator, Table C.1 shows two other indicators the Wijkprofiel provides under the section for care giving. To explore the effects in the results of employing the other indicators, this chapter shows the results of applying the same model to different conceptualisations of informal support.

## C.1. INFORMAL SUPPORT AS THE COMMON FACTOR BETWEEN WILLINGNESS TO HELP FRIENDS AND NEIGHBOURS, AND TO HELP OTHERS

*Informal support* was conceptualised and estimated as a latent construct from the *% of residents who say they are willing to care for neighbours or friends who need help* (*IS1*) and the *% of residents who say they are willing to care for others in the area who need help* (*IS2*). This conceptualisation is of interest as it expands the definition of the main results to include support to invisible or non-existent ties. As such, it can assess whether balanced neighbourhoods foster informal support in the different social spheres. The PLS-SEM algorithm could not find a common factor between the two indicators, as they are not correlated ($r^2 = 2.1 \times 10^{-5}$).

**Table C.1:** Characteristics of the indicators for care giving in the Wijkprofiel in 2019. **N** indicates the number of neighbourhoods included in the Wijkprofiel. Source: OBI.

| **Constructs and indicators** | | **N** | **Min/Max** | **Mean** | **s.d.** |
|---|---|---|---|---|---|
| *Informal support* | | | | | |
| IS1 | % of residents who say they are willing to care for neighbors or friends who need help | 70 | 45/71 | 57 | 6 |
| IS2 | % of residents who say they are willing to care for others in the area who need help | 70 | 9/36 | 22 | 4 |
| IS3 | % of residents who say they are willing to care for relatives who need help | 70 | 55/82 | 69 | 5 |

C

## C.2. INFORMAL SUPPORT AS WILLINGNESS TO HELP OTHERS

*Informal support* was conceptualised and estimated only as the *% of residents who say they are willing to care for others in the area who need help* (*IS2*). This conceptualisation differs from the one in the main results as it does not take into account forms of support to strong or weak ties, but it is still of relevance to find out whether balanced neighbourhoods foster support only between invisible or non-existent ties. However, the PLS-SEM algorithm did not yield any model with an acceptable fit (SRMR<0.08) for any distribution of balance.

## C.3. INFORMAL SUPPORT AS THE COMMON FACTOR BETWEEN WILLINGNESS TO HELP RELATIVES, FRIENDS AND NEIGHBOURS, AND OTHERS

The theory of this study argues that a change towards balanced neighbourhoods can trigger resilient actions between the residents of that neighbourhood. This theory is based on the grounds that geographically connected people become affected by the social mix in the area to promote solidarity. As such, the mechanism that drives help to relatives is other than the balance of a neighbourhood. Nevertheless, an existing effect could indicate that geographically bounded effects like neighbourhood balance can promote geographically unbounded actions like willingness to help relatives.

With this premise, *Informal support* was conceptualised and estimated as the common factor of the *% of residents who say they are willing to care for neighbours or friends who need help* (*IS1*), the *% of residents who say they are willing to care for others in the area who need help* (*IS2*), and the *% of residents who say they are willing to care for relatives who need help* (*IS3*). This conceptualisation differs from the one in the main results as it takes into account all forms of support that are available in the Wijkprofiel, strong, weak ties, and invisible or non-existent ties.

Out of 3,162 models — the total number of possible integer configurations for the distribution of balance—, 127 (≈ 4%) met the SRMR<0.08 criterion (see Figure C.1). In this case, the elbow method recommended 4 different clusters (Figure C.2).

### C.3.1. PLS-SEM MODEL RESULTS

The same procedure as in the main results was applied, so outcomes are simplified in the appendix.

#### MODEL GOODNESS-OF-FIT

All the models meet the 99% confidence interval (CI) quantile criteria for all the goodness-of-fit measures (see Table C.2).

#### REFLECTIVE MEASUREMENT MODEL

Examining the internal consistency reliability is the first step in evaluating a reflective measurement model. For that, Dijkstra-Henseler's rho, $\rho_A$, should lie between 0.70 and 0.95 to guarantee a good level of internal consistency that avoids indicator redundancy

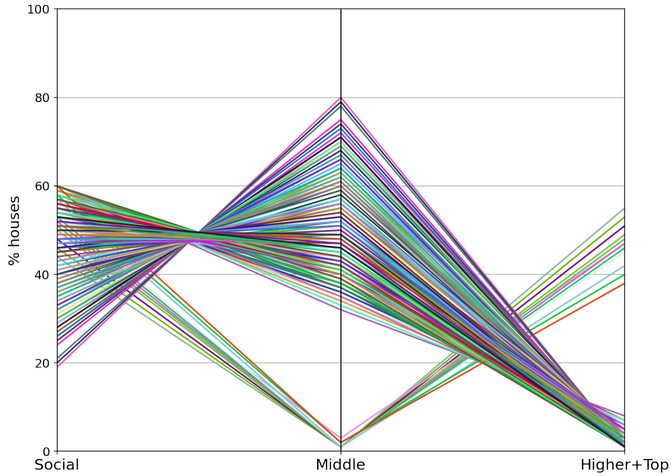



**Figure C.1:** House stock distributions within the balance definition of Rotterdam that have an acceptable goodness-of-fit (≈ 4%).

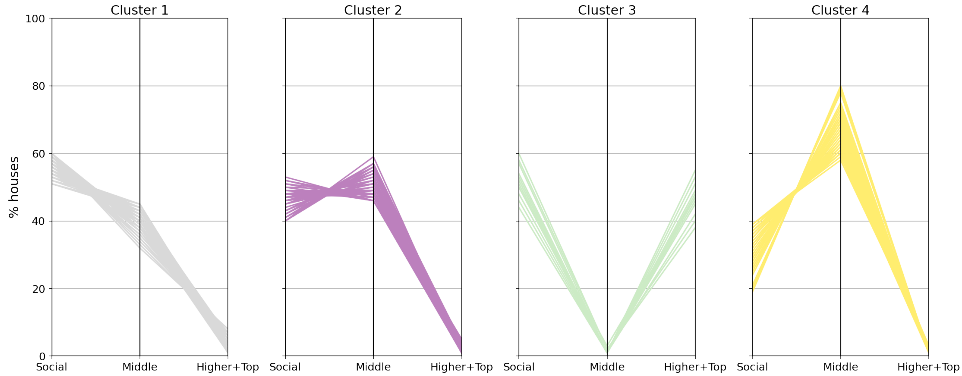
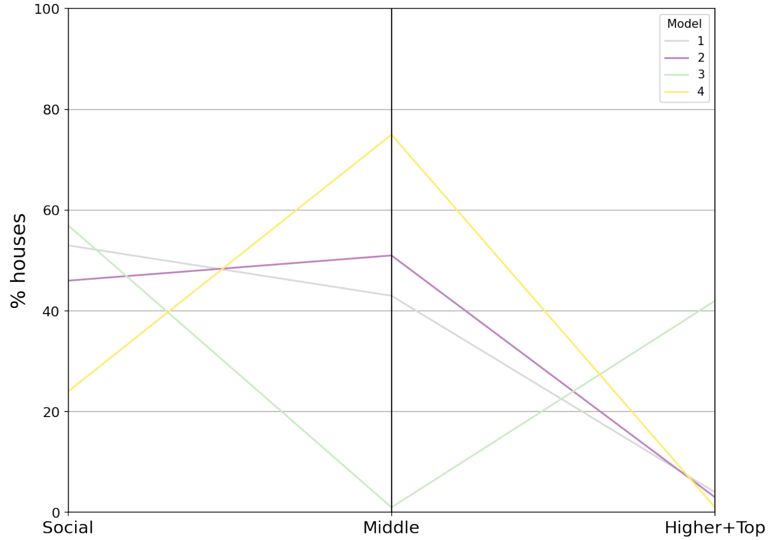



**Figure C.2:** Clusters of the house stock distributions that meet the definition of balance from the municipality and that have an acceptable goodness-of-fit. Clusters 1, 2, and 4 exhibit concave shapes, while Cluster 3 has a convex shape.

**Table C.2:** Goodness-of-fit of the estimated models.

| | **Model 1** | | **Model 2** | | **Model 3** | | **Model 4** | |
|---|---|---|---|---|---|---|---|---|
| | **Value** | **99% CI** | **Value** | **99% CI** | **Value** | **99% CI** | **Value** | **99% CI** |
| dG | 0.010 | 0.029 | 0.010 | 0.032 | 0.002 | 0.034 | 0.010 | 0.028 |
| SRMR | 0.037 | 0.061 | 0.037 | 0.061 | 0.016 | 0.065 | 0.038 | 0.057 |
| dL | 0.014 | 0.037 | 0.014 | 0.037 | 0.003 | 0.042 | 0.015 | 0.033 |
| dML | 0.050 | 0.145 | 0.051 | 0.155 | 0.008 | 0.166 | 0.055 | 0.140 |




| | Social (%) | Middle (%) | Higher+Top (%) |
|---|---|---|---|
| **Model 1** | 53 | 43 | 4 |
| **Model 2** | 46 | 51 | 3 |
| **Model 3** | 57 | 1 | 42 |
| **Model 4** | 24 | 75 | 1 |

**Figure C.3:** Housing stock distributions of the models with best goodness-of-fit for each identified cluster.

**Table C.3:** Correlation matrix of Informal support indicators.

| | aggIS1 | aggIS2 | aggIS3 |
|---|---|---|---|
| aggIS1 | 1.000 | 0.005 | 0.572 |
| aggIS2 | 0.005 | 1.000 | -0.283 |
| aggIS3 | 0.572 | -0.283 | 1.000 |

**Table C.4:** Reflective construct reliability assessment.

| | **Model 1** | | **Model 2** | | **Model 3** | | **Model 4** | |
|---|---|---|---|---|---|---|---|---|
| | $\rho_A$ | **AVE** | $\rho_A$ | **AVE** | $\rho_A$ | **AVE** | $\rho_A$ | **AVE** |
| Informal Support | 0.75 | 0.61 | 0.75 | 0.61 | 0.74 | 0.59 | 0.75 | 0.61 |

(Dijkstra & Henseler, 2015). The construction of *Informal support* with the three indicators yielded a $\rho_A$ under this threshold for all models, therefore, to increase internal consistency reliability, *IS2* was dropped because it had the lowest loading in all instances. As a result, $\rho_A$ increased to above 0.70 and lies within the accepted threshold for all models (Table C.4). The *% of residents who say they are willing to care for relatives who need help* (*IS3*) is correlated with the *% of residents who say they are willing to care for neighbours or friends who need help* (*IS1*), however, they are both lowly correlated to the *% of residents who say they are willing to care for others in the area who need help* (*IS2*) (see Table C.3).

The AVE of *Informal support* is higher than the accepted value of 0.50, which indicates that the construct explains at least 50% of the variance of its items and a dominant factor could be extracted in all models (Henseler, 2020). Finally, Table C.5 shows that *IS3* had a loading above 0.7 in all models, while *IS1* did not reach that threshold but was above 0.6 in all instances. This means that *IS3* is more closely related and explains more of the variance of the extracted latent variable *Informal support* than *IS1*.

### FORMATIVE MEASUREMENT MODEL

The model goodness-of-fit with an SRMR below 0.08 within the 99% CI (see Table C.2) indicates the confirmatory power of our emergent construct and is suggestive of its reliability and validity (Henseler, 2020).

When applying Mode BNNLS to Model 3, the results suggested that *Social cohesion* can be fully captured by *SC5*. On the other hand, when applied to Models 1, 2, and 4, the outcomes showed that *Social cohesion* was a composite of *SC3* and *SC5*. Nevertheless, the weight of *SC5* was not statistically significant, thus in those Models *Social cohesion* can be fully captured by *SC3*. These results are shown in Table C.6.

**Table C.5:** Reflective construct item loading assessment.

| | | **Model 1** | | **Model 2** | | **Model 3** | | **Model 4** | |
|---|---|---|---|---|---|---|---|---|---|
| | **Item** | **Loading** | **95% CI** | **Loading** | **95% CI** | **Loading** | **95% CI** | **Loading** | **95% CI** |
| Informal Support | IS3 | 0.911 | [0.591, 0.993] | 0.911 | [0.569, 0.991] | 0.840 | [0.632, 0.981] | 0.906 | [0.600, 0.987] |
| | IS1 | 0.628 | [0.522, 0.940] | 0.628 | [0.480, 0.936] | 0.681 | [0.496, 0.874] | 0.632 | [0.495, 0.954] |
| | IS2[a] | NA | NA | NA | NA | NA | NA | NA | NA |

*a*: Item dropped in order to increase internal consistency reliability

**Table C.6:** Formative construct assessment.

| | | Models 1, 2, and 4 | | Model 3 | |
|---|---|---|---|---|---|
| | **Item** | **Weight** | **95% CI** | **Weight** | **95% CI** |
| Social Cohesion | SC1 | NA[a] | NA[a] | NA[a] | NA[a] |
| | SC2 | NA[b] | NA[b] | NA[b] | NA[b] |
| | SC3 | 1.000 | [1.000, 1.000] | NA[a] | NA[a] |
| | SC4 | NA[b] | NA[b] | NA[b] | NA[b] |
| | SC5 | NA[b] | NA[b] | 1.000 | [1.000, 1.000] |
| Neighbourhood Balance | NB | 1.000 | [1.000, 1.000] | 1.000 | [1.000, 1.000] |

*a*: Item dropped due to high multicollinearity
*b*: Item dropped due to insignificant weight.

**Table C.7:** Assessment of the structural model reliability.

| | | Model 1 | | | Model 2 | | | Model 3 | | | Model 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Dependent variable** | **Independent variable** | **Adj. $R^2$** | **VIF** | **$f^2$** | **Adj. $R^2$** | **VIF** | **$f^2$** | **Adj. $R^2$** | **VIF** | **$f^2$** | **Adj. $R^2$** | **VIF** | **$f^2$** |
| Informal Support | | 0.16 | | | 0.16 | | | 0.24 | | | 0.16 | | |
| | Social Cohesion | | 1.19 | 0.184 | | 1.20 | 0.185 | | 1.11 | 0.323 | | 1.21 | 0.195 |
| | Neighbourhood Balance | | 1.19 | 0.000 | | 1.20 | 0.000 | | 1.11 | 0.000 | | 1.21 | 0.000 |
| Social Cohesion | | 0.15 | | | 0.16 | | | 0.09 | | | 0.16 | | |
| | Neighbourhood Balance | | | 0.194 | | | 0.203 | | | 0.115 | | | 0.215 |

## STRUCTURAL MODEL

After guaranteeing that the measurement model is satisfactory, the structural model results were assessed. First, Table C.7 shows that the VIF between the constructs is below 2 in all instances, so we can discard any multicollinearity issues.

Second, the adjusted coefficient of determination (Adjusted $R^2$ or Adj. $R^2$) was considered. All four models showed a weak explanatory power for the construct of *Social cohesion*, with Model 3 providing the least. On the other hand, Model 3 showed a stronger power when explaining *Informal support* compared to the other models, although it still ranged within the weak explanatory power range (Table C.7).

A third consideration to evaluate the PLS-SEM model was to calculate Cohen's effect size ($f^2$). Table C.7 shows that the effect size of *Social cohesion* on *Informal support* is medium for Models 1, 2, and 4, and large for Model 3. Second, *Neighbourhood balance* had a very small effect size in all Models. Third, the effect size of *Neighbourhood balance* on *Social cohesion* is medium to large in Models 1, 2, and 4, and medium to small in Model 3.

The next step to evaluate the predictive power of the structural model was to calculate the predictive relevance ($Q^2$) of the construct items (Hair et al., 2019). Table C.8 shows how *SC3* has a small to medium predictive power for *Social cohesion*, whereas *SC5* lacks accuracy. Regarding *Informal support*, Models 1 and 3 lack predictive power, whereas Models 2 and 4 have a small predictive power from the hand of *IS3* and lack of it from *IS1*. In addition, Table C.8 shows how almost all indicators have a higher pre-

**Table C.8:** Assessment of the predictive power of the structural model.

| | | Model 1 | | | Model 2 | | | Model 3 | | | Model 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Item** | **Δ MAE** | **Δ RMSE** | **$Q^2$** | **Δ MAE** | **Δ RMSE** | **$Q^2$** | **Δ MAE** | **Δ RMSE** | **$Q^2$** | **Δ MAE** | **Δ RMSE** | **$Q^2$** |
| Social Cohesion (SC) | SC1 | NA[a] | NA[a] | NA[a] | NA[a] | NA[a] | NA[a] | NA[a] | NA[a] | NA[a] | NA[a] | NA[a] | NA[a] |
| | SC2 | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] |
| | SC3 | -0.012 | -0.020 | 0.121 | 0.002 | 0.001 | 0.147 | NA[a] | NA[a] | NA[a] | 0.002 | 0.001 | 0.147 |
| | SC4 | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] |
| | SC5 | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | -0.113 | -0.123 | -0.020 | NA[b] | NA[b] | NA[b] |
| Informal Support (IS) | IS3 | -0.119 | -0.182 | -0.001 | -0.047 | -0.069 | 0.008 | -0.154 | -0.182 | -0.059 | -0.047 | -0.069 | 0.008 |
| | IS1 | -0.097 | -0.147 | -0.026 | -0.043 | -0.057 | -0.020 | -0.117 | -0.144 | -0.017 | -0.043 | -0.057 | -0.020 |
| | IS2[c] | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

*a*: Item dropped due to high multicollinearity
*b*: Item dropped due to insignificant weight.
*c*: Item dropped in order to increase internal consistency reliability

**Table C.9:** Structural model total, direct, and indirect path coefficients.

| | | Model 1 | | | Model 2 | | | Model 3 | | | Model 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Dependent variable** | **Independent variable** | **$\beta$ Total** | **$\beta$ Direct** | **$\beta$ Indirect** | **$\beta$ Total** | **$\beta$ Direct** | **$\beta$ Indirect** | **$\beta$ Total** | **$\beta$ Direct** | **$\beta$ Indirect** | **$\beta$ Total** | **$\beta$ Direct** | **$\beta$ Indirect** |
| Informal Support | | | | | | | | | | | | | |
| | Social Cohesion | 0.424* | 0.424* | | 0.426* | 0.426* | | 0.516* | 0.516* | | 0.439* | 0.439* | |
| | Neighbourhood Balance | -0.183 | -0.012 | -0.171 | -0.181 | -0.006 | -0.175*** | 0.151 | -0.014 | 0.166 | -0.162 | 0.022 | -0.185 |
| Social Cohesion | | | | | | | | | | | | | |
| | Neighbourhood Balance | -0.403* | -0.403* | | -0.411* | -0.411* | | 0.321 | 0.321 | | -0.421* | -0.421* | |

Significance levels: *p<0.001 **p<0.01 ***p<0.05
Note: No superscript indicates statistically non-significant values.

dicted error compared to the benchmark, so this is suggestive that the model has a low predictive power. Only *Social cohesion* in Models 2 and 4 has a smaller predicted error.

Finally, after verifying the PLS-SEM model's explanatory and predictive power, the final step is to assess the statistical significance and relevance of the path coefficients (see Table C.9). The results of the effects can be summarised as follows. First, in Models 1, 2, and 4, *Neighbourhood balance* has a significant negative association with *Social cohesion*. Second, the direct relationship between *Neighbourhood balance* and *Informal support* is non-significant. There is, however, the existence of a slight indirect effect brought by the mediation effect of *Social cohesion* in Model 2. Finally, we see a positive association between *Social cohesion* and *Informal support*.

We can see different results for Model 3. Here, *Neighbourhood balance* is positively associated with *Social cohesion*, but to the 90% CI. As in the previous models, the relationship between *Neighbourhood balance* and *Informal support* is non-significant, but here there is not even a slight indirect effect brought by *Social cohesion*. The association between *Social cohesion* and *Informal support* is again positive.

Regarding the mediation effects, we can see that the direct effect between *Neighbourhood balance* and *Informal support* is non-significant in Models 1 and 3, so we can talk about full mediation. The effects of balance on willingness to help are all due to social cohesion. In Models 2, the relationship between *Neighbourhood balance* and *Informal support* is significant to the 95% CI, so we talk about complementary partial mediation (Henseler, 2020).

# D

# Appendix D

This appendix includes additional information to the report results. First, it shows the assessment of the explanatory and predictive power of the PLS-SEM model. Then it shows the value of the outliers not included in Figure 4.8, and finally the results from spatial exploration by means of the LISA.

## D.1. PLS-SEM structural model

First, to guarantee that the results of the regression equations are not biased, multicollinearity between the constructs was considered. Using the reflective construct *Informal support* as dependent variable, we calculated the VIF. Table D.1 shows that the VIF between the constructs is below 2 in all instances, so we can discard any multicollinearity issues.

Second, the adjusted coefficient of determination (Adjusted $R^2$ or Adj. $R^2$) was considered. The Adjusted $R^2$ is the most commonly used measure to evaluate the measurement model and indicates the model's predictive accuracy and explanatory power. The values are context dependent, however, Hair et al. (2019) suggests that values of 0.25, 0.50 and 0.75 can be considered as weak, moderate, and substantial. All four models showed a weak explanatory power for the construct of *Social cohesion*, with Model 3 providing the least. On the other hand, Model 3 showed a stronger power when explaining *Informal support* compared to the other models, although it still ranged within the weak explanatory power range (Table D.1). In this interpretation, it is important to consider that Hair et al. (2019) highlights how Adjusted $R^2$ values that predict human attitudes like those in our study are usually lower than for physical processes.

A third consideration to evaluate the PLS-SEM model was to calculate Cohen's effect size ($f^2$). $f^2$ indicates the change in the $R^2$ value when a specified exogenous construct is removed from the model. Given that $R^2$ is context dependent, Cohen (1988) suggested that values higher than 0.02, 0.15 and 0.35 depict small, medium, and large $f^2$ effect size. First, Table D.1 shows that the effect size of *Social cohesion* on *Informal support* is medium for all Models. Second, *Neighbourhood balance* had a very small effect

**Table D.1:** Assessment of the structural model reliability.

| Dependent variable | Independent variable | Model 1 Adj. $R^2$ | Model 1 VIF | Model 1 $f^2$ | Model 2 Adj. $R^2$ | Model 2 VIF | Model 2 $f^2$ | Model 3 Adj. $R^2$ | Model 3 VIF | Model 3 $f^2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Informal Support | | 0.07 | | | 0.08 | | | 0.09 | | |
| | Social Cohesion | | 1.28 | 0.108 | | 1.20 | 0.114 | | 1.11 | 0.107 |
| | Neighbourhood Balance | | 1.28 | 0.008 | | 1.20 | 0.011 | | 1.11 | 0.001 |
| Social Cohesion | | 0.21 | | | 0.16 | | | 0.09 | | |
| | Neighbourhood Balance | | | 0.279 | | | 0.204 | | | 0.115 |

D

size in all Models. Third, the effect size of *Neighbourhood balance* on *Social cohesion* is medium to large in Models 1,and 2, and medium to small in Model 3.

The main takeaway of these results is that the *% of residents who say that local residents share each other's views* (*SC3*) is better at explaining *Social cohesion*, but that *SC5* captures a stronger dependency between *Social cohesion* and *Informal support* within our model, especially because it has a weaker association with *Neighbourhood balance*. Finally, Model 1 is considered superior to Models 2 and 3 as it presented the best goodness-of-fit.

The next step to evaluate the predictive power of the structural model was to calculate the predictive relevance ($Q^2$) of the construct items (Hair et al., 2019). In a nutshell, the value for $Q^2$ results from the difference between the true data points and the predicted ones. As a rule of thumb, $Q^2$ values higher than 0, 0.25 and 0.50 depict small, medium, and large predictive relevance. Values smaller than zero for all indicators of a construct suggest a lack of predictive accuracy for that construct. Table D.2 shows how Models 1, and 2 have a small to medium predictive power for *Social cohesion*, whereas Model 3 which specifies *Social cohesion* as the *% of residents who say they feel at home with local residents* (*SC5*) has lower accuracy. Regarding *Informal support*, all Models lack predictive power.

The assessment of the predictive accuracy of the structural model is finalised with the calculation of the prediction error. If $Q^2$ indicated the presence of predictive power (only for *Social cohesion* in our Models), then the difference between mean absolute error ($\Delta$MAE) and the root mean squared error ($\Delta$RMSE) of the predictions and a benchmark quantify the predictive power. The recommended benchmark is the most naïve and corresponds to a linear regression model (Hair et al., 2019). If the PLS-SEM prediction yields higher RMSE or MAE for all indicators compared to the naïve benchmark, this means that the model lacks predictive accuracy (positive $\Delta$ RMSE and $\Delta$ MAE). Table D.2 shows how Model 1 has a higher predicted error compared to the benchmark for *Social cohesion*, so this is suggestive that the model has a low predictive power. In Models 2, and the values are negative, which suggest the presence of higher predictive power.

**Table D.2:** Assessment of the predictive power of the structural model.

| | Item | Model 1 | | | Model 2 | | | Model 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Δ MAE** | **Δ RMSE** | **$Q^2$** | **Δ MAE** | **Δ RMSE** | **$Q^2$** | **Δ MAE** | **Δ RMSE** | **$Q^2$** |
| Social Cohesion | SC1 | NA[a] | NA[a] | NA[a] | NA[a] | NA[a] | NA[a] | NA[a] | NA[a] | NA[a] |
| | SC2 | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] |
| | SC3 | 0.001 | 0.001 | 0.184 | -0.013 | -0.022 | 0.139 | NA[b] | NA[b] | NA[b] |
| | SC4 | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] |
| | SC5 | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | NA[b] | -0.114 | -0.126 | 0.008 |
| Informal Support | IS1 | -0.046 | -0.069 | -0.032 | -0.099 | -0.152 | -0.043 | -0.117 | -0.145 | -0.020 |

*a*: Item dropped due to high multicollinearity
*b*: Item dropped due to insignificant weight.

**Table D.3:** Standardised *Neighbourhood balance* of the outliers not included in Figure 4.8 for visibility purposes.

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Noord Kethel | -3.93 | -3.51 | 1.27 |
| Strand en Duin | -3.71 | -4.15 | -3.71 |
| Nesselande | -3.42 | -3.46 | -1.21 |

## D.2. OUTLIERS

Table D.3 shows the value of the standardised *Neighbourhood balance* of outliers that were not included in Figure 4.8.

## D.3. LISA RESULTS

### D.3.1. LISA OF *Social cohesion*

To further explore the spatial distribution of *Social cohesion*, Figure D.1 shows its LISA classification. We can see a cluster of neighbourhoods with high *Social cohesion* surrounded by other neighbourhoods with high *Social cohesion* in the North of Rotterdam, and the opposite in the South. Model 3 created larger clusters and more polarised. The other Models showed a large HH cluster in the North, but several small LL clusters. In addition, they identified an HL cluster in the centre of the city, which could be brought by the fact that the river was not taken into account in the spatial model. The presence of HH and LL clusters is suggestive evidence about possible spillover or contagion effects. *Social cohesion* is not administratively bounded, so the interaction between residents of adjacent neighbourhoods can influence the level of cohesion of others.

### D.3.2. LISA OF *Informal support*

In order to obtain a more nuanced representation of the relevance of the geographical distribution, Figure D.2 shows the LISA clusters for *Informal support*. In the first figure, we can see that all models identify two clear clusters divided by their geographical location. In Southern neighbourhoods, citizens are less willing to help each other and are surrounded by neighbourhoods where the willingness is also low, while the opposite happens in the North-East of the city.

In addition, Figure D.3 shows the LISA choropleth of *Informal support* and its associ-

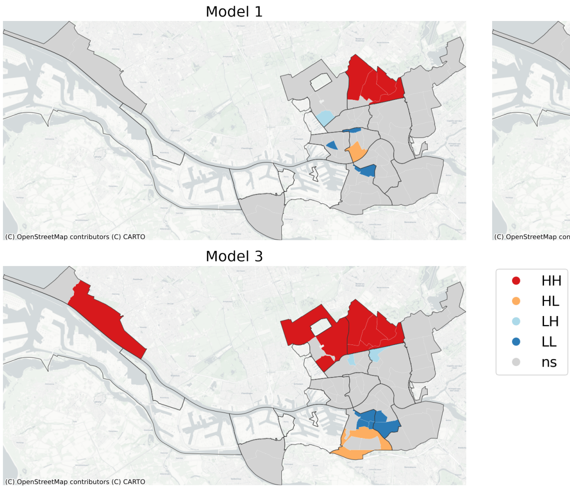



**Figure D.1:** LISA choropleth of *Social cohesion*. HH indicates neighbourhoods with high *Social cohesion* surrounded by neighbourhoods with high *Social cohesion*. HL indicates neighbourhoods with high *Social cohesion* surrounded by neighbourhoods with low *Social cohesion*. LH indicates neighbourhoods with low *Social cohesion* surrounded by neighbourhoods with high *Social cohesion*. LL indicates neighbourhoods with low *Social cohesion* surrounded by neighbourhoods with low *Social cohesion*. ns are neighbourhoods which do not belong to any of the LISA clusters, as results were non-significant. LISA clusters significant to 95% confidence interval.

ation with the average *Social cohesion* around a neighbourhood. We can see that Models 1, and 2 identified smaller clusters than Model 3. Again, this is due to a stronger polarisation in *Social cohesion* brought by the *% of residents who say they feel at home with local residents* (*SC5*). Of special attention are the neighbourhoods in the centre of Rotterdam, which show a mix of LL and HL LISA clusters and bring into picture the uniqueness of the centre in comparison to the rest of neighbourhoods.

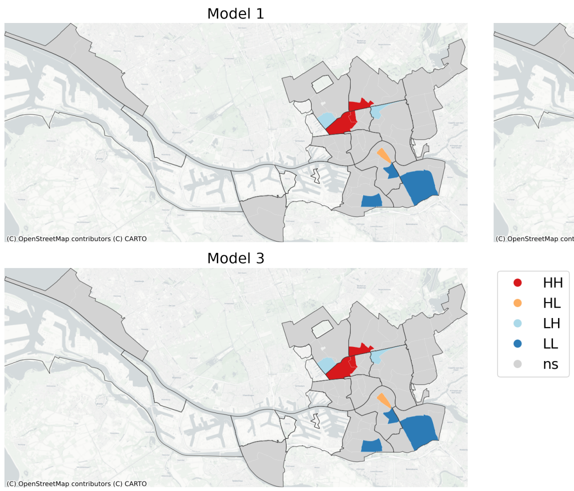



**Figure D.2:** LISA choropleth of *Informal support*. HH indicates neighbourhoods with high *Informal support* surrounded by neighbourhoods with high *Informal support*. HL indicates neighbourhoods with high *Informal support* surrounded by neighbourhoods with low *Informal support*. LH indicates neighbourhoods with low *Informal support* surrounded by neighbourhoods with high *Informal support*. LL indicates neighbourhoods with low *Informal support* surrounded by neighbourhoods with low *Informal support*. ns are neighbourhoods which do not belong to any of the LISA clusters, as results were non-significant. LISA clusters significant to 95% confidence interval.

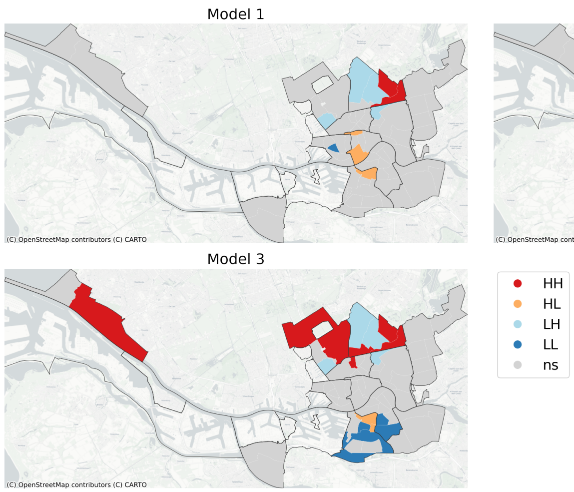



**Figure D.3:** LISA choropleth of *Informal support* and *Social cohesion*. HH indicates neighbourhoods with high *Informal support* surrounded by neighbourhoods with high *Social cohesion*. HL indicates neighbourhoods with high *Informal support* surrounded by neighbourhoods with low *Social cohesion*. LH indicates neighbourhoods with low *Informal support* surrounded by neighbourhoods with high *Social cohesion*. LL indicates neighbourhoods with low *Informal support* surrounded by neighbourhoods with low *Social cohesion*. ns are neighbourhoods which do not belong to any of the LISA clusters, as results were non-significant. LISA clusters significant to 95% confidence interval.

# E

# Appendix E

The main results of the research assume that the river that divides Rotterdam has no consequences on the spatial analysis, i.e. neighbouring neighbourhoods across the river have a spatial weight (Equation (3.8)) equivalent to 1. This appendix shows the same results by considering that neighbourhoods on both sides of the river are not neighbouring, with a spatial weight equivalent to a 0 for the neighbouring neighbourhoods across the river. This is equivalent to assuming that characteristics of neighbourhoods do not have an effect across the river.

## E.1. Spatial effects in Social cohesion taking into account river effects

The LISA choropleth of *Social cohesion* considering that the river does not allow the spillover of neighbourhood effects (see Figure E.1 shows a stronger polarisation in comparison to the LISA choropleth of the main results. We see the new presence of HH clusters towards the North of the city and of LL clusters towards the South in all models. In addition, the city centre also shows a new LL cluster which highlights the low *Social cohesion* characteristic of busy downtowns.

The identification of these clusters can be understood with the results from the Durbin model in Table E.1. We can see that the spillover or contagion effect is smaller when taking into account the river given the spatial segregation which does not allow spill over effects between South and North. The effects are still significant.

## E.2. Spatial effects in Informal support taking into account river effects

The LISA choropleth of *Informal support* considering that the river does not allow the spillover of neighbourhood effects (see Figure E.2 shows a stronger polarisation in comparison to the LISA choropleth of the main results. We see the new presence of large HH

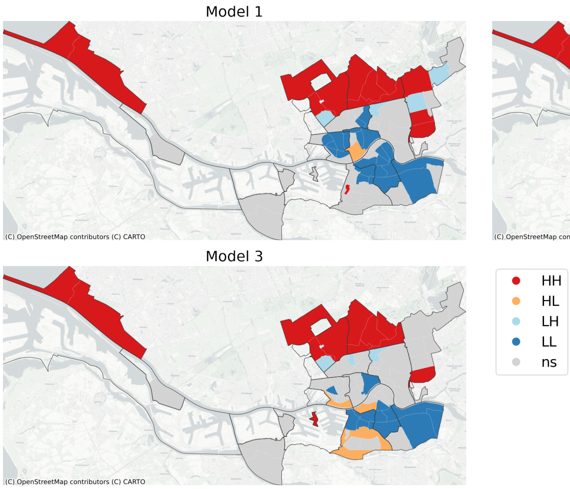





**Figure E.1:** LISA choropleth of *Social cohesion* taking into account river effects. HH indicates neighbourhoods with high *Social cohesion* surrounded by neighbourhoods with high *Social cohesion*. HL indicates neighbourhoods with high *Social cohesion* surrounded by neighbourhoods with low *Social cohesion*. LH indicates neighbourhoods with low *Social cohesion* surrounded by neighbourhoods with high *Social cohesion*. LL indicates neighbourhoods with low *Social cohesion* surrounded by neighbourhoods with low *Social cohesion*. ns are neighbourhoods which do not belong to any of the LISA clusters, as results were non-significant. LISA clusters significant to 95% confidence interval.

clusters towards the North of the city and of large LL clusters towards the South in all models.

In addition, Figure E.3 shows the LISA choropleth of *Informal support* and its association with the average *Social cohesion* around a neighbourhood considering the presence of the river. Once again, we can see the emergence of HH clusters in the North ans LL clusters in the South. Notably, the city centre shows a larger HL cluster than previously considered, showing the presence of a gradient in *Social cohesion* from South to North, but the presence of a higher *Informal support* in the city centre.

As in the case of *Social cohesion*, we can see from the Durbin model in Table E.2 that the spillover or contagion effect is smaller when taking into account the river given the spatial segregation which does not allow spill over effects between South and North. The effects are still significant.

**Table E.1:** Results of the Durbin spatial model with *Social cohesion* as dependent variable taking into account river effects. Lagged variables are the weighted averages of neighbouring values. Significant values of the lagged variables indicate spillover or contagion effects. In brackets, the standard deviations.

| Variable | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Intercept | -0.026 | -0.028 | -0.061 |
| | (0.098) | (0.101) | (0.103) |
| Neighbourhood Balance | -0.458* | -0.404* | 0.234*** |
| | (0.101) | (0.103) | (0.104) |
| Lagged Neighbourhood Balance | -0.242 | -0.178 | 0.208 |
| | (0.171) | (0.166) | (0.164) |
| Lagged Social Cohesion | 0.341** | 0.382** | 0.390** |
| | (0.132) | (0.128) | (0.127) |
| Log-likelihood | -81.466 | -83.727 | -84.765 |
| Akaike information criterion | 170.933 | 175.454 | 177.530 |
| $R^2$ (pseudo) | 0.375 | 0.340 | 0.2902 |

Significance levels: *p<0.001 **p<0.01 ***p<0.05
Note: No superscript indicates statistically non-significant values.

**Table E.2:** Results of the Durbin spatial model with *Informal support* as dependent variable taking into account river effects. Lagged variables are the weighted averages of neighbouring values. Significant values of the lagged variables indicate spillover or contagion effects. In brackets, the standard deviations.

| Variable | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Intercept | -0.010 | -0.011 | 0.000 |
| | (0.110) | (0.109) | (0.107) |
| Neighbourhood Balance | 0.083 | 0.086 | -0.028 |
| | (0.126) | (0.121) | (0.113) |
| Lagged Neighbourhood Balance | 0.136 | 0.144 | 0.084 |
| | (0.208) | (0.189) | (0.163) |
| Social Cohesion | 0.360** | 0.359** | 0.384** |
| | (0.135) | (0.131) | (0.128) |
| Lagged Social Cohesion | -0.120 | -0.121 | -0.147 |
| | (0.225) | (0.216) | (0.184) |
| Lagged Informal Support | 0.324*** | 0.317*** | 0.301*** |
| | (0.136) | (0.137) | (0.139) |
| Log-likelihood | -87.525 | -87.434 | -86.308 |
| Akaike information criterion | 187.051 | 186.867 | 184.616 |
| $R^2$ (pseudo) | 0.204 | 0.205 | 0.227 |

Significance levels: *p<0.001 **p<0.01 ***p<0.05
Note: No superscript indicates statistically non-significant values.

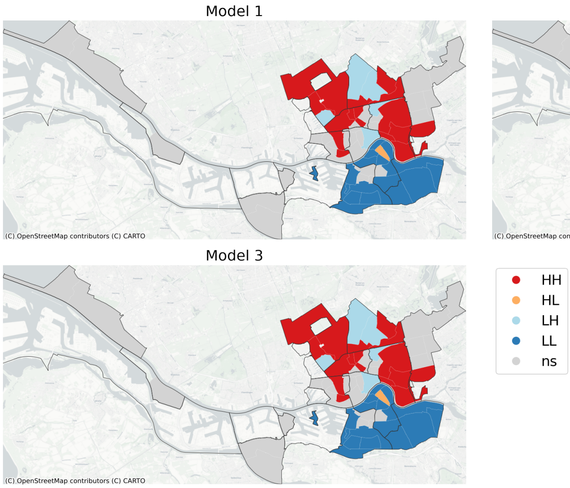





**Figure E.2:** LISA choropleth of *Informal support* taking into account river effects. HH indicates neighbourhoods with high *Informal support* surrounded by neighbourhoods with high *Informal support*. HL indicates neighbourhoods with high *Informal support* surrounded by neighbourhoods with low *Informal support*. LH indicates neighbourhoods with low *Informal support* surrounded by neighbourhoods with high *Informal support*. LL indicates neighbourhoods with low *Informal support* surrounded by neighbourhoods with low *Informal support*. ns are neighbourhoods which do not belong to any of the LISA clusters, as results were non-significant. LISA clusters significant to 95% confidence interval.

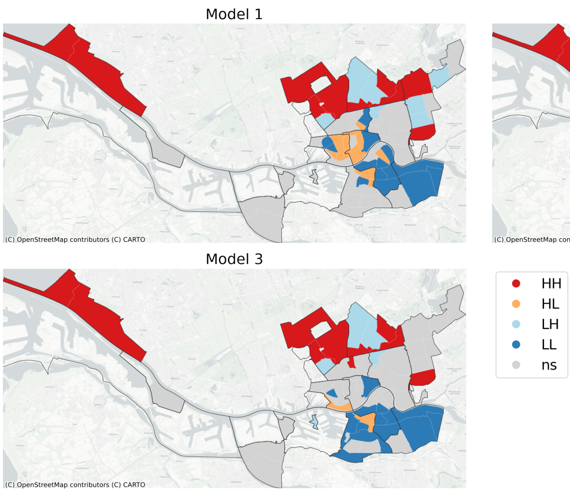



**Figure E.3:** LISA choropleth of *Informal support* and *Social cohesion* taking into account river effects. HH indicates neighbourhoods with high *Informal support* surrounded by neighbourhoods with high *Social cohesion*. HL indicates neighbourhoods with high *Informal support* surrounded by neighbourhoods with low *Social cohesion*. LH indicates neighbourhoods with low *Informal support* surrounded by neighbourhoods with high *Social cohesion*. LL indicates neighbourhoods with low *Informal support* surrounded by neighbourhoods with low *Social cohesion*. ns are neighbourhoods which do not belong to any of the LISA clusters, as results were non-significant. LISA clusters significant to 95% confidence interval.

# F

# Appendix F

This study takes a confirmatory approach, so elements hard to quantify are disregarded. Moderation analysis results indicate that none of the built environment or land use elements moderate the relationships between *Neighbourhood balance* and *Social cohesion* or *Neighbourhood balance* and *Informal support*. In addition, none of them are directly associated with *Social cohesion* and *Informal support*. However, we have seen in Section 2.2.4 that urban elements have been previously related to social cohesion. We therefore argue that our quantitative approach might not be capable to capture the effects that urban design elements have on the experience and perceptions of residents (Kim & Kaplan, 2004; Rogers & Sukolratanametee, 2009; Wood et al., 2010).

In this appendix, urban design elements that can have an effect on the sense of community are described by means of image deconstruction. To deconstruct means 'to unpack through analysis, but it also means to show the different connections that allow us to understand how something might take shape in another way' (Photographie, 2016). All images were taken on June $12^{th}$, 2022, between 3pm and 7pm. This appendix does not intend to be a rigorous qualitative analysis, but an opening door to future research on the effects of urban design on social cohesion.

## F.1. Image deconstruction of urban design elements

Figure F.1 compares special features of public spaces from selected neighbourhoods in the North and South of Rotterdam. We can see that Figure F.1a is inclusive for a larger age range: it has a kindergarten for the smallest and a larger sitting possibility for the eldest. Furthermore, it also provides a space for shopping which increases the possibilities of interaction and concentration of people (Mouratidis & Poortinga, 2020). The building elements on Figure F.1a promote the interaction between people while on Figure F.1b they encourage a sense of privacy. In that regard, the space in Figure F.1b could be labelled as semi-public (Peterson, 2017). We can see the presence of determined borders from the semi-public inside the park and the public street space. Having a group occupying the space in Figure F.1b would discourage other people from utilizing it. The space on Figure F.1a provides a more accessible transition from biking to walking into the public space while the other space has a green barrier. This could increase the interaction in Figure F.1b by forcing people to share the same entrance to the space (Wood et al., 2010). Finally, the space on Figure F.1a is provided with more lighting than the other. This allows people to spend a longer time in the area while in Figure F.1b people are dispersed when the sun goes down (Wood et al., 2010).

Figure F.2 compares special features of the public-private interplay from the same selected neighbourhoods in the North and South of Rotterdam. The comparison between these two images shows the possible conflict from private to public space. In Figure F.2a we can see that the recreational area is in front of small buildings. This creates a closer connection from the private to the public sphere (Garrido-Velarde et al., 2018). On the other hand, Figure F.2b shows that the buildings surrounding the park are taller, thus increasing the separation from the park. Next, the park on Figure F.2a is surrounded by a fence: on one hand, this creates a boundary between the street and the park, on the other, it also constraints the entrance to certain points. This single points of circulation can promote interaction between people (Rogers & Sukolratanametee, 2009; Wood et al., 2010). The presence of a fence can also emit a sense of danger and discourage people from using or else provide a feeling of safety and encourage the use (Park et al., 2014). Finally, on Figure F.2b, we can see that there is wider space, which could suggest a reduction in interaction between the park users (Mouratidis & Poortinga, 2020).



Figure F.3 compares special features of the buildings' facades and layout from the same selected neighbourhoods in the North and South of Rotterdam. Figure F.3a shows flats while the other terraced houses. Flats have a shared entrance and staircase for all residents which provide a space of encountering and interaction with the other people (Snow et al., 1981). In this case, the staircase is shared at both sides of the building. The buildings in Figure F.3b do not provide this, but increase the change of interaction with the neighbour by designing the entrances next to each other (Snow et al., 1981). Next, the flats have an open balcony, whereas the houses have an integrated balcony. An open balcony can connect the residents to the street as well as to neighbouring balconies, as widely seen during the COVID-19 pandemic (Problovski et al., 2022). The hanged clothes and the decorations of the balconies promote a sensation of inhabitation and appropriation by the people. Integrated balconies promote the sense of privacy. In addition, we can see an awning which strengthens the anonymity of the residents. Finally, we can see that on the houses in Figure F.3b, the facade is separated from the street by a set of bushes. These create a space between the public and the private spheres and increase the sensation of privacy (Rogers & Sukolratanametee, 2009). Instead, in Figure F.3a we can see that there is a basement directly pointed towards the street.


**(a)** Coordinates: 51.89320, 4.50150. South of Rotterdam. **(b)** Coordinates: 51.93564, 4.46737. North of Rotterdam.

**Figure F.1:** Special features of public-private interplay in selected neighbourhoods.

**(a)** Coordinates: 51.89015, 4.50147. South of Rotterdam. **(b)** Coordinates: 51.93379, 4.45993. North of Rotterdam.

**Figure F.2:** Special features of public spaces in selected neighbourhoods.

**(a)** Coordinates: 51.88842, 4.48655. South of Rotterdam. **(b)** Coordinates: 51.93574, 4.46750. North of Rotterdam.

**Figure F.3:** Special features of the buildings' facades and layout in selected neighbourhoods.

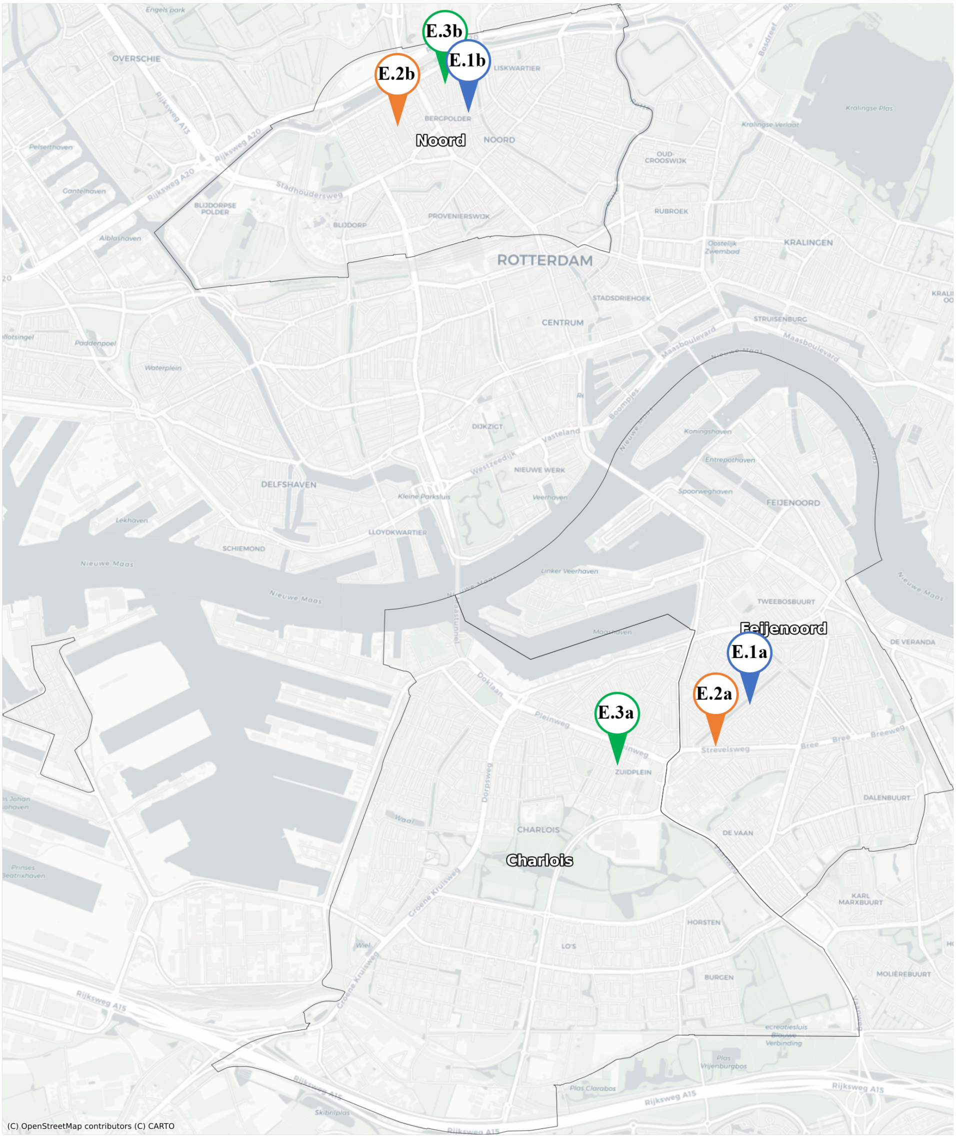



**Figure F.4:** Approximate location of the images in figures A.1a, A.1b, A.2a, A.2b, A.3a, and A.3b in Rotterdam.

F