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It's in the social network: The Social Neighbourhood model to unravel local social structures for liveable and safe neighbourhoods

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ABSTRACT

Fast growth of cities decreases the quality of life in these places. In response, Municipalities install policies aiming to improve local livability. While literature suggests social structures to have a defining impact on policy effectiveness, current evaluation metrics are not able to take this into account. This paper presents the Social Neighbourhood model, an agent-based model used to simulate and explore how livability changes in a neighbourhood given various social structures and policies. The model is applied to a neighbourhood in The Hague, Netherlands. The main result of the modelling experiments is that social structures have a very strong influence on whether or not a policy to improve livability is effective. Three hypotheses, concerning this relationship between social structures, livability, and policy interventions are drawn up as a starting point for future research.

1. Introduction

Global developments such as urbanisation and migration put pressure on cities as the number of city dwellers increases (Motieyan & Mesgari, 2018). Emerging evidence shows that the fast growth of cities decreases the quality of life in urban areas (Zhan et al., 2018). In the western European context, urban neighbourhoods face problems such as crime, bad housing quality, air pollution, or inadequate public spaces (Van Marissing et al., 2006). Most European cities house a diversity of residents living together in a relatively small space. This is not an issue particular to urban contexts, it may also happen in rural areas. As cities' densities increase, so does the pressure on resources such as green spaces, roads, and proper housing. While city dwellers aspire efficient transport, green spaces, and a sense of community in their neighbourhoods (Joffe & Smith, 2016), these things become less available given the current rapid urban development (Kaviari et al., 2019).

Local governments and municipalities attempt to address issues associated with urban growth by utilising urban planning approaches and policy making to sustain and improve the liveability and safety of their cities (Kaviari et al., 2019). As social cohesion and social ties are considered to be necessary for liveable cities (Putnam, 1995) they are often included in resulting restructuring policies. The effectiveness of such policies, however, is strongly influenced by the specific social structures in neighbourhoods (Blokland, 2003; Shenk et al., 2019). In this context, 'one size fits all' policies do not work. There is a need to understand the social structures at play to know which type of policy is fit for which context.

To measure the effect of implemented policies, municipalities currently use system level metrics. For example, the UK city liveable-sustainability indicator framework (Leach et al., 2017), the residential environment liveability assessment (Skalicky & Čerpes, 2019), the Dutch social index and safe index (Centraal Bureau voor de Statistiek (CBS), 2021), or liveability questionnaires (Zhan et al., 2018) measure, on a neighbourhood or city level, on how residents perceive liveability and/or safety. However, these system level metrics do not account for the variances between neighbourhoods and the social structures at play in relation to the social structures and the specificity's of a neighbourhood. This paper explores this relation through modelling and simulation.

This paper introduces an agent-based model (ABM), that simulates a neighbourhood with different social structures and citizen perceptions of liveability and safety in relation to specific policies. This model is applied to the case of a Dutch neighbourhood challenged by urban growth issues, to unravel the concepts of perceived liveability and safety of its residents in relation to local social structures after which the influence of possible policies is explored. The next sections introduce the relevant theory on social networks in urban neighbourhoods, the modelling approach, the model and the experiment setup. The Results section highlights how the perceived liveability and safety of citizens changes in four different social networks, and illustrates the potential

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effect of three policies. A discussion on the findings and an outlook for future work concludes the paper.

2. Background

The proposition of this article is that local governments need to understand the relationship between the social structure at play and the perceived liveability and safety of residents to design effective policies. As such, the key aspects that need to be captured in the ABM to be developed to explore this relationship are social cohesion, urban social networks, governance, and liveability and safety. Below the theoretical background of these concepts are discussed.

2.1. Theory of social cohesion and networks in urban neighbourhoods

Putnam (1995, 1996) was one of the first to address the problem of fewer social connections between neighbours in relation to local liveability and safety issues. Other researchers have also shown that residents associate liveability with a sense of community (Joffe & Smith, 2016), that social cohesion in neighbourhoods deter burglars from breaking into a home (Erete, 2013), and that many neighbourhood problems are linked to a decline in social cohesion (Van Marissing et al., 2006). Strong social cohesion may bring communities closer together, developing a shared identity or changing their current (Creţan et al., 2014). In light of this, governments stimulate local neighbourhood initiatives that have a focus on fostering a sense of community and bringing residents in contact with each other (De Koning et al., 2018), to support liveability.

Researchers theorise relationships in social cohesion as 'ties' that can be weak or strong (Granovetter, 1973; Kilduff & Brass, 2010). These ties go beyond resident relationships; they can also describe connections between residents and community workers or local police officers. Weak ties are just as relevant as strong ties, especially in the neighbourhood context (Aldrich & Meyer, 2015). Research from Hungary, for example, illustrates how weak ties may contribute to wellbeing and social mobility of marginalised residents (Méreiné-Berki et al., 2021). Blokland (Blokland, 2003) distinguishes four different types of neighbourhood ties that are relevant for this research as well: interdependencies, transactions, attachments, and bonds. *Interdependencies* describe the connection that is present between neighbours as a given, because living close together results in dependency in one or other way. *Transactions* are ties where exchange takes place, for instance sharing information about what is happening in the neighbourhood. *Attachments* describe connections that result from being part of a particular group, such as being member of an ethnic association. Finally, *bonds* refer to what others call strong ties; connections based on affection, such as friends of family. Recent research found that a high number of weak ties in neighbourhoods is positively associated with feeling attached to the neighbourhood and to the city (Iris Luo et al., 2022).

Social connections enable neighbourhood-based communities to respond fast and adequately to sudden changes or crises (Caruso et al., 2020). Weak ties especially help a neighbourhood community to function (Li et al., 2005), because they allow information to diffuse beyond family or friend networks, into the wider neighbourhood community (Lin et al., 1981). For example, Hampton and Wellman (2003) show in their *Neighbouring in Netville* project that neighbours are more easily mobilised around local issues, when there are a lot of weak ties. As such, weak ties enable social mobility (Méreiné-Berki et al., 2021; Pinkster, 2007) because they connect different social circles to each other, allowing residents to traverse into new networks (Murie & Musterd, 2004). Yet formation of these weak networks needs to be governed and supported through institutions for them to function well (Méreiné-Berki et al., 2021). In highly diverse neighbourhoods, for example, residents may start to articulate otherness and blame other ethnic groups for local problems (Creţan et al., 2021), when there is no community facilitation.

Neighbourhood networks with a lot of weak and strong ties will be able to support each other and solve local issues together (Wellman & Wortley, 1990), contributing to a safer and more liveable neighbourhood. Recent research into how neighbourhood communities responded to the social distancing and lockdown restrictions that were put in place due to the COVID-19 pandemic shows that existing relationships and connections between citizens enabled a fast and adequate response to this sudden crisis (Caruso et al., 2020; Slingerland et al., 2022). Nonetheless, other neighbourhood communities responded very differently to the lockdowns, possibly because they had a different type of social network in place. Building on our earlier work (Slingerland et al., 2020c), this paper hypothesises that the type of social network present in a neighbourhood has a defining influence on the effectiveness of certain policies. This means that to design effective policies, local governments need to understand the relationship between the social network at play and the perceived liveability and safety of residents.

2.2. Governance and policies to support liveable and safe cities

In whatever way citizens are connected in a neighbourhood, literature suggests a positive relationship between social cohesion and liveability (Iris Luo et al., 2022). These insights have also reached local governments; increasing social cohesion for liveability and safety is high on their agenda (Lelévrier, 2013). Local governments support citizen participation initiatives (Corbett & Le Dantec, 2018) or organise community spaces where residents can meet each other and engage in neighbourhood activities (De Koning et al., 2018; Lelévrier, 2013). Another popular approach is to invest in community workers, police officers, or a neighbourhood watch (Van Eijk et al., 2017). These citizens or officials spend much of their time in neighbourhoods, talking to citizens and gathering information on what is going on.

Despite the many theoretical promises of social networks and cohesion in urban neighbourhoods, practice shows different outcomes (Corbett & Le Dantec, 2018; Lelévrier, 2013; Méreiné-Berki et al., 2021; Van Marissing et al., 2006). This discrepancy between theory and practice challenges municipalities to decide how to best allocate their resources. Furthermore, the metrics that municipalities currently use to assess policies bring challenges; they are relatively abstract and aggregated, use different definitions of liveability, and are incapable to capture the local mechanisms at play (Leach et al., 2017). Méreiné-Berki et al. (2021) argue that using income as the only indicator of wellbeing of residents is not sufficient. The aggregated level of the used metrics complicates understanding how particular characteristics of a neighbourhood, such as its social structure or level of cohesion, influence the effectiveness of policies to increase liveability and safety. Due to the complex and dynamic nature of cities (Leach et al., 2017), other strategies to policy assessment are necessary and modelling and simulation has proven to be a suitable approach to this purpose.

3. Approach: modelling and simulation to unravel local mechanisms in urban neighbourhoods

This paper addresses the existing knowledge gap on the relation between neighbourhood social structures, liveability and safety, and urban policies. As agent-based models (ABM) provide a means to assess the impact of current policies, given the type of social network that is present in a neighbourhood, and to explore the possible effect of policies that are being considered, this approach has been chosen. What is unique about ABMs is that they can account for multiple factors that influence the neighbourhood at the same time (van Dam et al., 2013). An ABM is built bottom-up and behaves from this perspective, meaning that individual 'agents' move and interact with each other based on a set of individual characteristics and in parallel to each other. ABMs thus allow to include behaviour and preferences of individuals, that influence the systems at large and allow new patterns to emerge (Edmonds et al., 2019).

The guiding research question is: *Can agent-based models unravel the*

influence of local social structures on perceived liveability and safety of residents? In general, ABMs are used for generative social science (Epstein, 2006) to understand complex social systems, like urban neighbourhoods. In this paper an ABM of a synthetic neighbourhood is developed and applied to a case of an actual neighbourhood in The Hague (NL). The ABM simulates interactions between residents, community workers, and police officers in a neighbourhood to provide unique insights into how these individual interactions impact the perceived liveability and safety of residents. In addition to these interactions, the model simulates the spatial situation (e.g. how and where individuals meet on the streets), the social structures (e.g. how and which resident (groups) are connected), and the social environment (e.g. burglaries that happen to residents). All of these micro-level interactions are combined in the ABM to establish perceived liveability and safety of the neighbourhood.

3.1. Case study neighbourhood: Bouwlust in The Hague

Bouwlust is a neighbourhood in The Hague and has been selected as the input case for the model because 1) it is an urban neighbourhood where many issues as described in the introduction are observed (Van Marissing et al., 2006), and 2) Bouwlust is a well-known area to the researchers as a result of almost ten years of research engagement with this neighbourhood (see, e.g. (Slingerland et al., 2019; Slingerland et al., 2020a, b, c).

The Hague as a city is interesting for the model, because it is the most segregated city in the Netherlands (Meijers et al., 2014). Neighbourhoods in The Hague are unique to each other in terms of social structures. Some have rarely any, others are very fragmented, requiring different types of urban policies to address liveability and safety.

Bouwlust covers an area in the south-west part of The Hague and was originally built for middle-class residents such as civil servants, police officers, and teachers. The neighbourhood has experienced significant growth, from 16,000 residents in 2006 to 25,000 currently (Van Marissing et al., 2006) and with many changes which have resulted in a 'general decay of the neighbourhood' (Van Marissing et al., 2006). Issues that the neighbourhood currently faces include increased crime rates, poor housing, decreasing social cohesion, and a predominate number of vulnerable households. In light of this, the Municipality has initiated several programmes, several in collaboration with the University, to increase citizen participation and social cohesion. These efforts resulted in various short lived citizen initiatives (Slingerland et al., 2020). Experiences in other neighbourhoods has shown that the 'relationship between urban governance and social cohesion is not an easy one' (Van Marissing et al., 2006), which was also observed in Bouwlust. Many of the initiated programmes did not work as anticipated, and lasted only a short period of time. The key interactions that researchers observed in Bouwlust and identified in (academic) publications (Slingerland et al., 2019; Slingerland et al., 2020a, b, c) were incorporated in the model to influence how perceived liveability and safety is established.

3.2. Design of the model and experiments

The model has been designed to simulate Perceived Liveability and Safety (PLS) of citizens. The score attached to perceived liveability and safety, PLS, is the main output of the model and is the average of each individual's PLS. These PLS scores, in turn, are specific to each citizen and highly dependent on their individual experiences. Fig. 1 shows how PLS is conceptualised in the model. PLS is impacted by several different social factors: interactions with fellow citizens, police officers, and community workers; visiting or starting a neighbourhood initiative; experiencing a burglary; seeing a youth gang; or hearing from friends (of friends) about these events.

The residents of Bouwlust are modelled through 2750 individual agents who are unique. Their characteristics, such as employment or family status, are randomly divided and partially determine the course of a citizen's day. For instance, a citizen with a job and children will wake up, bring their kids to school, and then go to work. Besides residents, community workers and police officers are also present in the neighbourhood. The residents of Bouwlust act socially towards each other and greet each other when they meet on the streets. Citizens also greet police officers and community workers. All of these interactions have a positive impact on the personal PLS of a citizen, as shown in

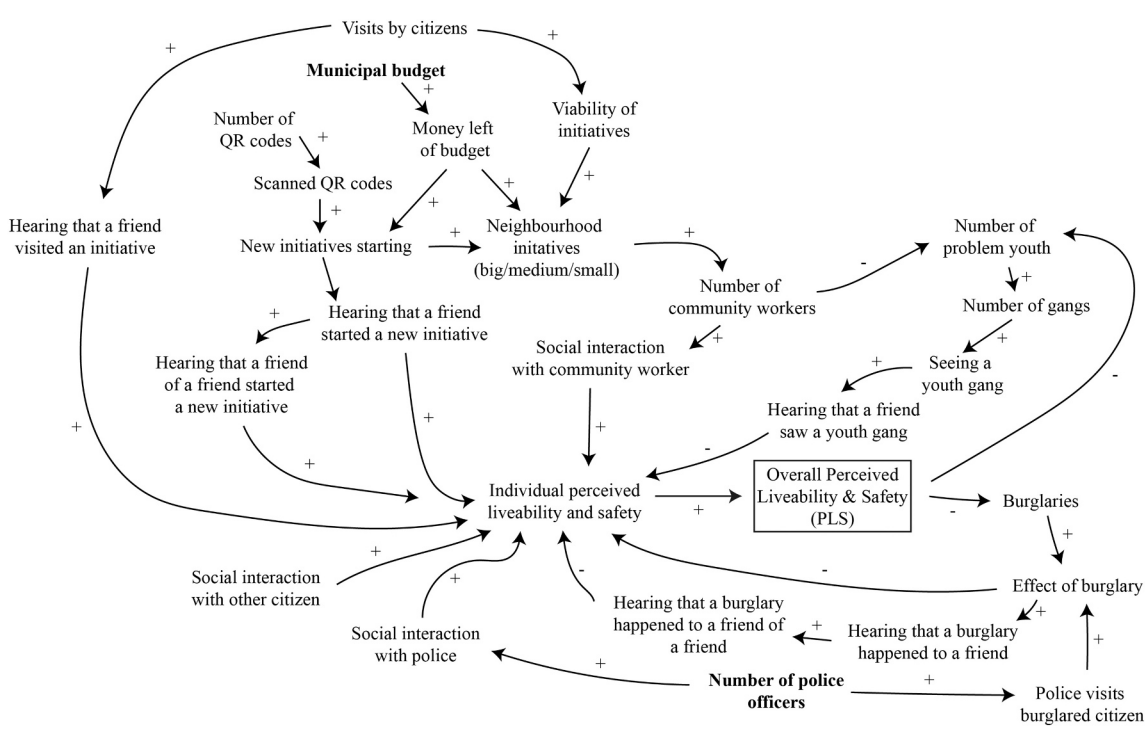

Fig. 1. Conceptualisation of overall perceived liveability and safety (PLS) in the model. In **bold** are the policy levers that are explored in the experiments.

Fig. 1.

Citizens experience all kinds of events during their day, with either a positive or negative impact on their PLS. During the night some citizens are burgled. This has a very strong negative impact on the feeling of safety, and hence the PLS decreases. Citizens may, during the day, also meet youth gangs on the streets. Youth gangs are constantly on the move in the neighbourhood. New members (young citizens) can join or leave the gang every week. When the overall liveability and safety of the neighbourhood is low, young citizens will be more inclined to join a youth gang. Community workers can talk to youngsters and try to convince them to leave a gang, but the gang members will try to keep them together. Police officers start their day by visiting citizens who have been burgled the night before. Once they are done, they patrol the neighbourhood, meet citizens, and hunt for youth gangs.

A low overall experience of liveability and safety also influences the motivation for citizens to start neighbourhood initiatives. Citizens are more willing to contribute to a better neighbourhood when there is work to be done: a lower PLS score increases the chance of citizens starting initiatives. Whether or not initiatives can be started and continued is influenced by the municipal budget, the number of other citizens who are willing to participate in an initiative, and the size of the initiative itself. There are different kinds of initiatives that can be started (small, medium, or big), with different budgets and different run times.

As outlined in Fig. 1, all of the events and interactions described above influence how individual citizens think of their neighbourhood in terms of liveability and safety. To be able to explore the influence of social structures on the perception of citizens, the model includes social groups in which citizens participate. Citizens talk to their friends, other citizens (in the same social group) with whom they share a strong connection, and sometimes also with friends of friends. At the end of the day, citizens tell their friends what happened to them, which then also changes the perception that these friends have of their neighbourhood. For example, when a citizen has been burgled and they tell their friends, these citizens will also start to feel less safe.

This model storyline guided the design of the model and the setup of the experiments. During the experiments, the model is run for different scenarios. Two policy levers, municipal budget and number of police officers (see also in bold in Fig. 1), as well as four distinct social structures are tested. A more detailed description of the experiment setup is given in Section 5. First, the section below presents the Social Neighbourhood model: the ABM designed and developed for this research.

4. The Social Neighbourhood model: modelling urban social structures in an ABM

4.1. Model description

A complete, detailed model description, following the ODD (Overview, Design concepts, Details) protocol (Grimm et al., 2010) is provided at https://www.comses.net/codebase-release/92a5af0c-739c-4e02-91c9-c0aab2803e18/. The model is implemented in the NetLogo agent based modelling environment (Wilensky, 1999) version 6.0.2 and its full source code is available at https://www.comses.net/codebase-release/92a5af0c-739c-4e02-91c9-c0aab2803e18/.

4.1.1. Purpose

The overall purpose of our model is theoretical exploration and exposition (Edmonds et al., 2019). The model exposes the complex interactions that influence how residents perceive the liveability and safety of their neighbourhood, in particular given various social structures. The model explores how the social structure mechanisms influence the establishment of perceived liveability and safety in neighbourhoods. The model includes the main relevant concepts identified in the literature discussed above: policies implemented by the municipality, social structures in the neighbourhood, social interactions between citizens, police officers, and community workers. The model (see Fig. 2) describes how these elements interact under three different policies and given four different types of social networks.

4.1.2. Entities

The model includes the following entities: (1) grid cells to represent various neighbourhood locations, (2) citizens, police officers, youth, and community workers as agents, and (3) youth gangs as collectives. The environment of the model includes burglaries that happen every night, neighbourhood initiatives, yearly municipal budget for initiatives, time and day of the week, social network, and the average perceived liveability and safety score of citizens (PLS). All agents are characterised by several state variables that keep track of their daily schedule and current activity they are undertaking. This includes travelling to locations, work, going to school, shopping, religious activities, leisure walks, talking to friends, and visiting neighbourhood initiatives.

As for the spatial and temporal resolution and extent: A time step in the model represents one minute and simulations are run for three years. The model is run with a set of patches that is created based on the 2D map of Bouwlust. The interface in Fig. 2 shows all of the options that can be set for running the model, that can be used to adjust the model to other types of neighbourhoods and contexts. The shown settings were used for the experiments described in this paper.

4.1.3. Schedule and agents

The most important processes of the model, that are repeated every time step, are 1) updating and keeping track of the time, 2) updating the entities in the environment and agents creating a daily schedule, and 3) agents performing their one-minute action, according to their daily schedule. Time-bound updates in the model are divided in updates related to a new day, a new week, a new month or a new year. These updates trigger changes in the environment and to agents, after which agents start to perform their actions (see Table 1).

Fig. 3 shows that adult citizens, police, community workers, and youngsters all start their day by creating a schedule. Adult citizen agents follow different schedules every day, depending on their personal situation (whether they have kids, a job, or are religious). The activities that are not related to the citizen's personal situation - for instance, go on a recreational walk or go shopping - are based on a probability. Police officers make a schedule for the day based on the number of burglaries that have happened. They first visit citizens who were burgled, and then patrol the neighbourhood. Police officers choose locations to patrol known to be 'hotspots' for youth gangs to hang out. Community workers schedule to visit initiatives that they support every day. After that they walk around in the neighbourhood to visit the hotspot locations, to talk to youngsters. Youngsters can be part of a youth gang which means they will be hanging around all day. Otherwise, youngsters go to school and plan their day similarly to adult citizens.

As shown in Fig. 3, once agents have their day schedule they all simultaneously perform a one-minute action in each timestep. During this action they can either travel to a destination (e.g. going to work), be occupied with an activity and keep track how many minutes this activity is still going on (e.g. being at work), or back at home finished the schedule for the day and resting until the next day starts. Throughout these activities, agents interact with each other as explained below.

4.1.4. Interactions between agents

While doing with their daily activities, agents interact with each other in the model in two ways (see Fig. 3). First, citizens meet other agents on the streets while they are travelling or out for a stroll. Community workers and police officers meet adult and youngster citizens while travelling and on patrol. These interactions have positive or negative impact on each of these agents PLS, as shown in Table 2.

The second way that agents interact is by sharing information about things that happened to agents during the day, as illustrated in Table 3, Figs. 1 and 3. At the end of the day, the model simulates agents 'talking to their friends' about what happened to them during that day. If an

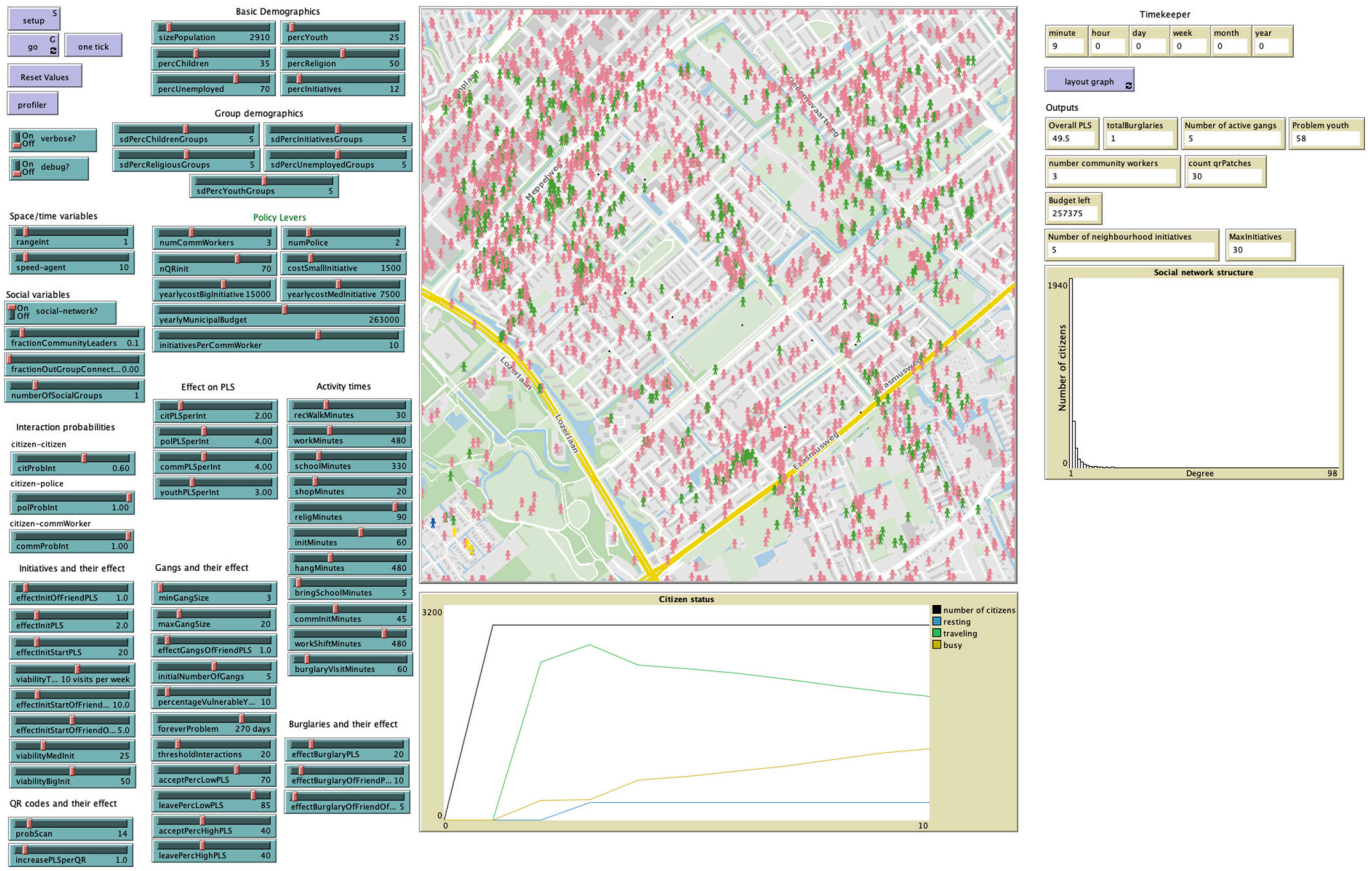

Fig. 2. Interface of the ABM. Green agents are youngsters, red agents are citizens, yellow agents are community workers, and blue agents are police officers. The interface also displays all settings that the model offers. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Time-bound updates that trigger agents or the environment to perform actions.

Time trigger	Entity	Action
New day	Environment	Burglaries happen
	Agents	Create a daily schedule
New week	Environment	Update output lists
	Agents	Youth join or leave gangs
	Environment	Initiatives that reach maximum operating time are removed
	Environment	Probabilities for burglaries and initiatives are recalculated
	Environment	Average PLS is calculated
New month	Environment	New community workers are created
	Environment	Available budget for initiatives is checked
	Agents	Citizens start new initiatives
New year	Environment	The yearly municipal budget for initiatives is restored

event has a lot of impact, like a burglary, these friends also share this information with their friends. Agents who receive information about what has happened to their friends also adapt their PLS accordingly.

4.1.5. *Main model output: PLS*

The key result of the model is the average perceived liveability and safety (PLS) of citizens. This score is a number between 0 and 100. Other outputs that the model produces are: number of initiatives, number of burglaries, municipal budget that is left, and number of youth gangs.

5. Experiments

The run-time of the model is relatively long hence 80 experiments (sixteen experiment scenarios, five runs per scenario) were run with the model, to explore the PLS for four different social network scenarios. After running experiments with no policy interventions, three policy options to intervene in Bouwlust are simulated with the model, to explore the difference in response depending on the social structure at play. The initialisation of the model for the experiments, as well as the four social network scenarios and the three policies are outlined below.

5.1. *Initialisation*

The initialisation of the model is case specific for Bouwlust. The first step of initialisation is to set the municipal budget and initiative costs, the number of burglaries per day, output lists, gangs, and patches for all locations. Neighbourhood initiatives are initialised, 25 % being a medium initiative and 75 % small. A random average neighbourhood PLS is generated between 40 and 70.

The second step is to initiate the population of Bouwlust. There are 29,106 inhabitants in Bouwlust. These inhabitants are translated to 2910 citizen agents. The properties of individuals are randomly and independently distributed as follows (corresponding the actual demographics in Bouwlust): 35 % has children; 30 % has a job; 50 % is religious; 12 % takes part in initiatives. Twenty five percent of all citizens are youth, and of this group, 10 % fall in the vulnerable group. These youth are divided in gangs. Depending on the social network scenario (see below), all citizens are placed in a social group and are connected to other citizens as friends.

Lastly, two police officers and three community workers are

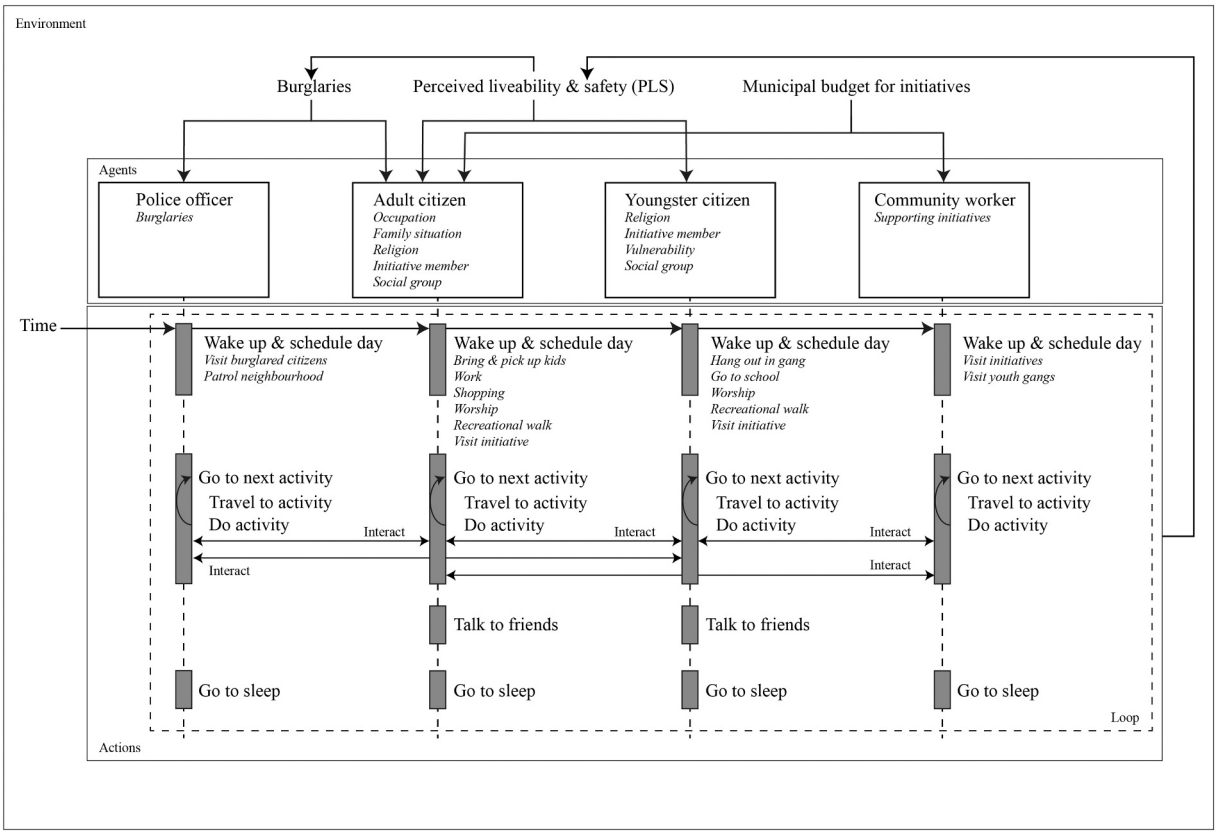

Fig. 3. Action sequence diagram and framework of the model.

Table 2
Effect on PLS of agents meeting each other.

Agent	Agent	Effect on PLS
Normal citizen	Normal citizen	Positive
Normal citizen	Police	Positive
Normal citizen	Community worker	Positive
Normal citizen	Gang member	Negative

Table 3
Activities about which agents report to their friends or friends of friends, whose PLS is also impacted.

Event	Effect on PLS	Shared with friends	Shared with friends of friends
Visit an initiative	Positive	X	
Started a new initiative	Positive	X	X
Saw a youth gang	Negative	X	
Got burglared	Negative	X	X

initialised. Each community worker can support ten initiatives. Note that all of the above described settings can be easily adjusted with the sliders in the interface of the model, to adjust the model to another type of neighbourhood or context.

5.2. Social structure scenarios

The experiments are performed for four different types of social structure scenarios in Bouwlust which are illustrated in Fig. 4. The social structures remain static during the model run. These scenarios are based on current literature on Bouwlust (Blokland, 2003; Van Marissing et al., 2006) and on observations that the authors made during their engagements with Bouwlust in the last ten years. The structure types are:

1. No network: In this neighbourhood, citizens are not connected to each other. They have no relationships and do not share information about what happens in the neighbourhood. Citizens can meet each other on the streets, and this will impact how they perceive the neighbourhood. But besides these direct interactions, they do not engage with each other. This social network corresponds with *Interdependence* relationship described by Blokland (2003).
2. One network: In this neighbourhood, all citizens are connected to each other in one social network. The top 10 % of citizens who have the most connections are community leaders. Citizens who have a relationship with another citizen are each other's friends. Citizens also have friends of friends. Citizens share important events (when a citizen gets burgled or when a citizen starts a new neighbourhood initiative) with their friends and with their friends of friends. Less important events (such as participating in an initiative or seeing a group of problem youth) are only shared with friends. This social network corresponds with *Transactions* relationship of Blokland (2003).
3. Four networks: In this neighbourhood, the social network of citizens is based on their social group. There are multiple social networks that work the same as in scenario 2. The social groups are completely separated and do not share information with each other. This means that information about events in the neighbourhood are only shared in the network of a citizen's own social group. This social network corresponds with *Bonds* relationship (Blokland, 2003).
4. Four connected networks: In this neighbourhood, there are, similar to network 3, four social groups that form separate networks. Because some citizens have a relationship with someone from outside their own social group, the different social networks in the neighbourhood are loosely connected. This means that information about the neighbourhood can travel from one social group to the

a) no connections between citizens (simplified)

b) one social network (simplified)

c) four unconnected social networks (simplified)

d) four loosely connected social networks (simplified)

Fig. 4. The initialisation of the four different social network scenarios. To make this visualisation the number of agents has been reduced to 350, for clarity purposes.

other. This social network corresponds with *Attachments* relationship (Blokland, 2003).

These social network structures are implemented in the model using the sliders and buttons in the model interface (see Fig. 2). For no social network, *social-network?* is turned off. The three sliders below are used to determine which fraction of citizens are a community leader (*fractionCommunityLeaders*), how many social groups there are in the neighbourhood (*numberOfSocialGroups*), and how strongly these are connected (*fractionOutGroupConnection*).

5.3. Policies

The experiments explore the effect of three different policies on the PLS of Bouwlust. First, experiments are run with no policy intervention, resulting in the following four policy scenarios:

1. **Doing nothing: remaining the status quo.** No specific policy is implemented: existing budgets are in place. The number of police officers and the municipal budget are initialised given the actual data from The Hague and Bouwlust.
2. **Investing in neighbourhood initiatives: doubling the municipal budget for neighbourhood initiatives.** For this policy, the municipal budget that is normally spent on neighbourhood initiatives is doubled and the barriers to start an initiative are lowered. This policy is often observed in municipalities (Corbett & Le Dantec, 2018). The assumption is that the more initiatives started, the higher the PLS.
3. **Investing in police officers: hiring three extra police officers in Bouwlust.** Another popular policy in the Netherlands is to increase the so-called ‘eyes and ears’ of the neighbourhood by hiring more community police officers. These officers spend much of their time talking to citizens and moving on the streets, so they can better concentrate on prevention (Van Eijk et al., 2017). Municipalities again assume that this will increase the PLS.
4. **Full investment: extra police officers and neighbourhood initiatives.** This policy combines the levers of policy 2 and 3 to create an extreme case (Yin, 2003). This policy scenario is included to illustrate the (limited) impact policies can make on the PLS.

In the experiments, the four policy scenarios are combined with the four social network scenarios, leading to sixteen different simulations. Each combination is run five times, leading to a total of 80 simulations that were done in the experiments.

5.4. Outputs

The experiments produce the following output variables: Average neighbourhood PLS, number of burglaries, number of initiatives, and left-over municipal budget. The model records these outputs on a weekly basis and the model is run to simulate three years in Bouwlust.

6. Results

The experiments explored the influence of four distinct social structures on the neighbourhood PLS, and illustrated how these four structures respond to four policy scenarios. Since the purpose of the model is to illustrate and expose social structures as a mechanism, experiment outcomes are analysed by visual inspection of the graph outputs, considering upward or downward trends and visually clear differences between social structures, PLS, and the simulated policies.

6.1. Development of PLS in the sixteen scenarios

Fig. 5 shows the weekly development of the overall neighbourhood PLS in each of the sixteen scenarios. There is a distinct difference

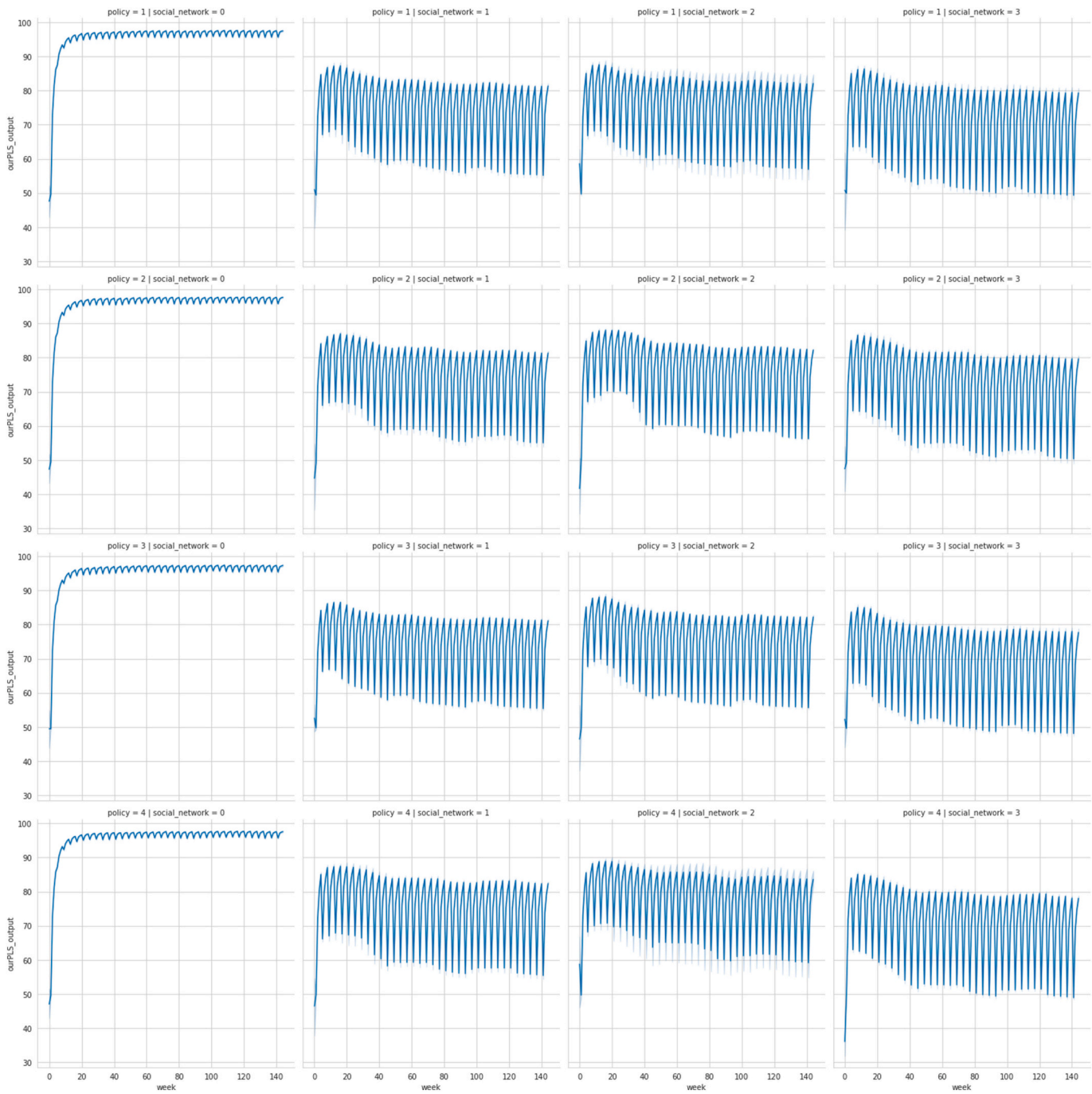

Fig. 5. Overview of how the PLS develops on a weekly basis during the sixteen scenarios.

between scenarios without a social structure implemented and the scenarios with a social structure. When there is no social structure, the PLS increases significantly during the first weeks and then stabilises between 90 and 100. When looking closer at the three social structure scenarios (social_network = 2–4), a slight downward trend of the overall PLS can be observed, as well as differences in how the PLS develops between the three social structures. In all social structure scenarios, the overall PLS fluctuates on a weekly basis between 50 and 90. Social network 4 shows the lowest PLS during the simulation runs, around 48, at the end of the model run (3 years). In contrast, social network 3 leads to the highest PLS score, around 89, after 20 weeks run time.

Fig. 6 plots the average monthly PLS in four different graphs (one for each social structure scenario), given the four policies. This Figure also shows the clear difference of the PLS development between the scenario without a social structure, and three scenarios with a social structure implemented. The right three graphs, furthermore, show that there is merely a difference in how the PLS develops, given the four policy interventions. Yet, in social_network = 2 the full investment policy (policy 4) seems to lead to a higher PLS compared to the other three policies. Nevertheless, in none of the three social structure scenarios, none of the policies is able to turn the negative trend of PLS to a positive or stabilised one.

6.2. Neighbourhood initiatives

Fig. 7 outlines the number of citizen initiatives in the sixteen scenarios that were explored. In all scenarios, the number of initiatives varies from 30 to 0 during the simulation runs. While for the PLS, policy interventions do not seem to make a lot of impact, the graphs in Fig. 7 show significant differences between policy 1 and 3, and 2 and 4. In policy 2 and 4, the Municipality creates easier circumstances for citizen initiatives to start. These policies both show that this also leads to more initiatives starting in the neighbourhood. Notwithstanding, in both cases after about half a year no initiatives remain existing, as the budget for initiatives has run out. In the scenarios with policy 1 and 3 only half the budget of policy 2 and 4 is available, hence initiatives cease to exist even sooner. The available budget for initiatives is definitely the critical factor.

Fig. 8 shows the monthly average number of initiatives under the four policy interventions, in each of the four social structure scenarios. The graphs look very similar, indicating that the social structure does not have a determining influence on the number of initiatives. In the first half year, a peak of initiatives is observed in all four social structure scenarios. After this, the initiative trend stabilises, following the available budget of the municipality.

6.3. Burglaries

Fig. 9 shows the number of burglaries in the sixteen scenarios. The number of burglaries remains relatively stable in each single scenario. Burglaries do not seem affected by any policy intervention, in the scenario with no social structure (see the left column). The remaining twelve graphs indicate that the number of burglaries changes, depending on the policy and on the social structure that was explored. Yet, no clear trend is observed from these graphs.

To consider the effect of policy interventions and social structures on the number of burglaries in more detail, Fig. 10 combines the results of the four policies in one plot, for each social scenario. In policy 3 and 4 more police officers were present in the neighbourhood. One would expect that more police officers lead to less burglaries. However, the plots in Fig. 10 do not show this trend. The number of burglaries is actually the highest for policy 4 in social network scenario 4. In network scenario 2 and 3, policies 4 and 3 respectively have the second largest number of burglaries of all four policies. As such, the results do not outline a consistent relationship between the number of police officers and the number of burglaries.

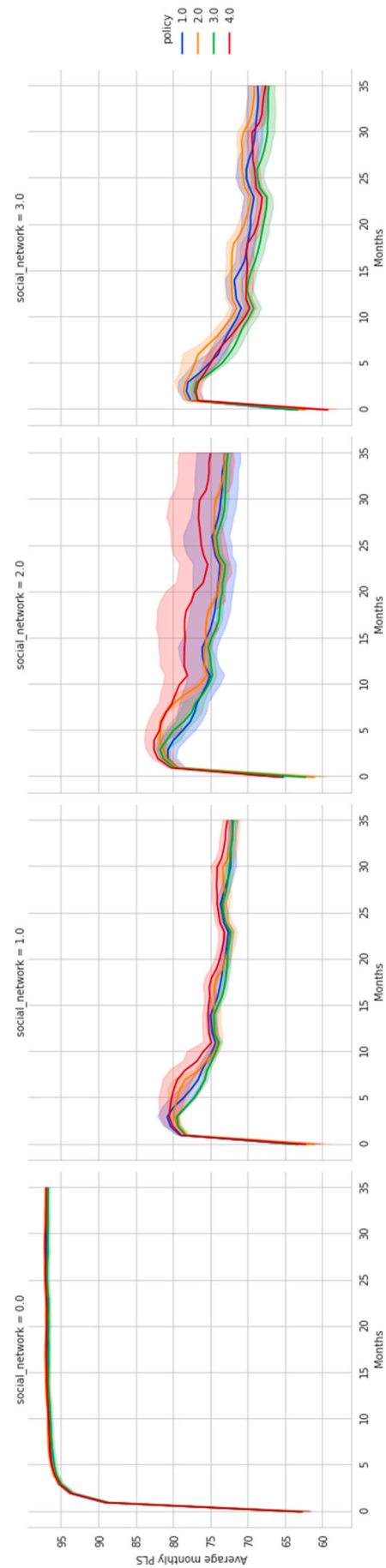

Fig. 6. Establishment of average monthly PLS given the four policies, divided over the four social structure plots. Shaded area shows standard deviation and the line is the mean.

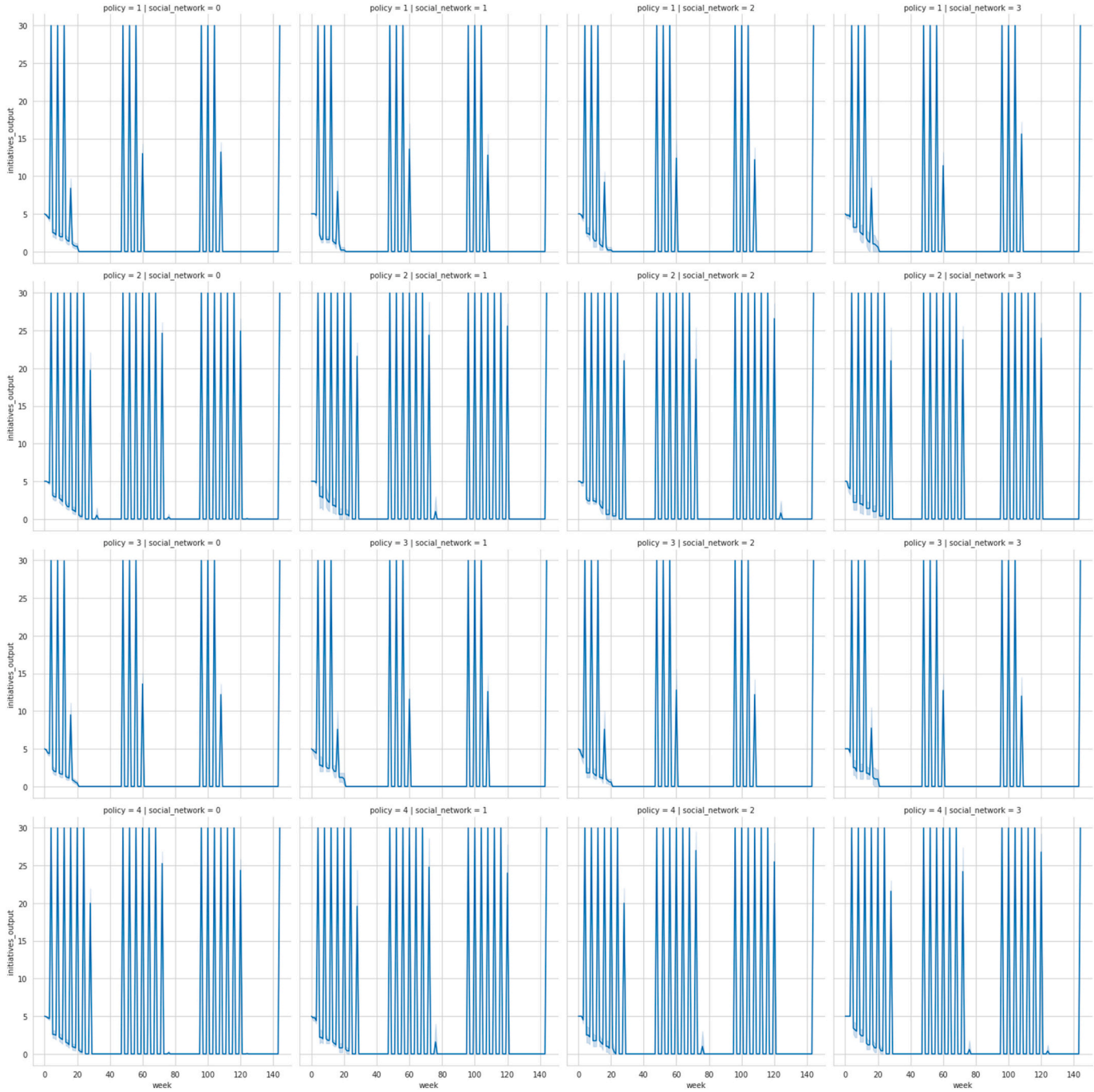

Fig. 7. Overview of the number of neighbourhood initiatives in the sixteen different scenarios.

7. Discussion and conclusion

The results of the experiments, presented above, reveal the influence of local social structures and policy interventions on the way a neighbourhood is perceived by its residents. Local social structures have been identified in literature to play a vital role on liveability and safety of urban neighbourhoods (Shenk et al., 2019). Yet this particular characteristic is often not taken into account when evaluating policies that aim to enhance liveability and safety. The Social Neighbourhood model presented in this paper connects these two concepts and explores how they relate and influence each other.

7.1. Impact of social structures on liveability and safety

Four social structure scenarios were explored using the Social Neighbourhood model. The first scenario incorporated no social structure to be at play in the neighbourhood, the other three varied in terms of number of social groups and in- and out-group connections. For the latter three scenarios, the results indicate a downward trend for the PLS in Bouwlust, suggesting that social connections between residents may have a negative influence on the perceived liveability and safety. This finding contrasts with the general presumption in literature that social connections between residents will improve the liveability and safety of neighbourhoods (Joffe & Smith, 2016; Putnam, 1995).

The observed decline of PLS may be explained through the information that connected networks and citizens share about what is

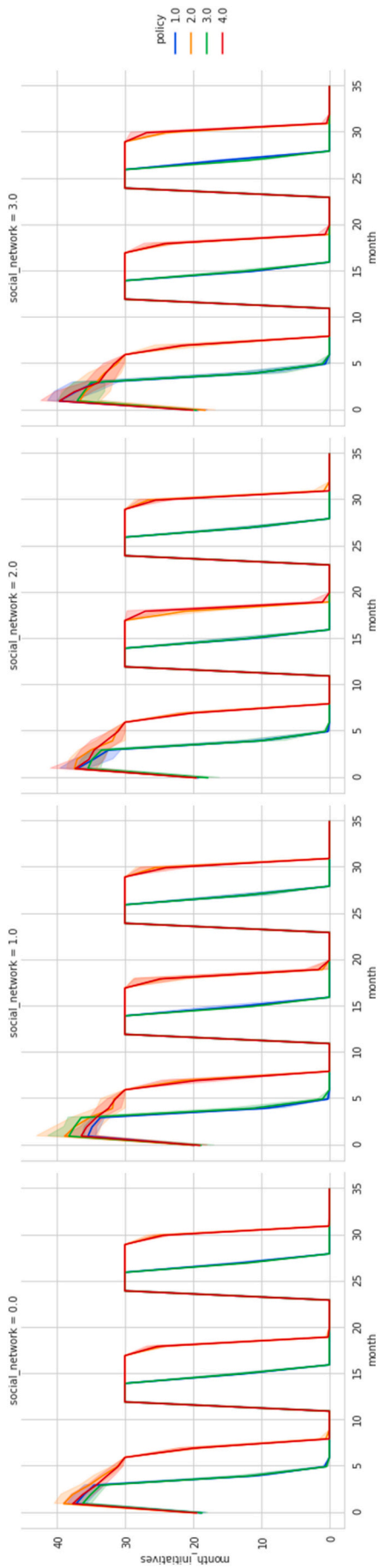

Fig. 8. Neighbourhood initiatives require continuous investment. Shaded area shows standard deviation and the line is the mean.

happening to them in their daily lives. While there are both positive and negative things happening to citizens in the model to talk about with their friends (see Fig. 1), the impact of burglaries and the frequency with which this happens, is likely to have a large influence on the overall PLS outcome. Burglaries lead to large psychological consequences on neighbourhoods (Erete, 2013). The Social Neighbourhood model showed that these consequences can become even more dramatic when citizens are strongly connected and tell each other about what is happening to them. Indeed, the decline of PLS is most steep and results in the lowest overall PLS in the social network scenario where citizens are most strongly connected. In this scenario, citizens also share most information about what is happening in their neighbourhood.

These results suggest that the social structure of a neighbourhood influences the way liveability and safety establishes and develops, leading to the following hypothesis:

Social structures play a significant role in how citizens perceive their neighbourhood.

This hypothesis is seconded by other research, for instance showing that increased information sharing between residents leads to a wider awareness of local issues (Hampton & Wellman, 2003). This hypothesis also echoes current theories on social cohesion and social capital (Putnam, 1995). Municipalities are currently already acting upon this, stimulating places for residents to share local information (Caldwell & Foth, 2014). Yet, the modelling results amplify the potential risk that lays in this strategy, because sharing more information may also lead to citizens feeling less safe. To conclude, municipalities should take the social structures into account when thinking about liveability and safety and consider its inevitable effect.

7.2. Policy interventions to create safer and more liveable neighbourhoods

Besides the impact of local social structures, the experiments considered the effect of policy interventions on the overall neighbourhood PLS, the number of burglaries, and the number of initiatives. The results showed that the policies do not seem to influence the PLS in Bouwlust. Notwithstanding the negative trend observed, indicating that municipalities need to act with policy interventions to break the negative trend of perceived liveability and safety, also suggested in literature (Van Marissing et al., 2006).

One of the explored policies in the model was to invest in neighbourhood initiatives, by doubling the municipal budget. The Neighbourhood Social model showed that the underlying assumption, also supported in literature (De Koning et al., 2018), namely that more initiatives will start, is valid. These results indicate that funding is a pressing issue for neighbourhood initiatives to continue. When municipalities make extra budget available, it will be used by citizens. Other researchers reflect that investments in initiatives are a continuous effort (Sejer Iversen & Dindler, 2014; Simonsen & Hertzum, 2012), and the results presented in this paper further confirm this, leading to the following hypothesis:

Neighbourhood initiatives need continuous support of municipalities to persist.

However, the influence of all three policy interventions on the perceived liveability and safety seems limited. Hiring extra police officers or doubling the budget for neighbourhood initiatives does not lead to a higher PLS. Instead, the Social Neighbourhood model signals the influence of social structures at play which is further discussed in the next section.

7.3. Combining social structures and policies in modelling

The experiments with three policy interventions implemented (supporting neighbourhood initiatives, increasing the number of police officers, or both) did not show to make any difference on the PLS outcome. These results suggests that the social structure at play in a neighbourhood impacts the way citizens perceive their neighbourhood, and that

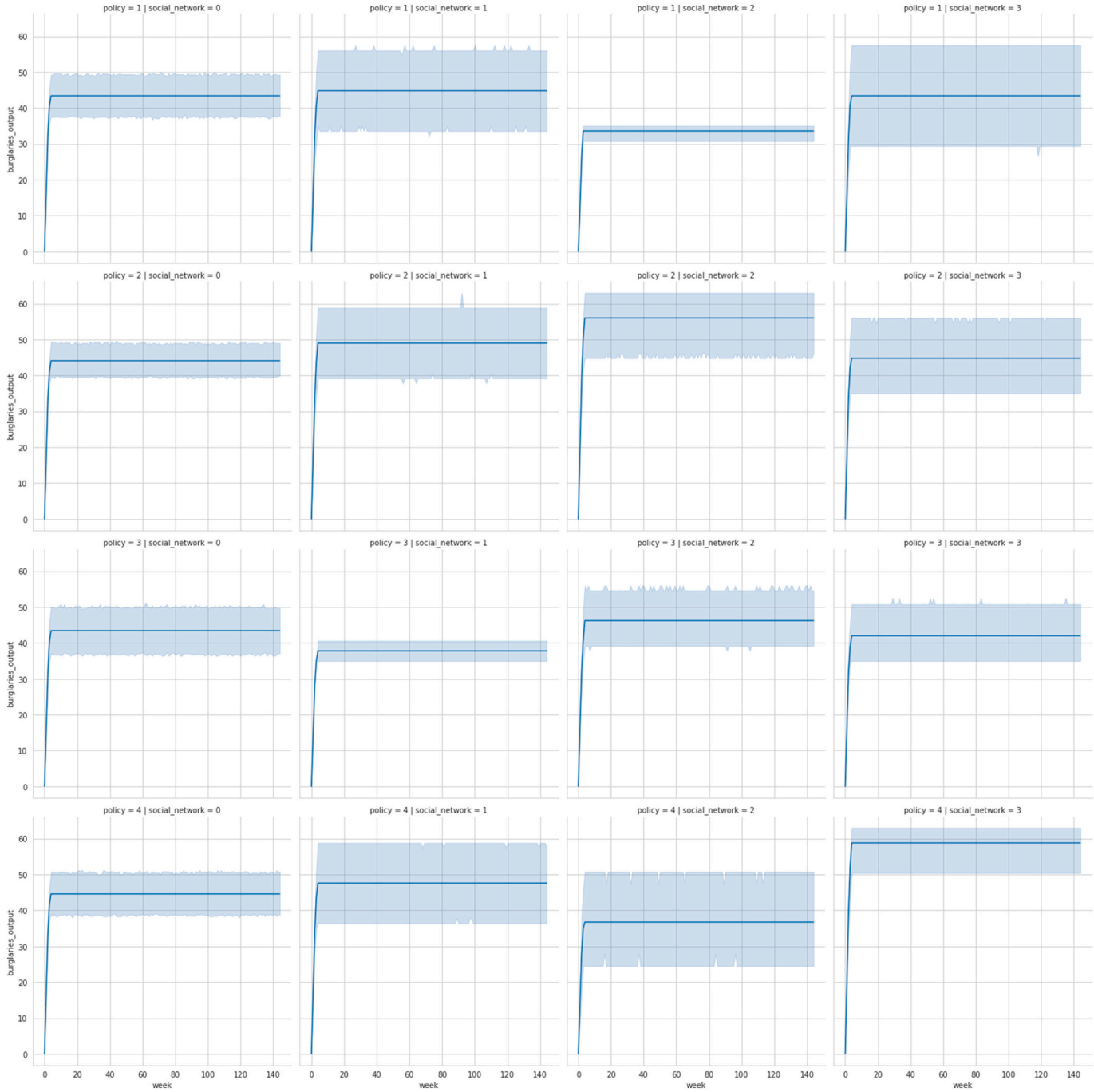

Fig. 9. Overview of the number of burglaries in the sixteen different scenarios. Shaded area shows standard deviation and the line is the mean.

policy interventions do not make much of a difference. This observation may support the hypothesis that social structures in a neighbourhood are more important to the way citizens perceive their neighbourhood than often is taken into account:

Social structures are more strongly correlated with PLS than the type of policy intervention.

This means that municipalities cannot only consider policy options when thinking about liveability and safety, because they miss a vital part of the picture. Local governments are often inclined to apply best practices in one neighbourhood directly in another, without taking into account the (social) structure at play (Slingerland et al., 2020). Yet, literature already signalled for instance the spatial structure as a determining factor for improving liveability and safety of neighbourhoods (Bottini, 2018). The findings of this paper highlight that social structures in neighbourhoods also have a substantial effect on how liveability and safety can be addressed.

7.4. Limitations and future work

The experiments run with the Social Neighbourhood model were based on the observations that researchers made in Bouwlust, a neighbourhood in The Hague, and hence includes patterns and behaviour that may be specific to this area. Furthermore, the conceptualisation of the PLS (see Fig. 1), including the weight that was given to certain interactions and events, was difficult to quantify and has a determining effect on the model outcome. Despite this, the interactions and patterns included reflect the theories of social cohesion and social networks. Future work on the model should focus on further detailing these

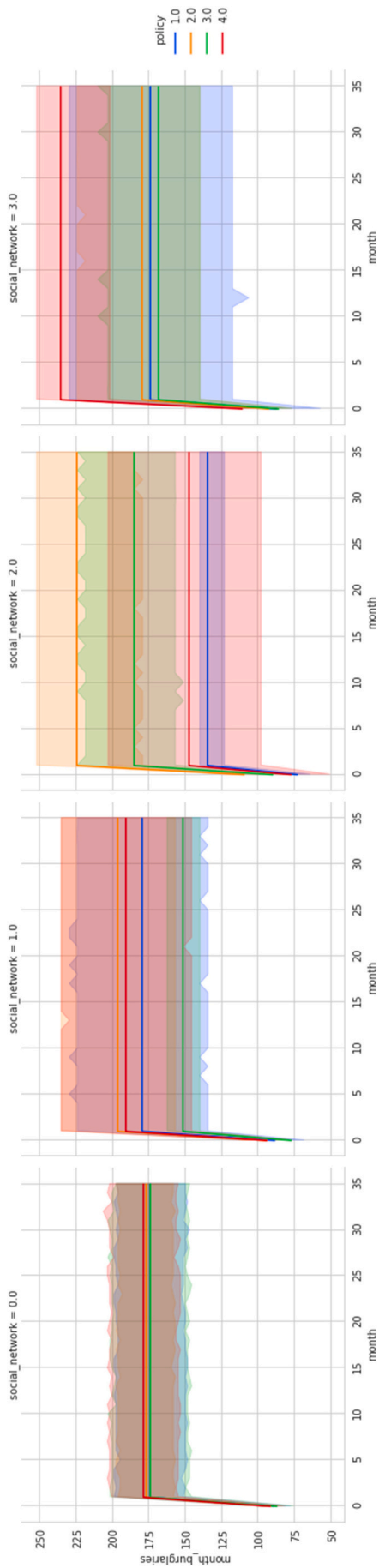

Fig. 10. Whether the policy of extra police officers is effective, is influenced by the social network in place. Shaded area shows standard deviation and the line is the mean.

patterns, especially the interactions between citizens and other agents. This could, for example, be done by cross-validations. This requires specific data to be available of urban neighbourhoods on social interactions and their effect on perceived liveability and safety. This empirical data is then to be used to simulate the neighbourhood and sophisticate the interaction patterns currently present in the model.

Despite its limitations, the Social Neighbourhood model has been designed to be easily used by other researchers to further understanding of how liveability and safety are established. The model is published open source and its interface includes many buttons and sliders for researchers to adjust the model to a different neighbourhood. Currently, the model does not support simulation of dynamic social networks: the social structures are initialised before running the simulations and remain static. This means that possibly the effect of dynamic social structures on liveability and safety is currently underestimated in the results presented in this study. Future development of the model should hence elaborate the social structure simulations, to better reflect the empirical world.

The Social Neighbourhood model was able to unravel the influence of local social structures on a neighbourhood's liveability and safety. The results of the simulation experiments lead to drawing up three hypothesis concerning the dynamic between policy interventions and local social structures in urban neighbourhoods. Based on the findings that this paper presented, a key policy priority of local government should be to design policies that take into account local social structures of neighbourhoods, to be effective in improving liveability and safety. Our results signal that social structures are more strongly correlated with liveability and safety in comparison to urban policies. Municipalities have already become aware that they need to adjust policy interventions to social structures at play. In the city of Rotterdam (Netherlands), for example, the municipality is now testing two different residential development programmes that are tailored to the targeted neighbourhoods. One programme focuses on strengthening and making use of the strong social networks that are present in the neighbourhoods, to improve liveability and safety, while the other programme has a more individual approach, as in these neighbourhoods social structures are lacking (Doff, 2017; Slingerland et al., 2022). This is an inspiring example of a more holistic approach to liveability and safety, taking both policies options and social structures into account. The findings of this paper provide further grounding for such tailored approaches, in which municipalities adjust policies based on the characteristics and social structure of a neighbourhood. The Social Neighbourhood brings a novel simulation tool for researchers and practitioners to better understand this relationship, ultimately leading to more effective urban interventions for liveability and safety.

CRediT authorship contribution statement

Geertje Slingerland: Conceptualisation, Methodology, Software, Validation, Formal analysis, Visualisation, Writing – Original Draft.

Igor Nikolic: Conceptualisation, Methodology, Software, Formal analysis, Visualisation, Writing – Review & Editing.

Frances Brazier: Conceptualisation, Writing – Review & Editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cities.2023.104215.

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