RESEARCH REPORT

Understanding urban social capital landscapes as an informant of digital twin use-cases in South Africa

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DECLARATION OF ORIGINALITY

I declare that the mini-dissertation, Understanding urban social capital landscapes as an informant of digital twins use-cases in South Africa, which has been submitted in fulfilment of part of the requirements for the module of DIT 801, at the University of Pretoria, is my own work and has not previously been submitted by me for any degree at the University of Pretoria or any other tertiary institution.

I declare that I obtained the applicable research ethics approval in order to conduct the research that has been described in this dissertation.

I declare that I have observed the ethical standards required in terms of the University of Pretoria's ethic code for researchers and have followed the policy guidelines for responsible research.

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Date: 24/7/2023

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Abstract

In the coming decades, Sub-Saharan Africa's urban growth is expected to be the highest globally (Dodman, D et al. 2017). These small to medium sized cities in Africa will experience rapid growth, more so than in urban centres, making it difficult to meet the requirements of infrastructure and services that can reduce urban risks (Dodman, D et al. 2017). These risks can happen across a spectrum, of varying scale, from everyday small events such as infectious diseases to larger less frequent risks such as earthquakes and storms, constant poverty, climate change and the problems that urban growth brings upon (Dodman, D et al 2017). Urban populations face genuine risks to their health, safety, and overall well-being due to the various challenges they encounter. In order to combat urban risk, urban resilience is required, because urban resilience is the adaptive capacity of a city or urban system to recover from shocks and various stressors such as urban risks (Harrison et al 2014). Urban resilience is not limited to technical and social aspects. Instead, social capital provides the flexibility that is able to support urban resilience and recovery effectively from those risks (Dobson (2017).Understanding the social capital landscape of an urban community offers a valuable means of comprehending the interdependencies and self-sufficiency of that community. This could lead to identifying appropriate and contextual urban strategies to enhance community well-being.

Emerging digital technologies could be effective tools to facilitate urban strategies for communities. One such technology is digital twins for cities. Digital twins for cities is the digitization of a city's physical elements, systems, and operations to observe and analyse its historical and current performance and actions (Davey et al 2023). These data driven responsive feedback tools can assist in bridging the gap between implementation and reality. However, most digital twins focus on the physical and technical (technology centric view) dimensions of the city (Ravid & Gutman 2022) such as the technical functionality of its infrastructure, data modelling, planning and management, as well as enhancing those related services (Nochta et al 2020). Nevertheless, this approach does not necessarily take into consideration what people do on the ground, how people navigate their built environment. As such, this approach may miss out on the social capital needs of urban communities and hinder the effectiveness of digital twins technologies in servicing real needs of people.

This paper explores how the understanding of social capital could inform relevant digital twins use-cases in South Africa. As such, by analysing the social aspects of a specific urban area, city makers can identify and leverage the opportunities, strengths, and needs of communities to articulate how digital technologies could be deployed to improve the effectiveness of urban interventions and help identify social issues in the city. This paper focuses on a middle-income case study of Hatfield, City of Tshwane, South Africa. Using a mixed-methods approach, this paper maps social capital metrics within a community, and analyses the mapping through a theoretical framework of grounded theory. This mapped information forms the data that can be used to build a viable digital twins city that takes into consideration the social aspect of communities.

Keywords
Digital twins, social capital, urban resilience

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1. Introduction

In the coming decades, small to medium-sized Sub-Saharan African cities will experience rapid urban growth and are expected to be the highest globally, this will pose significant challenges in meeting infrastructure and service requirements (Dodman, D et al. 2017). These challenges generate real urban risks threatening urban populations' health, safety, and well-being, including social, economic, environmental, and technological risks. To counteract and manage urban risk, new technologies like digital twins for cities show great promise. Digital twins for cities is the digitization of a city's physical elements, systems, and operations to observe and analyse its historical and current performance and actions (Davey et al 2023). However, the problem with digital twins for cities is that often, the technology isn't driven from a needs perspective, but from a technological or infrastructure perspective. The consequence is that many urban technology initiatives fail (see Google Sidewalk Labs as case study). As such, there is a need to study how understanding the social capital landscapes of communities could best be served through data-driven technologies, such as digital twins for cities.

To explore how emerging technology can service the real needs of urban communities, it is helpful to build a theoretical model of community needs. For this paper, we are exploring three concepts to articulate community needs. 1) Social capital , 2)Urban resilience and 3) Self-reliance.

Urban resilience is the counterbalance to urban risk, which is why many urbanists promote improving urban resilience in cities. Urban resilience is the capacity of people, communities, and socio-ecological systems, such as urban areas, to not just endure changes, disruptions, hardships, or catastrophes, but to be able to adapt and create new solutions that are improved and are more favourable states (Harrison et al 2014). Urban resilience is important in creating a sustainable environment, it promotes well-being of the people and supports inclusive and sustainable prosperity (Resilient Cities Network, 2022).

According to Dobson (2017), urban resilience encompasses technical and social aspects, which includes the capacity of households, organisations, governments, businesses, and the construction of buildings and infrastructure. While physical, financial, and social resources contribute to urban resilience's foundation capacity. Foundation capacity being the fundamental capabilities and resources that are needed to achieve its goals and effectively respond to challenges and opportunities. Social capital provides the flexibility necessary for effective recovery from shocks. Social capital is defined as the networks, norms, shared beliefs, relationships that facilitate cooperation and collaborative action for mutual benefits (Bhandari and Yasunobu 2009) and contributes to a community's economic and social wellbeing.

A shock is an unanticipated change, event or experience that endangers a group of people's way of life, customs, or economy (Collins 2023). This could be interpreted as sudden flooding in an area that does not receive heavy rainfall, but it suddenly experiences heavy rainfall and rising water levels that lead to the destruction of infrastructure. Whilst a risk is the likelihood of an uncertain event happening that has potential negative consequences (Oxford University press 2023). It would be flooding in a coastal area. Urban resilience would be the ability to

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handle the shock or risk of flooding by having the necessary provisions to handle both situations. In respect to shock, emergency response efforts, including evacuation, search and rescue operations, and the provision of emergency supplies and shelter. In respect to risk, flood prevention infrastructure, land use planning, and early warning systems. Social capital would be the community's intervention or action in such an event either through volunteering in search and rescue efforts or managing shelters in regards to shock, or in the case of a risk through financial contributions in flood prevention infrastructure or volunteering their services. Digital twins for cities that understand the social capital landscape and the urban resilience of the area would mean that shocks or risks that arise could be planned or managed for, identifying whom it'll affect and where the need arises.

The final aspect of our community needs model is community self-reliance. Self-reliance is the ability of an individual, household or community from a social and economic sense to be able to meet their own essential needs such as food and water, shelter, safety and protection and education in a way that is sustainable and that allows dignity (UNHCR 2023).

As such, the three core ideas help us see if understanding the social capital landscape can inform well-defined and contextual / relevant digital twins use-cases. The data collected would inform us of the existing social capital of the area, this information will help us understand its ability to be self-reliant in order to handle any shocks and stressors that arise.

Self-reliance and urban resilience are concepts that are similar in nature but differ in meaning. Urban resilience is the ability to be able to prepare and recover from shocks whilst self-reliance is the ability to look after oneself. One could say that an attribute of resilience is being self-reliant. Social capital could be a useful mechanism for understanding the dependencies or self-reliance of urban communities and which tools to implement to improve the community (figure 1). The paper will look at the social attributes, specifically social capital, the connections that are formed between people that can assist in self-reliance within communities.

Strong social capital in cities would help in building a stronger sense of community and belonging. This would mean that people would be better equipped and responsive to work together to address common local challenges. At neighbourhood levels, it not only contributes to lower levels of crime and strong social support systems but also to better health for the overall community (Aldridge et al 2002). At a regional level, social capital contributes to the local economic performance. There's an association between the trust that is held between people and the growth of the economy, there is a positive association between social capital and civic engagement (Aldridge et al 2002). When people feel connected to each other, there is access to information (Aldridge et al 2002).

1.1 Social Capital and emerging technology

If we are to examine South African cities, we will need technologies that can monitor and review such complex issues.These issues such as the social capital of cities, in close to real-time. One such technology is digital twins technology. Digital twins technology offers a promising solution for real-time monitoring of complex city issues. Digital twins for cities are data-driven feedback environments that could help cities better understand complex urban issues and test

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interventions in a virtual space (Ravid and Gutnman 2022). Most digital twins focus on the physical and technical (technology-centric view) dimensions of the city (Ravid & Gutman 2022) such as the technical functionality of its infrastructure, data modelling, planning and management, as well as enhancing those related services (Nochta et al 2020). However, this approach is focused on a physical level such as infrastructure and not necessarily at a social level (Ravid & Gutman 2022) on what people need or do on the ground.

To understand what people need on the ground and how digital twins technology could service that need, it could be helpful to look at how social capital landscapes are formed in a city. To do so, we focus on one aspect of urban resilience, namely social capital (figure 1). We think that examining social capital will help articulate better digital twins use-cases. As such city makers can identify and leverage the strengths of communities and social networks to improve the effectiveness of urban interventions.
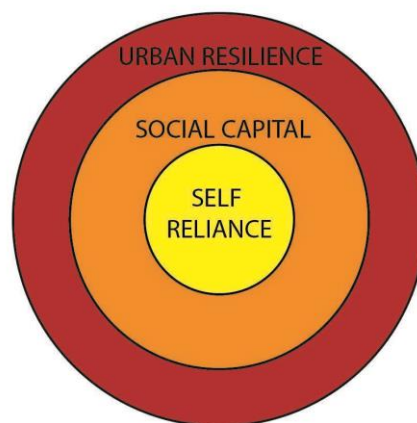

Figure 1 : Diagram depicting the relationship between urban resilience, social capital and self-reliance (Masu 2023)

Social capital is not easily measured but can be deduced from its determinants or observable outcomes. These determinants or observable outcomes are elements that influence social interactions and as a result, facilitate the development of social capital (Claridge 2017). This coupled with multiple definitions and indices makes it difficult to find a single unit of measure. This is problematic in developing digital twins city solutions as there is no set way to define or measure social capital. Digital twins need concrete data that is expressed in a manner that can be measured or counted, so quantitative in nature. While we understand social capital has a qualitative aspect, to make this intangible concept useful in urban tools, we need to quantify social capital for urban landscapes in terms of social capital metrics. In order to do that we need to identify quantitative metrics that will be useful in producing social capital landscapes. The intention is to identify what quantitative metrics will be useful in producing a social capital landscape so that we can leverage data for digital twin applications. Secondly is to build a

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social capital index that informs us of the social capital levels in Hatfield The social capital index is the sum of social accessibility and desirability of amenities in Hatfield.

Social capital can be measured through several factors including social networks, trust, local norms, values and governance (Grootaert et al 2001) . This paper suggests that understanding and mapping social capital may be an important aspect to consider in developing relevant digital twins use-cases in South Africa, as it will help us understand the real social problems of people on the ground. Taking on an inductive approach, a quantitative and qualitative approach is used to develop indicators specific to the urban built environment. This approach would then allow for the formation of context specific indicators that are based on social capital being mapped and speak to whether it contributes to digital twins use-cases. The approach taken is to explain the theoretical concepts of social capital. This is done by explaining the theory and situating it in the urban environment. The next chapter discusses the context of the research study, followed by the methodology. It will comprise of desktop research and the use of Geographical information systems (GIS) explaining the metrics used and how the data is collected. Next the data is analysed through grounded theory and is followed by the results, whilst discussing if the findings contain information that can contribute in assisting in a digital twins use-case.

2. Literature Review

2.1 Conceptualising Social Capital in the context for Digital Twins

Social Capital does not have one set definition, and the definitions taken on by a study will differ depending on the type of investigation and the discipline it is in (Claridge 2004). There are now considerable differences in theory due to the problems that have risen from the definitions and ideologies (Claridge 2004). This has then resulted in multiple approaches of conceptualization (Claridge 2004). What happens is that social capital is discussed as a concept and the variety of ways in which it can be used. Certain outstanding problems are then considered before a particular viewpoint is chosen and redefined to suit the study (Claridge 2004).

Bordieu, Coleman and Putnam popularised the concept but Robert Putnam is the most prominent figure in social capital theory (Aldridge et al 2002). Putnam describes it as "participants to act together more effectively to pursue shared objectives…". "Social capital, refers to "social connections and the attendant norms and trust" (Putnam, 1995). What is considered the main constituents by some authors is what occurs between the relationships such as the links and values. There are others that argue over the significance of the norms and trust that is put in them and shared (Acedo et al 2020).

More recent work that is commonly used as a framework for social capital has distinguished social capital into three main types; bonding, bridging and linking (Aldridge et al 2002). Bonding is characterised by having strong bonds (Claridge 2004). It is usually described as horizontal ties between people of the same social group and is seen among family members or people within an ethnic group or people associated within a local community that know each other

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(Aldridge et al 2002). Bridging social capital is characterised by weaker social connections but are more cross-cutting and is usually seen as vertical ties that work through formally ranked structures (Claridge 2004). These are acquaintances, friends of friends and associates (Aldridge et al 2002). Lastly, linking is characterised by a connection between those that have a different levels of power or social status such as people from different social classes, the politicians and the general public (Aldridge et al 2002).

Another significant distinction that was developed by Norman Uphoff and Wijayaratna (2000) relates to the structural and cognitive dimension of social capital. These two types of social capital are commonly connected and are mutually reinforcing (Grootaert et al 2001). Structural dimension of social capital relates to the attributes of the social system and the web of connections as a whole. It links to the characteristics of the social system and the different forms of social organisation that are the composition of society (Claridge 2004). These are networks, associations and institutions such as neighbourhood associations and sports groups. The structural dimension describes the links between people and units that are not personal. The structural dimension is more tangible and can easily be observed than the other dimensions (Claridge 2004), which makes it a good informant for data-driven technologies such as digital twins. On the other hand, the cognitive dimension of social capital refers to the cultural or societal context that determines the appropriate behaviour in various circumstances or environments. The cognitive dimension pertains to the correct rules for conduct within a social framework (Claridge 2004) such as general shared values, trust and behavioural norms that are acceptable. This intangible quality of cognitive social capital is harder to quantify. This paper will work within the structural dimension.

To develop a digital twins from a community needs perspective, social capital needs to be understood as more than merely a metaphor, it must refer to things. There needs to be a way social capital can be measured and observed to be quantitatively studied. Another theory in *Spatializing social capital* by Rutten et al (2010) discusses two main schools of thought in literature regarding the production of social capital (Rutten et al 2010). These are the structuralist approach and the interactionist approach. The structuralist considers social capital as the connection a person has with others; and the interactionists approach is the quality of the interaction between the individual and social interactions (Rutten et al 2010). With the structuralist approach, if an individual has many social connections they have high social capital, the connections they have allow for more access to resources and opportunities (Rutten et al 2010) these are acquaintances or business associates. With the interactionists, the connections alone are not enough, it's based on what happens between these connections that determines the value of their social capital (Rutten et al 2010) these are family and friends. Most definitions of social capital take into account both perspectives as they see the value of both. The context in which social interactions can occur is provided by the structure of the network (Rutten et al 2010). Both structuralist and interactionist approaches don't cover the function of social capital and what effect it has, because it only explains the connections and quality of the connections. For example, the connections and quality between family members but not how these connections work.

However not all social capital is advantageous. Sometimes these behaviours and connections do not always improve economic performances, but instead act as a barrier to social inclusion

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and mobility, causing segregation in communities and societies. This can lead to increases in crime, decreasing education achievement and behaviour that contributes to damaging health (Claridge 2004). This can be the formation of gangs, terrorist groups, sectarian societies and mafias or price fixing that happens when professionals of the same trade meet together.

For this paper, social capital will be defined as the social interactions between groups of people or organisations that foster feelings of trust and the ability to reciprocate. Social capital includes both the structuralist and interactionist approach as they are relevant. However,in the context of this study, this paper will focus more on the structural conditions, such as the number of connections an organisation has that allows them to access resources rather than the quality of the social interactions.

By understanding what social capital is we can begin to construct a definition and theoretical framework that is relevant and assists in creating metrics for the digital twins data needs. Social capital has the potential to serve as a valuable approach for comprehending the interdependencies or self-sufficiency of urban societies and determining which strategies can be employed to enhance the community. Social capital is the element needed for a community to be self reliant.

The paper derived themes through looking at different papers that could express social capital in a relational form. There are numerous papers on social capital, its attributes, effects and its influences that mainly focus on the intangible quality and effect on society. Though there are few that can express social capital and its relational nature in a manner that would allow us to derive themes for the social capital index. To build the social capital index comparable variables are needed, this is achieved by mapping information on certain aspects of social capital. This requires social capital to have spatial attributes that allow metrics to be mapped. Papers that mapped social capital using GIS were first investigated. This was seen through the lens of GIS mapping of social sciences. These papers were qualitative in nature and proved to be difficult to emulate in the study. The next step was to look at social capital and identify quantitative markers that could be used in the study. Through reading multiple different papers, themes started to arise that social capital manifests in many different ways but five different categories were chosen, these being place, distance, time, accessibility and quality (figure 2). The papers were then filtered to exclusively look at social capital through the five different categories, to better define the themes used throughout the paper.

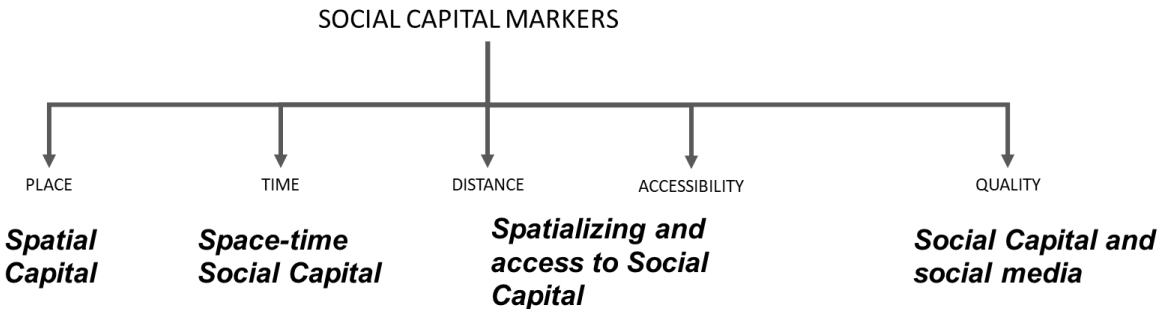SOCIAL CAPITAL MARKERS

PLACE	TIME	DISTANCE	ACCESSIBILITY	QUALITY
Spatial Capital	*Space-time Social Capital*	*Spatializing and access to Social Capital*		*Social Capital and social media*

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Figure 2: Diagram of social capital markers used in the study (Masu 2023)

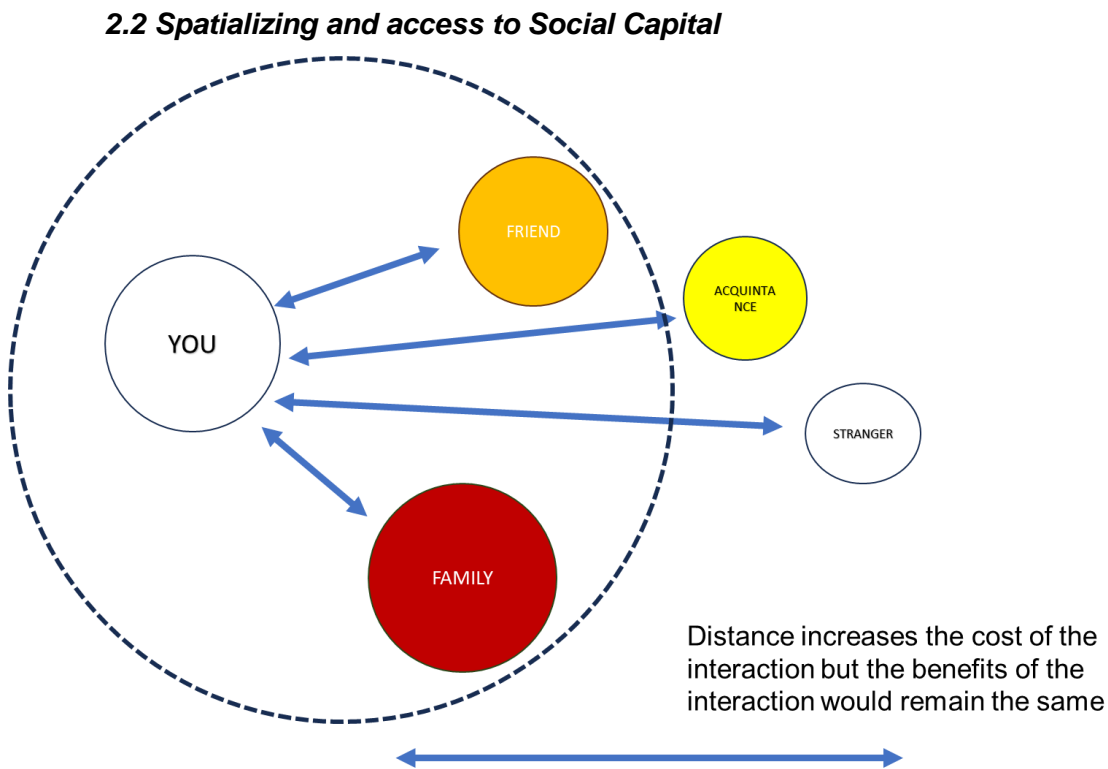## *2.2 Spatializing and access to Social Capital*

Figure 3: Relational nature of social capital, effects of distance on connections and social capital (Masu 2023)

Social capital has a relational nature as social individual activities tend to occur in physical space (Rutten et al 2010). The characteristics of social capital differ depending on the geographical location where social interactions take place, indicating that it is influenced by geographical variation (Mohan & Mohan 2002). There are several factors at work when it relates to spatial dimension to social capital. Depending on the type of social interaction and relation, and what happens within that relation, different social capitals can be formed (Rutten et al 2010). The type of social interactions that are within a network seems to be determined by the geographical distribution of the people that form the network and their connection to the structure of the social network (Rutten et al (2010). This could be the difference between an acquaintance that lives far and a friend that lives far. The type of connection you have with a friend could be strong and although they live far the connection could survive as opposed to an acquaintance where the connection is already low and there is distance between them, the interaction to distance cost increases (figure 3). This means it is easier to maintain social relations that are within close distance than afar, as distance would increase the cost of the interaction but the benefits of the interaction would remain the same (Rutten et al (2010).

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Spatial distribution is crucial as it influences social networks and the flow of resources for social capital (Foster et al 2019). If participating in different types of group activities helps build social capital, it is reasonable to expect differences in social capital across geographical regions (Mohan & Mohan 2002). Social capital can then be affected by unequal growth as the quality of the social connections are affected (Mohan & Mohan 2002). This begins to convey the complex issue of accessibility to resources which affects the social capital of an area. Privatisation of resources has positive and negative impacts on social capital. It can exacerbate social inequalities by limiting access to essential services or goods or when essential services become subject to profit-driven models. Accessible communities' foster inclusivity, participation, and connections. This allows for the development of stronger social ties, trust, and collective action.

In summary, geography plays a crucial role in shaping social capital. The geographic context influences the formation of social networks, access to resources, diversity, information flow, and regional disparities. All of these impact the level and distribution of social capital within a given area. Therefore social capital and geography are interlinked, and it affects the subgroups level within a regional population, instead of the entire region (Rutten et al 2010).

Social capital is also influenced by accessibility. This happens in two ways; access in terms of proximity and access in terms of privatisation of goods and services that can affect the marginalised. Accessibility and distance could be a metric that can be used in the digital twins.

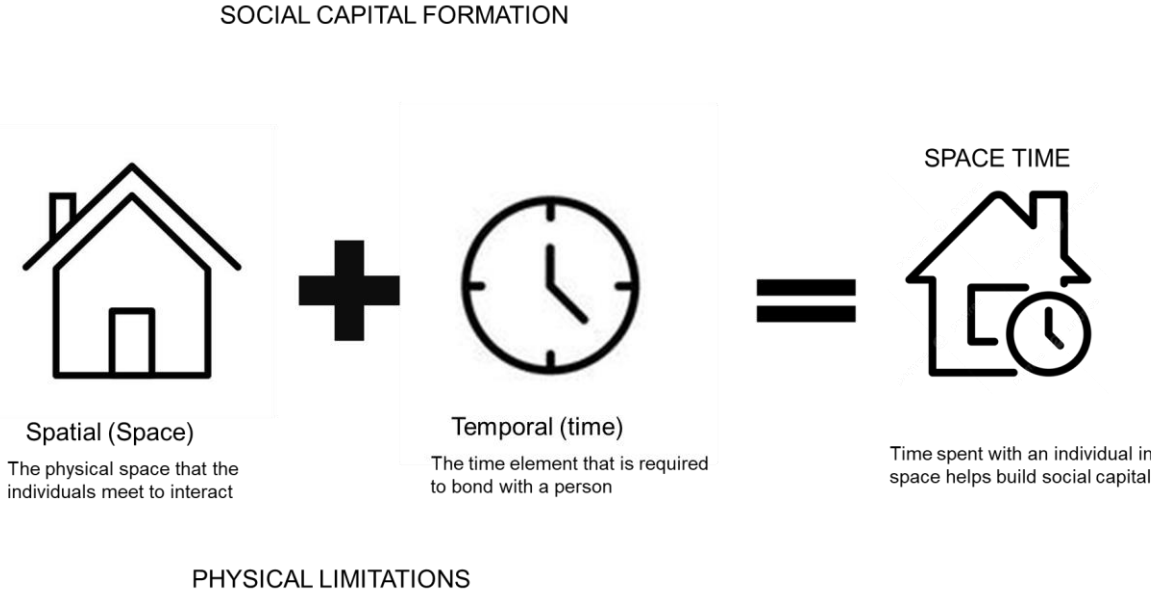### 2.3 Space-time Social Capital

Figure 4: Space time social capital formation (Masu 2023)

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Social capital requires effort and some form of investment to be able to maintain, which means it is constrained by the physical limitations of space, time and space-time (figure 4) (Claridge 2022). For example, maintaining a relationship with a family member, requires the individual to physically meet the person and take the time to engage/bond with them. By spending time with others, participating in community activities, and engaging in social interactions, individuals have the opportunity to develop and strengthen social connections. The more time invested in relationships, the greater the potential for social capital to develop. Relationships that are developed, maintained and share understandings, encompass both temporal and spatial aspects (figure 4) (Claridge 2022). Temporal being the time element that is required to bond with a person and the spatial aspect the physical space that the individuals meet to interact. The internet and advancements in communication technology have reduced social distances, reducing the gap between people regardless of geographic distance (Forster et al 2019). This communication technology encompasses the use of social media tools like Facebook and instant messaging applications like Whatsapp. There are aspects of social capital that are constrained because of space-time limitations (Claridge 2022). For example relationships between an employer and his employees that are limited to the work space. In order to build & maintain relationships interacting is required and this happens in space and time. In order to reach shared understanding, interaction and communication are required (Claridge 2022).

Trust is a crucial element of social capital. Over time, as individuals interact and build relationships, trust can develop and deepen. As relationships develop over time, individuals are more likely to engage in reciprocal behaviour, further strengthening social ties. While social capital can be built and maintained through time investment, it can also erode if relationships and connections are neglected or lost. If individuals do not invest sufficient time in maintaining social ties, trust may weaken, networks may shrink, and the benefits derived from social capital can diminish.

Time cannot be removed from space as strong ties are developed over time, it then allows positive social interactions to continue over long distance (Rutten et al (2010). Xu et al (2017) discovered that certain places depending on the time and day can impact social capital. For example a nightclub where social interactions happen at night in preexisting social spaces versus a church which is religious in nature and is established can create a particular type of bond over space and time. In summary, time is a significant factor in the development, maintenance, and erosion of social capital. It can be used as a key determinant on the type and strength of social capital being developed. Time is a metric that can be used in the digital twins.

2.4 Spatial Capital

Measuring social capital directly is not possible, but we can indirectly infer it from its causes or results (Claridge 2004). Unfortunately, there are few tools and instruments available to precisely describe the spatial aspects of human-urban settings such as social capital (Acedo et al 2020). This is due to its varied definitions and intangible aspects. However, for determining appropriate digital twins use-cases, social capital requires metrics that allow it to be reliably

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mapped in spatial data structures. This can be done through using the concept of spatial capital.

Spatial capital is the degree to which a community has access to most essential resources within close proximity (Sen & Quercia 2017). Access to these resources is beneficial in addressing health issues, car dependency and fuel consumption, which would lead to enhancing environmental sustainability (Sen & Quercia 2017). This makes neighbourhoods more liveable and therefore increases its social capital (Sen & Quercia 2017). In Sen & Quercia's (2017) paper *World wide spatial capital*, they map spatial capital by mapping amenities in hopes of creating a spatial metric that can be used anywhere in the world by using Google place data. It looks at how effective their metrics are at deciding what urban interventions are required in a city and more specifically determines which areas in a city require interventions.

A factor that limits the research into the spatial behaviour of social capital is due to the integration of spatial elements into political and administrative boundaries (Acedo et al 2020). Political boundaries are lines or borders that separates one political entity, such as a state, or province, from another. They are used to delineate the jurisdictional and administrative divisions between different territories. There are authors that associate social capital to the homes (Foster et al 2015), workplaces (Timberlake 2005) and neighbourhoods (Sampson and Graaif 2009). In this globalised era, it is too restrictive to use administrative boundaries as a means to delineate social capital, as there is now greater individual mobility and proximity to things relative to the individual's position (Acedo et al 2020). So, if your home is on the periphery your social capital could be in the next administrative boundary. Social capital is studied at a local level and administrative boundaries are political structures that don't necessarily correspond to uniform social entities (Acedo et al 2020).

Spatial capital highlights the need for resources within proximity. The presence of amenities can contribute to the formation and strengthening of social capital within a community. Social capital facilitates the creation and maintenance of amenities, and these serve as catalysts for social interaction, cohesion, and community development. Both aspects are important for the well-being and livability of a community. Spatial capital is an important aspect that can be used as a metric. Social capital has spatial attributes such as place, areas that promote or allow social capital to foster and this is a key factor that can be used as a metric for the digital twins use-case.

2.5 Social Capital and social media

Social media has an impact on social capital as connections of strong ties such as family and friends but also weak ties, such as acquaintances can be made and maintained (Utz & Muscanell 2015). Social network sites such as facebook have changed the manner in which bridging and bonding connections were originally made (Utz & Muscanell 2015). However, on social media, with Facebook sitting at 2.99 billion users, there is a convergence of different contexts and audiences allows for the individual to have larger and more varied networks. This

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allows them to communicate in many new and different ways than was previously possible (Utz & Muscanell 2015).

Social media can also affect the spatial capital, the physical amenity, of a place. These platforms can influence and shape social capital through the reviews and interactions that take place within these platforms. This is achieved through information sharing, providing reviews on the platforms and online communities. These amenities and businesses can benefit from social media platforms as it allows them to closely reach their customers, enhances information accessibility, reduces marketing costs and customer service (Harun et al 2021). Social media sites have a significant influence on the financial and non-financial performance of small and medium-sized enterprises (Harun et al 2021). Utilising social media platforms can assist owners in effectively monitoring and controlling their reputation, while also enhancing their visibility, as it influences the progress and success of the business going forward (Harun et al 2021).

This fundamentally changes the idea of physical space and the need for face to face interactions within the creation of social capital networks, as social media has the potential to facilitate the development and maintenance of social capital by connecting people, providing opportunities for communication and collaboration. In regards to the digital twins it adds a layer of complexity as this data being included into digital twins cities, decision-makers can gain a more comprehensive and timely understanding of the city's dynamics and the needs of its residents. However, it also allows a new metric of quality to be identified as users review and interact on this interface. This study uses social media of the spatial capital (the physical amenity) to collect the quality of the place data needed for the digital twins.

2.6 Methods in measuring Social Capital

A way to capture and gather data on a social capital on a spatial front is through the use of GIS and its related tools. There are many authors that have used the GIS system in mapping social oriented concepts Brown et al (2015), Acedo et al (2020) and Sen & Quercia (2017). It allows for a better spatial understanding of social capital. GIS allows for the ability of combining and mapping qualitative and quantitative methods. Using spatial capital with GIS allows for a quantifiable approach to mapping social capital.

Most studies use public participation GIS (PPGIS) and other similar methods involving crowdsourcing mapping to map social capital. This is a method that allows the public to map on a webGIS application places/spaces they consider to have social capital. These studies such as Acedo et al (2021) and Brown et al (2015) involve some form of questionnaire/directions that they answer in order to map the social capital or sense of place. Most studies of social capital look at the qualitative nature of social capital, such as bonding, bridging and linking through mapping out trust and social networks. PPGIS integrates GIS and mapping techniques at a local level to generate knowledge of place (Brown and Puller 2012).

The methods in which the studies are done differs from my approach. I do not interact with the public, what is being used is similar software, this being GIS.

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2.7 Conclusion

Social capital has many definitions and it differs depending on the nature of discipline and investigation. It is evident that social capital has spatial attributes that are place, time, accessibility, quality and distance. The studies that map social capital use GIS as it allows for a spatial understanding of social capital. This paper will follow suit and use the same methodology. Although many of those studies use PPGIS to map out social capital, this will prove difficult in this study. The data collection is quantitative in nature and does not use the public or any qualitative data to reach the findings. Instead, it will adapt the amenities list from the spatial capital paper (Sen & Quercia 2017) to be used in this study combined with the spatial attributes to create metrics that can be mapped to be used for digital twins use-cases.

Metric	Description	Source	Notes
Place (the physical attribute) capital	The number of urban amenities.	Sen & Quercia 2018	The spatial capital
Distance	Distance (m)	Rutten et al (2010	Ease of access to amenities
Time	Years & Hours	(Claridge 2022)	The age of urban amenities could be an indicator of urban resilience
Accessibility	Public or Private	Mohan & Mohan 2002	Government owned or privately owned
Quality	Out of 5 (count)	(Harun et al 2021)	Quality of the amenity and social engagement

Table 1 : Metrics derived from the literature review

This is a table (table 1) of the key metrics that will be used in the study to collect data. Spatial capital taken from Sen & Quercia (2018) allows for urban amenities to be mapped, taking on a physical component of social capital. The next set of metrics are based on the amenity mapped. Distance taken from Rutten et al (2010) analyses the spatial distribution of the amenities that are mapped. Time from Clairidge (2022) analyses the time frame and the age of the amenity. Accessibility taken from Mohan & Mohan (2002) considers if the amenity is government owned or privately owned. Lastly, quality from Harun et al (2021) uses social media to determine the quality of the amenity through reviews.

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3. Research methodology

This paper explores how the understanding of social capital could inform relevant digital twins use-cases in South Africa. The study will work within the pragmatic paradigm. The pragmatic approach focuses on practical effectiveness over what could be considered the objective truth or reality. The pioneers of this approach opposed the idea that a single scientific method of social inquiry could reveal truths about the actual world (Weaver 2018). The methodology of this paper is focused on the physical (i.e., structural) characteristics of social capital and their attributes to have a spatial understanding of social capital. The study uses a mixed method approach and includes both qualitative and quantitative methods.

Limited literature is available that examines the use of indicators or variables for mapping geographical differences in social capital, therefore this was the approach taken. The study starts with a conceptual review, with the aim of analysing different concepts and theories of social capital. The aim is to gain an understanding of different concepts that can contribute to creating different metrics of social capital that are quantifiable. The study comprises secondary data collection. The primary method of enquiry is desktop research and the use of GIS. The secondary data collection predominantly comes from using Google maps and social media applications such as Facebook, Twitter and Instagram. This information was then used to map out (using GIS) the physical attributes of social capital that either contribute or detract from social capital. Secondly the metrics also included additional attributes of social capital that were created through the literature review. Such as time, accessibility, quality and distance of social capital. This information was then put into a specific table, relevant to the category that was mapped. The data collected is analysed through grounded theory to form theories and conceptual frameworks.

The project is based in Hatfield, City of Tshwane, South Africa.

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3.1 Site Context
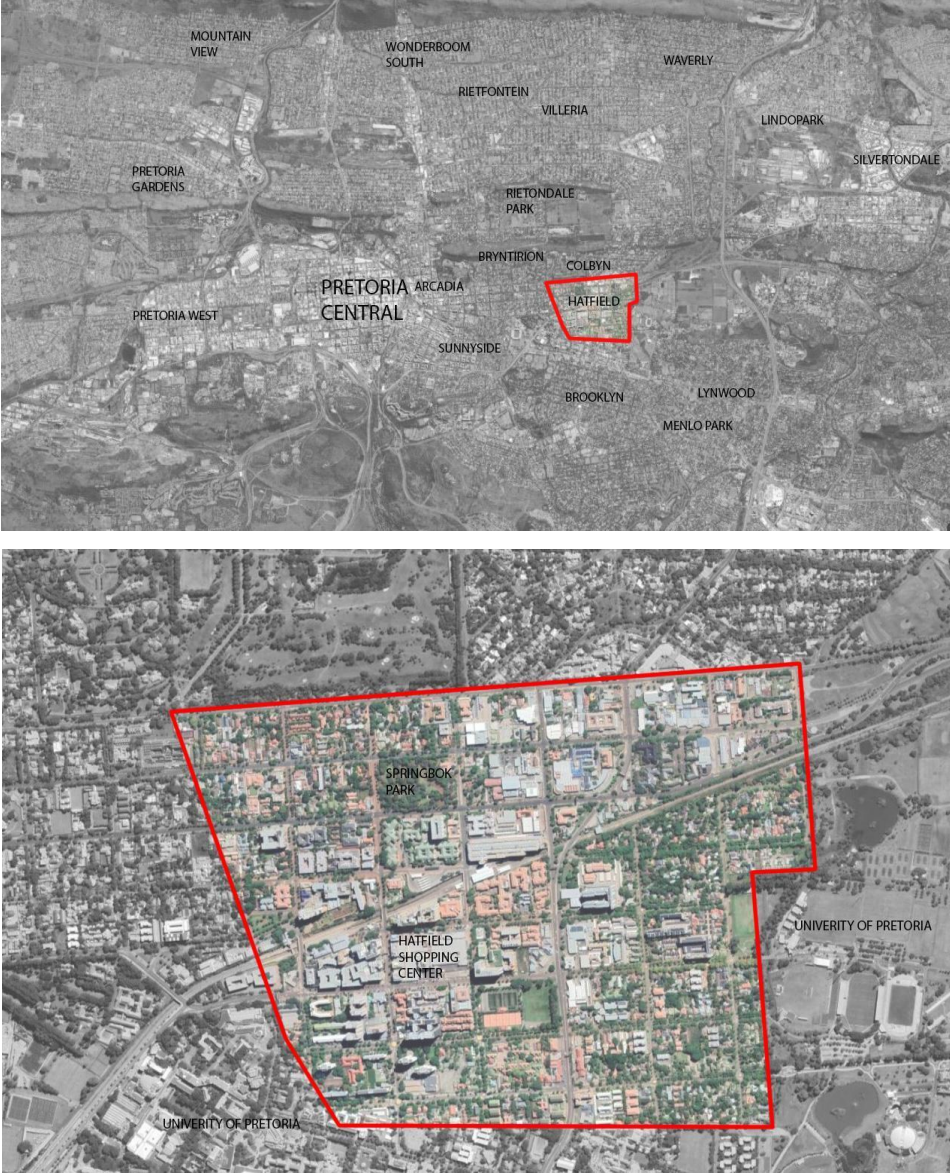
Figure 5: Map of Hatfield (Masu 2023)

The study area of this paper is in Hatfield, Tshwane, South Africa (figure 5). Hatfield has a population of roughly 15 000 residents (this was an assumption made from using the growth rate of Pretoria over the last 12 years which is 2%). The suburb of Hatfield was first proclaimed on a portion of the farm "Koedoespoort" (Du Plessis 2003). It was one of the first suburbs to be established in Tshwane (formerly known as Pretoria). It is 197 ha in size and was named after an estate in England, Hatfield House, Hertfordshire, which was owned by the second earl of Selbourne (1905) who became the governor of the Transvaal (Du Plessis 2003). In 1908 the University of Pretoria was built and is now a major organisation in the suburb (Du Plessis

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2003). In the mid-thirties Hatfield was a residential suburb, but because it sat on the periphery, it was isolated from the CBD and thus maintained its character (Du Plessis 2003. In the 40 to 70s the first commercial businesses were established with a commercial core (Du Plessis 2003). Development happened rapidly in the late eighties, and by the 90s to 2000s multi storey retail and office buildings were erected (Du Plessis 2003). In 2010 the Gautrain station was built in Hatfield, which is a high-speed railway line that connects different parts of Joburg and Pretoria.

Figure 6: The character of Hatfield (Masu 2023)

Over the past few decades, the Hatfield region has witnessed a significant transformation in terms of its population, economic and corporate profiles, road networks and transportation systems (DHK et al 2020. As one of the metropolitan nodes that make up the broader polycentric metropolis, Hatfield serves as a powerful, decentralised node that supports the inner city and other metropolitan nodes (DHK et al 2020). The main age of the population is between 19 to 22 years of age (61.3%), this is due to the changes that have occurred in the past 20 years (DHK et al 2020). The increase in students attending the university, increased student housing and densification, resulting in a decrease in families and pensioners in the area. As a result, residential dwellings were transformed into communal housing for students. This has been the area's predominant development typology (DHK et al 2020). Considerable

redevelopment is planned for Hatfield in response to the Gautrain and the growth of the University of Pretoria (DHK et al 2020). Although the neighbourhood's younger, primarily student population adds a vibrancy and variety that are uncommon in many other parts of the city (figure 6). The study area has suffered economically due to a lack of disposable cash and the transient nature of students. (DHK et al 2020).

The Hatfield grid is defined by large city blocks (usually 250m x 160m between road center lines) that form a coarse-grained, comparatively impermeable street network (DHK et al 2020). It influences how far pedestrians must walk to reach a specific location and is particularly crucial for pedestrian movement (DHK et al 2020). Hatfield has large city blocks to cross making it not a very pedestrian friendly area even though amenities can be accessed by foot. The major stakeholders and organisations in Hatfield are the University of Pretoria, and the Hatfield CID which is a nonprofit organisation funded by property owners that reside within the east of Tshwane.

3.1.2 Study Delimitations

The study delimitations are that no interviews were conducted and personal data collected in that manner. This limits the potential of mapping known social capital areas by individual participants but also mapping out the network of relationships. All data used in this study is limited to desktop studies, Google maps, and social media applications. Administrative boundaries are too restrictive to limit social capital, as they are only political structures, this study uses them to be able to measure social capital within a specific area. Even though this study has these delimitations it does not take away from the possibility of creating viable social capital metrics that could be used in digital twins use-cases.

3.2 Data collection

The study uses GIS tools to map the spatial capital metrics. The tools are Qgis software. The attributes mapped are spatial capital, as explained by table 2. A point representation is used to map out the areas of spatial capital.

3.2.1 Metric and Index Development

In terms of structural social capital created from the literature, the following metrics are specifically important to measure. These are place, distance, time, accessibility and quality. These metrics will assist in building the social capital index of Hatfield. These are the main themes that are used to measure spatial capital. Each category then has subcategories that allows for the actual collection of data (table 2).

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Metric	Description	Unit of Measurement	Source	Notes
Place (the physical attribute)	Amenities	Count	Sen & Quercia 2018	The number of urban amenities in the area
	Type			The variety of the amenity
Distance	Proximity to amenities	Distance (m)	Rutten et al (2010	Ease of access to amenities
Time	Date founded (Age)	Years	(Claridge 2022)	The age of urban amenities
	Trading hours	Hours		When activities occur more/less during a day or season/month etc.
Accessibility	Public or Private	Public or Private	Mohan & Mohan 2002	Government owned or privately owned
Quality	Reviews	Out of 5 (count)	(Harun et al 2021)	Quality of the amenity
	Social media presence	Yes/no		Do they use social media to engage their audiences
	Number of events	Count		Social engagement with the users

Table 2: Metrics table

Table 3 is a list of all the amenities mapped in Hatfield. This is adapted from Sen and Quericia (2018) amenities list that defined spatial capital. What was then mapped was where people tend to meet (place) which would then be the physical component to social capital in our social capital landscape. The attributes of distance, time, accessibility and quality are used with the mapped spatial capital to create the data. The metrics added are date founded, accessibility (public vs private), the types of entity it is; trading hours, social media presence, number of

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events posted and reviews. The number of events posted was analysed over a six-month period starting from November 2022 to April 2023 and the reviews were out of 5.

The amenities mapped are religious buildings, charity organisations, educational institutions, embassies, safety and security, sports and outdoor activities, medical institutions, shopping and retail entertainment (table 3) . The polygon tool is used to map out the residential areas and the university. The data was collected on the urban amenities using google places services API "Nearby search' request that allowed for finding a place within a chosen area. I began mapping all the identified spots that are associated with spatial capital. The City of Tshwane GIS(2023) web application was used to demarcate the study area of the paper.

Category	Points of interest
Religion	place of worship, church, temple, mosque
Shopping and retail	shopping mall, department store, clothing store
Medical institutions	doctor, dentist, physio, health institutions
Education	school, university, college, library
Safety and security	fire station, police, security services
Sports and outdoor activities	Parks, sport grounds, stadium, amusement park, campground, zoo
Community groups and organisations	Non-governmental organisation, Nonprofit Organisation, community center, charity
Entertainment	Bars, night clubs, adult entertainment, art gallery, museum
Foreign government services	Embassies

Table 3: List of amenity types

3.3 Data Analysis

The method in which the data is analysed is through grounded theory.
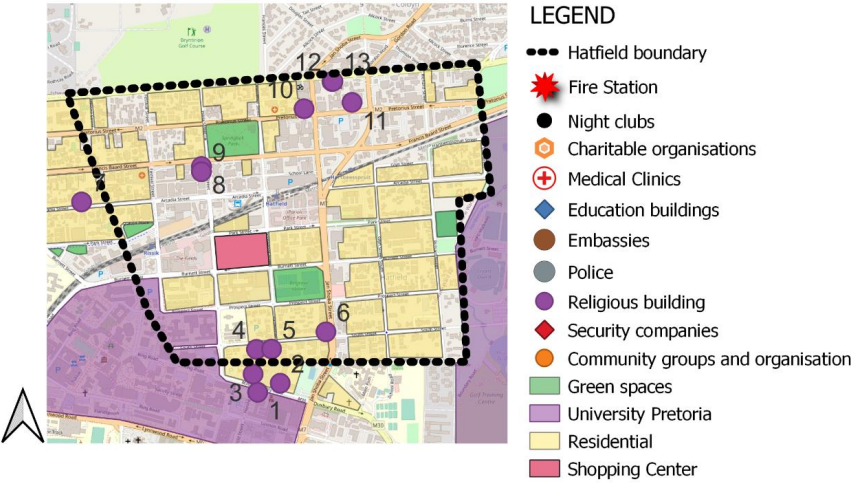
3.3.1 Grounded theory

Grounded theory is a research method that is inductive and comparative. Grounded theory involves the synthesis and conceptualization of data in a systematic way to construct theories

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(Charmaz 2001). It allows for qualitative and quantitative data to be used within this research method. It seeks to find out or create theory from data, which is obtained through a systematic approach and comparatively analysed (Tie et al 2019). Any form of data can be used to be analysed such as observation, interviews, surveys, visual and auditory media, newspapers or questionnaires (Holton and Walsh 2017). The intention of grounded theory is to generate statements and conceptual hypotheses on the likely relationships between concepts, and not merely reporting back on facts (Holton and Walsh 2017). Grounded theory is a type of conceptual abstraction, it's the distinction between conceptualization and description (Holton and Walsh 2017). It does not create accurate findings and descriptive reports of what is discovered in a study nor does it try to interpret meanings from participants in a study (Holton and Walsh 2017). What is important is the concepts found, the relationships between them, and the possibility of offering the reader conceptual explanation of important behaviours within the social context in a study (Holton and Walsh 2017).

What makes grounded theory stand out from other qualitative data analysis is its ability to abstract conceptual ideas from indicators in data that are being analysed (Holton and Walsh 2017). This is achieved by not taking on the details in the data and only taking the concepts and integrating it into a theory that can explain the inherent social pattern that underlies the behaviour (Holton and Walsh 2017).

There are three pillars to grounded theory research; exploration and emergence, constant comparative analysis and theoretical sampling (Holton and Walsh 2017). Exploration and emergence are when the data informs the concepts and relationships (Holton and Walsh 2017). Constant comparative analysis is when data is continuously compared with previously analysed data while searching for data that is similar or different in order to reach a point of creating a concept and theory (Holton and Walsh 2017). Lastly, theoretical sampling is when the sample is led by the theory that is forming and continues until it reaches the saturation point of the theory (Holton and Walsh 2017). There are techniques that are used for theoretical sampling and saturation that assist in building concepts and categories that have emerged. Handsorting memos are important in integrating the emergent theory that is done through theoretical coding (Holton and Walsh 2017). The analysing process of grounded theory is that data is collected and then goes through an iterative process of being compared and analysed while memoing happens alongside this process (Holton and Walsh 2017). The process begins with open coding until a core category emerges, then selective coding of the core category (Holton and Walsh 2017). Lastly, in order to uncover relationships between different concepts, theoretical coding is employed. (Holton and Walsh 2017). The disadvantages of grounded theory though is that there is the possibility of research induced bias through the coding and formation of the theory.

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id	Name	Date founded	Trading hours	Social media presence	No. events	Reviews	No. of reviewers
1	Nederduitse Gereformeerde Kerk - Universiteitsoord	1966	sun	yes	25	4.7	95
2	Elim Full Gospel Church	1965	sun/wed/frid	yes	41	4.7	53
3	St Wilfrid's Anglican Church	1925	mon-fri, sun	yes	8	4.4	53
4	Die Gemeente in Pretoria		-	no		-	
5	Second Church Of Christ, Scientist		-	yes	0	5	2
6	Yada Ministries Church	2003	sun	no		5	1
7	Victorious Life Ministries	1981	-	yes	1	4	1
8	St Columba's Presbyterian Church Hatfield	1959	sun	yes	3	4.5	29
9	Living Hope Church	2009	sun	yes	6	4.8	31
10	Shofar Pretoria	1992	sun	yes	1	4.5	25
11	Mmuso Church	2019	sun	yes	5	4.9	8
12	SWORDS A BLAZE INTERNATIONAL	2001	bi monthy	yes	5	5	3
13	Encore Hatfield AGS-AFM		sun	yes	6	4.2	18

Figure 7: Example of how data is collected (Masu 2023)

In the context of this study we are using grounded theory with our metrics. The data was collected in a manner that allowed the information to fall into categories and subcategories. Using the GIS interface, data is collected in a table form, as seen in figure 7. This format of collecting data allowed for the coding process to be more systematic compared to analysing interviews or observations. This became the selective coding of the data. Looking at the data collected, under each subcategory common themes and patterns start to emerge. The primary categories of distance, time, accessibility and quality were established as the primary metrics for analysing the social capital landscapes of Hatfield. They form the main broader categories and the subcategories are what provide additional information that is then used to create the theories. For example using the metric of quality (table 4).

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Main category	Quality
Subcategory	Reviews
	Social media presence
	Number of events

Table of 4 : Grounded theory approach on analysing a metric

The data collected under reviews, social media presence and number of events comprises the data that is then analysed. Through the analysis of the data of the subcategories, themes and patterns are then identified that relate to the social capital landscapes of Hatfield. For example a church that has high reviews and a social media presence with a medium amount of events could be seen to have high social capital in the area.

4. Analysis

The spatial capital and metrics have been mapped out. The objective is to analyse these points to generate social insights and establish a coherent framework that connects geographic space with social capital. The intention is to discover the social capital quality of the place and its implications.

The metrics made earlier formed the main broader categories, the subcategories were established for the data to be analysed, this made it possible for common themes and patterns to appear. The primary broader categories are the metrics of distance, place, time, accessibility, and quality, and the subcategories is the data that is then used to develop the hypotheses. The subcategory metrics added are date founded, accessibility (public vs private), the types of entity it is; trading hours, social media presence, number of events posted and reviews. The number of events posted was analysed over a six-month period starting from November 2022 to April 2023 and the reviews were out of 5. Theories will result from the analysis of the data itself, enabling the discovery and understanding of patterns, classifications and links. Therefore, the analysis of the subcategories will form the foundation of the grounded theory. Secondly memoing (additional notes) is used for data that did not fall into the subcategories but contributed to the theories formed. Only a few of the amenities are described in this section namely, embassies, medical institutions, religious buildings, education, charity organisations, community groups and lastly adult entertainment areas.

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4.1 The relationship between social capital and the study area
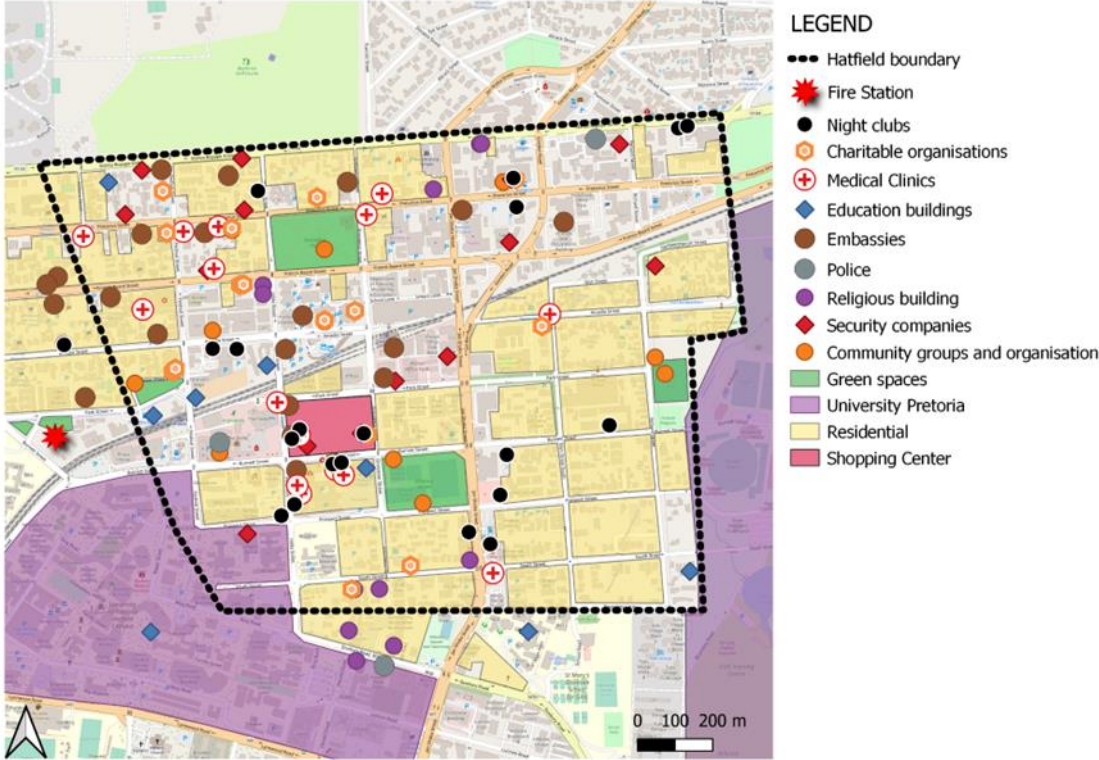
Figure 8 : All the amenities mapped in Hatfield (Masu 2023)

The results of the study are that there is an unequal distribution of amenities throughout the study focus. The amenities mapped is based on the amenities list that is (table 3) that links with spatial capital. There is a large cluster focusing on the north westerly portion of the site and around the center. There are twelve amenity types (figure 8) that were mapped each with their own attributes that were captured. Hatfield has 112 amenities meaning it provides approximately 74 amenities per 10 000 residents. There are amenities that sit outside of the site area that are mapped because of its proximity and influence on the area (figure 9).

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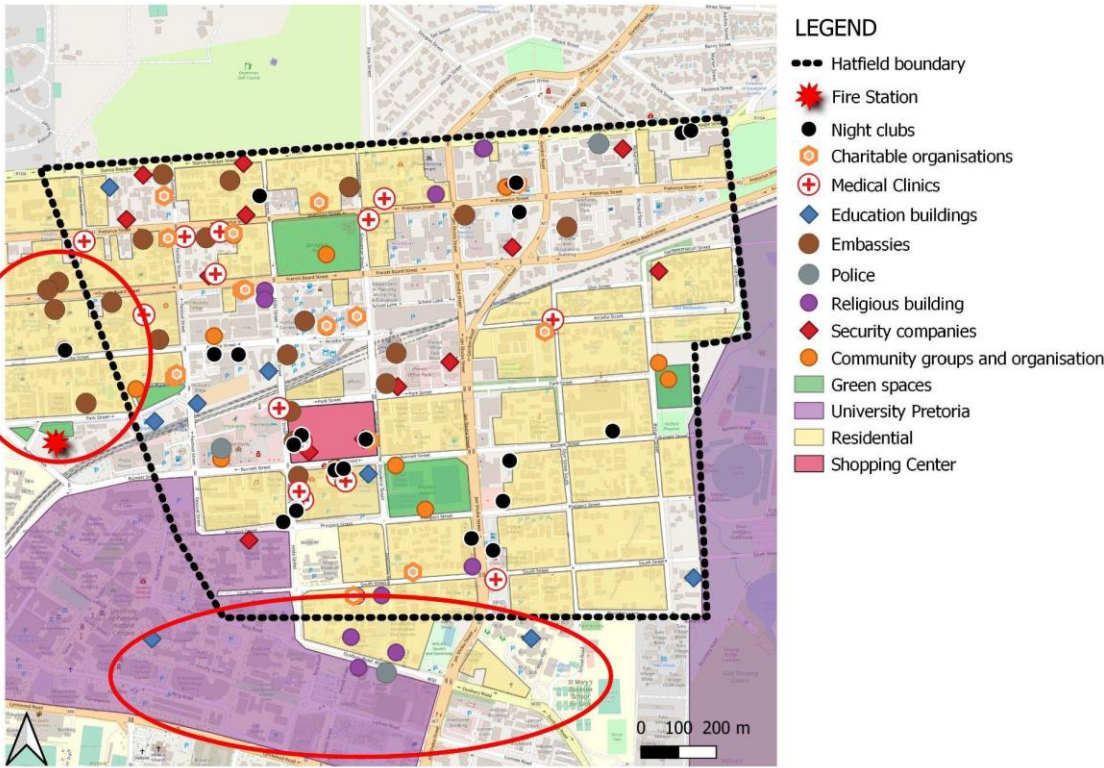
Figure 9 : Map of all amenities in Hatfield that sit outside of the administrative boundary (Masu 2023)

There is a large residential component that surrounds the business core, highlighted in yellow. The business core sits roughly at the center of the study and is predominantly north of the railway track. There are few green spaces in the area, one is a publicly accessible park at the north of the site, and two are private sports fields, and the rest are vacant spaces. There is one fire station that sits just outside the study focus, three security elements, one being the Police station to the south and Sheriff station to the north east and lastly the Hatfield City improvement district roughly at the south-westerly portion of the site. Although, there are 14 security companies that either supply or provide a service to the community.

The high number of security services could speak to either high levels of crime with the need of the residents to protect themselves or possibly the high numbers of embassies within the area that require such services. This information is inconclusive and does not contribute to the social capital index and will be omitted.

In terms of social capital, Hatfield has a large number of amenity types and are varied, this includes healthcare, educational institutions, shops and public services. These essential resources and services can contribute to the development and enhancement of social capital. If these amenities are easily accessible they reduce barriers and promote equal opportunities

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for all, and this leads to connectedness and social capital accumulation. Movement for both people and vehicles is made easier by a compact urban environment combined with a regular grid design and street block intervals of no more than 150m (DHK et al 2020) but Hatfield sits within a 250m block. This impermeable street network makes Hatfield an area that is not pedestrian friendly, even though the amenities are within walking distance.

1	Belgrave Square Park	SPORTFIELD	PRIVATE
2	Springbok Park	PARK	PUBLIC
3	OPEN SPACE	OPEN SPACE	PUBLIC
4	OPEN SPACE	OPEN SPACE	PUBLIC
5	OPEN SPACE	OPEN SPACE	PUBLIC
6	Hatfield soccer field	PARK	PRIVATE
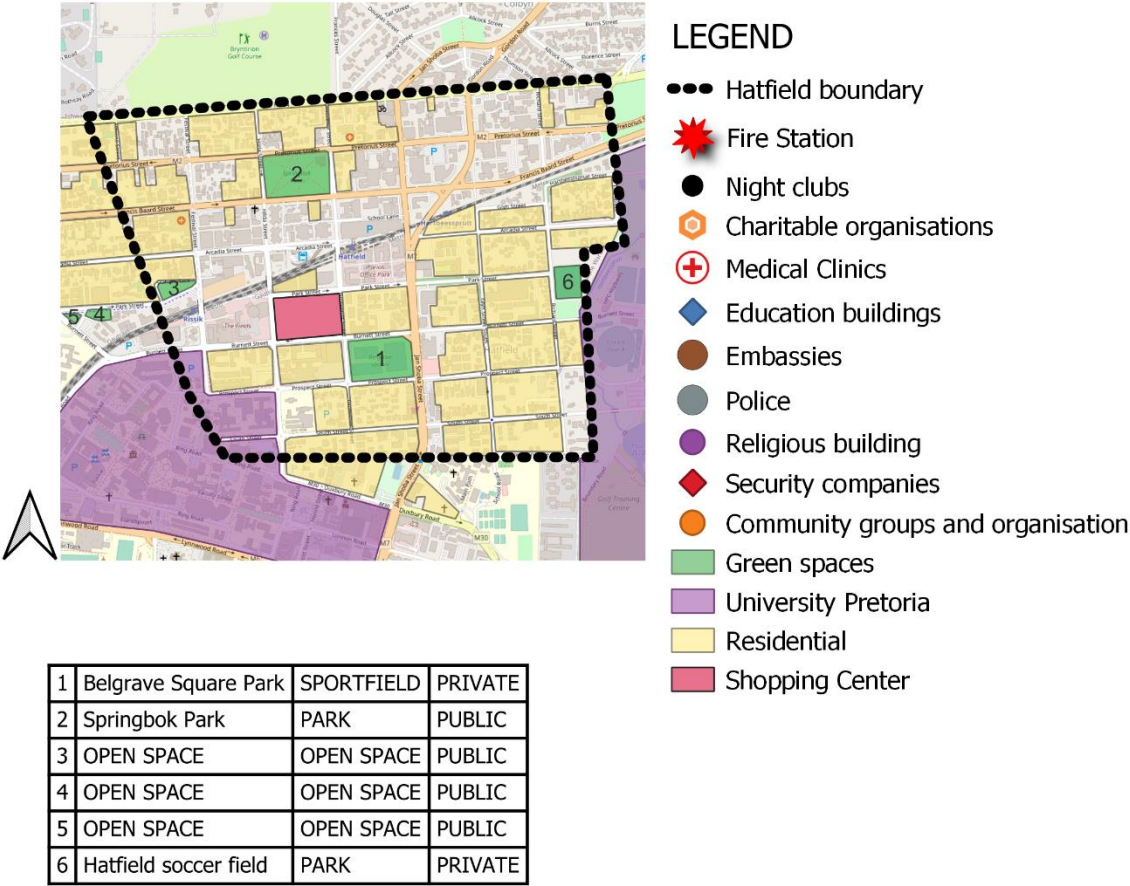
Figure 10: Map and data table of Green spaces (Masu 2023)

Even though the area has a variety of amenities and spatial capital, the public parks (figure 10) and areas where communities can gather are lacking, these spaces are meant to bring people of different backgrounds together to interact and build social connections. So as much as there is access to spatial capital it would then mean it has high social capital but if the main gathering spaces are lacking or inaccessible as two of the three gathering spots (sports fields) are privatised, it also subtracts from the social capital of the area. This would be beneficial for the digital twins as it would showcase what is lacking and what and where resources are available in the area and its spatial distribution to the residential component and business core.

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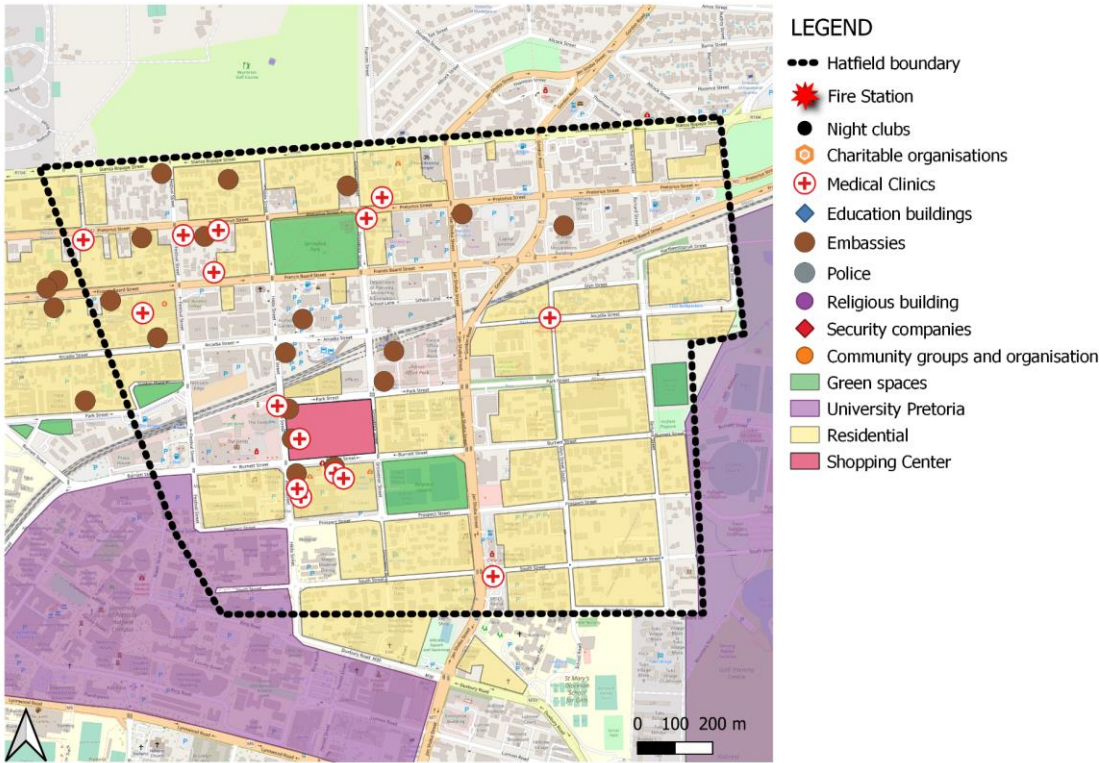
Figure 11: Map of embassies and medical buildings (Masu 2023)

There is a large presence of government buildings (figure 11), 21 embassies in the area, four outside the site and 17 within that are located on the north westerly portion of the site. There are 15 medical buildings (figure 12) of which five are general practitioners, four medical centres, three physiotherapists, two clinics, one specialist hospital. These amenities are clustered around the center and north westerly portion of the site, leaving the south easterly portion bare, although the greater portion of residential areas sit south of the railway tracks. However there are a few that are within walking distance of the university.

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Id	Name	Type	Date founded	Accessibility	Reviews	No. Review
1	Hatmed Medical Centre	Medical Centre	1995	private	3.7	103
2	The Travel Doctor Africa	GP		private	3	2
3	Dr Mashuda Ally	GP	2014	private	4.8	57
4	Unimed - Medical Doctor & Dentist	GP			4.2	5
5	Dr Luis Maracha	GP		private	4.6	33
6	Pienaar I G J Physiotherapy	Physiotherapy		private		
7	Diabetes Care Centre	Care Centre		private	5	1
8	ROAD ACCIDENT CLINIC	CLINIC		government	5	1
9	The Stress	CLINIC				
10	TEN81-General Practitioner	GP		government	2	3
12	Izak Pienaar Incorporated Physio	Physiotherapy		private		
13	Embassy Drive Medical Centre	Medical Centre		private	1	1
14	De Graaf J Physiotherapy	Physiotherapy		private		
15	SAOPHA child health care center	Care Centre				
16	Pretoria Urology Hospital	Hospital		private	3.8	8

Figure 12: Map and data table of medical buildings (Masu 2023)

The data collected was the amenity, the type, the date founded, its accessibility and the reviews and reviewers. The dates of when the medical buildings were established could not be retrieved but the number of years the doctor has worked could (figure 12). This could infer that the focus is on the competency of the medical professional and not when the practice has been established. So in regards to time, experience affects the establishment not necessarily the time of when the institution was founded. It is interesting to note that there are only two clinics, in an area that hosts a large number of students, who are not economically active but there is a medium level of diversity of medical buildings. In regards to the quality of the amenities, it appears that the medical institutions are above average quality just by looking at the ratings of them (See data table figure 12).

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In terms of social capital, embassies are diplomatic entities that are responsible for maintaining relationships between countries. These interactions facilitate the development of social capital on an international level but also provide support for expatriate communities, and contribute to a sense of belonging and development of social capital through creating a more inclusive environment. It also contributes to cultural exchange and cross-cultural connections within the existing neighbourhood. The embassies do not help the social capital index as it is more a political structure than an amenity that contributes social capital directly.

The variety of healthcare services and access that cater to the needs of the neighbourhood has a positive impact on social well-being and quality of life. The variety that Hatfield is afforded allows individuals to experience improved outcomes and increased overall well-being. This contributes to the social capital of the area, through fostering a healthier and more engaged community. Time does not affect the medical profession in Hatfield in terms of when it was established. Perhaps this showcases low levels of social capital as investment to develop social connection requires time, and this helps to develop bonds and trust. The clustering of the medical buildings to one side of the site has spatial implications, as it would not be easy to access through walking (for the residents on the periphery) and would require a vehicle, reducing the accessibility of the amenity. There would be an oversupply in one residential area and an undersupply in the other.
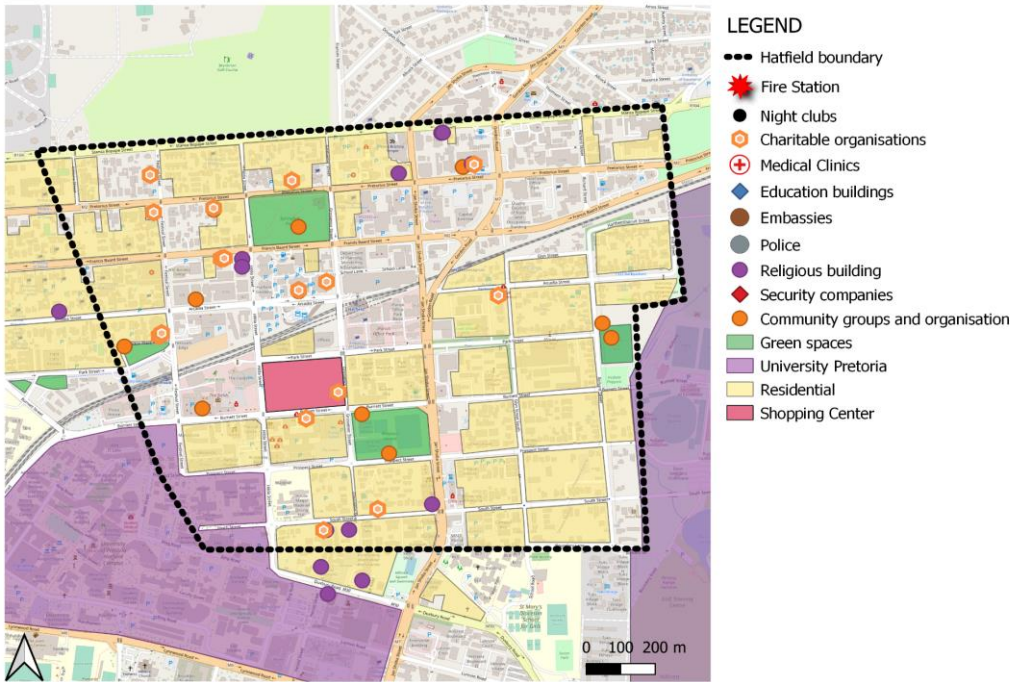
Figure 13: Map of Religious buildings, charity organisations and community groups and organisations (Masu 2023)

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id	Name	Date founded	Trading hours	Social media presence	No. events	Reviews	No. of reviewers
1	Nederduitse Gereformeerde Kerk - Universiteitsoord	1966	sun	yes	25	4.7	95
2	Elim Full Gospel Church	1965	sun/wed/frid	yes	41	4.7	53
3	St Wilfrid's Anglican Church	1925	mon-fri, sun	yes	8	4.4	53
4	Die Gemeente in Pretoria		-	no		-	
5	Second Church Of Christ, Scientist		-	yes	0	5	2
6	Yada Ministries Church	2003	sun	no		5	1
7	Victorious Life Ministries	1981	-	yes	1	4	1
8	St Columba's Presbyterian Church Hatfield	1959	sun	yes	3	4.5	29
9	Living Hope Church	2009	sun	yes	6	4.8	31
10	Shofar Pretoria	1992	sun	yes	1	4.5	25
11	Mmuso Church	2019	sun	yes	5	4.9	8
12	SWORDS A BLAZE INTERNATIONAL	2001	bi monthy	yes	5	5	3
13	Encore Hatfield AGS-AFM		sun	yes	6	4.2	18

Figure 14: Map and data table of religious buildings (Masu 2023)

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Hatfield does not have any other religious building except of the Christian faith which speaks to the predominant denomination of the populace, there are approximately 13 churches (figure 13) in the area that are clustered to the north and south of the site. The data collected was the amenity, the date founded, its trading hours, the reviews and reviewers. The age range of when the churches were established are from 1965 to 2019. Of those 13 churches 4 were heavily student focused. What was interesting to note is that most had a social media presence (see data table figure 14) but did not post events often which could possibly mean that they could be made up of an older generation that does not use as much social media or that it has established itself with a good following, well enough to not need a social media presence to influence the establishment. The dates of when the church was founded, could b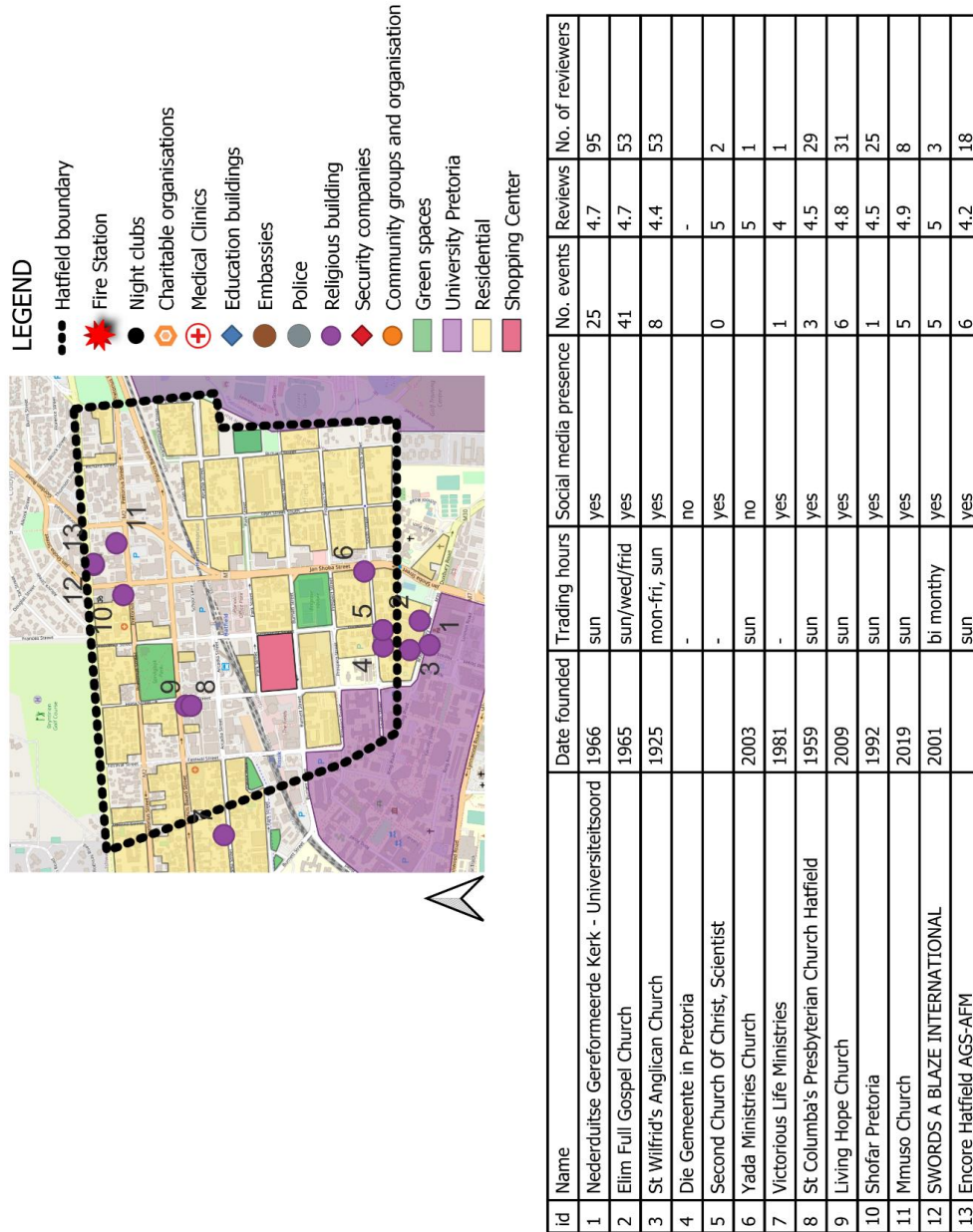e found on most of their websites and could be considered important for the mere fact that most mention and describe its inception. As established institutions that have been operating for a longer period often develop a reputation for reliability, quality, and trustworthiness. Most of the churches have a high rating that could possibly mean that the amenities are of a good quality (see data table figure 14), but in some cases the highest rating given also had the fewest users reviewing the place. The distribution of the amenity sits more on the left hand side of the site closer to the university and is unequally distributed in the residential area.

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Id	Name	Type	Date founded	Social media presence	No. of events	Reviews	No. Review
1	Ministry Of Life	CHARITY		no	1		
2	LadyBug Foundation SA	Non-profit organization		yes			
3	IRD South Africa	Non-profit organization	2014	yes		5	1
4	Save the Children South Africa	Non-profit organization	2013	yes	4	4.7	31
5	NOT IN MY NAME INTERNATIONAL	Association or organization	2017	yes	6	5	1
6	South African National AIDS Council (SANAC)	Non-profit organization	2000	yes	10	4.4	27
7	Pegasys Institute	Non-profit organization	1999	yes			
8	Oxfam Southern Africa Regional Centre	Charity	1942	yes	3	3.5	2
9	Wateraid	Non-profit organization	2012	yes international		5	2
10	O.U.T	Gay & lesbian organization	1994	yes	2	4.6	28
11	Fast Forward Entrepreneural Foundation	Non-profit organization		no		5	1
12	THE SOUTH AFRICAN RED CROSS SOCIETY	Non-governmental organization	1929	yes - different area		4.2	13
13	Tsholetsang Foundation	Non-governmental organization		yes		3.0	1
14	The Sapinda Rainbow Foundation Representative Office	Charity	2014	no			
15	Lethabo Development Agency	Charity		no			
16	Hatfield D O.	Association or organization		no			

LEGEND

- Hatfield boundary
- Fire Station
- Night clubs
- Charitable organisations
- Medical Clinics
- Education buildings
- Embassies
- Police
- Religious building
- Security companies
- Community groups and organisation
- Green spaces
- University Pretoria
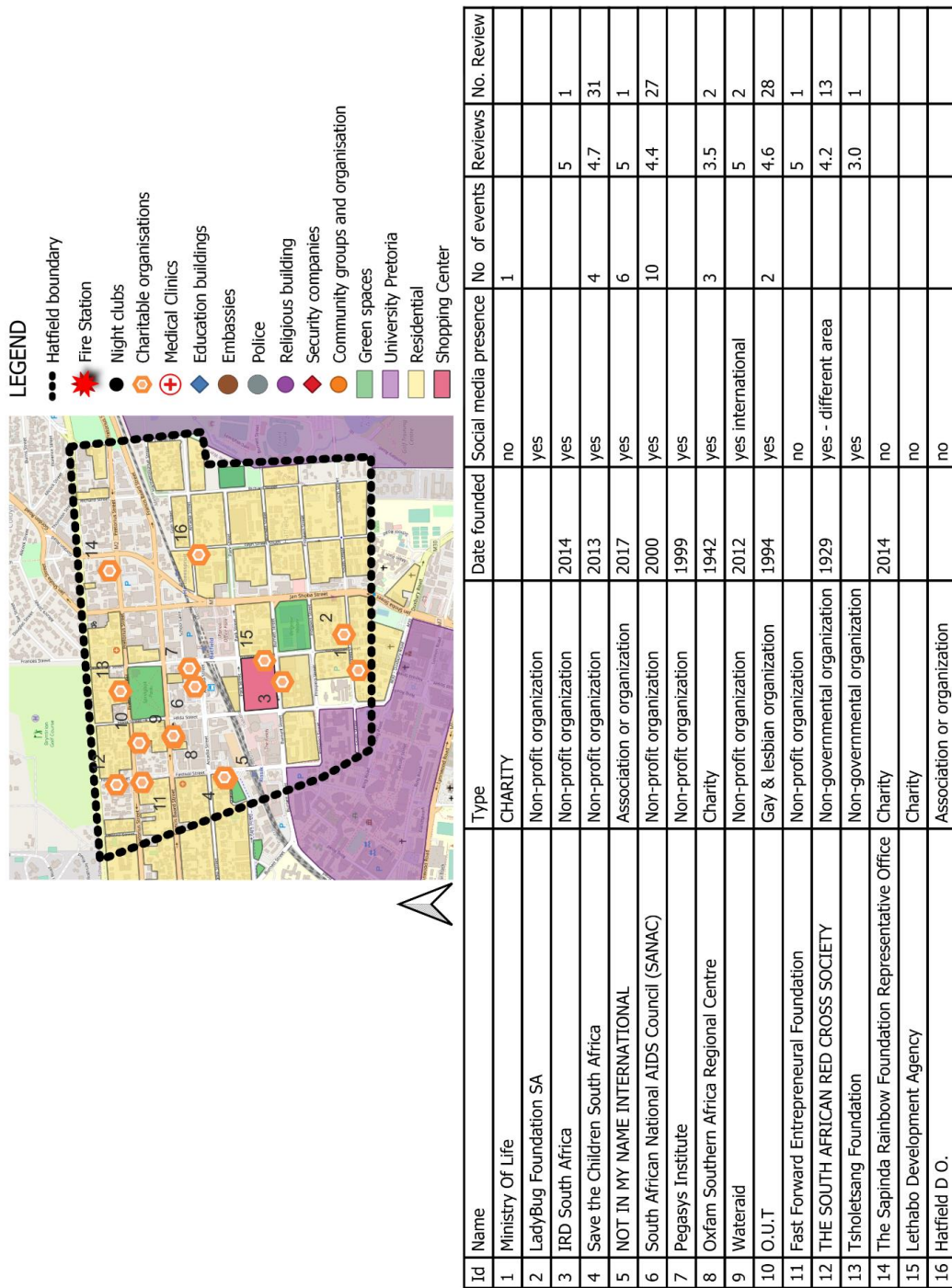- Residential
- Shopping Center

Figure 15: Map and data table of charity organisations (Masu 2023)

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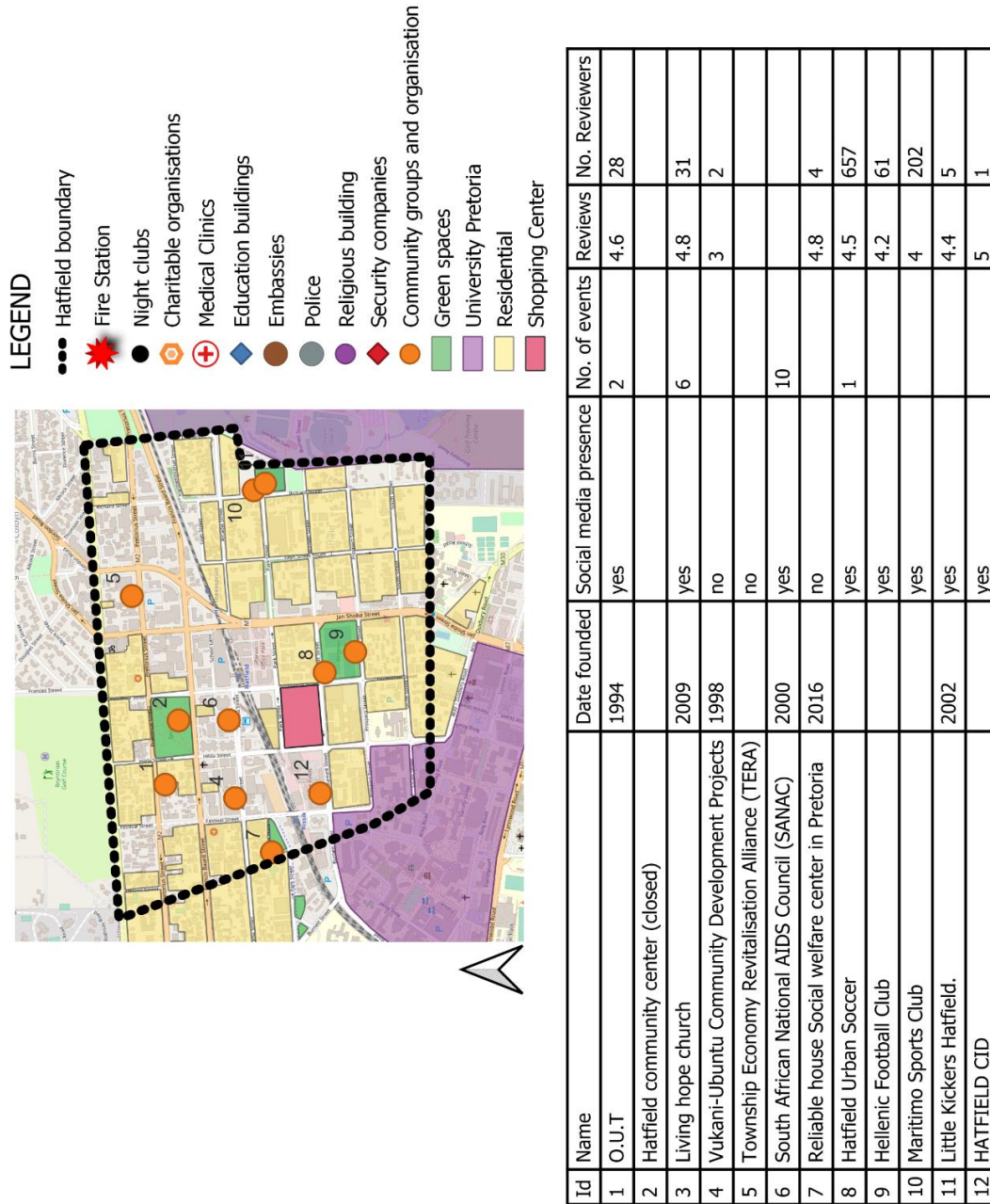
Figure 16: Map and data table of community organisations (Masu 2023)

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There are a large number of charity organisations and community groups in the area (figure 15 & figure 16), 16 and 12 respectively that overlap. Most of the charity organisations were established 9 years ago and approximately 68% of them have a social media presence but do not post events often (see data table on figure 15). Of the community groups in the area 66% have a social media presence and post even less than the charity organisations (see data table on figure 16). The activity that could be seen on the Facebook pages was of them visiting schools & businesses, hosting small workshops, campaigning or doing donations. It is surprising to see that they have a low social media presence as that would be the easiest way to communicate with their audience in informing them of any changes or new information and maintaining their perceived reputation. Time in regards to trading hours could not be retrieved.

Charity organisations, community groups, churches and social capital are closely linked. These institutions often bring together individuals who share a common goal of helping others. Charity organisations rely on the mobilisation of resources, including financial contributions, donations, and volunteers. These organisations build social networks, mobilise resources, foster collaboration, engage communities, and contribute to social impact. This indicator reflects that Hatfield has a strong sense of community as there are many organisations within its boundaries that relate to working and helping others. It is possible to say that Hatfield has a high social capital in this regard. In terms of the digital twins this information would be useful in terms of understanding the distribution and accessibility to the amenities but also understanding the current social bond and the self reliant nature of the area.
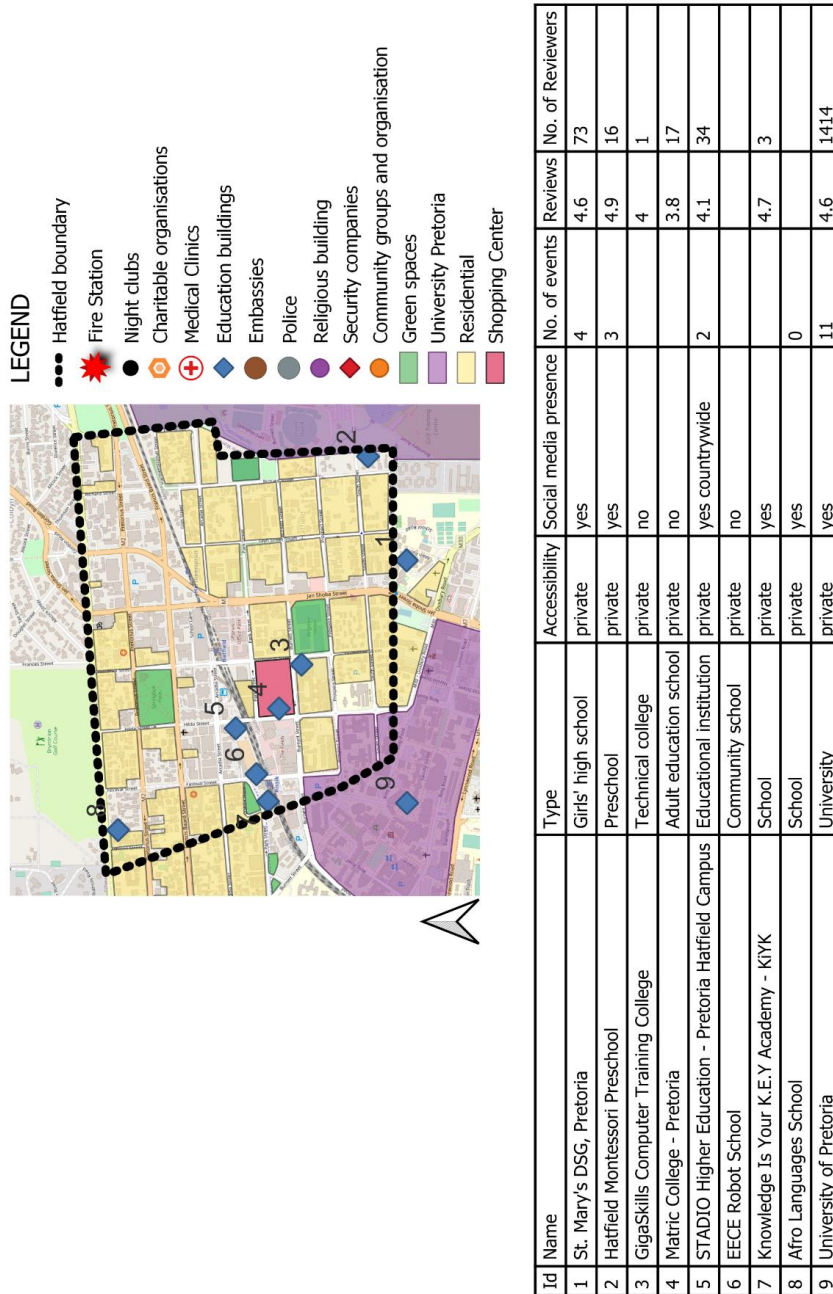
Id	Name	Type	Accessibility	Social media presence	No. of events	Reviews	No. of Reviewers
1	St. Mary's DSG, Pretoria	Girls' high school	private	yes	4	4.6	73
2	Hatfield Montessori Preschool	Preschool	private	yes	3	4.9	16
3	GigaSkills Computer Training College	Technical college	private	no		4	1
4	Matric College - Pretoria	Adult education school	private	no		3.8	17
5	STADIO Higher Education - Pretoria Hatfield Campus	Educational institution	private	yes countrywide	2	4.1	34
6	EECE Robot School	Community school	private	no			
7	Knowledge Is Your K.E.Y Academy - KIYK	School	private	yes		4.7	3
8	Afro Languages School	School	private	yes	0		
9	University of Pretoria	University	private	yes	11	4.6	1414

LEGEND

- Hatfield boundary
- Fire Station
- Night clubs
- Charitable organisations
- Medical Clinics
- Education buildings
- Embassies
- Police
- Religious building
- Security companies
- Community groups and organisation
- Green spaces
- University Pretoria
- Residential
- Shopping Center

Figure 17: Map and data table of educational buildings (Masu 2023)

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There are nine educational buildings (figure 17) of which all are private. The data collected was the amenity, the type, its accessibility, number of events posted, its social media presence, its reviews and reviewers. There is a diverse range starting from preschool to technical colleges, to universities. Approximately 55% of them have a social media presence such as Twitter and Facebook but similarly to the community organisations, few post regularly this being weekly or biweekly. They are clustered around the train track and sit more on the center of the site with the exception of the university that spans great portions of land. Time (operating hours) had no bearing on the social capital of this amenity.

Of the educational buildings (figure 17), few posted events, but most posted educational information and the going-ons of the school. Perhaps this is the case as events are more targeted to the learners and not the general public. It is also interesting to note that there are no public schools in Hatfield, this could speak to the socio-economic condition of Hatfield. Although a lack of public school can result in limited access to education, for those who are underprivileged or marginalised. The schools also have a high rating, implying that the amenities are of good quality. As mentioned earlier the variety of the educational building is important as it allows for options and caters to the needs of the residents.

Access to education plays a significant role in the development and utilisation of social capital. Education gives people chances for community engagement as well as knowledge, skills, social connections, shared ideals, and empowerment. At both the individual and communal levels, it aids in the building of social capital. The positioning of the education institutions sits closer to the residential component of the site, compared to the other amenities mentioned earlier. As mentioned prior, Hatfield is a student dominated suburb and this influences the low number of diverse educational institutions in the area, as the residential components focus has shifted from family homes to converted student accommodation. In terms of the digital twins this information would only matter in terms of understanding the distribution and accessibility to the amenities

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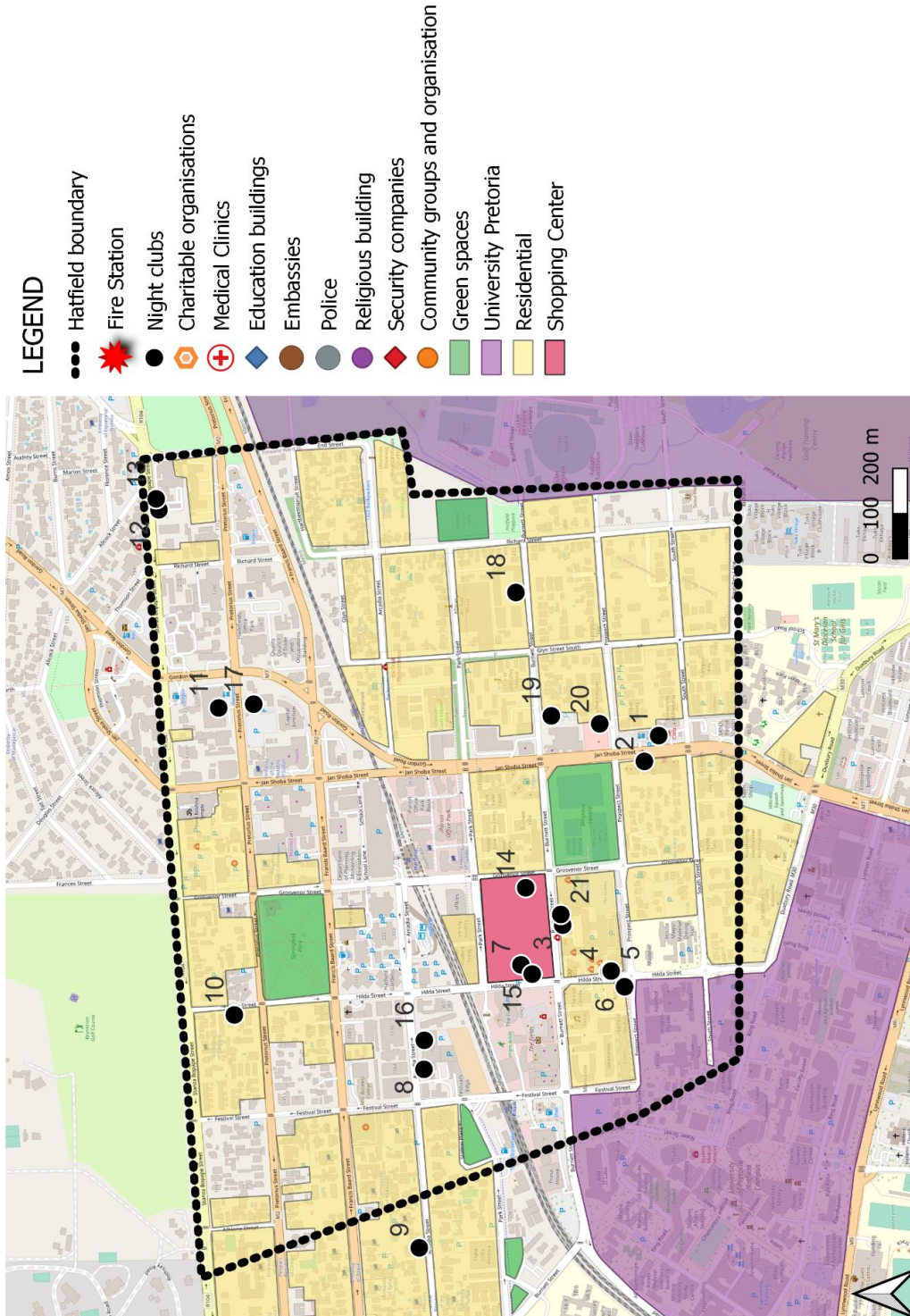
Id	Name	Type	Date founded	Trading hours	Social media presence	No of events	Reviews	No. of Reviewers
1	Mystic Hatfield	NIGHT CLUB		12:00-02:00am -sunday	yes	-2022	3	12
2	ZanZou Bar & Lounge	LOUNGE		19:00-05:00	yes	106	4.4	348
3	The Social Club Hatfield	NIGHT CLUB		11:00-02:00	yes	80	4.1	223
4	The Block 22	BAR		permanently closed	yes	8	4.2	1105
5	Square 2.0	BAR		10:00-22:00	yes	-2021	4.5	14
6	Springbok Bar	BAR		10:00-21:00, 10:00- 2:00	yes	3	4.1	1444
7	Barcode Kitchen & Bar	BAR		12:00 - 02:00	yes	3	4.0	29
8	The Blue Room Hatfield	LOUNGE		10:00-04:00	yes	55	4.4	4501
9	All	NIGHT CLUB			no		3	1
10	Round Table Exquisite Lounge	LOUNGE		10:00-02:00	yes	-2016	3.9	28
11	Altum Bar, Restaurant and Events	BAR		sporadic 12:00-02:00	yes	10	4.4	37
12	Flamingo Stripclub and Bar	ADULT ENTERTAINMENT BAR		10:30-02:00	no		3.9	23
13	Club Privilege	NIGHT CLUB		one day 19:00-04:00	yes	22	4.4	28
14	News Cafe	LOUNGE		07:23:00, 07:00-02:00	yes	3	4.1	1424
15	Pablo EscoBar - Pretoria		2023	14:00-01:30	yes		4.6	9
16	Boujee Shisanyama	BAR & GRILL		09:00-04:00	yes	-2022	4.2	83
17	Frost Bar Solutions	BAR		09:00-17:00	yes	-2020	3.2	5
18	Felo Restaurant Hatfield	RESTUARANT		06:00-22:00	yes	-2022	4.2	19
19	Cafe Livingstone	BAR		08:00-00:00, 12:00-02:00	yes		4.2	98
20	Time In A Bottle Pub & Grill	BAR		10:00-02:00	yes	-2022	4.7	1
21	Cheeky's Street Bar	BAR		08:00-02:00	yes	-2011	3.4	5

Figure 18: Map and data table of adult entertainment areas (Masu 2023)

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There are 21 adult entertainment areas (figure 18), (20 within and one sits outside) such as nightclubs, bars and lounges and are scattered throughout the site, 50% sit around the south westerly portion of the site close to the university. The data collected was the amenity, the type, the date founded, its trading hours, social media presence, number of events posted, its reviews and reviewers. Most operate from the morning to 02:00 am. Approximately 90% have a social media presence, and some do post events regularly. There are two bars that post weekly with 106 and 55 events over a period of 6 months. These two clubs posted quite frequently perhaps as their businesses need that level of engagement with the residents to keep it functioning. Only one date for one bar was found for when it was established. Those clubs would post events roughly 1-3 times a week attracting the young students of Hatfield to visit their premises There is a significant difference in the adult entertainment areas and the rest of the amenities in terms of the spatial distribution, and there is a large varied portion of them. More can be found within the larger portion of the residential component of the site. The nightclubs also have a high rating but also a lot of people reviewing the place, giving us a better picture of the amenities (see data table figure 18).

Adult entertainment areas are social gathering places where people come together to socialise, build relationships, and engage in social interactions. These social interactions contribute to the development of social connections and networks, fostering social capital. They can act as community hubs, bringing together residents from the local area. They provide a space for individuals within a community to gather, share experiences, and build a sense of belonging and identity. Although, these spaces can be seen as negative exclusionary spaces if not managed well. What is interesting to note is the large number of this specific amenity, but the lack of variety of entertainment areas. In terms of social capital It has high social capital in regards to the entertainment areas. In terms of the digital twins this information would only matter in terms of understanding the distribution and the activity of the amenities.

4.2 Conclusion

The amenities in Hatfield seem to be of a good quality according to the reviews and are varied within each subgroup. Most entities have a social media presence but don't post events often. Perhaps social media isn't as important in the digital age as we thought it would be, seeing the results of how social organisations have stayed afloat without using it to its fullest potential. Perhaps the social capital that can be found is established through other means such as face to face interactions, even though Hatfield is a young crowd. More data could be found through interviewing the public.

It is hard to determine if Hatfield has a high social capital or not, as there are so many factors that affect social capital. What can be said is categorically each amenity has its own social capital level and cumulatively we can determine if there is high or low levels of social capital in each. Certain elements have been removed from the social capital index as they do not contribute any data such as the metric time and distance, as not enough information could be collected and the social capital level couldn't be determined by time. The metric of distance was also omitted because the spatial distribution of the amenity was roughly the same, so the index would read the same for all amenities excluding the adult entertainment areas. But a great more deal of information is required to determine its overall index.

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The information mapped would matter to the digital twins if we looked at it holistically. What it can provide us currently is a general understanding of the existing structural social capital of the place and on a map level, assist us in determining what areas are lacking which resources, the possible accessibility and activity of the amenities.

5. Discussion

5.1 Social Capital index and the context

This study has made an effort to integrate the city's social and physical fabric. This has allowed access to the social fabric but also provided clues to the social issues of the city. What we learned is that Hatfield has many socio-physical amenities that are scattered around the suburb, the metrics tell us that it appears that Hatfield has high social capital based on the quantity of the amenities in the area and that are within walking distance 10min (1km walking radius each grid block is 250m in length) even though the city grid is not conducive to pedestrians. This has a positive impact on social capital as distance can affect the accessibility of the amenity.

What is also learned from these metrics is that these amenities have a social media presence constantly informing the public of their businesses and events. But many of the amenities do not regularly use them. In this digital age it is interesting to see that social media does not impact the structural social capital of these institutions and speaks to how people engage with social media in Hatfield. The age of the amenities tells us how long a place has been established for and speaks to the urban resilience of a place. Some of Hatfield's amenities have roots dating back to 1929, and that have found their way to being established there. The older an amenity or the older a branch is the more resilient it is. Established organisations with a longer track record frequently gain a reputation for dependability, quality, and trustworthiness,which contributes to the social capital of the area. Although Hatfield is made up of students who are transient in nature, it is interesting to note that these institutions still exist even with an ever changing group of people. Time informs us of the operating hours of an amenity but proved to be of little use in this study. The ownership of the amenities tells us if it's private or publicly accessible to the general public, and in Hatfield's case, a large number of the amenities are privately owned and run, which can possibly deny marginalised people access to these resources but speaks to the self reliant nature of Hatfield, and through this self reliance it could have a positive impact on social capital. The ratings of the amenities tells us that the amenities are of good quality and possibly speaks to Hatfield's residents being happy with the services, and indicates Hatfield having high social capital. Although there is not enough information to tell us the problems of the amenities and the ebb and flow within the amenities over time. Using this information we can start to find the opportunities for relevant digital twins use-cases and build the social capital index.

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SOCIAL CAPITAL LEVELS OF THE AMENITIES OF HATFIELD Levels of social capital range from low=1 medium= 2 high=3 **(All properties are weighted equally)**				
Category	**Number of amenities per group**	**Diversity Of the amenity (Type)**	**How accessible is the amenity**	**What is the Quality of the amenity**	**Total**
Religion	3=High	1=Low	3=High	3= High	2.5= medium to high
Medical institutions	2=Medium	2=Medium	1=Low	3=High	2= medium
Education	2=Medium	2=Medium	1=Low	3=High	2= medium
Community groups and organisations	3=High	3=High	3=High	2=Medium	2.8= medium to high
Entertainment	3=High	2=Medium	n/a	2=Medium	2= medium
Sports and outdoor activities	1=Low	1=Low	1=Low	2=Medium	1.3 =low
Overall total					2=medium

Table 5 : Social capital index

Not all the metrics could be brought together to create an index as some attributes did not contribute any data, not enough data was found for all amenities, or were inconclusive and would be hard to determine the social capital level. These attributes were time, distance, and the amenities of embassies, safety and security. What was used was the number of amenities, diversity of amenities, accessibility of amenity and the quality of amenity. This is a table of the

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social capital index (table 5) that has been created to rate each amenity group between low, medium and high and will attempt to determine the social capital level of Hatfield. The index score of Hatfield sits at two, with Hatfield having a medium structural social capital level. The index is the sum of the number, diversity, accessibility and quality of the spatial capital of Hatfield. It affects the social stability and well-being of the population of Hatfield and with a score of 2, it sits at above average level. What is being assessed is the networks and connections within a community from a spatial perspective. The Hatfield index is being pulled down by its lack of accessibility to the amenities and this is something that can be focused on and improved. Social capital cannot be seen through a single lens where a single answer can summarise the entirety of social capital, as it is multifaceted and has many attributes that contribute and subtract from it as seen through the index. Where it scores low, this has an impact on the type of social capital that is formed in that context and vice versa when it scores high. What would be interesting to see is other neighbourhoods' social capital index to compare these scores.

5.2 Social Capital landscapes in Hatfield

Understanding the social capital landscapes of Hatfield allows for a more social approach to technical solutions, like digital twins issues. It's important to know what happens from a social perspective as that is what makes up the daily life of people, and the problems and opportunities that can be brought to light can enable the government, the community, investors and policy makers to take charge and begin to address these issues. When the problems are known directly, and how it affects the community it begins to create a context that allows a first-hand understanding of what needs to be addressed. Unfortunately, this study did not look specifically to deeper social issues but to understand the social capital landscape as it is structurally.

While analysing the data, the structural social capital highlights the low levels of accessibility and diversity of some of the amenities. Such as the diversity of religious buildings, sports and outdoor activities. The lack of accessibility to medical institutions, sports and outdoor activities and educational buildings through privatisation. And also the times that the amenities are used, a time log of use. The number of amenities is also lacking in regards to the sports and outdoor activities. Diverse amenities cater to the needs and preferences of various groups within a community. Accessibility in amenities ensures that everyone and anyone can fully engage and participate. By enabling everyone to access and utilise amenities, communities promote equal opportunities, social integration, and a more inclusive social capital. This information is important in identifying areas that are lacking or require intervention for the digital twins. In the case of Hatfield, increasing accessibility and introducing more varied amenities could bring about more social capital. Hatfield has high and low levels of social capital depending on how you look at it, it scores high in certain categories but low in others as seen through the social capital index table (see table 5).

Crime is a common social issue and a problem in Hatfield and has negative effects on the community at large (Citizen Reporter 2022). Students are being targeted for their phones and valuables (Citizen Reporter 2022). Meaning that students and the community don't feel safe

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walking around and navigating the streets of Hatfield. The university has taken it upon itself to create safety initiatives but also has a co-operative role player that assists, the Hatfield CID (Baloyi 2019). The Hatfield CID is a non-profit organisation (NPO), funded by property owners that reside within the east of Tshwane (Baloyi 2019). The aim and purpose of the CID is to ensure safety of the residents of Hatfield. They achieved this through outsourcing two security companies (Baloyi 2019). Security personnel are deployed 24/7 within Hatfield and cameras have been installed on the streets as an added safety feature (Baloyi 2019). All this is done in conjunction with the Tshwane Metro Police Department (Baloyi 2019). This is an initiative that incorporates the government and the community working together for a better Hatfield.

When the issues are understood it helps to identify the strengths, gaps and opportunities, by assessing and addressing the different dimensions of social capital. By understanding social capital landscapes, it is easier to find common ground. Communities with high levels of social capital can produce a safer and more secure environment by fostering trust and collaboration, social integration, and neighbourhood cohesion. Communities are more likely to engage in neighbourhood watch programs, implement crime prevention strategies, and actively work together to create a safe environment. This deters criminal activity and fosters a healthy and a more secure environment. If the frequent trouble spots could be identified and mapped, the digital twins can then be used to target those areas with law enforcement or in the case of Hatfield with the CID.

5.3 Social Capital and digital twins

Mapping social capital in conjunction with the digital twins model can allow a sociological approach to social issues. It can integrate the social fabric with the built environment. The digital twins model mainly showcases the physical environment of the city, but it has ignored the social fabric of the city (Ravid and Gutnman 2022).

This lack of consideration for social perspectives within the context of digital twins has led to significant disparities in the economic progress and societal resilience among different cities (Ravid and Gutnman 2022). This gives rise to the main social issues of our era, these being displacement, gentrification and spatial inequality (Ravid and Gutnman 2022). These problems have arisen due to the technological differences between the social welfare and economic sectors of cities, among other contributing factors (Ravid and Gutnman 2022).

A community's social capital has been linked to a variety of advantageous outcomes, including better well-being, better health, more economic development, and stronger community resilience. By promoting collective action, resource sharing, and problem-solving, social capital can also help to address societal concerns. Societies can build a more inclusive, encouraging, and resilient environment for addressing a variety of social concerns by utilising social capital effectively.

These problems won't magically disappear now that we've included the social approach to the digital twins, but the goal is to aid in problem-finding and decision-making. Establishing a logical context that links geographical space and the social fabric through the use of spatial

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visualisation and analysis to provide social insights. The digital twin can take on a different dimension and not only serve in infrastructure and transportation but can begin to understand what people need and do on the ground and this is achieved through looking at how social capital landscapes are formed in a city.

In this study there were limitations on the data collection method which limited how much social information could be retrieved. It is a stepping stone into how digital twins can begin to provide insights on the social fabric of the city. It did not explicitly inform us of what people need on the ground but gave an indication of what is lacking. Digital twins and social capital can work hand in hand, if a problem is identified or what problems are already existing. Digital twins can be used in urban planning or community development to visualise and simulate changes in a neighbourhood which in turn would produce social capital.

5.4 Data and the digital twin

The ability of the digital twin concept to integrate substantial and changing data to create a foundation for conducting analyses and producing insightful information is at the heart of the concept (Ravid and Gutnman 2022). Digital twin data is not limited to one dimension and is not meant for a single purpose (Ravid and Gutnman 2022). Social data can originate from both institutional and non-institutional sources, and in order to understand the social complexity it requires examining it from different perspectives and scales (Ravid and Gutnman 2022). This requires the researchers to have a broad cultural and political contextual framework within which they can analyse phenomena and narratives (Ravid and Gutnman 2022). This then allows them to conduct analysis on both a macro and micro level that allows multiple interpretations, and to narrate a story that is not only reflective of one worldview (Ravid and Gutnman 2022). In essence it is not the data in isolation that is used in the digital twin but how it's interpreted by the user that allows for a useful twin. The current analysis of the social capital landscape of Hatfield, could have benefited from more in depth data, institutional data, the ebb and flow of the amenity, economic data such as the economic status of households, the demography of the residents, the distances between amenities and residential areas and the transportation networks. If the current data is overlaid with another data set new findings could arise. Such as identifying if the necessary amenities are sufficient for the residents (more accurate data). If there is a lack of particular amenities for a certain group of people identified, for example if there are more children than is surmised perhaps having more child orientated amenities (healthcare, entertainment, schools) would be necessary. The opposite could be said by looking at the minority group being the elderly, through looking at their access to amenities and implications on their health. And lastly looking at the efficiency of the public transport networks in regards to access to amenities.

Data plays an important role in digital twins especially looking at the social aspects, as it is not always hard data that can be easily input. This information can assist us in discovering new problems, identifying new connections or giving insights into existing problems in an area. If we look at muggings, more focus can be placed on security in specific areas and perhaps identifying unsafe spaces where similar crimes happen but also identifying what existing security structures are on site that can be utilised to tackle the problem.

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5.5 Social Capital and self-reliance

Self-reliance is the ability for an individual or community to help itself by meeting its own essential needs and social capital works hand in hand with this as it is the social networks that allow for this to happen. Strong social ties, trust, and cooperation among community members foster mutual support and collaboration, making it easier for individuals to rely on each other during challenging times. This sense of social cohesion strengthens self-reliance by promoting collective problem-solving and resource-sharing. Studying social capital landscapes in Hatfield has shown that Hatfield is self-reliant to a degree. It has the various amenities that are majority privately owned that speaks to its self-reliance but also indicates the socio-economic condition of Hatfield.

Although entertainment, tourism and outdoor activities were lacking in the area, the amenities present are rated between above average and good even when events were not posted regularly. This shows that the amenities are of good quality and links back to the social capital and self-reliance of the area. When public spaces are well-designed and managed, they can encourage people to interact with each other, form connections, and build trust. This, in turn, can contribute to the development of social capital and strengthen the social fabric of a community.

Social capital fosters self-reliance in communities. There are things that require more than an individual to be achieved. It is through the acts of the community that these acts are fulfilled and when there is a lack of assistance from the community the problems then fall to the government. This can be seen with the crime in Hatfield, the community came together to form the CID but if left to a single individual it would be a near impossible problem to tackle.

6. Conclusion

The purpose of this study was to explore how understanding of social capital could inform relevant digital twins use-cases in South Africa. The aim was to take the intangible concept of social capital, and quantify it for urban landscapes in terms of social capital metrics. In order to achieve that it required social capital metrics to be identified. So that this data can be used for digital twins applications. This paper has shown that social capital can be distilled into metrics that can be used to understand social capital in the context of an urban area. Social capital has a spatial quality that allows us to create measurements that can be used such as time, place, accessibility, quality and distance. These qualities could be translated into metrics that could assist in creating a digital twin. These metrics help us to understand the sociological level of how Hatfield is, which would not be easily attained without a method to measure. These metrics can help us understand the quality of the spatial capital and the possible social networks that are within Hatfield. Through using social media, we can have a possible lens of the networks that are formed.

The social fabric is what encompasses the daily life of people and it is important to know what happens in that perspective as this information could assist public and private entities in implementing appropriate urban interventions. In order for our cities to be resilient, they need

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to be able to withstand and recover from the shocks and disruptions but social capital brings the element of flexibility necessary for this.

As mentioned earlier social capital has multiple definitions and differs depending on the type of study being taken on. With this in mind it means that social capital can take on multiple conceptualizations. There are papers on social capital in urban areas but few take on a quantitative approach in social capital because of its qualitative nature. Existing literature focuses on using public participation but this limits the quality of the information as the user pool is usually limited, making it not a true reflection of the populace.

Hatfield has good social capital levels in respect to its amenities even though social media did not play a significant role in its existence, although the lack of accessibility significantly detracts from that making it a very closed community.

There were limitations in the study that if addressed could generate more insights into the social capital in urban areas. Time and distance were attributes that contribute to social capital significantly but could not be reflected in the study. More data is required to get a better understanding of social capital in the urban landscape. More specific social data would help in having a deeper understanding of the social fabric of Hatfield, but this would start to raise ethical and legal questions as some of this data would infringe on the privacy of individuals and the security of the populace. More research needs to be done in this space; this paper only focused on the spatial qualities of the structural aspect of social capital but there could be follow up studies that look to other social issues and the implications of distance on social capital.

In conclusion this study was the start of looking at social capital landscapes in the urban landscape, it combined theory and technology to understand the spatial quality of social capital. Sadly, there was not enough information to make in-depth conclusive decisions on the findings but it contributed to the approach of quantifying social capital in digital twins use-cases. This work opens the door for further research that promotes the growth of social capital in the urban environment for digital twins use-cases.

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