🏆 *reviewed paper*

Decoding Cities to Model, Assess and Redesign them as Complex Urban Systems

Nicholas P. Patorniti, Nicholas J. Stevens, Paul M. Salmon

(Nicholas P. Patorniti, Centre for Human Factors and Sociotechnical Systems, University of the Sunshine Coast, Sippy Downs, Queensland, Australia 4556, nick.patorniti@research.usc.edu.au)

(Dr Nicholas J. Stevens, Centre for Human Factors and Sociotechnical Systems, University of the Sunshine Coast, Sippy Downs, Queensland, Australia 4556, nstevens@usc.edu.au)

(Prof. Paul M. Salmon, Centre for Human Factors and Sociotechnical Systems, University of the Sunshine Coast, Sippy Downs, Queensland, Australia 4556, psalmon@usc.edu.au)

1 ABSTRACT

The complexity of cities presents a key challenge in being able to 'decode' and subsequently measure or describe them. Adding to these challenges is the transdisciplinary nature of city design which largely accords to disciplinary silos. This research argues that successful city design can benefit from understanding cities as complex sociotechnical systems – considering the interaction between humans, technology and the environment. This paper provides a precis of a programme of research which utilised the results of an international survey to 'decode' and construct a systems model of a main street to help understand and appropriately respond to city complexity. The research uses subject matter expert knowledge and insights from 70 survey participants, across 5 continents, to model an archetype main street. The project describes and models hundreds of physical objects, priority measures and main street functions with linkages between these components. The model allows for the exploration and measurement of a range of both technical characteristics such as engineering standards, as well as the influence and outcomes of necessary subjective measures like, user experience. It was able to provide an insight about which characteristics are critical to the city system, how they are delivered and why they are important - from a transdisciplinary perspective. This paper also highlights the work done to identify the relationships between the physical objects of a main street. Further details of the research programme are highlighted in the conclusions, including how the archetype model was used to explore the performance of a main street case study, identify missing components and locate them with consideration of their optimal proximity to other related features. We argue that this innovative approach may provide a more structured and process driven exploration of city design.

Keywords: urban model, sociotechnical systems, complex urban system, city design, urban planning

2 INTRODUCTION

2.1 Research Context

The world is experiencing a mass urban migration of people to cities. However, the current approaches to this urbanisation is often considered unsustainable, putting people at risk, creating unnecessary costs, negatively affecting the environment, and is recognised as intrinsically unfair (UN-Habitat, 2016). While urbanisation could present an opportunity to forge a new urban era where people can find freedom, inspiration, prosperity, health and security, many cities are grossly unprepared for the multidimensional challenges associated with urbanisation (UN-Habitat, 2016).

For cities to successfully accommodate world populations, new approaches to city design are required (United Nations, 2014). Current thinking is challenged by the complexity of urban systems and is not able to accurately represent and respond to emerging city paradigms (Batty, 2009; Polk, 2011; Moroni, 2015).

'City design' is used here as an all-inclusive term to describe the discipline processes and outputs involved in the planning and designing of urban settings. Disciplines typically involved in 'city design' include, but are not limited to, urban planners, landscape architects, urban designers, architects, economists, social planners, civil engineers and transports planners (Patorniti et al. 2018).

The shortcoming with many approaches to city design is that they accord to discipline and spatial silos and different perspectives are not considered inherently interdependent (Wilson, 2014). They are not able to sufficiently explore the opportunities or implications that different discipline design requirements have on the overall goals or on each other. Furthermore, inadequacies in city design can also be attributed to decisions that are typically made on individual intuition and judgement (Radford, 2010). A more structured

and process driven approach is therefore advocated in the literature (Ellis, 2013), and is explored here to 'decode' complex urban systems.

The research attempts to set out more than a new city modelling approach, it seeks to set out a new theory for understanding complex urban systems. Achieving effective theory for cities - which can then be applied in policy-making and planning - has represented, and represents, one of the great scientific challenges of the century (Wilson, 2014). Sociotechnical systems (STS) theory and methods are therefore explored to better represent and respond to the complexity of urban systems. This research, responds to a call from the UN-Habitat and World Urban Campaign, stating in their 2016 manifesto, The City We Need 2.0 (UN-Habitat, 2016, p. 2), that:

"New predictive planning and modelling tools based on systems approaches provide an unprecedented means for all stakeholder groups and city authorities to better understand the complex social, economic and political interconnections inherent in urban systems."

In response to this call, the overall aim of this work is to explore the use of Cognitive Work Analysis (CWA) (Vicente, 1999), a sociotechnical systems method, to model an ideal complex urban system - developed from transdisciplinary survey perspectives - and assess the performance of an existing main street and redesign it to reflect the archetype main street model.

The broader programme of research modelled, assessed and redesigned a complex urban system by using a sociotechnical systems method and adaptations. The phases of research included - model the ideal, assess the performance and redesign to conform to the ideal. In this paper, the 'model the ideal' phase is explored, whilst an overview of the other two phases is provided.

2.2 Cities as Complex Systems

Cities have been recognised as large complex open systems for more than half a century (Alexander, 1966; Batty, 1979). It was Jane Jacobs (1961), who first raised the notion that cities should be treated as problems of organised complexity (Batty, 2009; Moroni, 2015). Yet despite this long appreciation of the challenges, city design continues to struggle to identify and explore this complexity when considering the design or re-design of cities and their component parts (Batty, 2017).

General complexity theory has provided a basis to understand the complex nature of cities (Holland, 2014; Batty, 2017). The philosophy of 'complex systems' provides a theoretically based understanding of the uncertainty prevalent in cities and subsequent modelling or city design efforts (Cilliers, 2005). System emergence, in which dramatic transitions take place that propel the system towards a new state (Batty, 2009), is a primary characteristic which escalates a system from being complicated to being complex (Holland, 2014). These exponential and apparent random changes alter the system dynamics, leading to expected and unexpected occurrences. Emergence introduces a volatility that challenges city design.

Complexity characteristics are summarised by Cilliers (2005) as a large number of components which in themselves can be simple; comprising of non-linear interactions; many direct and indirect feedback loops; components interacting dynamically; open systems; having memory distributed throughout the system; emergent properties, and adaptive behaviours. This research sets out that it is through the collective imposition of these complexity characteristics and their unexplored properties in urban systems which makes city design more difficult.

A resurgence of complexity theory being applied to urban systems is driving recent works of enquiry, (e.g. Batty, 2017), into the methods that can cope with urban complexity. The timing is no coincidence to the challenges faced by an urbanising world population, and a need to optimise city design (UN-Habitat, 2016). While complexity theory has provided a basis to help understand the nature of cities; its practical and day-to-day application for city design is in its infancy (Stevens, 2016).

2.3 Current approaches to understanding cities as complex urban systems

Complexity theory based approaches have included a range of computer-based models. Some of the approaches include, agent-based models, cellular automata and fractals (Batty, 2007), spatial network analysis (Zhong et al., 2014), urban scaling (Bettencourt et al., 2010) and Bayesian belief networks (McCloskey et al., 2011). Part of the challenge is being able to:

- Define the boundaries of the study area (Batty & Torrens 2001; Bretagnolle et al., 2006);

210

REAL CORP 2019: IS THIS THE REAL WORLD?
Perfect Smart Cities vs. Real Emotional Cities – Karlsruhe, Germany

REAL CORP

- Capture the large number of parts and integrate them into a single model (Bura et al., 1996; Batty & Torrens 2001);

- Understand not just what happens but also being able to understand why and how (Bretagnolle et al., 2006; Pumain & Reuillon, 2017);

- Model changes over time and also changes to the spatial area being studied (Epstein, 1999; Bretagnolle et al., 2006);

- Model a preferred or optimal state (Abbott, 2016; Pumain & Reuillon, 2017); or

- Understand the interactions between components and the emergent behaviours that arise as a result (Moroni, 2015).

The city design approaches that acknowledge and respond to the challenges of urban complexity, are recognised as often being static and failing to make as thorough and radical consideration of complexity as seems necessary (Moroni, 2015; Batty, 2017). A considerable gap still exists between complex systems theory and the models that have been developed (Batty & Marshall, 2012; Batty, 2017), this works seeks to contribute to the knowledge gaps.

2.4 Sociotechnical systems (STS) approaches to city design

This research explored the compatibility and usefulness of a human factors and ergonomics (HFE) sociotechnical systems (STS) approach to city design. HFE is a scientific discipline which is concerned with the understanding of interactions among humans and other elements of a system, and a profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance (International Ergonomics Association, 2003).

STS is an approach with a theoretical underpinning and a range of methods which can assist in evaluating complex systems and improve system design (Vicente, 1999; Salmon et al., 2010; Read et al., 2015a). STS theory and methods have been widely used to analyse complex systems which rely on the interactions between humans, technology and the environment. Stevens (2016), has established that STS approaches, have a theoretical, methodological and practical legacy which is useful to city design. While Patorniti et al., (2017) supports the use of STS approaches by establishing that cities do indeed possess a number of the characteristics of both complexity and STS. Further, Patorniti et al., (2017) sets out that city design is compatible with the theory content principles of STS as set out in Read et al., (2015a).

2.4.1   Cognitive Work Analysis

Cognitive Work Analysis (CWA) (Vicente, 1999) has long been identified as an appropriate STS method for evaluating complex systems (Salmon et al., 2010; Read et al., 2015b) and it aims to improve system design (Vicente, 1999). CWA provides a framework of methods that are used to develop an in-depth analysis of the constraints that shape activity within complex systems (Stanton et al., 2013). It has its origins in studies at the RISØ laboratory in Denmark beginning in the 1960s. A cognitive systems engineering approach was developed (Wilson, 2014), including the CWA framework of tools to assist in the design of adaptive systems that enabled the worker to 'finish the design' (Vicente, 1999). The framework encompasses five phases of analysis. Two phases are used in this research, the first phase, work domain analysis (WDA) and the second phase control task analysis, incorporating the contextual activity template (CAT) analysis. CAT was utilised in the assess and redesign phases of the overall research programme and subsequently is not set out in detail here.

WDA uses an abstraction hierarchy to model sociotechnical systems in terms of their functional purposes (at the very top of the hierarchy), through to the values and priority measures, purpose related functions, object related processes, and physical objects (at the very bottom of the hierarchy). It has the ability to link different physical objects to required functions which enables analyses to specify not only what a design requires but also what objects can be introduced in the design to achieve the functions (Stevens and Salmon, 2014). The abstraction hierarchy represents the composite nodes of a system across the following five levels of abstraction:

- Functional purpose – The overall purpose(s) of the system. For instance, for what reasons does it exist? What are the highest-level objectives or ultimate purpose? E.g. economic prosperity; places for people; or a well-resourced infrastructure network.

- Values and priority measures – The criteria that the system uses for measuring progress towards its functional purpose. For instance, what criteria can be used to judge whether it is achieving the purpose outlined above? E.g. maximise economic capacity; maximise social interaction; or maximise access.

- Purpose related functions – The general functions of the system that are necessary for achieving the functional purposes. For instance, what must be accomplished? E.g. retail access; cultural functions; or network connectivity.

- Object related processes – The functional capabilities and limitations of the physical objects within the system that enable the generalised functions. E.g. retail at street level; generates human activity; or public transport service.

- Physical objects – the physical objects within the system. For instance, a physical object can be a type of infrastructure, fixtures, buildings, facilities. E.g. retail building; public art; pavement, seat or public transport station.

The concept of 'objects worlds' is used to supplement the WDA. Rasmussen et al., (1990) was the first to use the notion of object worlds in the context of a WDA. Naikar et al. (2005) describes object worlds as stakeholders' views of the work domain or problem. Object worlds may assist with representing a work domain from the perspective of different stakeholders (Naikar, 2013), and are established here via the transdisciplinary participation within the survey data collection.

2.4.2   Social Network Analysis

Social network analysis (SNA) is used in this modeling work to understand relationships between elements. It is commonly used to identify the ties as interactions, connections and flows between the nodes of people, groups or organisations (Corten, 2010; Miura, 2011; Pinheiro, 2011). Here, SNA is used to explore proximity relationships between the array of physical objects identified in the WDA. Proximity is a key factor to the success of pedestrian oriented urban areas (Özbil et al., 2015). Many texts refer to the need for the confluence of land uses, density, fine grained built form to enhance proximity (Cervero & Kockelman, 1997; Krizek, 2003). They refer to the reduction of distances to increase connectivity and accessibility. Understanding proximity will not just increase network movement efficiency but also encourage a safe, pleasant, comfortable urban environment, among other attributes (Ewing & Handy, 2009; Gehl et al., 2006).

Using proximity to describe the SNA ties is supported by concepts underpinning spatial interaction models such as distance impacts in gravity models (Haynes & Fotheringham, 1984). For example, distance impacts, distance decay or friction of distance relate to the concept that the farther places, people, or activities are apart, the less they interact. This research explored these proximity concepts using SNA to model physical objects with a proximity relationship.

2.5 Selection of Main Streets as an archetype complex urban system

Main streets, otherwise known as high streets are used here as an archetype complex urban system, representative of the broader complexities inherent in city-wide systems. As well as being complex urban systems, main streets have been selected as they have been identified as containing characteristics of complex STS and align with STS theory values and content principles (Read et al., 2015a; Patorniti et al., 2017). A main street is considered here to include the areas of the road pavement, road reserve and the land uses up to 100 metres from the road reserve. It is more than just the street itself, it is the area within the street corridor, the interface of pathways with roads and land uses immediately and further surrounding the main street. They may also be recognised as representing a convergence of many city design principles according to discipline and spatial silos. Further, they are also the convergence of many land uses (e.g. places to shop, live, eat, do business and for recreation) and have many intricate parts (e.g. fine grained built form and extensive street furniture). This multi-use and intricacy presents main streets as a suitable domain to describe a complex urban system from the many individual components and their interrelations, to meet many city-wide purposes, priorities and functions (Patorniti et al., 2018).

212

REAL CORP 2019: IS THIS THE REAL WORLD?
Perfect Smart Cities vs. Real Emotional Cities – Karlsruhe, Germany

3 METHOD

3.1 Model the ideal main street

Subject matter expert knowledge and insights informed the development of the WDA abstraction hierarchy. Patorniti et al., 2018 provides a detailed description of the method and results; however as an overview of the method, an online survey provided the data to inform the development of the main street abstraction hierarchy. The study involved 70 participants across 5 continents and 19 different countries (Fig. 1). Participants were from the key disciplines of strategic town planning (23), urban design (22), architecture (13), statutory town planning (13), transport planning (7), landscape architecture (6), civil engineering (4), economics (4) and social planning (2). Consistent with the multidisciplinary nature of urban development, twenty-four participants stated having more than one key discipline area. Therefore, more disciplines were reported than the total number of participants. The majority of the 70 survey participants were employed at consultancy services companies (26), then in academia (18), non-governmental organisations (8), government (7), professional institutions (2) and other (5). Four participants did not report their organisation.
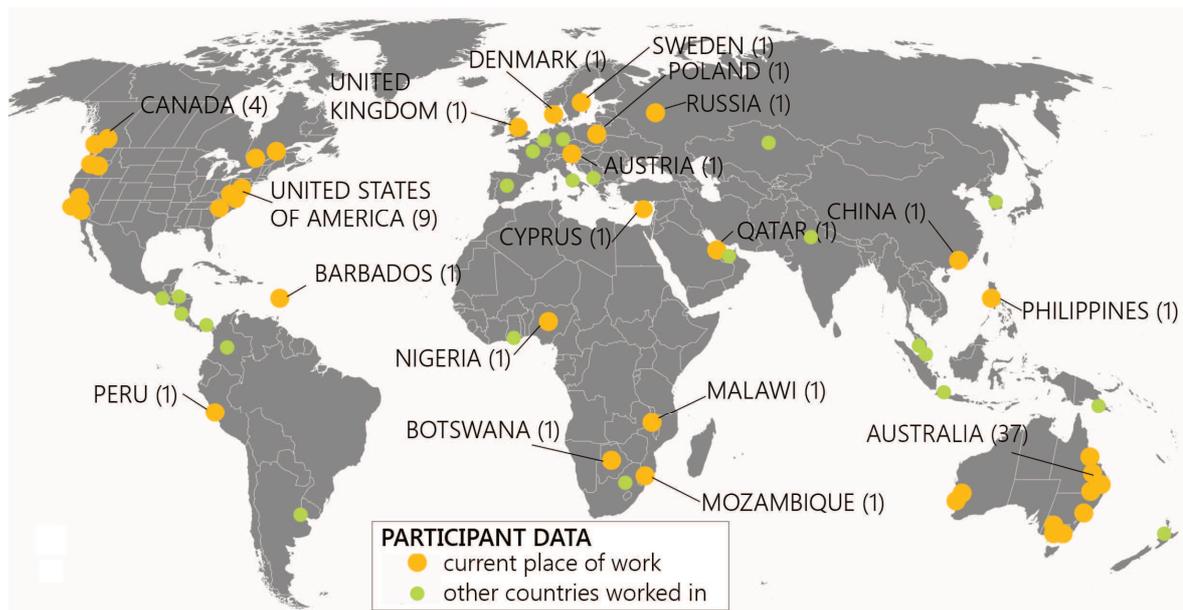

Fig. 1: Survey participant locations: current place of work and other countries worked in.

The purpose of the first online survey was to gather data to create a collection of possible nodes for each level of the WDA abstraction hierarchy for the 'main street system'. The questions therefore focussed on gathering data relating to each of the abstraction hierarchy levels. For example, what are the functional purposes of a main street? Through to - What physical objects should be within a main street? Survey results were coded using NVivo, a qualitative data software program. Inter-rater reliability testing was undertaken by two analysts on the coding of the survey responses to the created nodes (following Plant & Stanton, 2013). Consensus on the coded nodes occurred via a second online survey to the original respondent group, following a modified two-round Delphi study (Linstone & Turoff, 1975). The consensus nodes were the primary data used to create the WDA abstraction hierarchy. For the discipline object worlds overlay, nodes were labelled according to the participant's discipline from the first online survey.

Social Network Analysis (SNA) was also used to examine relationships between the ideal main street physical objects in the WDA abstraction hierarchy. The physical objects being the nodes and their ties being proximity connections. The ties in the SNA relate to the need for two connected physical objects (nodes) to be in proximity to each other. The aim is to model the relationships between physical objects that are better afforded the closer they are to related physical objects. For example, outdoor dining is better afforded when lighting, awnings and seating are closest; a landmark building with public transport, public toilets and waste receptacles nearby; or parks that have seating, drinking water fountains and trees. Three urban planner subject matter experts reviewed the SNA input table and highlighted any cell with which they disagreed on the proximity connections. Any disagreed cells were highlighted and the total number of disagreements for that cell were tallied. If two or more SMEs disagreed, the cell was changed from a proximity connection to no connection, or vice versa.

4 RESULTS

Results are set out below, according to the WDA and SNA methods involved to model the ideal main street. First, is an excerpt of the survey results.

4.1 Survey Results

Table 1 details the disciplines that included information relating to that coded node in their survey response for the purpose related function level. This table provides a more traditional view of the data and provides significant insights. For example, social interaction had the highest number of responses with responses from 9 of the 9 disciplines. While adaptive and resilient, educational services and special events and activation were only recognised by individual disciplines. It shows that it is important for a main street to be a place to live, but only from four of the nine disciplines. While interesting in unto itself, when assembled in the form of the WDA, the interdependent relationships and shared resources required in a main street environment begin to be revealed. The data was therefore used to build the WDA abstraction hierarchy main street model.

Purpose related function	Discipline types									Purpose related function	Discipline types								
Adaptive & Resilient			3							Place to Work	1	2						8	
Commercial Functions	1	2	3	4	5		7	8	9	Recreation & Entertainment	1	2	3	4		6	7	8	
Community Services	1	2	3	4			7	8	9	Respite Areas	1	2						8	
Cultural Functions	1	2	3		5	6		8		Retail Access	1	2	3	4	5		7	8	9
Educational Services	1									Safe Place	1	2							
Food & Drink Access		2						8		Slow Traffic Environment	1			4					
Network Connectivity	1	2	3	4	5		7	8		Social Interaction	1	2	3	4	5	6	7	8	9
Pedestrian & Cyclist Friendly		2	3							Special Events & Activation								8	
Place to Live	1	2		4				8		Tourist Destination			3	4					

Table 1: Number of purpose related function coded nodes according to survey participant discipline. 1= Statutory town planning; 2= Strategic town planning; 3= Urban design; 4=Transport Planning; 5=Architecture; 6= Social Planning; 7= Civil engineering; 8= Landscape architecture; 9= Economics.

4.2 WDA abstraction hierarchy model of the ideal main street

The entire WDA abstraction hierarchy, contained in Patorniti et al. (2018), brought together disciplinary knowledge to explore and make explicit the silos of knowledge that are apparent in designing complex urban systems. It also provided a framework to assemble the survey data by detailing what needs to be achieved, how and why by showing the interrelations between coded nodes across the levels of abstraction. The entire model contains and links 51 physical objects, 54 object related process, 18 purpose related functions, 10 values and priority measures and the five functional purposes to describe the ideal main street.

To demonstrate the efficacy of this approach Fig. 2 sets out the interrelations of one physical object, seating, across all abstraction hierarchy levels. The links for one the twelve processes that seating affords is also shown in bold to detail such a seemingly mundane urban element contributes to all abstraction hierarchy levels. Following this example, Fig. 2 links seating to many object related processes, including, a place to meet and wait. A place to meet and wait then links to many purpose related functions of seating, including, social interaction. The purpose related function of social interaction then links to many value and priority measures, including, maximise economic capacity which then links to many functional purposes including economic prosperity. The results for this one physical object show the importance of seating (e.g. seating

214

REAL CORP 2019: IS THIS THE REAL WORLD?
Perfect Smart Cities vs. Real Emotional Cities – Karlsruhe, Germany

contributes to all main street functions and purposes). For the seating example, the abstraction hierarchy describes potentially anticipated interrelations (e.g. seating maximises social interaction creating places for people) but also potentially uncovering unanticipated contributions (e.g. seating maximises economic capacity creating economic prosperity).
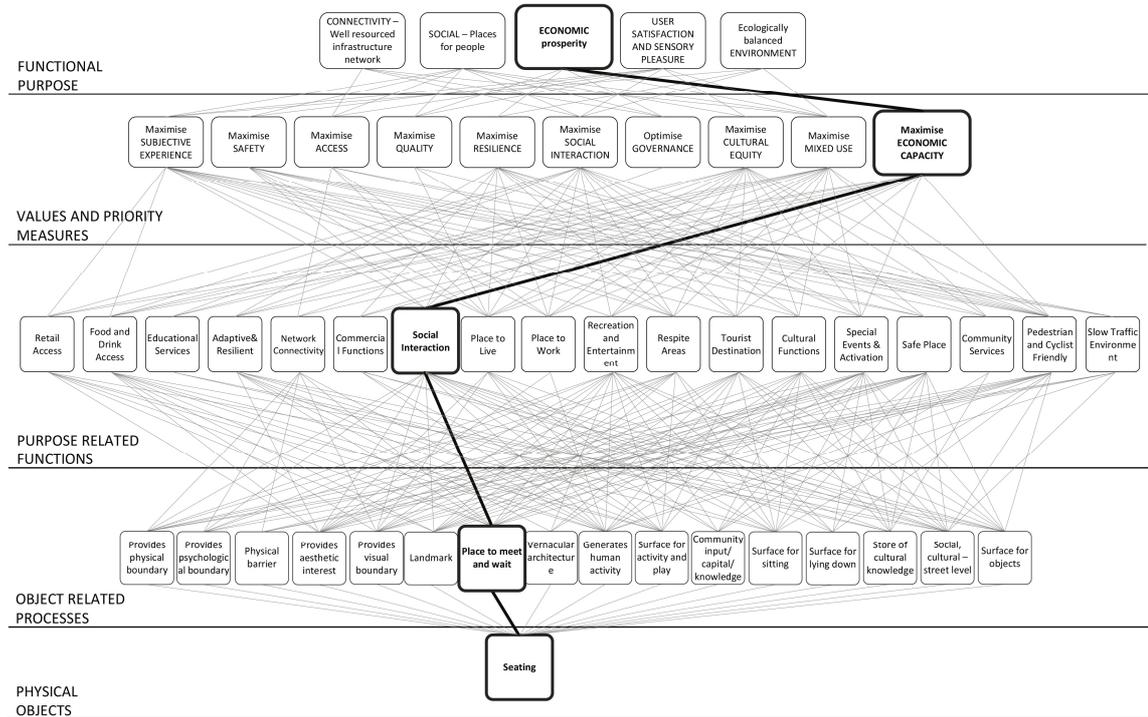

Fig. 2: Extract of the WDA abstraction hierarchy model detailing seating and its interrelations across the levels

4.3 Object worlds for the ideal main street

Perceptions of the archetype complex urban system were also overlaid, using object worlds, by labelling the coded nodes according to the disciplines from the participant responses (see Patorniti et al. (2018)). In the way Table 1 outlines these results for the purpose related functions, it was possible to identify which disciplines considered which aspects of a main street are important or indeed necessary across all levels of the WDA. The results demonstrate the importance of obtaining transdisciplinary views to assemble the wide-ranging perceptions of a complex urban system. For instance, if three of the nine disciplines, being statutory town planning, strategic town planning and urban design were removed for the model, the following nodes would be missing. Twelve of the fifty-one physical objects (including critical elements such as window fronts, footpath dining, community land uses, awnings etc.), four of the eighteen purpose related functions (e.g. adaptive and resilient, safe place, pedestrian and cyclist friendly) and thirteen of the forty-one measures within the values and priority measures level (e.g. lifestyle needs indicators, residential proximity, special events, redevelopment approval activity). The implications are more than missing nodes. For instance, one missing component and its interrelations could be the key to identifying and understanding unanticipated outcomes from system complexity such as emergence.

The discipline object worlds also show the risk associated with relying on one or a small group of disciplines to identify all related connections between levels to their specified node or nodes. For instance, the discipline object worlds overlay shows that civil engineering considered and identified the 'public art' physical object and 'social interaction' purpose related function part of the system and hence the link between levels. Civil engineering, however, did not specify the 'maximise resilience' measure or the 'economic prosperity' functional purpose. The discipline object worlds show that other disciplines are relied upon to provide a more complete view of the main street system as provided via the WDA.

4.4 SNA model of the ideal main street

Fig. 3 details the SNA model built from an input table in the SNA modeller and visualiser tool. In this figure, the outdoor dining physical object is highlighted and all of its proximity relationship ties to other physical object nodes. The results overall, show many proximity relationships between physical objects within the

ideal main street. It shows a physical object is needed to be in proximity for another physical object but how that same physical object is required to be in proximity to many other physical objects. Illustrating the interdependency across the physical object level.

Some physical objects have more proximity relationships than other others and these are represented in Fig. 3 as a larger node. Generally, physical objects with more ties will be placed in a more central position on the graph from the Fruchterman & Reingold (1991) drawing algorithm. Following the larger physical object nodes, the SNA shows the town square, sidewalk, laneway, footpath, signage, lighting, entertainment precinct, food and drink outlets, open public spaces and cycleway all require many physical objects in proximity or conversely are providing for many other physical objects. For example, a town square provides the area for many physical objects to be within or a town square requires many physical objects to be an ideal main street town square. Similarly, how lighting is needed to be in proximity to many other physical objects like outdoor dining.
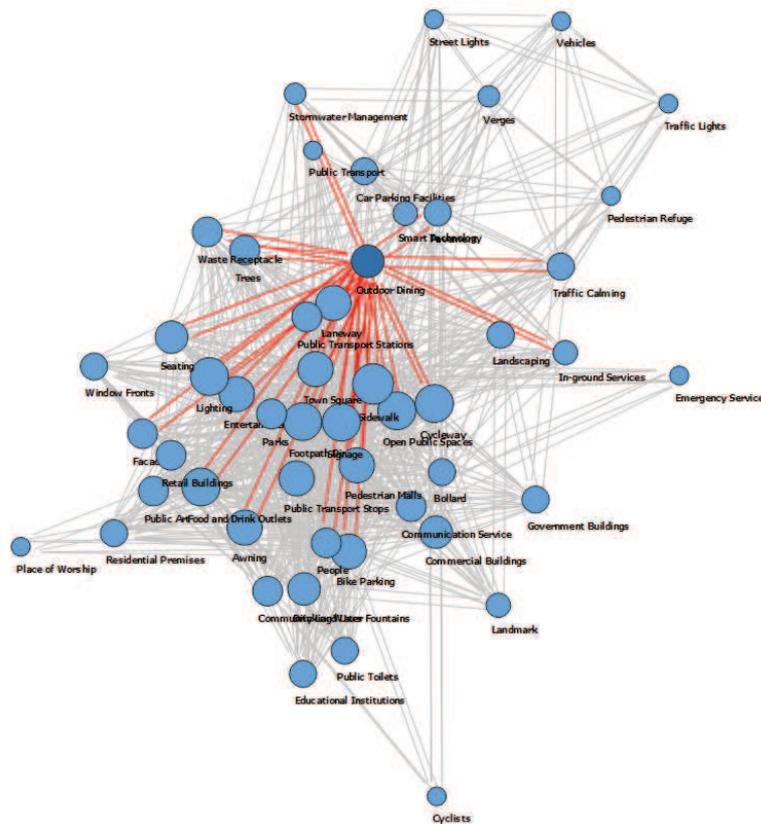
Fig. 3: SNA detailing the proximity relationships between main street physical objects

5 FURTHER DEVELOPMENTS

This section briefly outlines the following components of the programme of research which followed the modelling phase described above.

5.1 Assess a main street

The next step explored the application of the WDA to an existing main street. The model was used as a benchmark of what could be achieved. Understanding the performance of an existing main street was considered an important step in being able to identify the necessary nodes for redesign. The CAT requirements developed were also used for the assessment to determine where physical objects or purpose related functions should or could occur within the case study main street, in the buildings, parks, footpaths or roads.

Geographic Information Systems (GIS) was explored to translate and bring together the WDA and CAT requirements in a spatial context. With GIS, spatial information was mapped from the existing main street and was then able to be compared to the ideal WDA and CAT requirements. Incorporating GIS was also

216

REAL CORP 2019: IS THIS THE REAL WORLD?
Perfect Smart Cities vs. Real Emotional Cities – Karlsruhe, Germany

considered necessary for the ability to undertake future redesign. The redesign would then be better informed by the location of the necessary nodes identified in this assessment.

5.2 Redesign a main street

Prior to any redesign efforts, the accuracy of the models was explored. Observational surveys were conducted to examine the model's degree of validity and assist with any model calibrations. Standard error of estimate (otherwise known as standard error of the regression (S)) calculations were used to understand how well the observed data fit the model outputs (Norušis, 2006).

The WDA, CAT and GIS assessment findings were used to inform the redesign to redevelop under-performing areas within the case study main street. This redesign phase also used the physical objects SNA in the GIS model by preparing a method adaptation, referred to as 'SNA proximity constellation'. The SNA proximity constellation, identifies the optimal location of missing physical objects in the main street, based on arbitrary locations and existing locations of proximal objects. The first task for the redesign was therefore to use GIS to identify the most suitable location of missing physical objects from the ideal WDA model, using the SNA proximity constellation. The second task was to locate additional physical objects where the quantity and distribution was not optimal, as identified from the main street assessment phase. The third task prepared a concept redesign using the task 1 and 2 results.

6 CONCLUSIONS

This research argues that STS theory and methods may provide a new perspective to help overcome challenges and better identify and respond to opportunities for city design. The approaches developed set out a way to better understand and respond to the complexity of urban systems by considering all system design requirements and interrelations. It brings together disciplinary silos by providing a framework to integrate transdisciplinary perspectives. This structured approach to design may assist practitioners overcome the challenges associated with decisions made on intuition and judgement.

A STS based approach which integrated transdisciplinary perspectives, may highlight and further reveal the complexities and contradictions of city design. The WDA abstraction hierarchy details the highly interdependent nature of main streets and provides hints of a main street's complexity. It potentially explains the prioritisation of components over others. It also shows potential leveraging opportunities; potential conflicts of the system components and implications of missing nodes are also made apparent. The SNA showed the main street to have many proximity relationships between physical objects – useful for informing redesign.

The STS approach assists in 'decoding' and modeling a complex urban system and may bridge the gap between complexity theory and developed models. It provided contributions in this respect, by: 1) defining the boundaries of the study area; 2) capturing the large number of parts and integrating them into a single model; 3) help understand not just what happens but also being able to understand why and how; 4) model a preferred or optimal state; and 5) help understand the interactions between components and the emergent behaviours that arise as a result.

Further developments, helped identify areas that are under performing and understand why. It identified what needs to occur and where. In doing so, it provides practitioners with a set of approaches to better utilise existing urban areas to better accommodate an urbanising population. The approaches developed could be applied to a wide array of urban problems.

7 REFERENCES

Abbott, J. (2016). Modeling cities and regions as complex systems: from theory to planning applications.
Alexander, C. (1966). A City is not a Tree: Design. London: Council of Industrial Design.
Batty, M. and Marshall, S. (2012). The origins of complexity theory in cities and planning. In Complexity theories of cities have come of age (pp. 21-45). Springer, Berlin, Heidelberg.
Batty, M. and Torrens, P.M. (2001). Modelling complexity: the limits to prediction. Cybergeo: European Journal of Geography
Batty, M. (1979). Progress, success, and failure in urban modelling. Environment and Planning A, 11(8), 863-878.
Batty, M. (2007). Cities and complexity: understanding cities with cellular automata, agent-based models, and fractals. The MIT press.
Batty, M. (2009). Complexity and Emergency in City Systems: Implications for Urban Planning. Malaysian Journal of Environmental Management, 10(1), 15-32.

Batty, M. (2017). Benedikt's challenge: Reconstructing the whole from the parts. Environment and Planning B: Urban Analytics and City Science. 44(3) 395-397

Bettencourt, L. M., Lobo, J., Strumsky, D., & West, G. B. (2010). Urban scaling and its deviations: Revealing the structure of wealth, innovation and crime across cities. PloS one, 5(11), e13541.

Bretagnolle, A., Daudé, E. and Pumain, D. (2006). From theory to modelling: urban systems as complex systems. CyberGeo: European Journal of Geography.

Bura, S., Guérin-Pace, F., Mathian, H., Pumain, D. and Sanders, L. (1996). Multiagent systems and the dynamics of a settlement system. Geographical analysis, 28(2), pp.161-178.

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: density, diversity, and design. Transportation Research Part D: Transport and Environment, 2(3), 199-219.

Cilliers, P. (2005). Knowing complex systems. Managing Organisational Complexity: Philosophy, Theory, Application, IAP, Connecticut, pp.7-19.

Corten, R. (2010). Visualization of social networks in stata by multi-dimensional scaling.

Ellis, C. (2013). Process and Principles in Urban Design. Journal of Urban Design 19(1): 47-48.

Epstein, J.M. (1999). Agent-based computational models and generative social science. Complexity, 4(5), pp.41-60.

Ewing, R. and Handy, S. (2009). Measuring the unmeasurable: Urban design qualities related to walkability. Journal of Urban design, 14(1), pp.65-84.

Fruchterman, T. M., & Reingold, E. M. (1991). Graph drawing by force-directed placement. Software: Practice and experience, 21(11), 1129-1164.

Gehl, J., Kaefer, L. J., & Reigstad, S. (2006). Close encounters with buildings. Urban design international, 11(1), 29-47.

Haynes, K. E., & Fotheringham, A. S. (1984). Gravity and spatial interaction models (Vol. 2). Beverly Hills, CA: Sage.

Holland, J. H. (2014). Complexity: A very short introduction. OUP Oxford.

International Ergonomics Association. (2003). IEA Triennial Report 2000–2003. (Santa Monica, CA: IEA Press).

Jacobs, J. (1961). The Death and Life of Great American Cities, Random House, New York.

Krizek, K. J. (2003). Residential relocation and changes in urban travel: Does neighborhood-scale urban form matter?. Journal of the American Planning Association, 69(3), 265-281.

Linstone, A.H., Turoff, M. (1975). The Delphi Methods: Techniques and Applications. Addison–Wesley, Reading, Massachussetts.

McCloskey, J. T., Lilieholm, R. J., & Cronan, C. (2011). Using Bayesian belief networks to identify potential compatibilities and conflicts between development and landscape conservation. Landscape and Urban Planning, 101(2), 190-203

Miura, H. (2011). SGL: Stata graph library for network analysis. analysis, 2, 41.

Moroni, S. (2015). Complexity and the inherent limits of explanation and prediction: Urban codes for self-organising cities. Planning theory, 14(3), pp.248-267.

Naikar, N., Hopcroft, R., & Moylan, A. (2005). Work domain analysis: Theoretical concepts and methodology (No. DSTO-TR-1665). Defence Science and Technology Organisation Victoria (Australia) Air Operations Div.

Naikar, N. (2013). Work domain analysis: Concepts, guidelines, and cases. CRC Press.

Norušis, M. J. (2006). SPSS 14.0 guide to data analysis. Upper Saddle River, NJ: Prentice Hall.

Özbil, A., Yeşiltepe, D., & Argin, G. (2015). Modeling walkability: The effects of street design, street-network configuration and land-use on pedestrian movement. A| Z ITU Journal of the Faculty of Architecture, 12(3), 189-207.

Patorniti, N. P., Stevens, N. J., & Salmon, P. M. (2017). A systems approach to city design: Exploring the compatibility of sociotechnical systems. Habitat International, 66, 42-48.

Patorniti, N.P., Stevens, N.J. and Salmon, P.M. (2018). A sociotechnical systems approach to understand complex urban systems: A global transdisciplinary perspective. Human Factors and Ergonomics in Manufacturing & Service Industries.

Pinheiro, C. A. R. (2011). Social network analysis in telecommunications (Vol. 37). John Wiley & Sons.

Plant, K. L., & Stanton, N. A. (2013). What is on your mind? Using the perceptual cycle model and critical decision method to understand the decision-making process in the cockpit. Ergonomics, 56(8), 1232-1250.

Polk, M. (2011). Institutional capacity-building in urban planning and policy-making for sustainable development: success or failure?. Planning, Practice & Research, 26(2), 185-206.

Pumain, D. and Reuillon, R. (2017). Urban dynamics and simulation models. Springer International Publishing.

Radford, A. (2010). Urban design, ethics and responsive cohesion. Building Research & Information, 38(4), 379e389.

Rasmussen, J., Pejtersen, A.M., & Schmidt, K. (1990). Taxonomy for CWA (Risø-M-2871). Roskilde, Denmark: Risø National Laboratory.

Read, G. J., Salmon, P. M., Lenné, M. G., & Stanton, N. A. (2015a). Designing sociotechnical systems with CWA: putting theory back into practice. Ergonomics, 58(5), 822-851.

Read, G. J., Salmon, P. M., & Lenné, M. G. (2015b). CWA and design: current practice and future practitioner requirements. Theoretical Issues in Ergonomics Science, 16(2), 154-173.

Salmon, P. M., D. Jenkins, N. Stanton, and G. Walker. (2010). Hierarchical Task Analysis vs. CWA: Comparison of Theory, Methodology and Contribution to System Design. Theoretical Issues in Ergonomics Science 11: 504–531.

Stanton, N. A., McIlroy, R.C., Harvey, C., Blainey, S., Hickford, A., Preston, J.M. and Ryan, B. (2013). Following the CWA Train of Thought: Exploring the Constraints of Modal Shift to Rail Transport. Ergonomics 56: 522–540.

Stevens, N. and Salmon, P. (2014). Safe places for pedestrians: using CWA to consider the relationships between the engineering and urban design of footpaths. Accid Anal Prev 72: 257-266.

Stevens, N. J. (2016) Sociotechnical urbanism: new systems ergonomics perspectives on land use planning and urban design, Theoretical Issues in Ergonomics Science, 17:4, 443-451, DOI: 10.1080/1463922X.2016.1143988

UN-Habitat. (2016). The City We Need 2.0 Towards a New Urban Paradigm. United Nations Human Settlements Program (UN-Habitat), Nairobi.

United Nations. (2014). World Urbanization Prospects- Highlights, United Nations, New York.

Vicente, K.J. (1999). CWA: Toward Safe, Productive, and Healthy Computer-based Work. Lawrence Erlbaum Associates, Mahwah, NJ.

Wilson, A. G. (2014). Complex spatial systems: the modelling foundations of urban and regional analysis. Routledge.

REAL CORP 🧡

REAL CORP 2019: IS THIS THE REAL WORLD?
Perfect Smart Cities vs. Real Emotional Cities – Karlsruhe, Germany