A Grounded Theory of Design Innovation in Hospital Design: Contextualising and Understanding How Research Informs Practice

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Contextualising and Understanding How Research Informs Practice

by

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Submitted in fulfilment of the requirements for the degree of

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List of Publications

Directly related to this thesis[1]

1. Sal Moslehian, A., Kocaturk, T., & Tucker, R. (2021). An integral view of innovation in hospital building design: understanding the context of the research/practice gap. *Building Research & Information*, 1-16. https://doi.org/10.1080/09613218.2020.1740577

2. Sal Moslehian, A., Tucker, R., & Kocaturk, T. Diagrammatic Modelling Tools for Grounded Theory Research: The Implementation of a Multi-Representational Approach. *Submitted to Journal.*

3. Sal Moslehian, A., Kocaturk, T., Andrews, F. & Tucker, R. The Nature of Innovation in Hospital Building Design: A Mixed Grounded Theory Study. (2022). *Construction Innovation.* https://www.emerald.com/insight/content/doi/10.1108/CI-12-2021-0236/full/html

4. Sal Moslehian, A., Tucker, R., Kocaturk, T., & Andrews, F. An Analysis of Design Innovation in Hospital Building Design over the Past 100 Years. (2022). *Submitted to Journal.*

Three-Minute Thesis Competition:
https://www.youtube.com/watch?v=piGr0fKMvyg

Visualise Your Thesis Competition:
https://figshare.com/articles/media/Innovation_in_Hospital_Building_Design/12869918

Other Publications

5. Tucker, R., Sal Moslehian, A. Researching the socioeconomic factors that drive outcomes for communities affected by disadvantage: a scoping review informing Australian policy. *Submitted to Journal.*

6. Tucker, R., Sal Moslehian, A. Place-based intervention research to address locational disadvantage. *Submitted to Journal.*

7. Tucker, R., Andrews, F., Johnston, N., Sal Moslehian, A. Direct impacts of lifecycle construction quality characteristics on the health and safety of occupants in residential apartments. *Ongoing Research.*

8. Gaekwad, J., Sal Moslehian, A., Roos, P., Walker, A. A meta-analysis of emotional evidence for the biophilia hypothesis and implications for biophilic design. *Frontiers in Psychology*, *13.* https://philpapers.org/rec/GAEAMO

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9. Tucker, R., Andrews, F., Bartel, R., Hitch, D., Liang, J., Thornton, L., Bower, I., Sal Moslehian, A., Johnson, L. and Mundell, M. (2021), Strategies for Alleviating Locational Disadvantage in Geelong, Deakin University, Geelong, Australia. http://hdl.handle.net/10536/DRO/DU:30154332

10. Sal Moslehian, A. Tucker, R. and Andrews, F. (2021). Design considerations for child and family friendly apartments (Stage 3), Deakin University, Geelong, Australia. https://dro.deakin.edu.au/view/DU:30154335

11. Motalebi, G., Sal Moslehian, A., & Hasanzadeh, E. (2019). The most effective indoor environmental quality factors related to worker satisfaction and performance: a case of the administrative office building at Ferdowsi University of Mashhad. International Journal of Occupational Safety and Ergonomics, 1-13. https://doi.org/10.1080/10803548.2019.1582886

12. Sal Moslehian, A., Kamelnia, H. (2016). The analysis of influential parameters on stress reduction in healthcare environments. The 3rd international congress on new horizons in architecture and planning, Iran.

13. Sal Moslehian, A., Kamelnia, H. (2016). The role of nature in combating physiological and psychological stress in therapeutic environments. The 4th International Congress on Civil Engineering, Architecture and Urban Development.

14. Feizabadi, M., Soltanian, Y., Sal Moslehian, A. (2015). The usage of pneumatic retractable structure in optimized designing sport stadiums roof. The 3rd International Congress on Civil Engineering, Architecture and Urban Development.

15. Sal Moslehian, A., Soltanian, Y. (2015). Different types of atriums in energy efficiency for high buildings. Urban Planning, Urban Management, Sustainable Development Conference.

Abstract

It has been widely suggested that hospital building design has significant influence on quality of care, healing processes and organisational efficiency. Despite the undeniable need for innovative designs in hospital buildings, the literature highlights the Research-Practice (R-P) gap as hindering innovation in hospital design, leading to repeating similar shortcomings. This study shows such an understanding of the role of R-P gap to be an oversimplification of innovation in hospital building design, which instead must be seen as a complex ecosystem with various inhabitants; meaning the R-P gap is only a small part of a more complex picture. Overlooking this complexity, and therefore insufficient understanding of the nature of design innovation processes in hospital building design, has been one of the critical factors in the shortage of timely design innovations in this field.

The key aim of this thesis is to conceptualise the evolution of hospital building design and identify and explain the main factors triggering design innovation. A novel hybrid research design to Mixed Grounded Theory (MGT) methodology, with reference to Charmaz's constructivist paradigm, is developed as a new systematic way of constructing and interpreting the concepts and interconnections among them that have triggered design innovation over the past 100 years. Here, two diagrammatic representations (network and arc diagrams), along with their associated analytical frameworks, are employed and augmented by the qualitative and quantitative techniques provided by social network analysis (SNA). The aim is to understand the complex innovation ecosystem and leverage big data analysis through the development of a human-centred approach, which keeps both human and computational decision-making methods in the analysis loop. The prime analysis is achieved in four steps: 1) analysing the evolution of hospital design since the 1920s and providing a taxonomy of contributing factors, adopting actor-network theory as a rich theoretical lens; 2) conceptualising how contextual factors have triggered design innovations on account of the increasingly globalised world in a theoretical model based on complex systems theory - network approach; 3) examining the interrelationships between design innovations and contextual factors through characterising the structure of innovation networks, using SNA; and 4) developing an explanatory innovation framework elucidating the nature of innovation ecosystem in hospital building design, which can inform further innovation in this field. This research highlights the main components of the innovation ecosystem, the most influential contextual factors, the most interrelated factors, and the overall behaviour of the innovation ecosystem in this field.

This thesis represents both a taxonomy of concepts and an explanatory innovation framework, containing 617 interconnections between 146 factors classified across 14 categories: *Architectural Movements, Urban Reforms, Research Developments, Advances in Medical Science, Technological Developments, Shifts in Attitudes Towards Health, Transition in Institutional Identity, Healthcare Policy, Political Shifts, Economic Shifts, Social Transformations, Developments in Health Service, Shifts in Organisational Culture,* and *Shifts in Natural Environment*. This research argues that the complex innovation ecosystem involves several dynamic actors and multi-faceted processes with both individual and collective impacts on design innovations in hospital building design. The infrastructure of the innovation ecosystem suggests that the generation of design innovations generally occurs through infrequent ways and is subject to links between heterogeneous factors that are not mutually exclusive. Here, this study helps researchers, hospital designers, healthcare developers, policymakers, and stakeholders adopt a multidimensional outlook to further develop the system by representing and mapping the successful processes and prior interactions between less-examined contextual factors in this field. This knowledge also allows for the identification of the critical interventions and potential collaborations between key players on multiple fronts in generating innovation processes.

In the innovation ecosystem, factors with constant influence on design innovation processes are *Changes in Medical Practice*, different *Technological Developments* (medical, construction and information technology), *Economic Shifts*, and *Research Developments*. It is suggested that fast and revolutionary interactions induced by these factors are as influential as the slow and evolutionary process of change caused by factors in the categories of *Social Transformations*, *Transition in Institutional Identity*, and *Shifts in Attitude Towards Health*. This study highly recommends that hospital designers consider the force of the latter sets of factors while embracing the technological changes in generating design innovations. Further, it is evident that the interdependent factors of distinct natures have impacted different fields of research at certain times in relation to sociotechnical priorities. As a result of these interactions, research outcomes have been translated into design practice effectively to generate design innovations in hospital building design. Notably, mapping the impacts of contextual factors helps hospital designers understand both their systemic impact on the ecosystem and the crucial act of other factors on their decisions. This new, systems thinking would not focus on distinct components of the system but considers the individual and combined impacts of different parts on the system behaviour. This knowledge informs better understanding of design innovation and, in turn, can promote the better design of hospitals. Last, given the critical role of the healthcare industry, better knowledge of the nature of innovation in hospital building design can not only enhance healing processes and increase organisational efficiency, but can also inform stakeholders in other construction industries leading to further innovation and value creation.

Keywords

Hospital Building Design, Innovation Ecosystem, Design Innovation, Research-Practice Gap, Historical Analysis, Systems Thinking, Mixed Grounded Theory (MGT), Big Data Analysis.

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List of Abbreviations

MGT: Mixed Grounded Theory	RID: Research-Informed Design
HCF: Healthcare Facility	R-P gap: Research-Practice Gap
EBD: Evidence-Based Design	IDF: Integral Design Framework
EBM: Evidence-Based Medicine	POE: Post-Occupancy Evaluation

Key Terminologies

Evidence-Based Design (EBD) is defined as a process of critically integrating "credible evidence, practitioner design expertise, and client or population needs, preferences, and resources in the context of the project" in making design decisions (Peavey & Vander Wyst 2017; The Center for Health Design 1993).

Research-Informed Design (RID) is an emerging concept employed in the healthcare research and design practice (Hamilton, 2014). This type of design applies the best possible published research to inform design decisions and the creation of environmental design. RID process includes both collecting existing scientific findings and introducing new project-specific prototypes or research before the final design and construction (Peavey & Vander Wyst 2017).

Research-Practice Gap applies to a disconnection between researchers and practitioners in the same discipline. R-P gap typically involves "ineffective methods of communication, information dissemination, and knowledge transfer, as evidenced by researchers' failure to examine practitioners' critical questions and practitioners' failure to incorporate the available research into their work" (Marshall 2017, p. 287).

Innovation is the creation of a new value through an iterative process that could be emerged as products, processes, services, organisational and business models. Innovation provides a new application or a creative combination of pre-existing concepts, methods, and possibilities via radical or gradual changes (Aka 2019; Amit & Zott 2012; Lundvall 2016; OECD 1997; Tushman & Nadler 1986; Xavier et al. 2017).

Innovation Ecosystem applies to a heterogeneous and continuously evolving set of constituents, which are dynamically interconnected through a complex network of relationships and cooperate for co-creation of novel values (Dedehayir, Mäkinen & Ortt 2018; Estrin 2009, p. 37; Frenkel & Maital 2014; Gobble 2014; Jackson 2011; Russell et al. 2015). In this thesis, an innovation ecosystem is considered as: 1) inherently systemic and evolutionary composed of interdependent and interconnected components that co-evolve in an unpredictable and non-linear process to enable the co-creation of new value; 2) a process in the structure formation of a self-organised network, whose macro-behaviour cannot be described by the sum of the micro-behaviour of its parts; and 3) composed of different adaptive ecosystems and dependent to its social, economic, political, and cultural contexts.

Visualisation Idiom/Vis Idiom reflects the style of and the approach to creating visual representations; visualisations provide visual expressions of datasets designed to facilitate the process of understanding and doing tasks (Munzner 2014).

Preface

The built environment is widely known to play a key role in the health and wellbeing of individuals. The impact of interactions between the built environment and their occupants is a point of paramount significance in healthcare facilities compared with other building types. Healthcare design affects patients' experience and healing processes, staff productivity and satisfaction, and organisational efficiency (which has long-term influences on society). Thus, healthcare designers, architects, medical practitioners, engineers and environmental psychologists strive to address a vast range of associated issues in designing healthcare facilities. In spite of this effort, post-occupancy evaluation studies of healthcare facilities, public clinical reports, and government white papers have indicated that designers have not dealt with all the recognised considerations and highlighted the demand for a holistic approach in designing healthcare facilities.

My passion has been to develop an integrated model that takes account of almost all identified factors influencing the health and wellbeing of occupants in designing hospital buildings. Here, I prefaced the research by employing the Integral Design Framework (IDF) to classify related scientific knowledge into its four main quadrants (Sal Moslehian, Kocaturk & Tucker 2020). IDF develops a systems thinking perspective to assess the usefulness of research in the context of built environment according to the impact generated across four crucial knowledge domains, namely: building performance, user experience, policy/practice, and the economy/ecology (Kocaturk 2018). Each quadrant introduces a different perspective and four levels of understanding. These quadrants were adjusted in terms of hospital design features and redefined as improved occupants experience, improved performance, new policies and practices, new services and business models (see Figure 1-0).

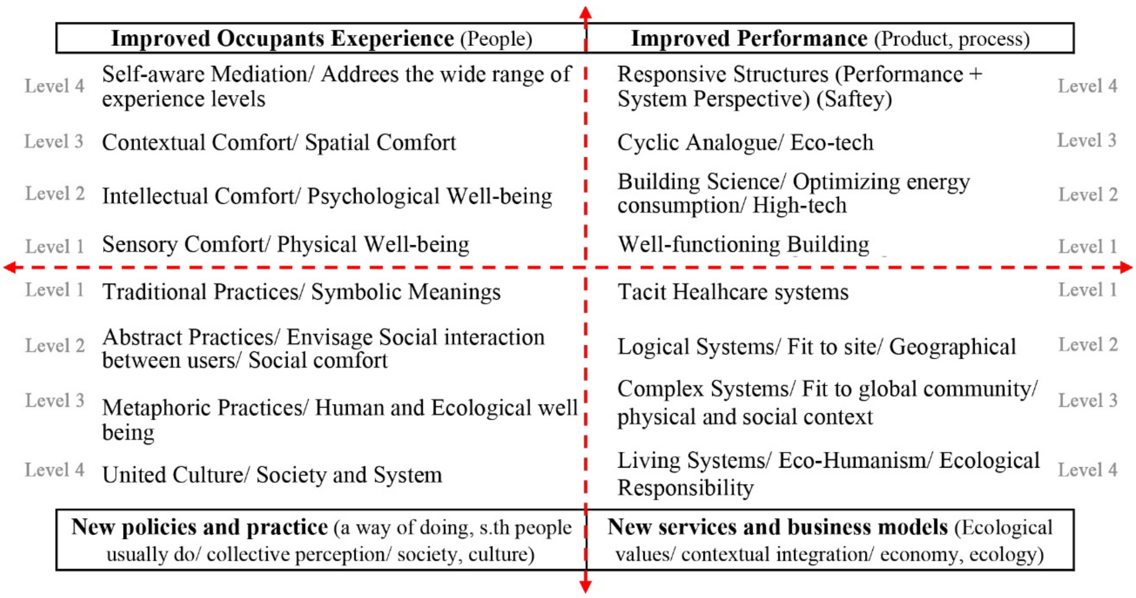


Figure 1-0: The updated version of Integral Design Framework in healthcare design (Kocaturk 2018)

After mapping nearly 80 articles in this framework (inclusion strategy: articles with different viewpoints covering more than one quadrant), it became noticeable that scientific articles have less contribution to the third and fourth quadrants. Findings also indicated that few researchers have developed a systematic approach or used a systematic lens in their studies. That is, there remains a lack of impactful research generated across knowledge domains and thus, it can be argued, a lack of transformative change or new value. This finding generated new ideas and questions for the study, such as what are the gaps in the research context? What are the strategies to improve practice? And why existing policies and research do not result in design innovations?

To fully understand this issue, the Research-Practice (R-P) gap in architecture as well as many other fields was investigated. In addition, the main reasons and scenarios, identified as the principal subjects of this gap in designing healthcare facilities, were examined and grouped according to their common features. Given the substantial role of the R-P gap, I thought it crucial to fully understand the nature of this gap. To do so, I analysed the evolution of hospital building design since the time research findings were employed in the design process. However, working on the key moments of innovation in hospital design and analysing the points when the gap was bridged or widened in history led to new thoughts.

Having conducted the initial historical analysis, I found out that research is only one of the many different factors that inform the design of hospitals. This new idea promised to transform the perceived image of the R-P gap. That is, there is a myriad of factors and interrelationships affecting the gap, which are overlooked by an oversimplification of the wider context. A critical literature review indicated that there is a lack of study offering an adequate explanation of all factors impacting hospital building design. A framework identifying and explaining the concepts and interactions impacting the design innovations can advise future innovations. This aim could be achieved through a historical analysis with the grounded theory method, which became this PhD thesis.

01 Introduction

This chapter provides a summary of the research background followed by the research proposal representing the research problem, research aim and its significance, as well as an overview of the research methodology. It also provides a comprehensive outline describing the structure of this thesis.

1.1. Research Background

The acknowledgement that people's behaviour and experiences are altered by changes in their environment has generated research interest in the transactions between individuals and their physical settings (Gifford, Steg & Reser 2011). There is correlational evidence that place can significantly impact a person's health, wellbeing, emotions, self-esteem, security and identity (Evans & McCoy 1998). The impacts on health and wellbeing of the built environment are particularly important to understand when designing healthcare facilities (HCFs), especially the most complex form of healthcare building – the hospital. Medical practitioners, architects, and environmental psychologists have long acknowledged the wealth of interactions between hospital buildings and the mitigation of ill-health, workplace performance and turnover, and organisational efficiency, to name just a few.

Hospital building design is recognised to have numerous impacts beyond patient wellbeing and healing e.g., re-evaluation of the hospital function, socialising these functions to address people in more immediate ways, contribution to the impressions patients have of a healthcare organisation, patient satisfaction, enhancing workplace performance, job satisfaction, retention and staff quality of life (including sleep patterns), redefining hospital planning and programs, integration with site and context, increased organisational efficiency, and optimising energy and building usage (Brambilla, Rebecchi & Capolongo 2019; Huisman et al. 2012; Mullins, B. Folmer & Fich 2015; Salonen et al. 2013; Wagenaar 2006). It is proposed therefore that rigorous analyses of these impacts can improve the design of hospitals via applying new knowledge into innovative designs (Alfonsi, Capolongo & Buffoli 2014; Bernhardt et al. 2021; Hamilton 2018, 2019; Zborowsky & Bunker-Hellmich 2010).

The importance is highlighted of Evidence-Based Design (EBD) and Research-Informed Design (RID) as useful tools in generating further innovation and achieving collective aims (Alfonsi, Capolongo & Buffoli 2014; Brambilla, Rebecchi & Capolongo 2019; Hamilton 2018; Joseph et al. 2014; Peavey & Vander Wyst 2017; Stichler 2016; Ulrich et al. 2008). Applying "current best scientific findings and evidence related to the physical environment's effects on wellbeing, and its critical interpretation to guide significant design decisions" is called EBD, developed from Evidence-Based Medicine (EBM) (Stichler 2013; The Center for Health Design 2016). RID is "the process of applying credible research in integration with project-, client-, or population-specific empirical inquiry" to inform design decisions, which includes both collecting existing scientific findings and introducing new project-specific prototypes or research before the final design and construction of buildings (Peavey & Vander Wyst 2017; Stichler 2016). The Center for Health Design (2016); (2009) proposed an eight-step process for EBD and confirmed "the importance of discovering new knowledge and feeding forward that knowledge to foster future innovations". However, similar to the development of EBM, hospital building designers, researchers and policymakers face a growing gap between the research evidence base and design practice.

Hospital building designers and policymakers face obstacles in fully integrating research evidence into design practice; a phenomenon known as the Research-Practice (R-P) gap (Criado-Perez et al. 2020; Freihoefer & Zborowsky 2017; Hall et al. 2017; Hamilton 2007, 2015; Lawson 2013; Taylor 2011; Wagenaar et al. 2018). Review of the literature reveals six groups of causes of the R-P gap in the context of healthcare design. First, the evidence materials are commonly prepared independently by researchers and handed off to designers who had no role in the knowledge generation (Hamilton 2015). Stichler (2016) and Tvedebrink and Jelić (2021) indicated that most design practitioners do not have adequate knowledge about how to best employ research in their designs. This is because the importance of learning how to apply research is often neglected in generic baccalaureate programs for design students. Second, this ignorance is exacerbated by fast-paced project deadlines, the incomprehensibility of scientific evidence, and the shortage of translational developers in the field of healthcare design (Marshall 2017; Norman 2010). If the research (such as post-occupancy evaluation (POE) studies) remains inaccessible and unread, the implementation of research findings will be exceedingly rare (Freihoefer & Zborowsky 2017; Hall et al. 2017; Joseph et al. 2014; Lawson 2013). Third, there are challenges in generalising research findings as well as in transforming raw scientific data into well-defined, “tangible and meaningful design concepts” that can practically inform design decisions (Codinhoto 2013; Freihoefer & Zborowsky 2017, p. 73; Rashid 2013; Wagenaar et al. 2018). Fourth, conducting EBD and taking the findings into the design process is an extra cost for both design firms and clients (Stichler 2016). Fifth, entrenched practice closed to new evidence is common, for as Hamilton (2014, p. 95) argued, almost all North American healthcare design decisions are made by “experienced design practitioners” who have a track record of experience and deep understanding of their clients’ issues. Lastly, most EBD studies are based on empirical research that is not conducted by architects. Thus, design-centric knowledge may have poor visibility to governments, which in turn causes problems with translation to policy (CABE 2008; Lawson 2013).

The literature highlights the R-P gap as “the biggest challenge of all” hindering innovation in hospital design (Singh 2017; Stichler 2017, p. 9), leading to repeating similar shortcomings and inaccuracies (Hamilton 2014). The issue of the knowledge acquisition and integration into practice is also considered the main underlying reason for “relatively few good hospital designs around the world” (Lawson 2013, p. 33), decreasing the chance of enhancements for the health and wellbeing of occupants (Chong, Brandt & Martin 2010; Rashid 2013). Here, some studies discussed a number of strategies, such as introducing practice-based research as a value-added tool, the use of POE, and educating architecture students, to bridge the R-P gap with the aim of completing the cycle of innovation (Freihoefer & Zborowsky 2017; Joseph et al. 2014; Tvedebrink & Jelić 2021). However, the R-P gap is only one factor impacting design innovation, for as Wagenaar et al. (2018, p. 41) argue, “there are many other factors in play” in hospital building design. A new systems thinking is required to understand the “complex” set of interdependent variables associated with hospital designs (Jones 2013, p. xv). Further, as Valkokari (2015), Oh et al. (2016) and Xu et al. (2018) propose, “innovation ecosystems” are “complex” and thus need to be considered more “holistically”. Only in recent years, the importance has been understood of the interactions between innovation and related ecosystems, such as knowledge and business. Moreover, the key interaction between actors and their environmental factors has become the interest of many studies (Harini & Thomas 2020; Long & Li 2014; Rabelo & Bernus 2015; Shayan et al. 2018; Silva & Guerrini 2018). It follows that developing a successful innovation ecosystem in hospital design requires in-depth understanding of its inhabitants (actors, their roles, and their relationships), linked cultural and societal features, and the interrelationships between dynamic system layers including overlapping ecosystems with independent but interrelated actors.

While various factors (including human and non-human actors) have been recognised to impact innovation in hospital building design, researchers have not been able to fully explain their interactions and thus to describe the innovation ecosystem that has been the context for the historical evolution of hospital design. This study argues that understanding is incomplete of the interrelationships between research and the many interconnected contextual factors that impact hospital building design. The thesis posits that understanding the nature of complex innovation ecosystems in hospital building design enlightens an in-depth appreciation of various dimensions of the R-P gap. It is anticipated that this shift of focus would potentially create new knowledge to help to bridge the R-P gap and generate further design innovations in this context.

1.2. Problem Definition

It is argued that the gap between research and practice in the design of hospital buildings is increasingly growing as the latest findings in science and psychology, technological and medical advancements accelerate (Biswas & Singh 2017; Gillen et al. 2021; Phiri & Chen 2014; Prasad 2008; Singha 2020). Considering the paramount impacts of the R-P gap on hindering timely innovations in hospital building design and decreasing the chance of design enhancements (Freihoefer & Zborowsky 2017; Hamilton 2015; Joseph et al. 2014; Lawson 2013; Sal Moslehian, Kocaturk & Tucker 2020; Stichler 2016; Tvedebrink & Jelić 2021; Verderber 2010; Wagenaar et al. 2018), it is crucial to understand the nature of this R-P gap.

This research posits that the R-P gap is clouded by an oversimplification of the wider context of the evidence base for the design of hospital buildings. The R-P gap is only a small part of a more complex picture, since there is a myriad of other factors that interconnect, interact and inter-influence one another while simultaneously impacting the R-P gap. Tracking the evolution of hospital building design through time reveals that hospital design has shifted and developed not just according to research, but also in relation to the strength of many other factors such as, to name just a few, social shifts, political decisions and policies, war, and architectural design trends as well as medical and technological advancements (see Figure 1-1). Indeed, innovation in hospital building design has various dimensions requiring a deep investigation.

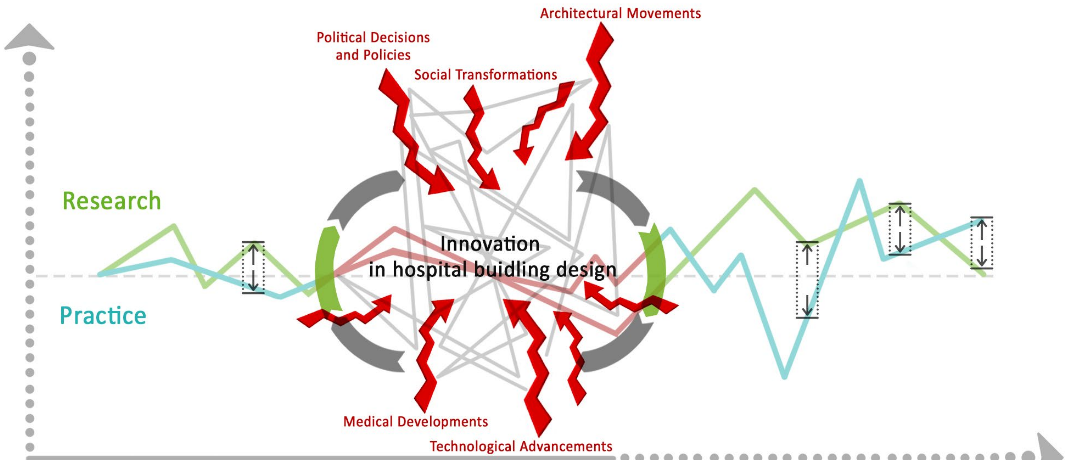


Figure 1-1: Schema illustrating the impacts of various factors on innovative moments in hospital design

Conceptualising the nature of and possibly bridging this gap is subject to our understanding of the nature of innovation ecosystems in this context. A critical review of the literature has indicated knowledge gaps in describing the interrelationships between innovations in hospital design and the many contextual factors that impact how effectively the evidence base of hospital design is translated to design practice. Given the widely acknowledged complexity of innovation ecosystems (Poutanen, Soliman & Ståhle 2016; Pyka & Scharnhorst 2010; Silva & Guerrini 2018), this research posits that the dynamic interrelationships between the very wide range of components of the innovation ecosystem need to be examined from a systemic perspective. It is notable that while the literature develops interconnections between some of the contributing factors of innovation, there lacks an adequate explanation of how the interrelationships between different factors have triggered a collective impact on design innovations.

Moreover, existing analyses of hospital design evolution are mostly limited to specific countries and "geographically proximate actors", and thus do not take into consideration the links between incidents in different countries (Valkokari 2015, p. 19). It is crucial to consider the global dimension of innovation ecosystems in examining the innovations generated and exploited over the past 100 years on account of the increasingly globalised world (Zheng et al. 2019). According to the latest *Globalisation Index*, the process of overall globalisation has climbed from 39.66 to 60.94, in 1970 and 2015 respectively (Gygli et al. 2019). The distributional effects of globalisation are seen to heavily bolster innovation by facilitating the exchange and diffusion of knowledge and technology worldwide, so that an innovation developed in one geographical location is easily implemented in another location that triggers different innovations (Archibugi & Iammarino 1999; Broitman & Czamanski 2020; Feng et al. 2019; Zheng et al. 2019). Here, the literature has suggested the need to developing a broader perspective to truly understand the relationships between interacting actors in innovation ecosystems (Valkokari 2015; Weber & Hine 2015; Xu et al. 2020).

In sum, effort by healthcare designers, architects, practitioners, and policymakers to narrow the R-P gap is based on a simplification of the complex context of hospital design innovation. Furthermore, the dearth of a holistic historical analysis of innovation in hospital design has led to misleading assertions and an incomplete understanding of relevant occurrences and critical chains of shifts in hospital development. It is posited that progress in hospital design must be subject to accurate knowledge about the influential factors of this evolution.

1.3. Research Aim and Objectives

This research aims to conceptualise the evolution of hospital design and identify and explain the main factors triggering design innovation in this field. Through this understanding, the present study will create new knowledge positioned to bring a new perspective to the understanding of the R-P gap and its wider context. It also informs future innovation in hospital building design by highlighting the strength of different contextual factors and interactions among them triggering innovation in hospital building design and recommending new research areas. The research has four prime objectives that follow an iterative process (see Figure 1-2):

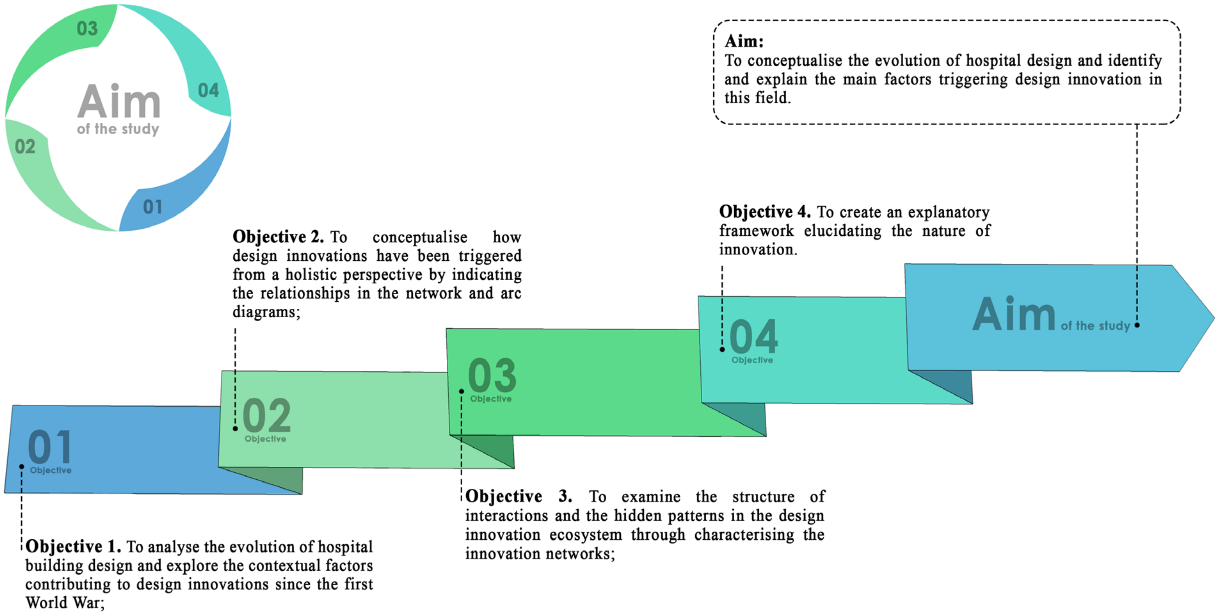


Figure 1-2: The conceptual diagram depicting the iterative process of research objectives in achieving the aim

Research Objectives

1. To analyse the evolution of hospital building design and explore the contextual factors contributing to design innovations since the First World War (resulting in a taxonomy of domain concepts);

2. To conceptualise how design innovations have been triggered from a holistic perspective by indicating the relationships in the network and arc diagrams (resulting in a series of theoretical models);

3. To examine the structure of interactions and the hidden patterns in the design innovation ecosystem through characterising the innovation networks using techniques of SNA; and

4. To create an explanatory framework elucidating the nature of innovation, which can inform, therefore, further innovation in this field.

1.4. Research Questions

1. What factors contribute to innovations in hospital design?

2. How do those contextual factors trigger design innovation?

3. What is the structure of interactions and the hidden patterns between different contextual factors?

4. What is the nature of innovation ecosystems in hospital building design?

1.5. Significance of Study

This study elucidates the nature of innovation in hospital building design from a systems perspective to understand its key triggers. Such perspective will facilitate the understanding of innovations not only from a linear cause-effect relationship between key events and innovations, but also in terms of the interactions between various actors (human and non-human factors) and forces distributed across different spaces and times with a combined triggering effect on the overall system. The knowledge of the structure of the innovation ecosystem allows us to determine the main generative interactions that support design innovation processes. Re-reading and re-appraising design innovations over the last 100 years will make it possible to revisit the R-P gap, establish new grounds for research in this field and introduce potential novel ways of collaborations with the aim of further innovation (Sal Moslehian, Kocaturk & Tucker 2020).

The biannual Consensus Construction Forecast (2021) by the American Institute of Architects highlighted that the construction of healthcare facilities is expected to experience a considerable growth by 3.2% in 2022, which is one of only two non-residential sectors estimated to see a rise. In line with the Australia 2030 Plan (Innovation and Science Australia 2017), timely design innovation is of utmost importance for maintaining a balance between the healthcare construction expenditure and the provision of high quality care for consumers. Here, it is anticipated that the explicit understanding of the nature of design innovation will pave the way for policymakers, hospital designers, practitioners, managers and decision-makers concerned about existing gaps in the practice realms. This study can also provide hospital designers with a deeper understanding of their professional role and where their potential impact would be in the innovation ecosystem. They will find out how the interactions between different contextual factors have resulted in the evolution of hospital design. This framework of understanding can be applied as one basis for policymakers and stakeholders to analyse the strength of all influential factors and systematically influence the system behaviour when formulating future innovations or intending to promote an existing one, and thereby contributing to narrowing the R-P gap. This understanding can ultimately lead to increased efficiency, satisfaction, performance, as well as enhanced healing process (to name just a few).

Due to the fast pace of technological change, big data analysis has gained considerable impetus in generating innovative theories and insights (Günther et al. 2017; Jones 2019). However, the complex nature of big data is widely considered to challenge traditional methodologies and techniques in theory building and research design (Clark & Golder 2015; Constantiou & Kallinikos 2015; Günther et al. 2017; Jones 2019). Specifically, increasingly growing interest in addressing complex phenomena and dealing with big data sets have given rise to "hybrid mixed grounded theory" research designs, involving new methods of data collection, analysis and interpretation (Constantiou & Kallinikos 2015; Johnson & Walsh 2019, p. 13; Jones 2019). Here, the present study develops a novel hybrid research design to Mixed Grounded Theory (MGT), which promotes systematic and systemic thinking and expands the possibility of alternative interpretations of big data. The proposed approach to understanding the complexity of the innovation ecosystem and introduced systematic interventions at different stages of analysis has been instrumental in interpreting the behaviour of the system being studied in connection with its constituent phenomena. Grounded theory researchers can follow this methodology both to further explore different dynamics of this complex phenomenon and, more importantly, to employ the growing body of big data sets in developing theories and insights in other studies.

1.6. Research Focus

It should be noted that it is not the intention of this thesis to present a framework grounded in all factors that have affected the innovative moments in hospital design evolution. Here, the literature has widely highlighted the critical interrelationships between architectural, construction, service, and organisational design and their collective influence on "operations and infrastructure" as the main components of design innovation in this field (Guthknecht 2018; Singh 2017, p. 7; Verderber 2015). Thus, the present thesis focuses on architectural design and analyses of related organisational and service design practices. The study excludes other types of design such as information system design, program design, clinical process design, and industrial design, etc. Moreover, in view of the study's principal objective, which is to develop a comprehensive framework explaining the nature of innovation in hospital building design, this research intentionally covers a broad and open definition of innovation. This had an impact on both the nature and the degree of novelty while selecting the design innovations. Innovation is defined here as a completely novel design or adaptation/s to typical architectural, service and organisational design that can positively improve one, or a number, of key values underpinning hospitals, such as the quality of healing processes, care providers' performance, cost, organisational efficiency, and environmental impacts, to name just a few. Here, the hospital design innovations are selected subjectively in reference to innovations generated from different factors (Djellal & Gallouj 2005). However, it is beyond the scope of this thesis to identify particular examples of design innovations that occurred in hospital building design and the resultant cost savings and (or) other benefits.

Due to the decentralisation of healthcare institutions, the involvement of the private sector (private finance initiative) and shifts in public health policies, different types of HCFs were introduced since the 1980s. The scope of the study does not extend to considering all these models. Here, the incidents and events related to innovations in the design of acute general hospitals are examined. Due to similarities between university/teaching hospitals and specialty hospitals with acute general hospitals in departmental structure and medical services (Wagenaar et al. 2018), design innovations related to these two hospital typologies were also considered. Public and private hospitals will not generally be differentiated in this study in terms of functionality, service design, philosophy and ideas behind their construction, as there have always been numerous parallel interactions in their development processes.

The information for analysis is gathered from critical texts on the evolution of hospital building design (historical books, articles, and white reports). Exploring the concepts to explain various interrelations is conducted through a careful semantic investigation within the terms and concepts across documents, as there might be seemingly distinct concepts and causes in different sources with the same meanings. Regarding the temporal and geographic scope, this research covers all the events and factors impacting the hospital evolution in most of the developed economies (with similar socioeconomic status), including the USA, Canada, Australia, the UK, the Netherlands, France, Germany, Austria, Denmark, Switzerland, Norway, Sweden, and Finland since the 1920s (as most of the developments occurred after the First World War). This geographical and epochal restriction reflects the focus in the literature on the significant developments in hospital building design that occurred after WWI in relation to substantial advances in science and technology, as well as on the increasingly expanding functions, systems and operations of hospitals in the modern era that catalysed design innovations. While the absence here of innovative hospital buildings designed in countries like Singapore, United Arab Emirates, and South Korea is due to the neglect of these countries in the literature, I argue that the higher-level concepts and interrelationships explained in the analysis are applicable to a wider geography of modern economies.

1.7. Overview of the Research Methodology

Choice of research approach is a critical decision, and is widely affected by the research problem, the way one comprehends it and the procedures of inquiry (Van 1990). As Creswell and Creswell (2017, p. 13) highlighted, research strategy, methodological choice and paradigm are tightly intertwined with one another and contribute to the overall research approach. In this study, the Mixed Grounded Theory (MGT) methodology with Charmaz's constructivist approach has been chosen via an iterative process to best support the development of an explanatory framework. My philosophical stance in this study is derived from Charmaz (2006, p. 187), who defined GT as "a systematic, inductive and comparative approach of using empirical data without preconceived theories to develop abstract ideas and construct a theory".

Regarding the unique characteristics of GT methodology, it is an inductive approach and does not begin with testing a hypothesis or a defined theory. However, it aims to disclose a theory/framework through repetitive cycles of examining data (Corbin & Strauss 2014). Indeed, grounded theorising is an iterative process, in sharp contrast to the rigid pre-established sampling procedures in traditional forms of research. The process of analysis starts simultaneously with data collection, and each informs and streamlines the other. This method helps researchers examine all possible relationships and theoretical explanations through a back-and-forth procedure between emerging analysis and data (Corbin & Strauss 2014; Holton 2011). Furthermore, GT is entirely an interpretive, systematic methodology focusing on a particular context to develop the related framework/theory (Charmaz 2006; Haig 1995).

Four main reasons lie behind the selection of MGT methodology for this research. First, GT can be employed in studies that aim to develop an interpretive, context-based and process-oriented explanation of the phenomenon based on empirical data (Birks & Mills 2015; Charmaz 2014). Due to the main aim of this thesis, the interconnections between incidents will be analysed through GT methodology to elucidate a framework that fully fits in the situation rather than an objective and static description indicated in terms of causality (Chun Tie, Birks & Francis 2019; Creswell & Creswell 2005). Secondly, this methodology helps researchers explore a contextualised domain without a dominant theory. Regarding the literature review, there is a lack of theory explaining the nature of innovation in hospital design and exploring the interconnections between incidents. Thus, through an interpretive methodology like GT, the aim is to comprehend the phenomena and develop a framework explaining its nature (Suddaby 2006; Timonen, Foley & Conlon 2018). Thirdly, constructivist GT brings data into focus, acknowledge prior knowledge and makes the researcher highly engaged with the data interpretation process (Allen & Davey 2018; El Hussein, Kennedy & Oliver 2017). It is applicable in this research, as understanding the nature of innovation and constructing an explanatory framework through a historical analysis requires an in-depth consideration of the context of hospital design evolution. GT aids the process of exploring contextual factors and relationships among them. Last, researchers adopting the MGT approach are widely encouraged to creatively use different types of data, analysis strategies (qualitative and/or quantitative), and logics of inquiry for inductive theory development (Gorra 2019). More importantly, this approach co-evolves with the analysis process, meaning that the research design is not supposed to be planned (Johnson & Walsh 2019). Considering the complexity of innovation ecosystems and the lack of research on the interactions between contextual factors involved, the MGT with concurrent data collection is deemed best suited to support the novel and holistic knowledge building involved in this research.

The prime data sources to identify and examine the contextual factors and the relationships among them triggering design innovations are the literature on hospital design evolution in the past 100 years. Here, the analysis of documents (text and image analysis) was selected as the principal data collection method (Creswell & Creswell 2017). Adopting the MGT approach, the analysis process began with the Charmaz's strategies to constructivist GT methodology, using NVivo as a data management tool. Immediately after the collection of the first data set, manual *initial coding* was conducted to find concepts and codes to different incidences through line-by-line analysis. Next, via *focused coding*, the most useful initial abstract codes were selected and examined against more incidents across different data sources to generate new theoretical concepts, and higher-level concepts. Via vertical and horizontal analyses categories were generated and the links between concepts were developed incisively. Concurrently, analytic memos and annotations to the datasets were added to capture the emergent ideation of theoretical codes. These codes were then sorted analytically to make a comparison between categories towards the theoretical integration of categories.

As the study progressed, textual analysis was not adequate to describe the several relationships explored in line with Charmaz (2014). It was not possible to determine the relational compositions by retrieving the attached annotations and memos to codes. This situation was exacerbated after conducting equivalent analyses for the next data sets. Considering the complexity of the innovation ecosystems and the importance and complicatedness of big data cross-sectional analysis, I developed a novel hybrid research design to MGT methodology. The proposed multi-representational approach, which has been integral to the research design, promoted systemic and systematic thinking and enhanced the process of grounded theorising. In so doing, a set of network and arc diagrams were used to represent the relational composition between contextual factors and the chronological order of incidents respectively. Next, those diagrams and their associated analytical techniques were employed to develop a new understanding of both individual and collective impacts of the factors triggering design innovations over the past 100 years. Notably, the literature on systems thinking and complexity theory related to innovation ecosystems has widely suggested the use of *network approach* as both a systemic way of thinking and a methodology to examine complex relational data (Barile, Spohrer & Polese 2010; Poutanen, Soliman & Ståhle 2016; Vicsek, Kiraly & Konya 2016). Thus, this novel approach was developed to use 1) the strengths of Actor-Network Theory (ANT) as a rich theoretical lens - to identify and explore which kinds of interactions among which kinds of factors resulted in design innovations; and 2) Social Network Analysis (SNA) as a technique - to systematically analyse interactions and processes within the innovation ecosystem.

Network diagram was used to generate relational compositions that rendered the complete picture of dynamic interactions between factors. Next, a collection of analytical techniques offered by the SNA method were employed to characterise the network topology and examine its main structural properties (Boccaletti et al. 2006; Pyka & Scharnhorst 2010; Xu et al. 2020). Here, codes and links were imported to Flourish Studio web-based platform and Pajek software, and the form and structural properties of networks (centrality, subgroup, and cohesion measures) were computed at three levels. The aim was to:

1. at micro-level: identify the contextual factors (nodes) most actively involved in relationships with other actors (using degree centrality, betweenness, closeness, and eigenvector metrics);

2. at meso-level: detect the presence of cohesive clusters, and interconnections between clusters (using Louvian clustering analysis); and
3. at macro-level: explore the cohesion and interconnectedness of actors within the whole network (using degree centralisation, density, and homophily metrics).

Arc diagram was also used to classify concepts and links in relation to time as the second variable. Observable web-based platform was employed to construct the arc diagrams indicating the chronology of incidents. The final arc diagram demonstrated both the most influential contextual factors at each decade and the critical role of some factors with constant influence on the structural formation of the process.

The processes of data collection and data analysis were repeated until the categories were sufficiently saturated. The saturation point was recognised after the analysis of eleven data sources (Francis et al. (1999), Willis, Goad and Logan (2018), Sloane and Sloane (2003), Verderber (2010), Rivett (2017), Wagenaar et al. (2018), Prasad (2008), Schrank and Ekici (2016), Verderber and Fine (2000), Kisacky (2017), and Guenther and Vittori (2013)), when the process of constant comparison yielded to neither new properties of each category nor new conceptual ideation (Holton 2011). At this stage of the study, the categories became theoretically saturated, and theoretical completeness was reached for my research questions. Notably, the accumulated knowledge of the nature of design innovation was revealed after the analysis of all data sources. That is, the structure of the innovation ecosystem as a whole was changed by the introduction or the removal of each node and/or link, and in turn, our understanding of its nature evolved. Thus, it was critical to examine its process of evolution through this research in terms of developing transparency for both justifying the saturation point as well as the process of advancing the research by adding new information.

Last, as emphasised by the constructivist GT methodology, the qualitative analysis was conducted to make sense of the context and content of the network structure and the nature of ties as a central component to explain the nature of innovation (Decuypere 2020; Luxton & Sbicca 2020; Venturini, Jacomy & Pereira 2015). The final innovation framework was interpreted to address who and what played a key role in design innovations, how their interplay triggered design innovation and when the incidents occurred by considering the position of actors of the innovation ecosystem, as well as intensity, direction, and the number of ties between them. Further, as Thornberg and Dunne (2019, p. 9) suggested, the final literature review was conducted during the analysis of the innovation framework to locate the study "within or across disciplines". This new knowledge of design innovation is compared with the prior literature to complement and develop a holistic understanding and image of the complex innovation ecosystem, as well as explore new knowledge gaps in this field.

1.8. Research Output

This study provides two main knowledge contributions. First, a taxonomy and theoretical models leading to an explanatory innovation framework have been constructed to elucidate the nature of design innovation and address the main research aim. Second, as an indirect output of the study, a novel multi-representational approach to MGT methodology has been developed. Since developing a new approach to MGT has not been one of the objectives of this study, the proposed approach may be referred to as an *exploratory expanded approach to MGT*. In sum, the direct and indirect research outputs of this thesis are:

1. A *taxonomy* - a representational, hierarchically organised vocabulary of domain concepts/constructs - providing a common structure and shared set of descriptive terms. Parallel to this, after a thorough analysis of hospital design evolution, a set of *theoretical models* has been developed, which is a *relational composition* representing how codes are systematically related to one another in the context of hospital building design. The final theoretical model has led to an *explanatory framework*, a system in which a collection of concepts and verified relationships are unified to understand the nature of innovation in hospital building design (Barry & Roux 2012, p. 305; Kivunja 2018; Saariluoma 2005). According to Timonen, Foley and Conlon (2018, p. 4), GT research in most cases results in “a new or better conceptualization or a framework that links concepts”; and expecting the emergence of a theory from all GT studies regardless of the research background and problem is “incorrect, misleading, and unnecessarily intimidating”. In this study, the explanatory innovation framework illustrates all the interconnections between innovation triggers to facilitate a systemic understanding of the nature of innovation in hospital building design.

2. A detailed procedure of the novel hybrid MGT methodology is represented in relation to the research objectives. Explanations are provided on how two complementary analysis techniques and methods were merged into Chramaz’s initial and focused coding. The proposed multi-representational approach, which has been integral to the research design, promotes systematic and systemic thinking and enhances the process of grounded theorising. This human-centred approach enables the human GT researcher to use digital tools to address complex phenomena and leverage the big data analysis by keeping both human and computational decision-making methods in the analysis loop.

1.9. Thesis Overview

This thesis is presented in seven chapters. It begins with this introductory chapter, which includes examining the research background, determining the knowledge gaps and proposing the research problem, aim, objectives, questions, and methodology.

Chapter two represents the critical literature review in four key sections (see Figure 1-3). The first section aims to render a context for analysing hospital design evolution through determining different types of design components. The significant interdependency between architectural, service and organisational design in impacting operations and infrastructure as the main components of hospital building innovations are also explained. The second section provides an understanding of the innovation concept (including different modes of innovation and aspects of innovation ecosystems), and different types of innovation in the context of hospital design. As the literature revealed the impacts of the R-P gap on building design innovations, the third section explains the R-P gap and the evidence for its existence in designing HCFs. The fourth section reflects on the complexity of innovation ecosystems in hospital building design and explores the interplay between involved contextual factors at different sub-ecosystems. This part suggests the use of complex systems theory to provide a comprehensive understanding of the innovation ecosystem. Moreover, the network approach to complex systems theory and its potential to map the complex relational data are explained. This section ends with an explanation on how adopting Actor-Network Theory (ANT) as a theoretical lens and using Social Network Analysis (SNA) for empirical purposes helped to understand the nature of design innovation ecosystem.

In the third chapter (see Figure 1-3), a chronological essay of hospital design evolution before the study's focus is provided. This knowledge of the context is necessary for interpretation and analysis purposes. Moreover, the critical texts focusing on the evolution of hospital building designs are reviewed. The ways that authors approached and presented their analyses are thoroughly investigated in this section. The strengths and weaknesses are also discussed, as well as the features distinguishing the present study from these existing ones. Those sources were then used as the prime data sets to explore the key moments of design innovations.

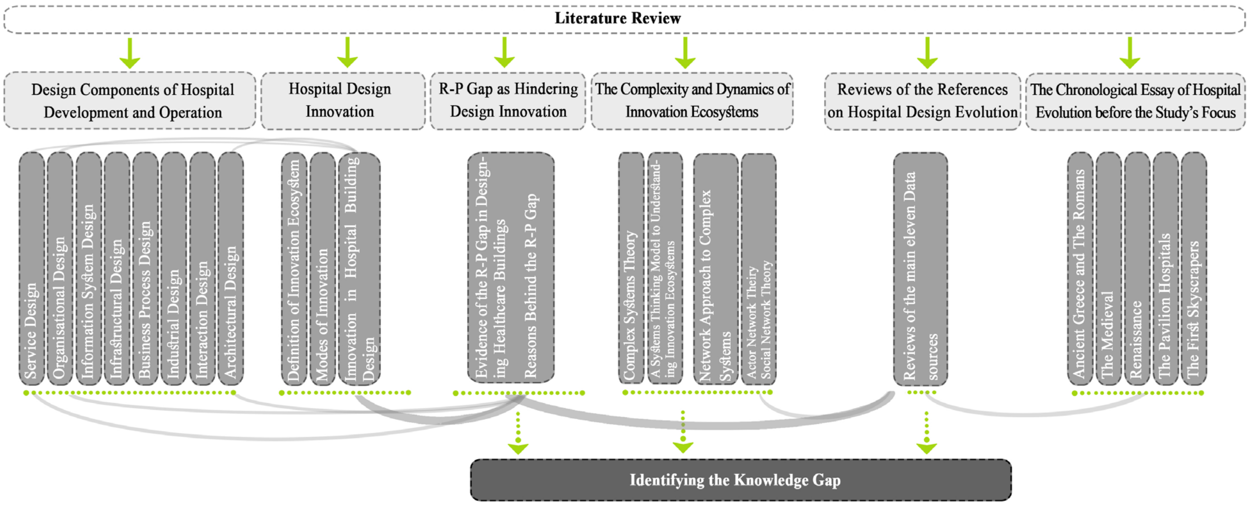


Figure 1-3: Literature Review Framework

Chapter four focuses on a novel hybrid research design to MGT. Here, the choices of research paradigm, methodology and strategy are explained in detail in relation to the research objectives. The historical background of GT and the pivotal differences between the three main approaches in conducting a GT methodology are noted. Different stages and strategies for data collection and analysis following the Charmazian GT (2014) are described. Furthermore, the use of a multi-representational approach and a set of analytical strategies and techniques are suggested to aid the analysis process of GT. Later in this chapter, the diagram of research design depicts the back and force relationships between the research aim, research questions, conceptual framework, and research method.

The fifth chapter explains the analysis process in relation to the specific properties of the data collected through this study - *how* I applied the proposed strategies and *what* resulted from each stage of the analysis. It reports on the process of constructing and analysing the theoretical models. The process of data analysing, coding and categorising during the initial coding, as well as cross-sectional analysis and the construction and analysis of diagrammatic representations during the focused coding are explained in detail for each data source. This process ends with the development of a taxonomy of domain concepts, and two theoretical models comprised of interactions between contextual factors triggering design innovations over the past 100 years. This chapter concludes with a summary of findings delineating the results of the analysis process.

Chapter six represents a narrative interpretation of how the accumulated understanding of design innovation processes was evolved through the analysis process, and explains the nature of design innovation using the explanatory innovation framework. The first three research objectives were addressed by depicting the chronology of the theoretical models acquired from the process of focused coding and analysing the structure of networks. This knowledge led to the construction of an explanatory innovation framework. The second section provides an explanation of the final framework at three levels (mirco-, meso-, and macro-level) by synthesising the behaviour of individual and combined actors. This discussion elucidates the complex structure of interactions implemented by different actors (both human and non-human) that triggered innovations in hospital building design over the past 100 years. The explanatory innovation framework is then developed based on the current issues and the predictions of the future of hospital designs. The usefulness of the proposed multi-representational approach is also explained in relation to the prime research aim, interpreting the behaviour of the innovation ecosystem in connection with its constituent phenomena. Moreover, the quality of the findings is evaluated according to four criteria suggested by Charmaz: namely credibility, originality, resonance, and usefulness. Last, the limitations of the study are explained.

The final chapter summarises the two prime contributions of this study: 1) a taxonomy of concepts and theoretical models leading to an explanatory innovation framework; and 2) a novel approach to MGT methodology. A detailed assessment is provided of the contributions and impacts of the research to the field of hospital building design. This study culminated in recommendations for future research and a short reflective section on my PhD journey.

02 The Complexity of Design Innovations

The literature review represents a critical overview of the linked subjects in this research, determined in chapter one. It encompasses four main sections:

1. Design components of hospital development and operation: describing various types of design component in hospital building design such as service design, organisational design, information system design, infrastructural design, business process design, industrial design, interaction design, and architectural design, as well as the role of innovation in enhancing the quality of care.

2. Innovation in hospital design: representing the definition of innovation ecosystems and innovation modes, followed by a literature review on hospital innovations related to operations and infrastructure.

3. R-P gap as hindering design innovation: reporting on evidence for the existence of the R-P gap in designing hospitals, their adverse impacts on innovation and healing process, and the prime obstacles resulting in this gap.

4. The complexity and dynamics of the innovation ecosystem: exploring the potential interrelationships between actors residing at different overlapped ecosystems in the design innovation ecosystem, and suggesting the use of complex systems theory with a network approach to fully understand the nature of design innovations.

2.1. Design Components of Hospital Development and Operation (Systemic Approach)

There are various types of design in healthcare facility (HCF) design including service design, information system design, organisational design, infrastructural design, business process design, instructional design, interaction design, industrial design, graphic design, web design, and product design as well as architectural design (Rashid 2013). While all together these aim to enhance the quality of HCFs, designers often do not give sufficient consideration to their interdependency.

Jones (2014, p. 93) argued that "industrial design, interaction design, service design, information and visual design all have relevant differential cases and unique adaptations" of a new way of thinking called *systematic thinking*. According to Jones (2014, p. 94), newly discovered transdisciplinary applications of design science is leading to a more *systematic design* approach, involving greater scale systems with different subsystems. It is an orientation aiming to "co-design better policies, programs and service systems", which could be employed in the design of human-centred HCFs. Healthcare designers face various problems, as HCFs are multi-organisational institutions with multi-stakeholder service systems that must be socially organised (Jones 2013). In order to understand this complexity in design, Jones and VanPatter (2009) proposed four different domains in the design process; advancing from level 1.0 to 4.0 (Figure 2-1):

1. *Artefacts and communications:* referring to traditional design practice (a simple design project);
2. *Products and services:* design as integrating or design to enhance the user experience (a market-facing product or service);
3. *Organisational transformation:* design of organisational structures and work practices, "which involves governance, operations, product line and service strategies, human resources, and all internal systems"; and
4. *Social transformation:* a design for complicated societal circumstances, social systems, policy-making, and community design, which is entirely complex and unbounded.

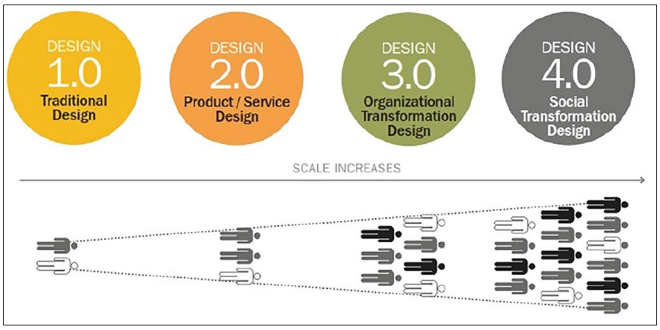


Figure 2-1: Mapping the design process to challenge complexity (Jones & VanPatter 2009)

It is also suggested that designing in domain 4.0 while taking a systems thinking approach can adapt the design to various system issues (which apply to different product and service systems, information systems, and social organisational systems). Here, the hospital building is widely known as a complex system of interrelated functions and operational services with diverse stakeholders. Thereby, the inherent complexities of hospital buildings make it critical to program, plan and design hospital buildings from a systemic perspective to co-create complex, multistakeholder care services (Jones 2013). In the next subsections, these challenging and complex types of design in HCFs are explored and their impacts on hospital building design are examined.

2.1.1. Service design

The research area of service design is vast and continues to evolve and change (Sangiorgi & Junginger 2015). In healthcare design, service design concentrates mainly on an occupant's journey and holistic experience of services provided. Fry (2019, p. 4) defines service design as a user-centric approach and "the activity of planning and implementing change to improve a service's quality". A high quality service design contributes to enhancements in patient safety, care quality, patient flow, satisfaction, and decreases the waiting times and visits to emergency departments (Melo 2018; Noël & Frascara 2016). Service design is an iterative and complex process, but its process can be explained by four main phases including exploration, creation, reflection, and implementation. For implementing measures in service design, five principles should be taken into consideration. Firstly, end-users and their contextual features; secondly, involving and empowering stakeholders in the problem solving, production and development (Freire & Sangiorgi 2010); thirdly, exploring mistakes and acquiring lessons from them; fourthly, using more expressive tools such as sketches and pictures for communication purposes; and lastly, thinking about the whole user journey (Fry 2019). In this respect, the Design Council (UK) conducted a study around their project aiming to enhance the patient experience in Accident and Emergency (A&E) departments. The findings indicated that most patients mentioned the new signage as a tool that clarified the A&E process (88%); 75% of patients said their frustration was decreased by the new signage; and aggressive behaviour was dropped by half. The council predicted three pounds return on each pound invested in this new service design (Design Council 2011).

The literature discussed the direct impacts of healthcare building design on healthcare services, such as its influences on occupants' flows, delivering patient-focused environments, patient perception, service configuration and staff performance level. Yet, this interaction does not seem to be fully addressed in the existing literature (Tzortzopoulos et al. 2009). Tzortzopoulos et al. (2009) pointed out that the integration of operation management, service operation management and healthcare service operations is critical for enhancing the relationship between building design and service design. The authors described the former as a vehicle for identifying problems, improving the process, and advancing the productivity and efficiency of goods delivery and services. The service operation management was explained with its focus on delivering services to patients and healthcare providers, dealing with the understanding of needs, and servicing from the end-users' perspective. Here, the latter was defined as a "design, planning and control of all of the steps necessary to provide healthcare service for a client" (Tzortzopoulos et al. 2009, p. 42). Similarly, Melo (2018, p. 141) highlighted the importance of the interactions between the physical, social, and symbolic dimensions of a hospital building on service design. The authors argued that the hospital building is neither "a single receptor of the hospital's procedures", nor an "instrument capable of changing the clinical practice". Rather, the physical built environment interconnected with health services must be examined as a *stage* that impacts, and is impacted by, the social environment and organisational processes.

2.1.2. Organisational design

Organisational design is breaking down an organisation into subparts and integrating those subparts to make organisational strategy and aims achievable. Carroll and Rudolph (2006, p. 2) described a formal organisational design process as "separating what the organisation will do itself rather than buy from others, dividing sub-tasks and assigning roles, choosing or developing technology, and establishing and enforcing policies and procedures". It is widely believed that organisational design can enhance efficiency, creativity, productivity and communication in the system (Luebke 2011). A successful organisational design defines roles and makes employees more confident about their responsibilities and contributions to the system (Navigate team 2015).

Regarding hospital organisational designs, Hands (2000, p. 6) claimed that clinical and management practices are completely interwoven. An effective clinical intervention might appear ineffective by *poor organisations* that "either limits access to treatment or fails to ensure that it is available to the appropriate people in the appropriate manner from professionals with the appropriate skills at the appropriate place and time". While good management and organisational design cannot substitute for good clinical practices, a well-designed organisation based on evidence provides the required context and infrastructure for successful and efficient clinical processes (Hands 2000). Besides the enhancements in care quality, a successful organisational design has huge impacts on emotional exhaustion, psychological distress, and turnover of healthcare providers (Rickard et al. 2012).

It is worth mentioning that after a report published by the Institute of Medicine (IOM, 2001) considering the quality chasm as a system problem, organisational contributions in delivering clinical care has gained much attention (Hearld et al. 2008). Researchers, policymakers, designers, and practitioners strive to enhance the design of organisational culture and systems that facilitate hospital's approach to coping with complex and dynamic challenges (Andres et al. 2019, p. 2; Curry et al. 2018). Here, health care organisations with cultures characterised by "collaboration, flexibility, and risk-taking" are seen to provide the best context for the implementation of high quality improvement initiatives (Andres et al. 2019, p. 2; Parmelli et al. 2011). Further, the importance of considering patients' and families' voices within the health care organisational design has been widely highlighted for improvements in patient care (Carman et al. 2013; Mockford et al. 2012; Prior & Campbell 2018).

2.1.3. Information system design

HCFs are commonly known to be complex and multi-specialised organisations. The nature of the healthcare work environment entails a myriad of different experts and specialists working together to enhance the quality of care. Kuziemsky et al. (2009, p. 9) stated that "nowhere is interdisciplinary team communication more important than in healthcare settings". This diversity in relationships between several subsets makes it impossible to develop a paper-based information system because of its restrictions in establishing the links between numerous related factors. With the aid of computer systems, healthcare organisations have now a comprehensive information system called the Healthcare Information System (HIS) (Moghaddasi 2018). Moghaddasi (2018) suggested that for designing the HIS, a combination of meta-models is required to meet system demands. In addition, it is important to include the ideas of professional users in the design process to increase design success (Saleem et al. 2006).

2.1.4. Infrastructural design

Tillmann, Tzortzopoulos and Formoso (2010, p. 84) defined the healthcare infrastructure design as "services and the physical environment that supports their provision". A successful infrastructure design provides creative working patterns, delivers patient-centred environments, improves patients' experience, redesigns the provision of health services around patients, unifies the built environment and service, and reaches the highest level of performance within the system life-cycle (Francis 2002). In addition, HCFs are seen to enhance the health and wellbeing of people by preventative measures, which makes its scope wider and transforms the health infrastructure design (Health 2006).

Gray et al. (2014) argued that practices and scientific knowledge from related fields, such as social and humanity sciences, psychology, economics, must be integrated to extend the understanding of healthcare infrastructure. This knowledge increases the chance of enhancements in the infrastructure design in relation to service design and operation requirements. An appropriate healthcare infrastructure is affected by several factors, including facility buildings that make care accessible, modern information systems, well-qualified health workforces and organisational managers, reliable supplies of pharmaceuticals and other materials, and mechanisms to deliver those resources to people. Indeed, the proper system should be qualified in providing preventive, diagnostic, and curative care based on societal demands (IZUMI Foundation 2019).

2.1.5. Business process design

A main concern around patient satisfaction is the complexity of the design of the business process of care delivery. The design of a business process defines the limitations and potentials of system efficiency. For instance, when the process of referral to a specialised practitioner requires paperwork by many people, the organisation cannot be considered as efficient, effective, and accurate (Plsek 1997). The design of a healthcare business process involves mapping both clinical and nonclinical activities in a flowchart or matrix with identified decision points (Blake et al. 2016). To promote a better process design, the Agency for Clinical Innovation (2015, p. 6) suggested that the following points should be taken into account: “1) waste or redundancies in the process; 2) staff experience and appropriateness of activities and tasks; 3) improved patient flow and access; and 4) improved patient experience”. The analysis of these variables assists in exploring the causes of existing problems and generating novel solutions to efficient, quality care.

By the 1980s, when public and private reimbursement rates for healthcare changed, efficiency and productivity became the words of day. Relationships between existing poorly planned processes in healthcare environments and low quality of care made demands for HCFs to develop ways to promote their operational plan (Boston-Fleischhauer 2008). While the literature indicates that progress is being made, the operational outcomes and clinical reports in terms of practitioners’ error, patient harm and the complexity of the health environment recommend more enhancements in process design.

2.1.6. Industrial design

Industrial design focusing on medical furniture, medical tools, and fabrication of prosthetics play a crucial role in promoting patient satisfaction as well as staff productivity and efficiency. It increases the range of abilities for physically impaired individuals by creating vehicles that allow them to act in a way that was considered impossible (such as exercise machines) (Noël & Frascara 2016, p. 27). There are many other examples of the contribution of industrial design in the quality of care. For example, in relation to:

- Rehabilitation medicine and surgery, the application of 3-D printing assists in reconstructive surgery for trauma and cancer patients by decreasing the number of surgeries from two to one. Thus, it cuts down the patient risks, healing process time and costs (Noël & Frascara 2016).

- Furniture and devices for enhancing individuals' independencies, there are more than 100 independent living tools created for dementia patients and older adult populations (Noël & Frascara 2016).
- Rehabilitation equipment, exercise machines for paraplegic patients (Davoodi et al. 2002), devices for the aging population (Liu & Lederer 2009), and community-based emergency tools for emergency outpatient visits (Swann 2012).

2.1.7. Interaction design and user experience design

Interaction design focuses on the way users interact with products or services. It aims to provide users with the best possible method for addressing their demands. In doing so, interaction designers should examine their clients' needs, restrictions and contextual features (Martikainen, Ikävalko & Korpela 2010). To consider these interactions holistically and envision users' demands, designers can apply five different dimensions: words, visual representations, physical objects or space, time, and behaviour (Interaction Design Foundation 2019). Notably, there is considerable overlap between interaction design (IxD) and user experience design (UXD). UXD aims to enhance the entire user journey by improving the experience of clients in using a service or product from the aspects of branding, design, usability and function. This involves the knowledge about users' conditions and preferences and performing user testing (Interaction Design Foundation 2019).

These two types of design are mostly employed in designing software or information systems in HCFs. As it was mentioned previously, any software development process related to HCFs is challenging due to the variety of specialties and heterogeneous user groups. Here, interaction design makes an important contribution to information technology developments (Löwgren & Stolterman 2004), computer-based counselling systems in healthcare (Herzberg et al. 2009), a common understanding of the user requirements specification in healthcare (Martikainen, Ikävalko & Korpela 2010), patient-focused innovation and the design of patient quality of life surveys for digital devices, digital systems with improved accuracy, advancements in human interface, and the management of information (Yamamoto 2013), to name just a few.

2.1.8. Architectural design

The architectural design of hospitals is widely seen to encompass far more than a spatial configuration, building's form and appearance, the use of materials, and the selection of colour and furniture. Hospital building is commonly seen as a composition of all discussed components and more, the architectural design of which is recognised to have numerous direct/indirect impacts on: patient safety (nosocomial infections, patient falls and medical errors), healing process (reducing pain, reducing stress and depression, sleep patterns), patient satisfaction (impression of a healthcare organisation), patient privacy and confidentiality (fostering social support), wayfinding, staff performance (stress, fatigue, annoyance, satisfaction, burnout), hospital integration with site and context, organisational efficiency, energy and building usage (Biswas & Singh 2017; Goetz et al. 2010; Halawa et al. 2020; Huisman et al. 2012; Jellema, Annemans & Heylighen 2019; Mullins, B. Folmer & Fich 2015; Ulrich et al. 2008; van Hoof et al. 2014; Wagenaar 2006; Zhang, Tzortzopoulos & Kagioglou 2019). Here, to enhance the experience of hospital users (patients, visitors, and healthcare providers), architects are looking for the best design solutions for "efficiency of medical processes, efficient use of facilities and cost-effectiveness, flexibility and expandability, therapeutic environment, cleanliness and sanitation, patient transfers and accessibility, wayfinding, controlled circulation, aesthetics, security and safety, and sustainability" (Wagenaar et al. 2018; WBDG 2017).

Given the interdisciplinary nature of hospital planning and design, much of the research on hospital design involves collaborations between a wide range of experts (environmental researchers, psychologists, computer scientists, service designers, organisational designers, building designers, urban designers, etc.) (Halawa et al. 2020). Thus, architects need to address a wide range of issues from different perspectives in an integral manner (Wagenaar et al. 2018). Further, the different functions, systems and operations within a hospital make it one of the most dynamic and complex building typologies (Halawa et al. 2020; Wagenaar 2006). Indeed, hospital architectural design is widely seen to be a complex process addressing multivariate issues that brings together diverse stakeholders and ideally aligns operational, environmental, experiential, clinical, and organisational objectives (Halawa et al. 2020; Hicks et al. 2015; WBDG 2017). Thereby, hospital building designers need to adopt a more *systematic thinking approach* and consider different impacts of the design types, ranging from service and organisational design to information system design to industrial design, on hospital building design (Jones 2013). Willis, Goad and Logan (2018, p. 11) believed that hospital architecture is a field that needs an "open mind" and a readiness to "wander outside the traditional ways of thinking about architectural design and its boundaries". In this thesis, the focus is on what have been identified as the critical interrelationships between the hospital organisational design, care delivery processes and service design, and spatial and environmental design (Singh 2017; Wagenaar et al. 2018). In other words, innovations related to architectural design, organisational and service design practices and their collective influence on "operations and infrastructure" (Singh 2017, p. 7), as the main components of hospital innovation, are examined.

Considering the significant impacts of the built environment on the health and wellbeing of users, it is necessary to generate innovative design solutions that lead to enhancements and improvements in the quality of care, healing process and organisational efficiency. Yet, generating innovations in hospital building design requires an accurate understanding of the concept of innovation ecosystems. The following section provides a general description of innovation ecosystems and reviews literature on architectural innovation in hospital design.

2.2. Hospital Design Innovation

Innovation is almost never an isolated occurrence (Olson & Dahlberg 2013), and achieving an agreement on what innovation entails or how it can be facilitated has always been challenging. In this part, the literature around innovation in hospital design is represented. It begins with the definition of main concepts such as innovation, creativity and invention, followed by the explanations of innovation ecosystems and modes of innovation. Then, the interactions between inhabitants at different innovation ecosystems in hospital design are examined.

2.2.1. Definition of innovation

- **Innovation**

Innovation is the creation of a new value through an iterative process which could be emerged as products (the product a company makes or the service it provides), processes (the way a product is made, or the service is provided), and services (Aka 2019; Amit & Zott 2012; Tushman & Nadler 1986), as well as organisational and business models (Aka 2019; Amit & Zott 2012; Xavier et al. 2017). Innovation provides a new application or a creative combination of pre-existing concepts, methods, and possibilities via radical or gradual changes (Lundvall 2016; OECD 1997; Xavier et al. 2017). Notably, innovation has broadened its scope from just dealing with products and processes to being considered as a *global strategic mean*s. Here, the *innovation ecosystem* has become the most important kind of environment provided for addressing this scope (Jackson 2011; Rabelo & Bernus 2015). The following subsections focus on the innovation ecosystems after explaining the main differences between creativity, invention and innovation.

- **Creativity vs Innovation**

Amabile (1988, p. 126) explained the term creativity based on three different views researchers had adopted, namely characteristics of a person, its process, and its product. She argued creativity is "the production of novel and useful ideas by an individual or small group of individuals working together". However, innovation is the successful implementation of those creative ideas as the basic elements implicitly or explicitly by a larger group (Van de Ven 1986; West & Altink 1996; Zaltman, Duncan & Holbek 1973).

- **Invention vs Innovation**

Jarchow and Röhm (2019, p. 407) defined invention as "the outcome of R&D that can be disclosed and protected by intellectual property rights" in comparison with innovation which is "the stage where a new product or process generates turnover or productivity increases". In other words, invention is the process of exploring or generating a new idea, whereas innovation is the application or exploitation of an idea to create novel values (Brookes & Poole 2012).

2.2.2. Innovation ecosystem

The first ecosystem concept was defined by ecology research dating from 1930 (Valkokari 2015). In this definition, a biological ecosystem consists of several complex interrelationships between the living habitats of a specific zone, whose principal purpose is to make a sustainable state (as explain in (Jackson 2011)). It is notable that the *ecosystem* concept has been employed in a vast range of disciplines. For instance, Rothschild (1990) approached the economy as an ecosystem, whereby living organisms were made up of market organisations and consumers interacting with their environment (Audretsch et al. 2019). In addition, Moore (1996, p. 26) explained the business ecosystem as "an economic community supported by a foundation of interacting organisations and individuals-the organisms of the business world". In management research, it was also applied to organisations interconnected around a particular platform (Autio & Thomas 2014). Therefore, there are various definitions for an ecosystem in relation to its context. In the present study, ecosystem is a nonlinear, dynamic, adaptive, and complex system where the emergent output is not necessarily the sum of individual inputs. According to Gobble (2014), there are also several definitions for innovation as an ecosystem that differ in vision, scope and detail.

Innovation ecosystem is a term that applies to a heterogeneous and continuously evolving set of constituents that are dynamically interconnected through a complex network of relationships and cooperate for co-creation of novel values (Dedehayir, Mäkinen & Ortt 2018; Estrin 2009, p. 37; Frenkel & Maital 2014; Gobble 2014; Jackson 2011; Russell et al. 2015). One of the key features of an innovation ecosystem is that it evolves once designed and makes a new entity that is different from the previous ecosystem (Garud, Tuertscher & Van de Ven 2013; Oh et al. 2016). Moreover, this value creation within ecosystem contexts is entirely a non-linear, non-sequential and iterative process, which adds both horizontal and vertical linkages between network participants of value networks (Autio & Thomas 2014; Frenkel & Maital 2014). Given the interactive network attribute of innovation ecosystems, Pyka and Scharnhorst (2010) defined it as a critical process that destabilises one state of the system to achieve a new stable state in relation to the new interactions between inhabitants.

The innovation ecosystem in hospital design is associated with *technologies* (tools employed by actors); *networked actors/human resources* (the people who can solve problems and the opportunities to build their capacity; such as medical centres, manufacturers, universities, government/ federal agencies, patient organizations, medical practitioners and healthcare personnel); *infrastructure* (the institutions, policies, structures, and financial infrastructure making innovation possible); *communication/ collaboration* (resources that allow researchers, innovators, and others to exchange ideas and interact); and *knowledge* (the data and indigenous knowledge that actors within an innovation system use, produce, or convey) (Global Knowledge Initiative 2016; Gulbrandsen et al. 2016; Rabelo & Bernus 2015). Additionally, *culture* is known to be one of the most significant ingredients of an innovation ecosystem (Hwang & Horowitt 2012). Culture applies to the mindset of people and organisations as well as the customs and social behaviour of a society that provides the context for innovation initiatives and impacts the way actors develop the innovation ecosystem (Rabelo & Bernus 2015). These components play a key role in providing the appropriate environment and promoting the innovation capabilities of individual corporations, industries, regions, and nations (Jackson 2011; Xu et al. 2018).

2.2.2.1. Innovation ecosystem in narrow sense vs broad sense approaches

According to Lundvall (2016), an innovation ecosystem could be described in terms of its involved processes and subsystems from two different approaches called narrow sense and broad sense. This process might be complicated, requiring theoretical considerations and historical analysis. For instance, in each historical period, different economic subsystems and interrelationships have had various roles in the innovation ecosystem. Lundvall (2016, p. 96) explained this via a good example: in the early British industrialisation, the learning and subsequent innovations inside firms were introduced by the proliferation of new technologies; in the late-18th century, advancements in chemistry and electricity took the innovation nexus to the R&D laboratories of big firms; and the growing and radical innovations in information technology focused on the coupling of routine-based learning with searching and R&D. In this respect, the broad definition includes "parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring" (Lundvall 2016, p. 96). Here, organisations engaged in searching and exploring are included in the narrow definition (e.g., R&D departments, technological institutes and universities).

It is worth mentioning that to determine the reasons for the emergence or evolution of innovation ecosystems, an analysis from a broader perspective is essential (Rabelo & Bernus 2015). This will be possible by taking into consideration all the involved actors, their roles, interactions, regulations, cultural values and boosting mechanisms (Hwang & Horowitt 2012). The present study will adopt the system of innovation in a broad sense to find the causal relationships between subsystems and processes. In doing so, understanding different modes of innovation is also worthy of notice.

2.2.3. Modes of innovation

Jensen et al. (2007, p. 155) highlighted two distinct modes of learning and innovation. The first one emphasises the application of codified scientific knowledge in the development of new technologies, which provides the basis for new processes or products, called Science, Technology and Innovation (STI-mode). The second one looks at innovative problem-solving, via experience-based modes, through Doing, Using and Interacting (DUI-mode), such as learning from informal interaction within an organisation (Fitjar & Rodríguez-Pose 2013; Lundvall 2016).

2.2.3.1. STI-mode

As Jensen et al. (2007, p. 155) argued, scientific findings support and have indirect interactions with technological advancements. To realise this connection, he highlighted the definition of technology by Nelson (2004, p. 457): "involving both a body of practice, manifest in the artefacts and techniques that are produced and used as well as a body of understanding which supports, surrounds and rationalises the former". Indeed, technology incorporates generic understanding (similar to science), and yet it is related to specific techniques and artefacts. Here, R&D labs in firms use and expand the "science-like understanding" and codified scientific findings in their innovation processes (Lundvall 2016, p. 159). The main indicators of STI-mode include deductive methods and quantitative strategies that use R&D, patenting, and the formal education of workforces (Fitjar & Rodríguez-Pose 2013).

2.2.3.2. DUI-mode

As it was mentioned in STI-mode, scientific knowledge has widely come to brighten and support technological practice. However, there are still several practical problems that remained partially understood. These issues can be solved only by professional engineers who learned the work without any appreciation of why (Nelson 2004, p. 458). In some circumstances, employees may confront an unpredicted challenge that can be addressed through some interactions between team members. Thus, DUI-mode can be vital to a healthy and successful innovation, too. While the DUI mode of innovation has more diversity, the inductive and qualitative approaches have become dominant (Fitjar & Rodríguez-Pose 2013).

Salge (2012) highlighted these two modes as science-based and practice-based modes of hospital innovation, which is the scope of this study as well. After examining the relationship between investment in these two types of innovative activities, he argued that both of them are essential to enhancing the performance of hospitals (Gulbrandsen et al. 2016).

2.2.4. Innovation in hospital building design

The literature on innovation related to human health is quite extensive, varying from medical and biotechnological advancements to enhancements in health services. These innovations are widely associated with networked actors such as medical centres, manufacturers, universities, government/federal agencies, patient organisations, medical practitioners and healthcare personnel, as well as the organisations employing them (Gulbrandsen et al. 2016; Morlacchi & Nelson 2011; Powell, Koput & Smith-Doerr 1996). Given the variety of studies around innovations in hospitals, a comprehensive categorisation of the existing research provides informative context for understanding the gaps. There exist two pivotal systematic reviews conducted by Djellal and Gallouj (2007) and Gulbrandsen et al. (2016). The former classified studies in accordance with their approach in four main categories. The latter examined studies related to hospital and medical innovations to explore the role of hospital as an innovator in the healthcare system. Importantly, these two reviews provide limited explanations of innovations in hospital building design by focusing mostly on medical and service innovations.

Regarding types of innovation in this context, the main four scopes of approach are “hospitals as production function”, “hospitals as a set of medical and technological capacities”, “hospitals as information systems”, and “hospitals as service providers” (Djellal & Gallouj 2005, 2007). The first approach is mainly employed in health and industrial economic studies and examines the interactions between technological advancements and production functions (i.e., with the ease of technology, less medical care can provide the same amount of health). The second approach refers to medical innovations and accounts for the largest proportion of articles from medicine, economics, sociology and management contexts. These mostly examine the nature and dynamics of medical innovation and its interactions with developments in science, technology, medical practice and policy. This group contains three subdivisions: “biomedical or bio-pharmacological innovation”, “tangible/hard medical innovation such as technological devices”, and “intangible/soft medical innovation such as therapeutic strategies”. The developments in information system technologies and the links between hospital innovations and informational paradigms make up the third group. Related studies can be subdivided into two views, including administration/management IT (material flows, productivity) and medical care IT (diagnosis or treatment). The last set of articles considers hospitals as service providers and healthcare system hubs, as patients are consumers in a broad service-providing organisation. This issue is mostly investigated in fields such as sociology, socioeconomics or management.

Regarding the role of hospital as an innovator in the healthcare system, the literature has offered explanations for a great range of innovations in HCFs that can be classified in the following categories: 1) biomedical innovation (scientific and practice-based); 2) service innovation (medical procedure/treatment/mode of delivery of health services); 3) product innovation (drug/ medical devices); 4) process innovation; and 5) organisational innovation (administrative innovation) (Gulbrandsen et al. 2016). Here, studies related to innovation in hospital building design have mostly intended to depict the evolutionary process of innovation, which have either examined the impacts of interventions in generating innovation in medical, service and organisational facilities (Consoli & Mina 2009; Galbrun & Kijima 2009; Gulbrandsen et al. 2016; Thakur, Hsu & Fontenot 2012; Williams 2011), or have explored the forces driving the need for innovation (Akenroye 2012). However, investigating those different evolutionary models in-depth or focusing on the architectural creativity, architectural design process and paths to innovation generation is beyond the intention of this study.

Research exploring innovation in hospital building design is surprisingly limited. Here, the importance is highlighted of Evidence-based Design (EBD) and Research-Informed Design (RID) as useful tools/frameworks in generating further innovation and achieving collective aims in recent construction, expansion or remodelling activities (Alfonsi, Capolongo & Buffoli 2014; Criado-Perez et al. 2020; Hamilton 2019; Joseph et al. 2014; Martin 2014; Peavey & Vander Wyst 2017). EBD is a framework used by architects, interior designers, facility managers and others involved in the planning, design and construction of hospitals to improve the quality of design in support of improved healthcare delivery outcomes (Goetz et al. 2010; Halawa et al. 2020). The Center for Health Design (2016); (2009) proposed an eight-step process for EBD and confirmed “the importance of discovering new knowledge and feeding forward that knowledge to foster future innovations". However, hospital building designers and policymakers face obstacles in fully integrating research evidence into design practice; a phenomenon known as the research-practice (R-P) gap (Criado-Perez et al. 2020; Freihoefer & Zborowsky 2017; Hall et al. 2017; Hamilton 2007, 2015; Lawson 2013; Taylor 2011; Wagenaar et al. 2018).

The literature highlights that the R-P gap hinders innovation in hospital design, leading to repeating similar shortcomings and decreasing the chance of enhancements in health and wellbeing of occupants (Chong, Brandt & Martin 2010; Freihoefer & Zborowsky 2017; Hamilton 2015; Joseph et al. 2014; Lawson 2013; Stichler 2016; Taylor 2011; Tvedebrink & Jelić 2021). The next section explains the R-P gap and the reasons behind its existence in the field of healthcare design.

2.3. R-P Gap as Hindering Design Innovation

It is not infrequent for research institutions around the world to fail in creating the knowledge that guides practice, resulting in a significant problem called the R-P gap. Practitioners doing their own work, and scientists thinking practitioners will apply their research, are both to blame for the existing gap (Green 2008). On the one side, it would be problematic for practitioners to base practice on evidence-based interventions as they usually have limited access to the latest research. It is, on the other side, problematic for researchers to become engaged in practice-based research, when there is a lack of information about the local context and indigenously developed solutions (Neal 2015). Practitioners also deride the efforts of researchers by citing findings as ill-suited for their use (Huber 2018). Eventually, while this gap plays a significant role in both realms of research and practice, each group gets on with its own research/practice that makes the gap wider and prevents design enhancements.

The importance of the R-P gap has been identified in several disciplines. Studies have tried to bridge it through understanding the different aims and activities of each side, including the gap between current evidence-based guidelines and the clinical care delivered (Marshall 2017); the obstacles on the path from research to practice and policy in School Mental Health (Hoover 2018); high levels of variability in post Resuscitation Care and guideline adherence influencing the survival and functional status at hospital discharge (Milonas 2017); the creative and critical thinking skills to bridge the gap between education, research and practice for nurses (Moore & Tierney 2019; Seymour, Kinn & Sutherland 2003); reasons for R-P gap from the viewpoint of Complementary Medicine Academics affecting the improvements in the safety and quality of complementary and alternative medicine (Leach & Tucker 2017); identification of barriers to implementation in a Critical Access Hospital (Stavor, Zedreck-Gonzalez & Hoffmann 2017); the gap between law school and law practice (Bingaman 2000); safety learning and the impacts of the gap on safe working practices across contexts and addressing the needs of industry practice (Zou, Sunindijo & Dainty 2014); and research coming from business schools ignore the connections to problems of management practice (Gubbins & Rousseau 2015), to name just a few. These studies are great examples of the R-P gap in various contexts and the way other researchers struggle to address the gap.

In the next subsection, studies examining the R-P gap in healthcare building design are discussed. Notably, research examining this gap commonly focuses on architectural design and its related issues as the main factor hampering building design progress. Evidence of the R-P gap in this field and its reasons are explained.

2.3.1. Evidence of the R-P gap in designing healthcare buildings

One way to confirm the possibility of the R-P gap in healthcare building design is to assess the integration of research evidence base into the design practice. Some studies highlighted the successful application of EBD in the design process. Important research in this regard was a survey conducted by Taylor (2011) in the USA on the use and impacts of EBD from the professionals associated with the Centre for Health Design (CHD). Taylor suggested that nearly all respondents (98%) knew the importance of EBD in promoting the healing processes, and that about 82% either used research regularly (36.2%) or sometimes (45.5%) in their design decisions making. She also mentioned that almost half of the respondents determined the Facility Guidelines and Institute guidelines as the main sources, followed by the CHD publication and conferences with 43.4% and 24.5% respectively. Furthermore, respondents highlighted some methods in gathering design strategies and methods such as Internet searches (43.8%), past projects (38.8%), and reading articles (31.7%) or published research (29.0%) (Zborowsky & Bunker-Hellmich 2010). Secondly, a survey was conducted in 40 top healthcare interior design firms in the USA. It was found that approximately 90% of the respondents were involved in some form of EBD and more than 75% of them claimed that they used their interpretations of scientific evidence found in peer-reviewed journals to enhance their design (Cama 2009; Haq 2010). However, according to Peavey and Vander Wyst (2017), most of these designers did not have a clear idea about the differences between the processes of EBD and RID and often used them interchangeably.

In sharp contrast to these studies, Lawson (2013, p. 33) proposed that design practice has not progressed at the same speed as research. While satisfactory designs always exist around the world, they still account for the minority and most of the design works “achieve well below the best practice that the EBD research evidence suggests is possible”. He represented the results of a study conducted in 2008 and published by CABE (Commission for Architecture and the Built environment; the UK government architectural surveillance). It revealed that the weakest architectural features of 20 primary care centres were those with the strongest evidence in research, which according to Lawson (2013) was intimidating. Moreover, in answer to the item about “overall experience of a building and the impression of the standard of service delivery” only one-third of the respondents rated “good” and 6% as “excellent” (CABE 2008). In another study, 18 cancer centres were evaluated after their occupancy and the same poor results associated with EBD and advancements in their quality over four years were reported. Taylor (2011) indicated that in the Third Annual Survey of Research Design in Healthcare Environments, a great number of organisations claimed that they normally conducted POE studies to measure results (73%); however, they did not consider those reports as a way for acquiring evidence and knowledge about the application of new design methods (12.5%). Similarly, Kalantari and Snell (2017, p. 125) argued that “the industry has been somewhat slow to adopt the regular use of POEs”, making POE less impactful on design decisions. Further, Singha (2020) noted a huge gap between hospital designers and clinicians. While medical professionals were aware of the impacts of the built environment on the health of inhabitants, a survey indicated that about 85 percent of the medical professionals did not receive any information about these impacts (Bernstein & Russo 2014). This lack of knowledge transmission between the most involved groups in the design process is widely seen to result in poor design outcomes.

The R-P gap in designing HCFs is a controversial issue needing immediate action. To do so, the main reasons widening this gap need to be first reconsidered. The next subsection explores the main reasons lying behind this gap and provides explanations for each issue.

2.3.2. Reasons behind the R-P gap

A critical literature review determined some of the barriers impacting the R-P gap in designing healthcare buildings. They are represented in an order based on their importance and are categorised on their similarities in their nature and fundamentals, including research methodology, knowledge creation, knowledge transfer, architectural education, knowledge accessibility, and economic constraints. There are six groups of reasons for this gap that should be considered before implementing any measure.

1. Reasons regarding the knowledge creation relevant to practice

1.1. Challenges in transforming raw scientific data into well-defined, "tangible and meaningful design concepts" that are practical in making design decisions (Codinhoto 2013; Freihoefer & Zborowsky 2017, p. 73; Wagenaar et al. 2018);

1.2. Difficulties in generalising the research outcomes and knowledge for using in the design process (Freihoefer & Zborowsky 2017; Tvedebrink & Jelić 2021);

First, the nature of scientific studies justifies the need for removing all factors that may confound the final results, and therefore the numerous contextual conditions are removed. This fact makes translating research outcomes into design decisions challenging and generalisation difficult (Mullins, B. Folmer & Fich 2015). Moreover, the difference between the study's parameters and design problems exacerbates the situation (Freihoefer & Zborowsky 2017).

1.3. The gap between the knowledge defined as "relevant evidence" and knowledge needed for designing (Codinhoto 2013; Rashid 2013, p. 103);

Rashid (2013) refuted the application of experimental research studies (acquired by Cochran's view of EBM, 1972) for creating valid empirical knowledge for healthcare designers. He proposed that well-designed qualitative research provides professional designers with a better source of relevant evidence required for making decisions in the design process. The main reasons for this argument are evident in the difficulties of conducting experimental research, the level of certainty and validity it brings, and its extensive focus. Moreover, due to the semantic and episodic knowledge needed for enhancing the quality of design, "architects need qualitative knowledge that tells the story of how messy individuals and organisations are in any given environmental setting so that they can try to make things better by design" (Rashid 2013, p. 121).

1.4. Underusing the knowledge extracted from POE studies (Joseph et al. 2014);

Post-occupancy evaluation studies are widely seen as one of the pivotal sources of the implementation loop, particularly for HCFs, which play a key role in the planning and designing stages of future projects. While there are myriad POE reports, the findings are not sufficiently communicated to or employed by designers (Joseph et al. 2014).

2. Reasons regarding the research methodology

2.1. The distinctions between how "evidence" has been employed in medical care and building design (Codinhoto 2013; Mullins, B. Folmer & Fich 2015; Zborowsky & Bunker-Hellmich 2010);

EBD is considered to be "methodologically similar with EBM", whereas the knowledge resulting from EBM hugely relies on the explanatory theory with completely different theoretical concepts (Hamilton 2004). In this respect, Stankos and Schwarz (2007) highlighted that EBD studies can hardly explain what is happening and predict what will happen. They mentioned that EBD is not capable of providing an explanatory theory and describing the reasons for successful design solutions (Mullins, B. Folmer & Fich 2015; Stankos & Schwarz 2007)Johnson & Walsh 2019.

2.2. Variety in research methods and impracticality of Randomised Control Trials (Hall et al. 2017);

Some fundamental features make EBD distinguished from EBM. Hall et al. (2017) argued that built environment studies are much more complex as it is not possible to have two identical buildings for testing different conditions (Hall et al. 2017).

3. Reasons regarding architectural education

3.1. Neglecting the importance of learning how to apply research and EBD in generic baccalaureate programs for design students (Stichler 2016; Tvedebrink & Jelić 2021);
3.2. Evidence-based designers do not often conduct empirical studies that are the basis for EBD (Davidson 2010; Lawson 2013);

As a rule, professionals contribute to the design process mostly based on their own knowledge and within the limitations of what they are accustomed to and expert in. Thus, when architecture students do not have a high level of confidence in applying recent research in their design, the existing R-P gap is an inevitable outcome. Consider a designer who is not capable of critically reading and evaluating the research on the measurements of human performance, perceptions and the consequent use of descriptive and inferential statistics. Expecting such an architect to make design decisions based on a thousand studies is clearly unrealistic (Lawson 2013). Stichler (2016) highlighted the considerable improvements in nursing care after adding evidence-based projects to baccalaureate programs for architectural students. Furthermore, most of the EBD studies are based on empirical research that is not conducted by architects. Thus, designers who do not add much amount of knowledge may not be seen by governments which causes problems at the policy level (CABE 2008).

3.3. The application of Episodic knowledge, Theoretical knowledge, or Semantic knowledge in Architecture (Lawson 2013);

Lawson (2013) confirmed that design knowledge extensively relies on episodic (related to specific events) and semantic (related to meanings and understanding) knowledge rather than theoretical knowledge. Given this fact, the puzzling relationship between theoretical courses and design studios would be clear. For instance, an architectural student might "pass a theoretical examination in structural mechanics, and yet apparently be unable to use that knowledge creatively in design" (CABE 2008).

4. Reasons regarding the knowledge transfer

4.1. Fast-paced project deadlines (Freihoefer & Zborowsky 2017);

Due to the fast-paced project schedules, designers might not give sufficient consideration to research findings and look for data collection tools and strategies for employing them in their design process. However, the knowledge that comes from EBD research plays a key role in the design process and must be spread through the whole design (CABE 2008).

4.2. The contributions of various fields and the lack of mutual awareness among the different professions of each other's work result in "an inefficient use of available data and knowledge" (Wagenaar et al. 2018, p. 38);
4.3. The incomprehensibility of scientific evidence and the shortage of translational developers in the field of healthcare Design (Marshall 2017; Norman 2010);

Norman (2010) pointed out that scientific research should be translated to practical application for the use of designers, a trend he called transactional knowledge. He mentioned that sometimes misunderstanding on both sides makes the R-P gap wider, and therefore there is a need for a third discipline. This trend emerged through medicine, biology, and health sciences. In addition, sometimes existing research is not likely to be understood by designers, since "they are likely to be from the realms of psychology, sociology, biology or any number of other related fields, but certainly not from design" (CABE 2008). Altogether, architecture is not an exception in this regard and suffers from the absence of translational developers or knowledge transfer programs. Translational developers should act as an intermediary by conveying research findings into the designers' language and translating designers' issues into those solvable by researchers (Fisher 2016; Marshall 2017; Norman 2010).

4.4. Various stakeholders should be involved in this process (Elf et al. 2015);

Elf et al. (2015, p. 114) suggested "a shared-decision making and collaborative design process between representatives from healthcare, construction sector, and architecture based on evidence and end-user's perspective" to convey the needs more easily and improve the quality of HCFs.

5. Reasons regarding the knowledge accessibility and research layouts

5.1. Challenges in accessing scientific evidence by design practitioners (Hall et al. 2017; Joseph et al. 2014);
5.2. There is a lack of mechanism for evidence-based designers to collect existing design-relevant data and scientific findings;

According to an industry-based survey of evidence-based practice architecture and urban planning conducted in 2015, only 16% of practitioners employ research findings in their normal practice. While healthcare designers are not separated in this study, it is a valuable study as it includes many architects from all over the world. It highlighted the need for explicit data gathering tools, as designers, or their clients, do not normally pay for it (EBD 2015).

Currently, in the field of healthcare design, some web-based databases are available to access research information, such as Informe Design (http://www.informedesign.umn.edu/), the RIPPLE database (http://ripple.healthdesign.org/) and the Centre for Health Design (https://www.healthdesign.org/). However, Rashid (2013, p. 103) argued that EBD supporters and existing searching tools only take account of "the design-relevant knowledge developed in domains related to healthcare, such as healthcare design (most often limited to architecture, interior design, and environmental systems), medical sciences, healthcare economics, healthcare management, healthcare policy and law, and healthcare practice". Consequently, other important pertinent research might be neglected such as natural and social sciences related to human health, anthropology, biology, economics, engineering, geography, history, psychology.

5.3. The way research findings are presented may hinder designers in professional firms to comprehend and get the pertinent information to their projects (Haq 2010; Huber 2016);

Haq (2010, p. 90) stated that researchers should provide design practitioners with the best vehicle for extracting information to save their time and funds. In this manner, the "textual representations in a flat, hierarchical format" are not the best way. It is also assumed that designers, who may not comprehend the scientific literature but could gain advantages of the provided information, judge information sources and academic literature largely based on their graphics (Huber 2016). Huber suggested that some small components with clear labelling within an article (e.g., implications of the study) can significantly help designers understand the findings.

6. Reasons regarding economic constraints

    6.1. Conducting EBD and taking the findings into a design process is an extra cost for both design firms and clients (Stichler 2016);

According to Sadler et al. (2011, p. 19), the evidence from Fable Hospital "justifies initial incremental cost increases" for improvements in patient and staff safety, operational performance, and sustainability. While the mentioned study is a strong proof for the specific design innovations in HCFs and the return on investment, in developing or underdeveloped economies with financial restrictions, funds are simply not available to support design recommendations (McCuskey Shepley & Song 2014; Pati 2011). Moreover, McCuskey Shepley and Song (2014) confirmed that legal and cultural constraints influence the design decision-making process. The authors indicated that most guidelines and design recommendations are based on the developed economies' demands, and they need a considerable amount of money and cultural implications that altogether hinder their implementation in less developed economies.

In sum, the adverse influences of the R-P gap in the design of HCFs and the reasons causing them have been recognised. Despite the efforts of studies to inform further innovations in hospital building design through examining and narrowing the R-P gap, it is evident that the interactions between research and the many other contextual factors affecting the HCF design remain to be found. Indeed, the innovation ecosystem is complex including many inhabitants positioned at dynamic overlapped sub-ecosystems and the current picture of design innovation is oversimplified. This prompts the need for more conversations about how the knowledge on hospital design evolution could be expanded into a broader field that explores and examines the interrelationships between the contextual factors triggering innovations in hospital building design. In the following section, complex innovation ecosystems are explained and some strategies to understand this complexity are provided.

2.4. The Complexity and Dynamics of Innovation Ecosystems

A real-world innovation ecosystem is comprised of various inhabitants from multiple ecosystems, where changes inside the sub-systems significantly impact/are impacted by the main system. Valkokari (2015) highlighted the real-world ecosystem as one entity and the impossibility of identifying the exact borders between intensely interconnected sub-ecosystems. Research, however, has emphasised examining each ecosystem separately rather than providing a holistic understanding of the whole innovation ecosystem and associated contextual factors. In recent years, there has been a gradual growth in exploring the interrelationships between a few ecosystems by examining the overlapped inhabitants and relationships (Oh et al. 2016; Valkokari 2015; Weber & Hine 2015; Xu et al. 2018), and understanding the key interactions between actors and their environmental factors (Harini & Thomas 2020; Long & Li 2014; Rabelo & Bernus 2015; Shayan et al. 2018; Silva & Guerrini 2018).

Valkokari (2015) investigated interactions between three economic ecosystem types –business, knowledge and innovation ecosystems – each with different outcomes, logics of action, and actor roles (see Figure 2-2). She proposed a different logic of action for each dynamic ecosystem explaining the distinct roles of similar actors from different ecosystems. She argued that highly active and adjustable actors and platforms may enhance interactions between overlapping ecosystems, leading to the co-evolution of the whole ecosystem. Here, knowledge ecosystems generate novel scientific and technological knowledge by the contribution of researchers and technology entrepreneurs, business ecosystems principally provide customer value creation, and the innovation ecosystem consists of the integration of new knowledge generation and its application for value co-creation in business ecosystems. Xu et al. (2018, p. 210) proposed a similar framework in accordance with the two prime attributes of successful innovation ecosystems: "the integrated value chain" and "the interactive network". The authors argued that the innovation ecosystem is a complex interconnected and integrated system that must be analysed in relation to its two distinct sub-ecosystems -the knowledge and business ecosystems (Clarysse et al. 2014; Freeman & Soete 2009; Xu et al. 2020; Xu et al. 2018). The existing literature puts emphasis on inter-organisational relationships and coordination between actors of science, technology and business sub-ecosystems as an essential attribute for value creation in a successful innovation ecosystem. The indispensable role of tangible and intangible interactions in the process of knowledge flow between actors has been suggested from different theoretical perspectives, such as open innovation, platform leadership, keystone strategies, value networks, and hyperlinked organisations (Battistella et al. 2013; Oh et al. 2016; Xu et al. 2018).

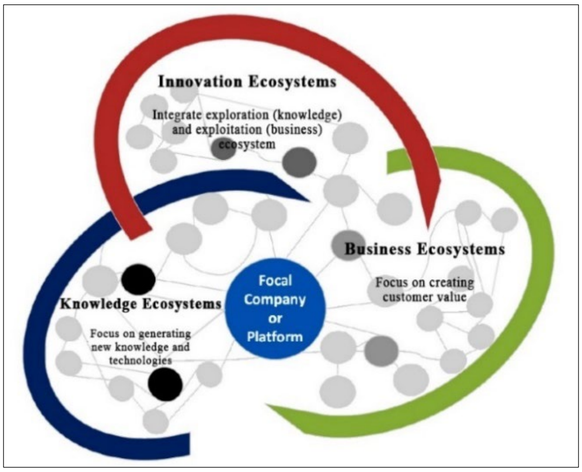


Figure 2-2: Relationship between overlapping ecosystem types (Valkokari 2015)

The development of innovation is considered to be significantly affected by environmental factors (Klerkx, Aarts & Leeuwis 2010; Rabelo & Bernus 2015). That is, the interplay between actors is impacted by exogenous factors, including changes in technologies, socioeconomic climate, political and legal climate, and cultural and geographical contexts (Harini & Thomas 2020; Long & Li 2014; Shayan et al. 2018). Thereby, favourable contextual factors, including dynamic layers and diversified players, are widely considered to contribute to the value-creation of the whole ecosystem. However, the literature on innovation ecosystems is mostly limited to the analysis of interactions between some specific elements of the system such as firms, researchers, and government agencies and their social interactions (Panetti et al. 2019; Russo-Spena, Tregua & Bifulco 2017; Xu et al. 2020). In a recent literature review, Harini and Thomas (2020) also pointed out the lack of studies on "environmental causes" of inter-organisational network evolution.

It follows that understanding the innovation ecosystem of hospital building design is highly subject to understanding the dynamics and relationships between actors within overlapped ecosystems. While elements located at different layers have been considerably impacting this innovation ecosystem for a long time, researchers have not yet examined their interactions holistically. Thus, little progress has been made exploring the properties of multi-faceted processes triggering historical innovation in hospital design. The present study posits that the interactions between contextual factors have considerably impacted innovations in architectural, organisational and service design over the last 100 years. Consequently, and in line with Valkokari (2015) and Xu et al. (2020), the prime aim is to elucidate the interplay between contextual factors via an explanatory framework that spans ecosystems. I argue that *Complex Systems Theory* can help to understand how these complex systems interact and evolve from a multi-layer perspective, since complexity theory is based on the significance of mutual causality and interactions. To this end, the next subsections elucidate: 1) the main features of complex systems, 2) the idea of innovation as a complex system, and 3) a systems-thinking approach and strategy to understand the complex innovation ecosystem.

2.4.1. Complex systems theory

There is a wide range of literature on the idea of "complex systems", yet research to date has not offered an accurate technical definition. Most researchers working on *Complex Systems Theory* would concur with the idea that a complex system is a functional whole composed of many interdependent self-organised components interacting in a disordered way that gives rise to the complex emergent behaviours. Here, the "emergent" behaviour is a collective behaviour that cannot be easily described or predicted by the sum of individual behaviours of the interacting elements (Condorelli 2016; Engler & Kusiak 2011; Ladyman, Lambert & Wiesner 2013; Lucas 2000; Mitchell 2009; Mitchell & Newman 2002; Newman 2011). Complex systems are believed to shape the majority of our world, including ecosystems and living organisms, human society and social systems, economies, etc. Abstracting from the literature, the following seven features are associated with the concept of complex systems:

1. *Nonlinearity:* the inherent nonlinearity of strongly linked components is widely considered to be a necessary condition for a complex system. Nonlinearity means that the causes and effects are interdependent, such that small changes in values of one condition might lead to radical differences in the final output, and the emergent behaviour can be completely different from the sum of the individual parts (Chiva, Ghauri & Alegre 2014; Condorelli 2016; Foote 2007; Ladyman, Lambert & Wiesner 2013; Lucas 2000);

2. *Feedback/Signalling:* all individual components of a complex system get feedbacks dynamically from their neighbours. The interplay between an element and its neighbours at a later time is dependent on how it interacts with the neighbour in the first place. Moreover, each part of a system can produce for and utilise information from both their internal and external environments (Ladyman, Lambert & Wiesner 2013; Mitchell 2009);

3. *Adaptation:* complex systems adapt themselves to increase their chance of success by changing their emergent behaviour. This collaborative dynamic works towards common aims and shared needs by "learning or evolutionary processes" (Chiva, Ghauri & Alegre 2014, p. 690; Mitchell 2009; Silva & Guerrini 2018);

4. *Spontaneous order:* complex systems exhibit neither complete order nor randomness, yet there is a kind of spontaneous order in the aggregated interactions between parts. In other words, disorderly interconnected elements lead to the emergence of the order of the complex system (Ladyman, Lambert & Wiesner 2013);

5. *Self-organisation:* the ability to integrate and rearrange the system's elements, where there is no internal or external controller and the order is distributed over the involved elements of a complex system. Self-organisation is also considered as a spontaneous evolution of structures that is directly associated with the adaptability of the system. While the self-organising characteristic is always seen in complex systems, it is not sufficient for complexity (non-complex systems might not have any control or order) (Condorelli 2016; Ladyman, Lambert & Wiesner 2013; Lucas 2000; Pyka & Scharnhorst 2010; Silva & Guerrini 2018);

6. *Hierarchical organisation:* a complex system is often composed of subsystems, which may have their own subsystems, in a hierarchical order. The emergent behaviour of the system takes place when the order of interactions between lower levels is robust (Condorelli 2016; Ladyman, Lambert & Wiesner 2013; Silva & Guerrini 2018);

7. *Numerosity:* having a large number of individual elements in a hierarchical structure with many interconnections is considered essential for a complex system. Notably, these elements need to have similar nature to be able to get feedback and interact with each other resulting in system development (Foote 2007; Ladyman, Lambert & Wiesner 2013; Weng, Bhalla & Iyengar 1999).

Due to the importance of holism and simultaneous interconnectivity between a large number of elements in innovation ecosystems, adopting the complexity lens is widely considered to help researchers explain the nature of innovation (Atun 2012; Chiva, Ghauri & Alegre 2014; Frenkel & Maital 2014; Frenken 2006; Katz 2016; Poutanen, Soliman & Ståhle 2016; Silva & Guerrini 2018). Russo and Rossi (2009, p. 76) believed that considering innovation as a linear process has become outdated and highlighted the importance of theories that aim to study "innovation as a complex process" in exploring the generative interactions between various actors that support the innovation process. Adopting conventional approaches focusing on reduction and abstraction of the nature of innovation has led to an open problem and substantial failure in design improvements (Condorelli 2016; Engler & Kusiak 2011; Lucas 2000). Furthermore, as the structure of the bidirectional connections in an innovation ecosystem adapts to and co-evolves with the function of involved components, only complexity theory is adequately able to explain this development (Poutanen, Soliman & Ståhle 2016; Pyka & Scharnhorst 2010; Silva & Guerrini 2018). Here, one of the most frequently used tools for systems thinking is the iceberg model (Ecochallenge Organization 2020; Waters Centre for Systems Thinking 2020). This model helps researchers explore various dimensions of a phenomenon and fully understand the interactions between seemingly unrelated components of a system.

2.4.1.1. A system thinking model to understanding the innovation ecosystem

The iceberg model is based on the prime idea of thinking at the system level, considering patterns over time and looking for interconnections between different components of a system rather than examining individual parts. In other words, like an iceberg, only 10% is visible and 90% is hidden. Yet, the behaviour of this iceberg is completely dependent on the action of ocean on the hidden part (see Figure 2-3). Thus, it is necessary to adopt a deeper understanding and examine the interacting, interrelated, and interdependent parts of a unified whole that shape the structure and behaviour of the complex system.

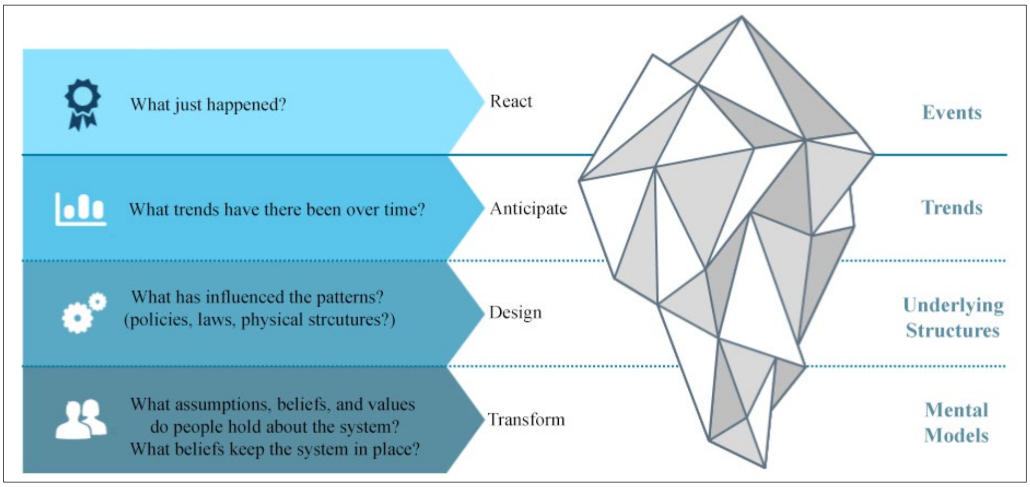


Figure 2-3: Iceberg model, a tool for guiding systems thinking (Ecochallenge Organization 2020; Waters Centre for Systems Thinking 2020)

The iceberg model looks at four complementary levels to explain a phenomenon, three of which are usually overlooked by researchers. The layers, from top to bottom, are events, trends, structures and mental models respectively:

1. *The Event Level*: we observe and react to a phenomenon at this level. Yet, addressing the related issues needs more consideration of the reasons and patterns generating that event, rather than simply treating the symptom at the event level;

2. *The Pattern Level*: systems thinkers look for similar events that have been occurring over time. Exploring the structures generating the phenomenon allows us to anticipate future events;

3. *The Structure Level*: The answer to questions like "what has influenced the patterns?" lies behind the structure level. The underlying structures might be physical things, organisations, policies and regulations, and ritual (unconsciously habitual behaviours); and

4. *The Mental Model Level*: At the deepest level of the iceberg, we need to take into account the attitudes, beliefs, values, morals, and expectations that significantly impact the emergent behaviour and functionality of the system. These mental models lie in society and are often learned subconsciously.

In this thesis, the iceberg model is employed to explore various components and themes involved in different layers of the design innovation ecosystem. Here, an innovation ecosystem is considered as: 1) inherently systemic and evolutionary composed of interdependent and interconnected components that co-evolve in an unpredictable and non-linear process to enable the co-creation of new value; 2) a process in the structure formation of a self-organised network, whose macro-behaviour cannot be described by the sum of the micro-behaviour of its parts; and 3) composed of different adaptive ecosystems and dependent on its social, economic, political, and cultural contexts (Pyka & Scharnhorst 2010; Russo-Spena, Tregua & Bifulco 2017; Silva & Guerrini 2018; Valkokari 2015; Xu et al. 2020). In what follows, a well-established approach to understanding the innovation complex ecosystem is represented.

2.4.2. Network approach to complex systems

In a highly cited paper, Newman (2011, p. 1112) proposed two basic approaches in research adopting complexity theory. The first approach focuses on the most significant qualitative components in constructing a framework to understand the behaviour of the real complex ecosystem, using tools such as dynamical systems theory, game theory, information theory, cellular automata, networks, computational complexity theory, and numerical methods. The second approach stresses the accuracy and comprehensiveness of the models, using specific sophisticated tools to construct computer simulations of the real system. Due to the main scope of this study, I mainly examine the literature adopting the first approach. Here, the network approach of complexity theory is commonly suggested to accurately understand and examine the innovation ecosystem (Andriani 2011; Carroll 2016b; Pyka & Scharnhorst 2010; Silva & Guerrini 2018; Xu et al. 2020).

As Borgatti and Halgin (2011, p. 1169) pointed out, *network theory* refers to “the mechanisms and processes that interact with network structures to yield certain outcomes for individuals and groups”. Employing *network theory* allows us to explore and analyse the dynamic relationship-based structure of an innovation ecosystem through an abstract representation of interactions and using specific tools to answer questions about this complex phenomenon (Hartmann-Sonntag, Scharnhorst & Ebeling 2004; Mitchell 2009; Poutanen, Soliman & Ståhle 2016; Pyka & Scharnhorst 2010; Russell et al. 2015; Russo & Rossi 2009). However, the increasing interest in the network subject has resulted in the development of several different schools of network theory and analysis (Vicsek, Kiraly & Konya 2016). As Barile, Spohrer and Polese (2010, p. i) pointed out, network theory is both a “systemic way of thinking” to deal with interrelationships and a “methodology” to appreciate and address the complexity of reality. Here, the literature has commonly suggested the use of two prominent network-centric approaches in relation to innovation ecosystems, namely *Actor-Network Theory (ANT)* and *Social Network Analysis (SNA)*. These two approaches have been developed from different philosophical backgrounds, yet scholars are encouraged to carefully find “the potentially fruitful convergence of these two theories” to possibly bridge the weaknesses of each approach (Carroll 2016b; Vicsek, Kiraly & Konya 2016, p. 93; Wickramasinghe & Bali 2011). In the following subsections, ANT and SNA are described in terms of background and theoretical elements. The studies on innovation ecosystems employing these methods are also reviewed. The aim of this study is to build on the relative strengths of these two approaches to meet the research objectives.

2.4.2.1. Actor-Network Theory (ANT)

Actor-Network Theory is an interdisciplinary approach derived from the sociology of translation to understand the complex network of relationships (Latour 1987; Law 1992; Priyatma 2013). It is often considered as a systematic approach to exploring the chain of interactions between diverse actors, including any source of “action regardless of its status as a human or non-human" (Cresswell, Worth & Sheikh 2010; Doolin & Lowe 2002, p. 72; Sayes 2014). This material-semiotic approach aids researchers with examining agency as a relational effect between both human and non-human subjects whose activities are constituted in a heterogeneous network of which they are parts (Carroll 2016b; Cresswell, Worth & Sheikh 2010; Priyatma 2013). This approach is developed based on the idea that the ability of any actor to act lies under the interaction of a multitude of people and things (Bencherki 2017).

The network components are assumed to co-evolve and co-exist with one another, and constantly get translated and reconfigured to reach a stable state over time (Kaghan & Bowker 2001). The stabilisation occurs through the alignment and translation of actors that affect the functioning of the whole network in four prime stages (Cresswell 2019; Greenhalgh & Stones 2010). Having examined the relationships between actors, researchers can suggest how network components need to be reconfigured to arrive at temporary stability to achieve a certain aim (Cresswell, Worth & Sheikh 2010; McLean & Hassard 2004). Moreover, this approach is argued to help to capture the interplay between actors of different ontologies, of different places and of different times (Cresswell, Worth & Sheikh 2010; Latour 1996; Sayes 2014). According to Latour (2009, p. 142), in this ontology, space does not reflect "inside which objects reside" rather space is "one of the many connections made by objects and subjects". Indeed, actors of variable ontologies generate a shared space through the process of translation within an integrated network. The mapped connections between factors "transform the scattered resources into a net that may seem to extend everywhere" (Faik, Thompson & Walsham 2013; Latour 1987, p. 180).

The ANT approach is widely adopted in innovation studies, as it addresses how particular entities and forces become connected and assembled in larger units to serve a common goal (Aka 2019; Carroll 2016b; Cresswell 2019; Latour 1991; Tatnall 2005; Vicsek, Kiraly & Konya 2016). It is believed that human and non-human actors are all equal in an innovation process and the interaction among heterogeneous actors lead to the development of an innovation. Concerning the studies on innovation in the information system, Degelsegger and Kesselring (2012) used the concept of ANT to define and explain the process of social innovations (such as micro-finance, complementary currencies or alternative education programs). Given the relations, translations, and reconfigurations of human and non-human associates, the authors argued that separating technological artefacts from the "social sphere" of humans, where elements of the network co-constitute each other, provides "a naive image of social innovation". Cresswell, Worth and Sheikh (2010) aimed to understand the process of integrating an innovative technological artefact into the healthcare environment. They investigated the formation of new connections between components around a new actor (the new EHR system). As for Cresswell (2019), ANT was adopted to examine how health information technology interventions actively shape human relationships and vice versa. As for Aka (2019), the development of sustainable innovations (as a solution to sustainability issues) require both technological artefacts and business models to capture the relational dimension, as the collaboration between different stakeholders over time is essential to value creation. The author considered innovation as a process and employed the ANT to track the actor's interactions. The relational and temporal dimensions of innovation process were analysed using a sociotechnical diagram. The results indicated that innovation development is a matter of interactions and transformations of actors through time and space.

Although ANT is labelled a "theory" of actants as networks, it is widely considered as a "framework" (Wickramasinghe & Bali 2009, p. 46). Indeed, it may be most appropriately viewed as a tool to describe "how relations do/do not assemble" in a heterogeneous web of connections and "what phenomena are emerging from the network" rather than explain why the phenomena happened (Greenhalgh & Stones 2010; Wickramasinghe & Bali 2011, p. 1288). Further, this descriptive approach fails to assist the researcher with any detailed suggestion of "how actors should be seen, and their actions analysed and interpreted" (Cresswell, Worth & Sheikh 2010, p. 6). In the present study, ANT is adopted as a rich lens of analysis to facilitate a deep understanding of design innovations by examining influential factors within a heterogeneous network without neglecting their interrelatedness.

2.4.2.2. Social Network Analysis (SNA)

Network theory argues that the final behaviour of a network emerges from a combination of seemingly free individual actions. Yet, at the same time, the network acts as a constraint/potential for individual actions and its topology determines the function of the whole system. Thereby, network topology is widely used to analyse factors that impact the properties of the whole network and to examine the outcomes of the network. Considering innovation as a process in the structure formation of a heterogeneous network, there has been a growing interest in mapping innovation ecosystems by adopting concepts of social networks, which is a significant area of the application of complex network theory. SNA allows researchers to characterise the network topology by measuring indicators related to its relational properties (Cherifi et al. 2017; Hartmann-Sonntag, Scharnhorst & Ebeling 2004; Pyka & Scharnhorst 2010; Shipilov & Gawer 2020; Xu et al. 2020).

SNA is a method that aids the process of mapping and examining relationships and flows between network components. Here, actors are represented as nodes while the relationships are shown as edges/arcs. These nodes and edges build the network under consideration, whereby the location of nodes shapes our understanding of the network as a whole and the significant role of individual actors (Wickramasinghe & Bali 2011). Kadushin (2005) and Freeman (2004) described five central features of SNA: 1) SNA employs relational data instead of attribute data; 2) it uses data collected in a systematic method; 3) it relies on the concepts developed from graph theory; 4) it draws on the use of computational tools; and 5) it is the study of flows in a network.

Vicsek, Kiraly and Konya (2016) reviewed studies adopting SNA to indicate the nature of ties mapped in networks. The authors highlighted a variety of ties in the literature, namely kinships, friendships, co-workers, co-authors, the diffusion of innovations, trade flows, flows of information, the transmission of disease, material support, military support, institutional affiliations, and political affiliation. Notably, while most studies investigated relationships between human actors, the method is also considered useful for examining interactions among non-human actors (Vicsek, Kiraly & Konya 2016). Despite the rich literature on innovation ecosystems mapped with SNA, most studies are from the perspective of business, economics and management research focusing on interactions between firms, university and government agencies to evaluate the knowledge flow, and intersections of industry, technology sectors and market relationship (Russo-Spena, Tregua & Bifulco 2017). They commonly apply quantitative strategies (developed from graph theory, chaos theory, fractal theory, percolation theory) to simulate the statistical properties of innovation networks and explain the complexity of innovation ecosystems (Andriani 2011; Pyka & Scharnhorst 2010; Scharnhorst 2003). As pointed out by Andriani (2011) and Xu et al. (2020), the literature on innovation ecosystems using *network analytic approaches* can be divided into:

1. Studies that investigate the topology of networks in relation to innovation diffusion, using *whole-network* analysis. This perspective aims to provide an understanding of the overall structure of the network. For instance, the small-world behaviour of the whole network can be determined by measuring the local density and the average path length between any two agents to examine the knowledge flow (Basole 2016; Cowan 2005; Frenken 2006; Panetti et al. 2019);
2. Studies that examine the ecosystem's sub-environment from a network community viewpoint. The central goal is to examine the structural groups shaped by the network algorithm, using

meso-level analyses (Russell et al. 2015; Xu et al. 2020). Xu et al. (2020) suggested that adopting clusters as a new analysis unit can explain a firm's activities in the inter-organisational system and the evolution of innovation ecosystems; and

3. Studies that focus on the impacts of cooperation and co-evolution between agents in an *ego-networks* and examine the network structural (static) properties (using random graph theory and percolation theory). For example, by calculating the centrality property, the role of a firm in the network can be determined (Pyka & Scharnhorst 2010; Salavisa, Sousa & Fontes 2012; Schilling & Phelps 2007).

Given the lack of studies on innovation ecosystems conducted from a holistic point of view, this thesis stresses the network character of innovation ecosystems and explores both individual and collective impacts of the factors leading to design innovations in hospital buildings. Here, the theoretical concepts adopted from ANT regarding the interactions between both human and non-human actors help to identify and explore which kinds of interactions among which kinds of factors resulted in design innovations within a real complex network. The study of these complex networks requires new suites of methods and might be best to use a combination of complementary theoretical approaches for analysis and interpretation (Cresswell, Worth & Sheikh 2010). Vicsek, Kiraly and Konya (2016) and Wickramasinghe and Bali (2011) discussed the potentially fruitful convergence of ANT and SNA in addressing complex issues. The suggested approach is a hybrid approach that combines the respective strengths of ANT as a *theoretical lens* and tools employed in SNA for *empirical purposes* to map and analyse the relationships in a network (Carroll 2016b; Wickramasinghe & Bali 2009, 2011).

2.5. Summary

This chapter provided the background knowledge of different concepts, theories, and approaches required to understand the complexity of design innovations. It started with explaining the need to adopt a more systematic thinking approach to hospital building design that aims to address multivariate design problems involved in this dynamic and complex building typology. Section 2.1 explored eight interdependent types of design with collective influence on overall hospital building design. Here, the literature widely highlighted the need for considering the close interplay between architectural design, service design and organisational design in impacting operations and infrastructure as the main components of hospital innovation, and therefore these design fields were selected for further analysis. Next, as a prerequisite to the analysis of building design innovations, the concept of innovation ecosystem and its properties were explained (section 2.2). In this thesis, an innovation ecosystem is considered as: 1) inherently systemic and evolutionary composed of interdependent and interconnected components that co-evolve in an unpredictable and non-linear process to enable the co-creation of new value; 2) a process in the structure formation of a self-organised network, whose macro-behaviour cannot be described by the sum of the micro-behaviour of its parts; and 3) composed of different adaptive ecosystems and dependent on its social, economic, political, and cultural contexts.

In section 2.2.4, different types of innovations in hospital design highlighted in the literature were classified into five main categories, namely medical, product, service, process, and organisational innovations. Studies to date aimed to understand drivers and outcomes of innovations, interactive innovation processes, and cross-layer interplays between actors of science, technology and business sub-ecosystems as essential attributes for value creation. However, research exploring design innovations in hospital building design is surprisingly limited. Here, the importance is highlighted of Evidence-based Design (EBD) and Research-Informed Design (RID) as useful tools in generating design innovation and in support of improved healthcare delivery outcomes. The Center for Health Design (2016) proposed an eight-step process for EBD and confirmed "the importance of discovering new knowledge and feeding forward that knowledge to foster future innovations". However, as discussed in the first chapter, hospital building designers, researchers and policymakers face a growing gap between the research evidence base and design practice. In section 2.3 evidence for the existence of the R-P gap in hospital building design was provided and the six chief obstacles leading to widening this gap were explained.

Despite the efforts of studies to inform further innovations in hospital building design through examining and narrowing the R-P gap, the interactions between research and the many other contextual factors affecting hospital design remain to be examined from a holistic viewpoint. Indeed, a real-world innovation ecosystem is comprised of various inhabitants from multiple ecosystems, where changes inside the sub-systems significantly impact/are impacted by the main system (section 2.4). This informs further conversations about how our knowledge on hospital design evolution could be expanded into a broader field, which explores and examines the interrelationships between actors and the contextual factors contributing to the value-creation of the whole ecosystem.

The prime aim of this study is to elucidate the interplay between contextual factors via an explanatory framework that spans ecosystems. I argued that *Complex Systems Theory* can help to understand how these complex systems interact and evolve from a holistic perspective, since complexity theory is based on the significance of mutual causality and interactions between various actors (section 2.4.1). Here, the network approach of complexity theory is commonly suggested to accurately understand, explore and analyse the dynamic relationship-based structure of an innovation ecosystem. Network theory is both a "systemic way of thinking" to deal with interrelationships and a "methodology" to appreciate and address the complexity of reality. Here, two prominent network-centric approaches were widely suggested, namely *Actor-Network Theory (ANT),* and *Social Network Analysis (SNA),* to explore innovation ecosystems. As for ANT (section 2.4.2.1), it is often considered as a systematic tool exploring the chain of interactions between diverse actors, including any source of "action regardless of its status as a human or non-human". The ANT approach is widely adopted in innovation studies, as it addresses how particular entities and forces become connected and assembled in larger units to serve a common goal, where human and non-human actors are all equal in an innovation process. Turning to SNA (section 2.4.2.2), network topology is widely used to analyse factors that impact the properties of the whole network and to examine the outcomes of the network. Considering innovation as a process in the structure formation of a heterogeneous network, there has been a growing interest in mapping innovation ecosystems by adopting concepts of social networks. SNA allows researchers to characterise the network topology by measuring indicators related to its relational properties.

In this study, following a complexity-driven approach, it is necessary to first examine different parts of the system, and the involved factors and patterns triggering design innovation. The theoretical lens adopted from ANT helps to identify and explore which kinds of interactions among which kinds of factors (both human and non-human actors) resulted in design innovations. As this descriptive approach fails to assist with any detailed suggestion of how those contextual factors should be seen, analysed and interpreted, I employ techniques embedded in SNA. Here, the recognised actors and forces are reassembled in a real complex network; the topology and structural properties of which are examined using SNA techniques. The suggested approach is a hybrid approach that combines the respective strengths of ANT as a "theoretical lens", and SNA for "empirical purposes" to visualise and quantitatively analyse the evolution process. For this purpose, the existing data describing the process of hospital design evolution over different time frames constitute the prime source. The next chapter represents the main references and describes the central focus of each source in relation to the larger system. GT studies adopting the theoretical lens of ANT and those employing SNA techniques and strategies are reviewed in chapter four (section 4.4).

03 The Evolution of Hospital Building Design

As explained in the previous chapter, the study of complex innovation ecosystems requires a combination of complementary theoretical approaches for analysis and interpretation. In this study, ANT is adopted as a theoretical lens to explore and identify a very wide range of contextual factors. Techniques embedded in SNA are then employed to visualise and analyse the innovation processes. This chapter reports on the critical texts on the evolution of hospital buildings as the main data sources for the analysis.

First, a historical analysis of hospital design evolution before the study's focus is presented. This explanation is necessary to provide the context for the development of the innovation framework. In the second part of this chapter, a literature review is conducted on the critical texts focusing on hospital design evolution from different perspectives. The key thesis of each source, the structure of the document, as well as their strengths and weaknesses are explained in detail. Moreover, as these references constitute the datasets used in the analysis process, the prime scope of each reference is determined in relation to the larger system. This helps to examine how they complement each other to provide a holistic picture of the innovation ecosystem in hospital building design over the last 100 years.

3.1. The Chronological Essay of Hospital Evolution Before the Study's Focus

History is hardly ever a simple linear process and the historical evolution of hospital building design is not an exception. There have always been some slow transitions followed by radical shifts that make considerable changes in the way hospitals operate (Wagenaar 2006). These patterns of transformation have not always impacted the process of evolution positively. This section aims to sketch the way the modern hospital came into being to provide the necessary context for the rest of the historical analysis.

3.1.1. Ancient Greece and the Romans

Given the definition of hospital as a building designed for care and cure of the ill, it is widely argued that the first hospitals arose in ancient Greece, called Asclepieia (Risse 1999). Since the concept of health and healing was highly affected by religious rites and rituals, the classical temples were taken as a model in designing hospital buildings for the god of health who provided a wholly spiritual treatment (Van den Berg 2005; Wagenaar 2006; Wagenaar et al. 2018). The architecture of Asclepieia indicates that the ancient Greeks believed in the spiritual character of healthcare, particularly the divine powers of nature. They were mainly designed as long and narrow buildings facing south for sunlight and ventilation and were located in valleys at favourable wooded lands near hot or cold springs (see Figure 3-1, Figure 3-2, Figure 3-3).

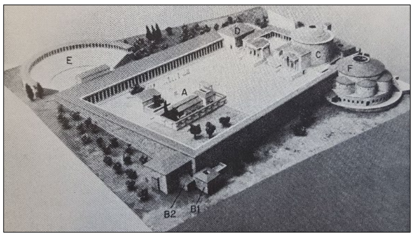
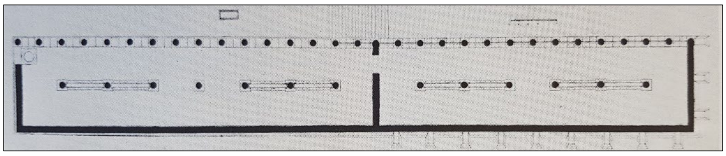




Figure 3-1: The site of the Asclepion of Kos (http://viagallica.com/grece/lang_en/site_asclepieion.htm)
Figure 3-2: A model of the Asclepieion of Pergamon
Figure 3-3: Double hall for dreamer-patients at the Asklepieion of Epidauros (Thompson & Goldin 1975)

By the 1st century, the works and writings of some practitioners started influencing medical philosophy and making foundations for the movement from the Dark Ages to the Renaissance. The Romans mostly contributed to medicine through enhancing public health, such as their innovative public works in advancing sanitary systems, inventing indoor plumbing, and constructing a network of massive aqueducts across the empire (Verderber 2010, p. 13).

3.1.2. The Medieval

The fall of Rome in the 4th century led to considerable chaos that coincided with epidemics such as the bubonic plague across Europe (Verderber 2010, p. 17). With the decline of the secular city-states, the Catholic Church appeared to be more involved in the provision of healthcare from the 3rd to the late 14th centuries. They aimed to heal their sick brethren in flesh and spirit with rituals of prayer, meditation, rest, and the administration of sacraments (Van den Berg 2005). One of the most significant examples in this regard is the monastery and infirmary of Cluny (1043), designed with large open halls (see Figure 3-4). An increase in the size of the wards largely reflects the plan of contemporary churches along with the general tendency toward community living and the growing security after the destruction of the Dark Ages (Thompson & Goldin 1975, p. 15).

It is noteworthy that the structural separation between medicine and surgery was made in the late Middle Ages (Gerstner 1966). Before that, the surgery was done by knowledgeable monks who had some experience in surgical practice. However, in the early 13th century, the Catholic church prohibited surgical procedures - involving contact with blood or bodily fluids. The barbers, the most skilled in the use of knives and other sharp instruments, took charge of the surgery (Liepert, Babu & Leichtle 2011). This separation between medicine and surgery lasted for centuries, and resulted in the design of separate spaces for surgical patients.

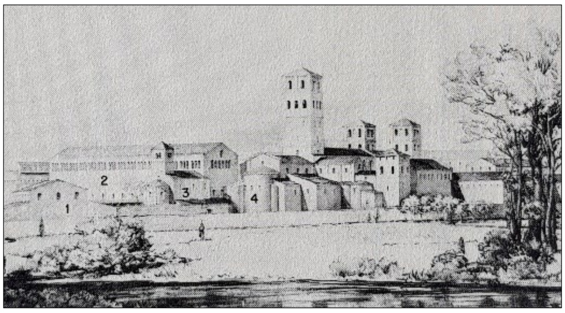


Figure 3-4: The monastery and infirmary of Cluny (1043) (Thompson & Goldin 1975)

Churches tended to create charitable institutions for the poor to help them (Wagenaar et al. 2018). These monastic hospitals placed a central courtyard or garden to encourage patients to contemplate in scenery and God (Van den Berg 2005; Wagenaar et al. 2018). In the 12th century, infirmary hall (ward) and chapel formed one building, yet the ward was entirely separated from the chapel by a wall to the ceiling with a single, central door. The ward was surrounded by large arched windows for air, while the apse was surrounded by much larger windows like those of churches. However, due to the low intolerable temperature of the great stone halls, the open wards were subdivided into individual units with curtains, so patients could warm their cubicles with their own breath. This idea was most evident at the Hotel-Dieu of St. Jean in Angers (1153) with its chapel attached to the rear of the building (Thompson & Goldin 1975, p. 22) (see Figure 3-5). Probably the Hospital Notre Dame is the most noticeable example still standing of a ward opening into its own chapel (see Figure 3-6).

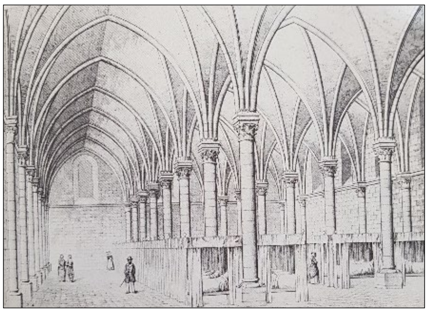


Figure 3-5: Hotel-Dieu of St. Jean in Angers (1153) (Thompson & Goldin 1975)
Figure 3-6: The Cathedral of Notre-Dame de Paris (1293) (https://wallhere.com/en/wallpaper/837666)

This kind of large open ward plan was widely applicable for many years and dozens of such medical centres were built. However, by the 14th century the existing open wards could not support the growth of the population. Given the importance of seeing or hearing the Mass for patients, the best solution was to place the altar in the middle of a cross having wings of the same size. These cross-shaped wards spread across Europe, whereby four times as many patients would be able to hear and see the same Mass (Thompson & Goldin 1975, p. 30).

Gradually, with the rise of the Catholic Church and its singular emphasis on faith as the means to redemption, belief in nature and the therapeutic potentials of the natural environments in treatment was diminished. According to Verderber (2010), natural daylight and ventilation were not the fundamental concerns anymore in most cross-ward monastic hospitals, such as the Hospital des Fontenilles, in France.

3.1.3. Renaissance

The Renaissance revealed a reawakening of interest in classical philosophy, literature, art and architecture. It was mostly developed in Italy between the 14th and 16th centuries. Humanism, as one of its principals, placed emphasis on man in the hospital design and took the account of the human body and scientifically based medical education and practice during the period. In sharp contrast to the previous centuries, designers reconsidered the healing potentials of natural environments in sickness and disease (Verderber 2010, p. 20). The first hospital designed based on the geometrical principles of the Renaissance is the Ospedale Maggiore hospital in Milan (Wagenaar 2006). It was a symmetrical composition with a large central courtyard and eight smaller courtyards formed around two huge crosses. Each cross had two stories that included peripheral rooms for staff, services, and gentlemen (whom were kept separately from the commoners through respect) (see Figure 3-7) (Wagenaar et al. 2018).

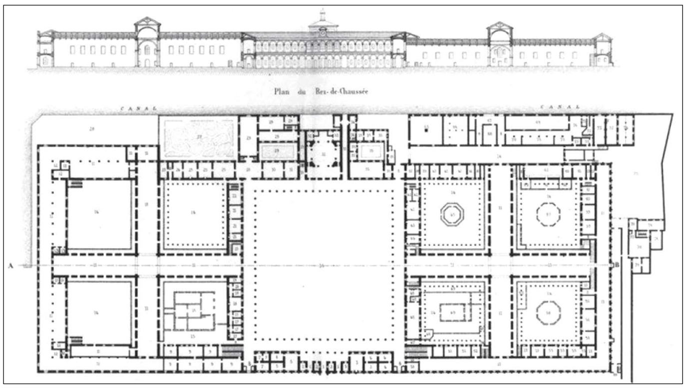


Figure 3-7: Ospedale Maggiore hospital, Milan (1456) (Thompson & Goldin 1975, p. 32)

This growing interest in privacy was also experienced by partitioning of the lord's hall or the monk's dormitory. This trend could be traced to Fountains Abbey, which experienced a significant subdivision after two centuries of its construction - in the 12th century. The hall was separated into fifteen rooms with stone walls and doors (see Figure 3-8). This is also evident in the St. Mary's cathedral hospital at Chichester and the Holy Ghost hospital at Nykobing, Denmark (Thompson & Goldin 1975, p. 41). Feudalism in the late Middle Ages in France led to the design of hospitals with two stories for separating the poor and wealthy more explicitly. The Hotel-Dieu, founded in 1443, is one of the famous cases in which private rooms appeared for the benefit of the upper class (Verderber 2010, p. 20) (see Figure 3-9). In sum, Thompson and Goldin (1975, p. 79) argued that hospitals in the Renaissance were made up of medium-sized wards and some private rooms allocated to the rich people.

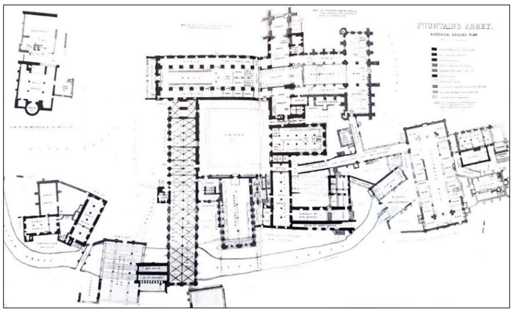


Figure 3-8: Ground plan of Fountains Abbey, Yorkshire, England, showing the infirmary hall as later subdivided into rooms (Thompson & Goldin 1975, p. 43)
Figure 3-9: Hôtel-Dieu de Beaune (1443) (https://it.wikipedia.org/wiki/H%C3%B4tel-Dieu(Beaune))

Another considerable evolution in hospital building design was a decrease in the physical size and the importance of the chapel. It was seen at the palace hospital in Wurtzburg, Germany 1585 and similar institutions built in this period in Italy, England and France (Verderber 2010) (see Figure 3-10). The bourgeoisie built hospitals standing apart from the ecclesiastical institutions in Europe's growing cities. Though often run by the religious orders, they were definitely civic, urban buildings, "donated as an act of charity by a wealthy philanthropist or private benefactor" (Verderber 2003, p. 288).

Figure 3-10: The palace hospital in Wurzburg, Germany (1585)
(https://commons.wikimedia.org/wiki/File:Juliusspital(W%C3%BCrzburg)_02.JPG)

3.1.4. Pavilion hospitals

In the 18th century, new revolutionary thoughts and principles in designing hospitals were realised after one of the most significant hospitals in Paris, the Hôtel-Dieu (1772), was demolished by fire. The Hôtel-Dieu had long been criticised for its inadequate plan design and, eventually, fire resulted in several innovative and fundamental reforms. Jean-Baptiste Le Roy (a physician) and Charles-François Viel (an architect) proposed the replacement of the single massive old institution with 11 smaller hospitals (called pavilion) on either side of a great court. Due to the recognised correlation between high mortality rates and inappropriate ventilation, their design aimed to provide sufficient light coupled with a free circulation of air (Cook 2002; Van den Berg 2005). The design was published in 1789 in the form of Leroy's Précis d'un ouvrage sur les hôpitaux as one of the first examples of a healing machine (Wagenaar et al. 2018) (see Figure 3-11).

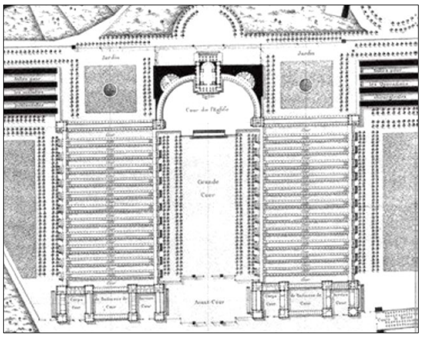


Figure 3-11: Design for the Hôtel-Dieu, Paris, France, Jean-Baptiste Le Roy, Charles-François Viel, 1773 (Wagenaar et al. 2018)

In the mid-19th century, the pavilion architectural style became widespread in many Western countries and was commonly used for hospital design (Cook 2002). However, in almost all constructions, the pavilions were poorly oriented and their inadequate placements caused deficiencies in ventilation (Thompson & Goldin 1975, p. 139). Almost half-century after the first hospital revolution, the Hospital Lariboisière was built on those lines and became widely known as the first pavilion hospital (see Figure 3-12).

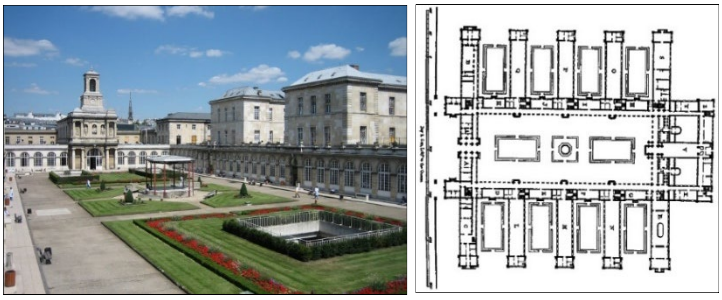


Figure 3-12: Hôpital Lariboisière and its ground floor plan (1846-54) (http://hopital-lariboisiere.aphp.fr/)

Meanwhile, political pressures in the UK for victory in wars boosted the importance of overseas military hospitals. Nightingale experienced an unexpected mortality rate in barracks hospitals in the Crimean war (1855). To enhance the quality of care, she suggested the application of effective medical and nursing principles in the design of military hospitals and published her innovative ideas in two books entitled “Notes on Nursing” (1858) and “Notes on Hospitals” (1859). Nightingale highlighted the importance of five elements in sanitary reforms and securing a health-promoting environment: “Pure air, pure water, efficient drainage, cleanliness, and natural daylight” (Verderber 2010, p. 21). At the same time, the British engineer Brunel designed and pretested an innovative prefabricated barracks hospital that became known as the Nightingale ward.

Among the main features of this ward was the provision of fresh air circulating within a bright, cheerful open space. Each ward accommodated about 30 patients and was replicated in the site in a way that shaped courtyards in between (Verderber 2010). One of the most noticeable hospitals constructed in the American Civil War (1862-65) was the Chimborazo Hospital in Richmond, Virginia. It accommodated 7000 patients in 150 wooden barracks with the same system and plan suggested by Nightingale and Brunel. In 1864, the first Nightingale hospital, called Herbert Hospital, was built entirely under her supervision. As it is shown in Figure 3-13, the pavilions were connected by a central corridor (Thompson & Goldin 1975, p. 165). While the success of Nightingale hospital design was out of the question, even pavilions were liable to become infected and therefore dangerous. American post-war hospital designers, thus, thought to build cheap and temporary hospitals (10-15 years) to prevent infectious diseases by demolishing hospitals after their operation period (Thompson & Goldin 1975, p. 183).

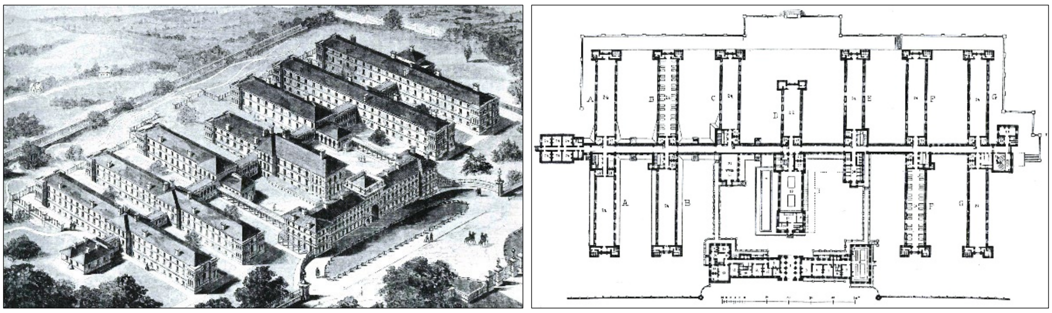


Figure 3-13: The elevation and plan of Herbert Hospital, Woolwich, UK (1864) (Thompson & Goldin 1975, p. 163)

In the late-19th, a major pedagogical shift took place in American medical education. "Poorly regulated, commercial schools offering repetitious lectures" shifted into "standardised, university-affiliated departments dedicated to experiential learning and scientific medicine". Modern medical college buildings were expected to do more than providing the required lecture halls and laboratories (Carroll 2016a, p. 48). At this time a local businessman, John Hopkins, offered seven million dollars for the construction of a teaching hospital in the city of Baltimore. For the first time, a group of hospital professionals consisting of architects, building committee members and hospital consultants drew up five different sets of plans. The selected plan was entirely symmetrical with the administration building in the centre of the façade. Two pay wards for women and men were accommodated on either side of the façade. The whole hospital was built eight years after it was commenced in 1877, as the rest of it was to be constructed with income from its own endowment (Thompson & Goldin 1975, p. 183) (see Figure 3-14).

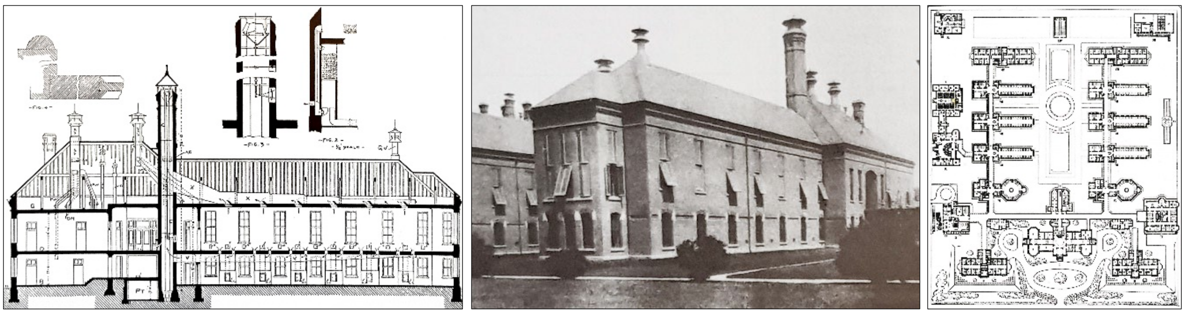


Figure 3-14: Inpatient ward section indicating the small vent openings in the sidewall between every two beds and exterior view, Elevation, and Site plan of John Hopkins Hospital (1877-1885) (Verderber 2010, p. 24).

Regarding the state of chapels and religious beliefs, Wagenaar (2006) pointed out that hospitals built in the late-19th had a new approach to the placement and importance of the chapel. It was no longer dedicated to nature, as had been the case in many late 18th century revolutionary designs. It was, rather, a small Catholic church, located on the central symmetrical axis of the complex. Moreover, liberating the hospital from religion and superstition transformed the hospital into the first functional medical building typology in the history of architecture. While behind the walls of hospitals, science and technology reigned supreme, outside them the church and the old aristocracy still maintained their power. That division made hospitals stand out "as rational islands in a sea of religious and superstitious concepts, as symbols of progress in a world in desperate need of a revolution" (Wagenaar 2006, p. 31). Since this time, hospitals have nearly always been designed as representational public buildings and a precursor of a complete reconstruction of society.

3.1.5. First skyscrapers

In the 19th century, although medical sciences saw drastic advancements in understanding the causes of diseases (such as the introduction of empirical medicine and morphine, the discovery of antiseptic methods, the bacillus of tuberculosis and many other diseases), this knowledge was not reflected in hospital design until the late 19th century - when the medical technologies saw dramatic changes. After the emergence of certain medical technologies like Röntgen's X-Ray machines (1897), building designers gradually placed emphasis on ambience and functional efficiency (Thompson & Goldin 1975). Prior to these innovations, rich people were treated in their convenient homes. Yet, as the physicians no longer had the required equipment for diagnosis, a full population became customers of the modern hospital with its technologically sophisticated diagnostic and treatment capability. As soon as hospitals developed into the pinnacle of medical science and technology, their service became out of reach for the poor (Wagenaar 2006).

Due to population growth and the shortage of large sites in crowded American cities of the early 20th century, the construction of multi-storey buildings was widely demanded. Eventually, in 1910, a detailed plan for a high-rise hospital that would fit into the average New York City block was introduced by Goldwater (a hospital superintendent and consultant) (Thompson & Goldin 1975, p. 193) (see Figure 3-15). As hospitals rose 20 or more stories, the main aim was to fit everything within one shaft or pattern (square, rectangular, X-shaped, or irregular). Furthermore, incredible discoveries in medicine led to defining new design constraints based on the requirements of services. At this stage, the discipline of architecture was largely reduced to the theory of functionalism. That is, forms must be designed for specific purposes. This level of functionality and efficiency was imposed on the entire design of hospitals built before the First World War.

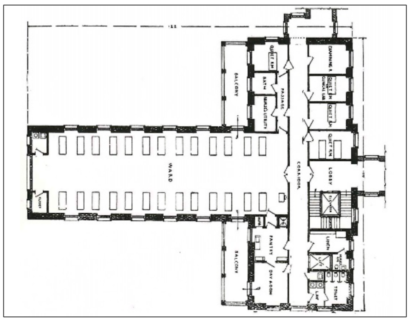


Figure 3-15: Goldwater's proposed T-shaped hospital for a city lot (Thompson & Goldin 1975, p. 197)

To conclude, Figure 3-16 depicts a summary of this chronological essay on hospital evolution. The main features of the hospital building in each diagram demonstrate the patterns of change in hospital design during these ages.

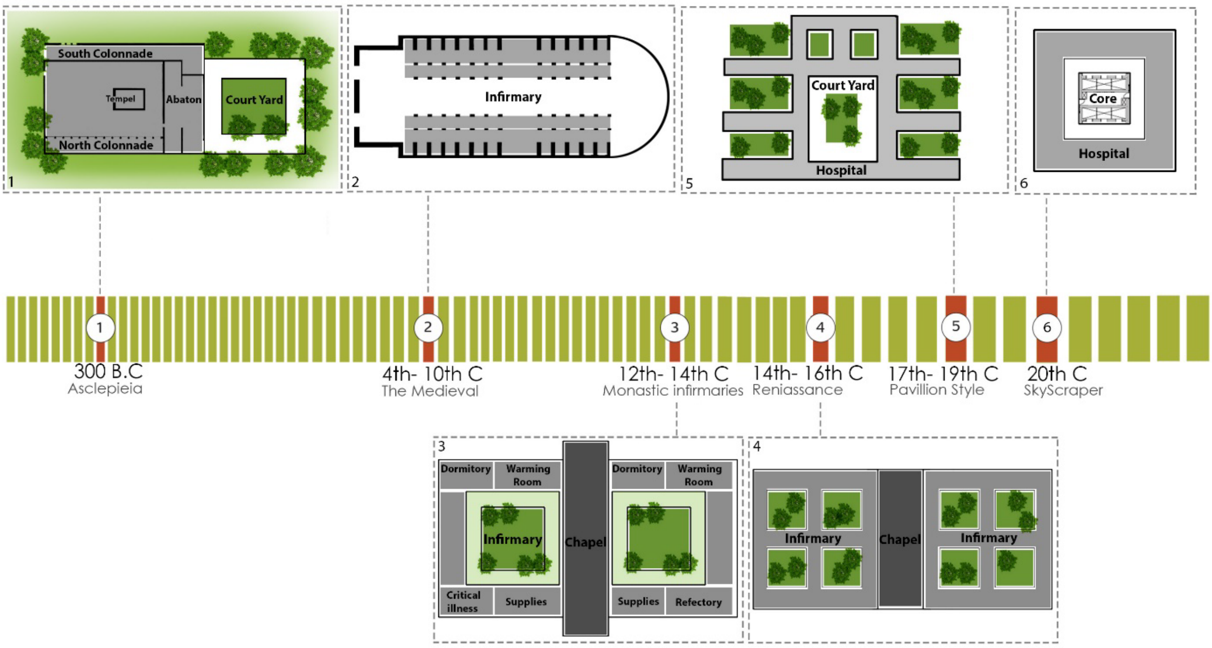


Figure 3-16: Hospital design evolution before the First World War

3.2. Reviews of the References on Hospital Design Evolution

The literature about historical analysis of hospital developments in the 20th century is limited in comparison with those focused on industrial architecture, tall commercial buildings or 20th century housing (Willis, Goad & Logan 2018) (see Figure 3-17). However, the historically focused literature on hospital evolution has experienced a gradual growth recently with the latest books published in this field. "*Architecture and the Modern Hospital: Nosokomeion to Hygeia*" by Willis et al. (2018), and "*Rise of the Modern Hospital, An Architectural History of Health and Healing*" by Kisacky (2017) are the most recent and thorough studies examining the interplay between medical advancements and architectural developments in the evolution of modern hospitals. However, focus on the specific period of modernism highly restricted both studies. The former considered modernism as a global phenomenon, mostly focused on Australian hospitals and limited international hospital design to Stephenson's descriptions gathered from his trips. The authors examined interactions from seven scales (beginning with developments in bed and nurse's stations and ending with the hospital site and the relationships between patients, health providers and architects). Kisacky's book had an extensive literature review addressing the same issue for the period of 1870-1940. She argued that architects should know their role in designing and the lack of studies in the process of hospital evolution may lead to a misunderstanding of "critical sequences of change". Her book was built on John D. Thompson and Grace Goldin's book "*The Hospital: a Social and Architectural History*" (1975), which focused on inpatient wards as a reflection of social and medical developments. It narrated a comprehensive history of hospital evolution from the Roman and ancient time to 1970s hospitals in chronological and descriptive essays, thereby neglecting the main causes behind hospital developments.

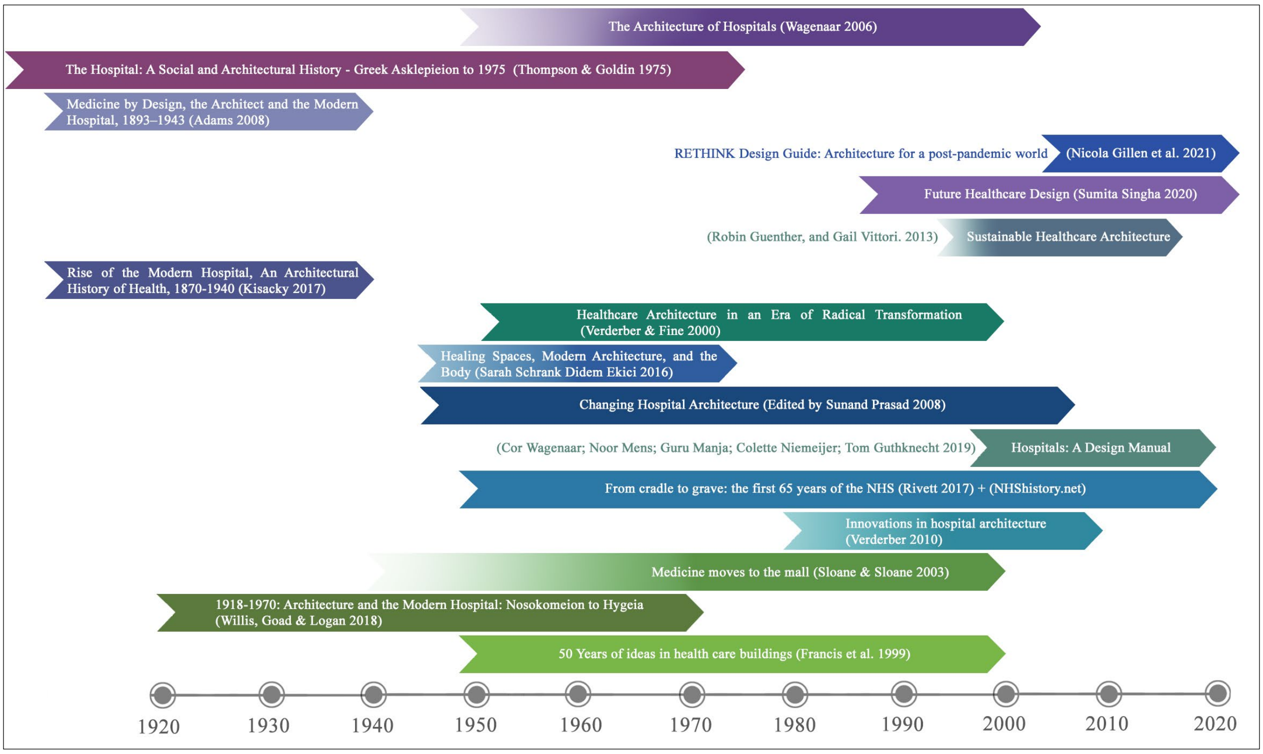


Figure 3-17: The main data sources for the analysis

Similar to Thompson and Goldin (1975), Stephen Verderber and David J. Fine's "*Healthcare Architecture in an Age of Radical Transformation*" (2000) examined the plan as the fundamental generator of hospital design. They aimed to investigate hospital evolution from the 1970s to the end of the 20th century and determine what had worked and failed. Accordingly, the relationship between transformations in social, economic, and technical revolutions and various types of healthcare provision of the 20th century was explored. While the key effects of social, economic or political shifts on hospital building evolution were mentioned at the beginning of each chapter, they failed to support their claims via the related causal relationships between events and documented case studies. Both of these books (Thompson and Goldin (1975) and Verderber and Fine (2000)) represented some Western European and American hospitals as examples.

Verderber, furthermore, published "*Innovations in Hospital Architecture*" (2010) as a sequel to his previous study to reveal the ecological impacts of HCFs. He asserted that hospitals should be designed to not only enhance individual health and wellbeing but also to address ecological challenges. In so doing, Verderber presented a historical analysis to indicate what has worked in specific time periods and examined the evolving role of natural environments in promoting health. However, the principal reasons and causes lying behind these shifts are concealed and the links between incidents are unrevealed. The book ended with a myriad of innovative design suggestions promoting therapeutic support in healthcare buildings. Stephen Verderber also published another book entitled "*Innovations in Transportable Healthcare Architecture*" (2015). This study focused on healthcare design for better assistance in disaster circumstances. He represented a historical analysis on re-deployable hospitals used in past militaries. However, this work cannot be considered an historical analysis of hospital design.

Similarly, three sets of books were published with the same approach as that of Verderber and Fine (2000). The first, Sloane and Sloane (2003)'s "*Medicine Moves to the Mall*", aimed to answer how the evolution of HCFs has introduced new ways of medical practice and new places to practice in the early-21st century. In so doing, an historical case study analysis of American hospitals was employed. It was revealed that the advent of new healthcare landscapes could be described based on the three principal processes: shifts from moral medicine to scientific medicine; humanising hospitals and deconstructing the rationale scientific spatial configuration through post-modernist approach; and changes from centralised to decentralised facilities.

The edited collection of Cor Wagenaar entitled "*The Architecture of Hospitals*" (2006) also aimed to improve hospital architecture through an understanding of its substantial implications on medical outcomes. Wagenaar argued that to attain enhancements in health architecture, we firstly must reassess contemporary hospital architecture and the history of its evolution in the 19th and 20th centuries. This book examines the emergence of modernism, medical advancements, and views on patients as well as the impacts of social, economic, cultural and moral values on historical hospital developments. Wagenaar narrated the story creatively, but only a few selective points and events were covered.

In 2008, nine researchers, architects, policymakers and managers in the field of healthcare design published a book, entitled "*Changing Hospital Architecture*". Prasad (2008) argued that hospitals are "background buildings" in mainstream architectural culture, requiring a significant shift in their design paradigm. The authors examined the evolution of hospital designs in the UK, Europe, the USA, and Australia, and highlighted issues and problems in the design of hospitals from different perspectives. They also used exemplars to show high quality designs and how they had been achieved. Although Prasad (2008, p. 3) believed that the hospital design has not kept up with "the most inventive and progressive developments in art and science", Wagenaar et al. (2018, p. 9) stressed in contrast that "hospitals are back in the frontlines of architecture".

The last set of recently published books aiming to enhance hospital design includes "*Hospitals: A Design Manual*" by Cor Wagenaar et al. (2018), "*Sustainable Healthcare Architecture*" by Guenther and Vittori (2013), and "*Future healthcare design*" by Singha (2020). The authors represented the latest trends and potential issues in hospital building designs for architects, planners, medical practitioners and policymakers. While a summary of hospital evolution was provided in these three works, the main focus was on recent design changes. These books suggest that an innovative building requires designers to adopt a systems perspective and consider various issues related to society, medical processes, organisational efficiency, functionality, natural resources, and environmental and ecological ecosystems. By examining recent successful hospital designs, they aimed to inspire hospital designers to put architectural, social, and environmental design strategies into practice. Further, Singha (2020) argued that current trends (such as growing aged population, wellness revolution and health promotion, greater prevalence of chronic diseases, advances in costly digital technologies, and global warming) are increasing the demand for and expenditures of healthcare centres. She found solution in creating healthy cities and towns.

Annmarie Adams, another key architectural historian, focused mostly on Canadian hospitals of the 20th century. In her book "*Medicine by Design*" (2008), she described existing hospital buildings as historical records of the hidden story behind medical developments. Similar to the aforementioned books, Adams looked for a historical relationship between architectural and medical advancements. The author mainly focused on one hospital (Royal Victoria, Montreal) to trace the impacts of social, political, technical, medical and architectural shifts. Although this focus made her study highly contextualised within international hospital movements, her telling of the story in five thematic essays, instead of chronological themes, is invaluable. She also published two articles about Modernism and Medicine in Canadian hospitals, which examined the main five Canadian hospitals designed by the Boston-based Stevens & Lee's firm. Adams proposed that modern plans designed by the firm were applied in hospital buildings that were covered by historic appearances to smooth their unpleasant impact on urban life (Adams 1999, 2016).

Another innovative book aiming to explain the evolution of hospital building design is "*Mending bodies saving souls*" written by a medical historian (Risse 1999). Risse stated that to fully understand the reasons for the failure of late-20th hospitals, the history behind their evolution should be examined. He continued the approach employed by Thompson and Golden, beginning with ancient and Greek healing spaces. However, Risse narrated the tale via real stories from patients and healthcare providers. His method is worthwhile in farming hospital developments with occupants' viewpoints. However, as Risse is both a medical doctor and a historian, he did not give great consideration to architectural building design; concentrated instead on medical advancements, social and economic aspects. Moreover, the stories of each decade are restricted to specific countries and thus exclude the interactive relationships between place and time.

It is worth mentioning that there are two well-known studies on the evolution of the UK's NHS hospitals. One of them is a report entitled "*50 years of Ideas in Healthcare Building*" (1999), published a year after the fiftieth anniversary of the NHS. It was to report the ideas behind developments in NHS hospitals. The authors classified principal factors and ideas in four categories: "ideas in medicine, ideas in architecture and building, ideas in society and people, and ideas in healthcare policy". Despite their innovative perspective on influential design factors, they only documented ideas related to NHS hospitals for a fifty-year period. This study could be extended to examine influential factors on hospitals built in other developed economies. The second book is "*From Cradle to Grave: The First 65 Years of the NHS*", first published by Geoffrey Rivett in 1988. In 2017, he continued his historical analysis and provided the most comprehensive historical analysis of NHS hospitals. Rivett is a general practitioner by background and a former medical civil servant in the Department of Health and thus involved in many of the linked policy issues. His book indicated a chronological framework of events in terms of both clinical medicine and organisational policies. Yet, the impacts of these transformations on NHS hospital design were not indicated. Moreover, while the author highlighted some background events, such as social shifts, wars, political changes, natural disasters, and technological evolution, interactions between NHS development and other variables were not considered. This is a valuable book revealing medical and technological advancements and their substantial influences on the financial, organisational and structural health system.

There are a few more focused studies on the history of hospital evolution. For instance, Taylor (1997) investigated built hospitals up to 1914 with stress on shifts in British pavilion hospitals. In addition, Wallenstein (2008) examined some hospitals constructed in 1900-1930s and focused on sanatoria (a type of hospital with low height and decentralised organisation base on its design necessities). Here, he considered hospital building as a tool for conveying political subjects to people in an essay-length study.

The next subsections provide details about the aforementioned books and reports, explaining the authors' arguments, their method to address the recognised issues and their strategies to represent the historical analyses. In the last paragraph of each review the strengths and weaknesses are discussed, as well as the features distinguishing the present study from these existing ones.

3.2.1. Architecture and the Modern Hospital: Nosokomeion to Hygeia

The book *Architecture and the Modern Hospital: Nosokomeion to Hygeia* is one of the most recent sources for hospital historians. Willis, Goad and Logan (2018) posited that hospital design was a vehicle for architectural innovation during history – particularly during the modern period. They argued that there was a lack of literature on this topic and most of the existing analyses on modernism were concerned with tall commercial buildings, industrial architecture, and 20th century housing. The authors were interested in modernism as a "global phenomenon" (occurred in approximately 1918-1970) and considered the modern hospital as "a bulwark against persistent ill-health" (Willis, Goad & Logan 2018, p. 1). The main aim of this research is to understand the impacts of modernism and international health architecture on the modern hospital in Australia and conversely their influences on global healthcare centres. Due to the complexities of the 20th century hospitals, the authors examined the development of the modern hospital from different scales and lenses, beginning with the body-centred scale of the bed and culminating in the urban scale of the hospital campus. As the construction of the first significant hospitals in Australia with functional and aesthetic rationales began with the works of Arthur Stephenson (from the 1930s after his international visits of European and American hospitals), the authors mostly restricted case studies to Stephenson hospital designs and his descriptions of the international modern hospital.

This study indicates political beliefs about the importance of physical health on human welfare. It wisely takes into consideration both the profound impacts of hospital buildings on medical practice and providing care, and the inevitable influences of medical technologies on architecture and building design. Moreover, hospital evolution is analysed from seven perspectives of design sites to control for complexity, which distinguishes this book from other historical analyses. The book starts with examining the developments of the hospital bed, which was the site of clinical investigation, a unit for defining hospital capacity in the early-20th century, and a mobile place based on the patients' needs in the 1960s. After that, the authors focused on the improvements of nurses' stations. They found that shifting the position of stations was behind changes in nurses' roles, activities, and social expectations. In the next scale, the properties of operating theatres are examined, including their positions within the hospital, ability of observation by students, necessary equipment, and aseptic standards.

The fifth chapter investigates inventions in treatment and diagnostic machines. They proposed that the shift to drug and radiation therapies decreased the importance of environment and natural treatments. Moreover, the architectural expression of hospitals saw a gradual shift from sun-filled balconies for heliotherapies to completely controlled built environments. Challenges for the design and creation of these highly specialised spaces are documented. The process of change in designing specialised functions is clarified based on the need for adaptation to the latest technical and medical innovations in each decade. About servicing the complex modern hospital, various innovative ways with which architects shaped hospitals are enlightened in chapter six.

In the mid-1940s, modernisation and modernism were integrated, and their social, political and aesthetic values substantially affected the process of programming and designing hospitals. Thus, "aesthetic sophistication" was one of the architectural features for the hospitals that transformed the people's image of hygiene and medical space. These hospitals resembled hotels to meet the needs of being welcoming and marvellous places. In chapter seven, a large number of Australian and international hospitals were examined as a typology based on this approach in terms of beauty and utility, functionality. Chapter eight considers the whole site as a "healing machine" to highlight ideas of scientific progress, medical efficiency and patient wellbeing. Finally, in the last chapter, the authors took the relationship between patients, health givers and architects into consideration. The power of these related groups was reflected in hospital building design; from a controlled, completely mute and passive patient to the advent of evidence-based design focusing on patients' and health providers' needs.

In sum, the authors pointed out that analysing modern hospital developments is significant due to the crucial impacts of design innovations and ways architects reinterpreted the modern hospital via mainstream architecture. Considering the aforementioned points, while this book has a precise look at modernism and its impacts on hospital design, it obviously has not dealt with other architectural styles and periods, particularly hospital developments after the 1970s. While the main aim of this book is to consider modernism globally, it lacks a comprehensive global perspective because it is restricted to Stephenson's descriptions of international cases. Moreover, the authors overlooked the fact that there have been many other influential factors rather than technological and medical developments contributing to this evolution. Last, it might be suggested that it would be more inclusive to examine the influences of mentioned factors on all scales and use subcategories in their classification.

3.2.2. Healthcare Architecture in an Era of Radical Transformation

Healthcare Architecture in an Era of Radical Transformation is one of the most comprehensive sources on health architecture. Verderer and Fine claimed that there are many books focusing on the history of healthcare developments from ancient times to the 1960s, such as the one written by Thompson and Golden. Yet, there is not any comprehensive book that continues the story from where they all left off to the end of the 20th century. Thereby, the main aim of this book is to bridge the gap in the literature of historical analysis and to explore what worked and what failed, as well as why. The authors also targeted the impacts of postmodernism and social shifts on the evolution of health architecture. Here, important transformations in not only the outpatient clinics, but also in psychiatric facilities, retirement communities, and community clinics were classified in six main trends. A critical evaluation of these trends was conducted based on patient perspectives, which reflected a considerable shift from a "provider-driven system" to a "patient-driven one" (Verderber & Fine 2000, p. 5).

Verderber and Fine highlighted that hospitals were the core part of the healthcare system by 1965. However, this role changed during the second half of the 20th century when the decentralised system of community-based care setting came about. This book starts with a very short history of the main waves in the evolution of health architecture from ancient to minimalist mega-hospitals and to the virtual health-scape. The next chapters are made up of descriptions about the dissatisfaction process against modern high-tech medical centres and the advent of the "anti-hospitalism" movement. The first part ends with searching for exemplar schemes for hospitals as a machine for healing, since there were so many pulls and pushes onto the modern hospital by utopian ideas and the social upheaval between 1965 and 1975. They also examined a myriad of related case studies located mostly in North America, and also considered the relationship between this techno-utopian thinking and patients.

The second part begins with emphasising outpatient care in places rather than hospitals and the concept of decentralisation of services. Chapter six focuses on the evolution of patient rooms, particularly the rise of private rooms and the death of open wards in the USA. The study continues with historical analysis of aged care design - from modern nursing homes in the 1960s to the assisted-living movement in the 2000s. Moreover, the rise of the community care clinics, such as specialised outpatient surgery centres in the suburbs, from the storefront urban advocacy clinics of the 1960s is explored. The concluding chapter examines new trends in healthcare architecture defining the new "health culture", such as health villages, home healthcares for the aging and aged population, advancements in medical technologies, sustainability in architecture, and the modified relationships between patients and health givers.

The authors argued the following list of six trends since the 1960s to define a general conclusion within the architecture of the contemporary health landscape: 1) The re-emergence of home and health village; 2) Functional deconstruction and shift from acute-care hospital to the critical care centre; 3) Tension between recipient empowerment and provider empowerment; 4) The advent of sustainable health landscape; 5) Incorporating the natural environment and health architecture as a therapeutic modality in design; and 6) The emergence of interdisciplinary approaches in health architecture to address complex health, environmental design, and biotechnical problems.

In outline, Verderber and Fine considered the connection between postmodernism and transformations in health architecture, as well as innovations in HCFs globally, particularly in the USA. In this regard, they studied plans as "the fundamental generator of the hospital architecture (like Stevens in the early-20th) to track the evolution", based on the economic movement, information revolution and social shifts (Willis, Goad & Logan 2018, p. 16). While this study analyses health architectural trends, Adams argued that "it might not be construed as a historical book" (Adams 2000). The authors began each chapter with statements describing the impacts of social, economic or political shifts on hospital transformations followed by many case studies. However, they only examined the architectural features of each case study in detail, which are not adequate to prove their initial statements and do not represent the causal relationships between them. Altogether, this book is a good source for healthcare historians as it highlights benchmark dates in the international evolution of the postmodern hospital, and the rise of virtual healthcare centres, by stressing commonalities between building types.

3.2.3. Innovations in Hospital Architecture

Stephen Verderber's *Innovations in Hospital Architecture* (2010) is a sequel to his previous book (Verderber & Fine 2000). The key reason for writing his second work was the impacts of urban catastrophes occurring all around the world, particularly Hurricane Katrina in New Orleans in 2005. Verderber thought more thoroughly about cities and their interdependent subsystems after this disaster. He argued that "A medical centre can no longer think of itself as an island, or for whatever reasons exempt from its urban ecological context. It must now demonstrate leadership in environmental stewardship from the building and campus-scale to its neighbourhood, city, and entire planet" (Verderber 2010, p. 4). The purpose of this book is therefore to convince healthcare architects to look at the design process ecologically as well as aesthetically.

The author proposed that hospitals should be designed to foster individual health and wellbeing through ecological responsibility, which addresses issues in terms of psychological health, meaningful work, intellectual openness, individual and social empowerment, cultural diversity, sense of heritage and history, supply-demand tensions over the earth's limited, clean air and water, and healthy standards of living, etc. Regarding these challenges, he suggested that healthcare scientists should set a paragon of ecological stewardship by which the success or failure of HCFs can be evaluated regarding the sustainability, functionality, and aesthetic aspects. In this respect, the applications of Green Guide for Healthcare, Leadership through Energy Efficient Environmental Design, Whole Building Design Guide, Green Star System, and Commission for Architecture and Built Environment are discussed. However, based on global warming, the global shortage of natural resources and the global economic recession have all become daunting. Thus, it is essential to reflect on "how and where we live and work, which equally applies to how and where we receive healthcare, and what those places like" (Verderber 2010, p. 7). To figure out this issue, three main parts constitute the study based on the three recent movements in healthcare architecture: human and ecological sustainability, Evidence-based Design, and aesthetic advances with functional deconstruction.

In the first part, hospital developments are discussed based on the "six aspects of the relationship between the built environment, human health, and sustainability" such as natural ventilation, natural light and view, water etc., which are the recent challenges of designers (Verderber 2010, pp. 9-10). The historical narrative illuminates links between healthcare buildings and these six aspects, which are named as patterns. It is concluded that the importance of these patterns was seen by ancient, lost by medieval designers, reconsidered by Nightingale in the 19^{th} century, forgotten by the emergence of skyscraper hospitals, and rediscovered in the early-21^{st} century. This descriptive essay ends with a comprehensive summative diagram depicting hospital developments and influential features of each decade. The next chapter describes the evolving role of site and landscape in contemporary architecture for promoting health, including the emergence of biophilic design and five recent strategies to integrate indoor and outdoor spaces and break down unnecessary walls. The process of developments in the patient room, along with innovative case studies in terms of aesthetic, functional and experiential aspects, are explored in the fourth chapter. Eventually, Verderber prognosticated nine main trends of health for upcoming hospitals based on the existing global crisis.

The second part represents 100 healthcare planning and design principles for seven categories: site, public and semi-public spaces, PCU, diagnostic units, outpatient service, serialisation, and administration. This chapter provides hospital building designers with innovative ideas in the architectural expression of "aesthetic, functional, symbolic, and spiritual dimensions of a hospital's internal elements, its connection to its immediate site, the role of environmental stewardship, and the importance of local culture and tradition" (Verderber 2010, p. 118). These solutions enhance the level of therapeutic and curative support of healthcare building, which consists of instrumental, aesthetic, emotional and spiritual support. Eventually, in part three, 28 case studies are presented for their creativity in extending convention.

To put it briefly, the historical analysis was presented to explore what worked in healthcare design as it may help "to make sense of recent developments and foster engagement in paradigmatic discourse" (Verderber 2010, p. 10). One of the main deductions of this part is the failure of post-World War II mega-hospitals in sustainability. Thus, architects should learn from the past and broaden healthcare healing missions to embrace and respond to other challenges, such as site, social community, the natural environment, cultural identity, and resource conservation etc. While this book explores the main trends and events in the history of hospital development, reasons and causal relationships between incidents are not determined. This is also evident in chapters such as those on "the evolving role of site and landscape" and "the evolving role of patient room". The causes of these developments and advancements remain unrevealed. While many innovative design considerations, along with successful case studies, are recommended, in-depth explanations about their direct and indirect impacts on the healing process are needed.

3.2.4. Hospitals: A Design Manual

The book *Hospitals: A Design Manual* is the result of teamwork between healthcare architects, hospital historians, theoreticians and researchers. Wagenaar et al. (2018) aimed to provide a tool that aids hospital architects, planners, policymakers and medical practitioners in changing designs for better care by representing the latest trends and potential issues in hospital architecture. Here, design decisions are argued to be considerably impacted by a wide range of contextual factors specific to each design. The authors highly recommended architects not to limit their contribution to spatial configuration and building form. Indeed, a successful and innovative hospital design requires architects to adopt a systems perspective to issues related to medical processes, organisational and financial efficiency, spatial logistics, infrastructure and programming.

This book contains four main sections explaining recent developments and future challenges in hospital building design, as well as a selection of case studies describing design ideas of forty recently designed hospitals and clinics. The first section entitled "defining the hospitals of tomorrow" describes a paradigm shift in the position of hospital users (particularly patients), which goes beyond the concept of patient-centred care to making patients involved in their medical decisions with the use of information technologies. Moreover, this part represents a summary of the role of hospitals in promoting public health since the 19th century, and a comparison between traditional supply-based systems and demand-driven systems in healthcare facilities. It is argued that a sound business model that considers different aspects of hospital design and future needs is essential to make this paradigm-change happen efficiently. The second section (designing hospitals) explores three phenomena that have recently impacted hospital architecture, including the transition in institution identity (centralised vs decentralised and network facilities), the new care pathways and the role of evidence-based design. This part concludes with a historical overview examining the emergence of different hospital typologies since the 15th century, and the failure of those types. The third and fourth parts introduce most of the functional components of a hospital in their public spaces and treatment areas. Here, different design options adopted from contemporary successful designs are investigated in relation to issues and trends in the patient care pathway. Last, pictures, drawing documents, and explanations of concepts and issues in the design of forty hospitals across Europe and the USA are presented.

In sum, this manual assists architects with understanding their substantial contribution during the entire lifespan of a hospital building and finding their way in the current evolving field. It focuses on the profound responsibility of architects in designing hospital buildings in a way that considers the aforementioned factors to enhance hospital functionality, organisational efficiency and service processes. Here, while advancements in medicine and technology have a significant role in hospital design, the prime focus is suggested to be on caring for people and improving the care processes they experience. This book provides a valuable data source of recent trends and design innovations in relation to the specific context of each hospital (such as the demographic and population characteristics, healthcare systems and political decisions, economic realities, etc.). However, explanations of different hospital designs are mostly limited to recent case studies and the reasons behind those innovative designs and the role of contextual factors are not examined in detail. Moreover, while Wagenaar et al. (2018, p. 11) argued that shifts we experience today have been preceded "by similar transitions in the past", this book does not describe such an interconnected history of hospital design. Thus, the information provided covers only a part of the bigger picture of hospital design evolution. Notably, the books "Hospitals: A Design Manual" and "Innovations in hospital architecture" both provide arguments about the current and possible fundamental trends in hospital building design that makes them distinct from other historical books.

3.2.5. Medicine Moves to the Mall

David Charles Sloane and Beverlie Conant Sloane, who are a practising physician and a professor in policy, planning and development respectively, published their book to add knowledge about new healthcare landscapes to the existing history of the hospital developments. They focused on the spatial relationship of patients to places where medicine was practised, and the impacts of modern market culture on them. The authors considered "how the creation of the hospital represented not just a new way to practice medicine but also a new place to practice it" (Sloane & Sloane 2003, p. 5), how HCFs changed, and what were the impacts of the shopping mall model on current hospitals. The shifting process of medicine to the mall is represented in three chapters based on three main transformations. Each chapter is followed by a section depicting a series of case studies regarding respective change in American hospitals. Firstly, a change from moral medicine and pavilion hospitals to scientific medicine and healthcare designs of the early 20th century. The authors examined this process from home-style medicine to home as a hospital, hospital as home, pavilion styles with natural ventilation, hospital as an accepted necessity for everyone, and finally the efficient vertical hospitals of the modern period. This chapter ends with several critiques about technology-centred medicine and modern hospitals.

Secondly, the second chapter discusses the transformation caused by the impacts of postmodernism on the scientific spatial configuration of hospitals. It starts with the description of the Mary Hitchcock Hospital design (1991) using elements of the shopping mall, the hotel and the home via four principal movements in its design. The first was the loss of modernist faith in the hospital design and demands for a post-modernist approach. Secondly, due to considerable dissatisfaction among patients and nurses, there was a need for considering patients' both physical and psychological aspects. Thirdly, growth of outpatient medicine led to the importance of accessibility. Lastly, hospitals stood in need of other sources of income because of competition and the lack of government reimbursements. This chapter also discusses the transformation in the way the patient is viewed as one of the steps in the process of humanising hospitals, and the advent of the patient-centred approach.

Thirdly, a drastic shift occurred from centralised hospitals to decentralised HCFs, many of which moved to commercial venues as a result of the changing relationships of medicine and modern market culture. However, many concurred with the idea that "they are not appropriate places for professionals to practice the sacred art of medicine" (Sloane & Sloane 2003, p. 136). While centralised HCFs might provide patients with a plethora of amenities for acute care, the fast pace of the medical system is evolving and making access, visibility, and expense increasingly important, which centralised hospitals may not come up with. This chapter ends with explanations of the new healthcare landscape, such as satellite clinics in malls for minor illnesses. The author proposed that "from the dental offices in the local shopping centre and the "doc-in-a-box" in the mini-mall to the optometrist's shop in the regional shopping centre, these decentralised HCFs are reshaping our experience and perception of healthcare" (Sloane & Sloane 2003, p. 165).

Consequently, due to shifts in the location and architectural design of HCFs, the relationship between doctor and patient, as well as the perceptions of medicine, will be changed; which in turn will reinforce other institutional shifts occurring in HCFs.

In sum, this book represents the relationship of healthcare design evolution with transformations in medical practice, market culture, and the perspectives and demands of patients and health givers. The main argument centres on the inevitable advent of hospital malls as a reflection of economic and social shifts of the late 20th century, such as the growth of automobile culture and the need for more consumer-friendly, accessible, flexible and cost-effective health centres. The authors employed a historical approach and used American hospitals as case studies for evidencing their claims. They also suggested how a fragmented healthcare landscape with highly specialised facilities will lead to a different health culture in the near future. It is an invaluable essay-length study about the history of American health architecture from the 19th to the end of the 20th century.

3.2.6. From Cradle to Grave: The First 65 Years of the NHS

The book *From cradle to grave: the first 65 years of the NHS* was first published by Geoffrey Rivett in 1988, and covered the first 50 years of the NHS's history. In 2017, he continued his historical analysis and changed the topic to the first 65 years of the NHS. Rivett is a general practitioner by background and a former medical civil servant in the Department of Health, who was involved in many of the policy issues. He was personally engaged in policymaking, and that experience triggered the publication of this book. The author believed that the NHS has few employees born when the NHS was established in 1948. Thus, people might not pay sufficient consideration to its beginnings or how it progressed.

This book indicates the story of the NHS, how it was founded, and a chronological framework of the important events that happened during these years in terms of both clinical and organisational incidents. Clinical advancements are examined to demonstrate the impacts on the whole financial, organisational and structural health system, such as the emergence of new methods of care or even new models of organisation. Moreover, Rivett looked at interactions between three main parties engaged in the NHS developments, namely "those needing care, those who deliver skilled care and those whose task it is to raise the money and see it properly spent". He mentioned that there was not an ideal method to split this long story. Thereby, he began his book with an introduction of the fragmentation of pre-war health services and the NHS status in 1948. The following chapters provide a chronology of events in the NHS for each decade. Despite the apparent complication in the range of events and topics at each decade, the author chose a consistent structure for every chapter. Consecutive chapters start with changes in social demands, and developments in medical science, followed by advancements in general practice and primary healthcare, as well as hospital and specialist services. Last, transformations in medical education and organisational systems are explored, so the reader can follow a particular phenomenon or event during each epoch.

This book has limitations but also strengths that distinguish it from other studies. First, the story is limited to England and excludes Scotland, Wales and Northern Irland, let alone other countries. Moreover, Rivett argued that this book did not aim to investigate the political background of the story deeply. On the other side, a strength is the use of contemporary terminology by the author in describing the events. It is also worth mentioning that in the chronological content of each decade, the author highlighted background events such as wars, natural disasters, Energy privatisation, housing boom, and technological advancements and etc. In sum, this book provides the most comprehensive historical analysis of the NHS since 1948. It mostly places emphasis on the medical and organisational progression of the NHS and its relationships with technological shifts as well as brief links with corresponding social, political, educational transformations. Indeed, as Berridge (1998) argued, this is essentially a medico-technical view of the NHS. However, the sections describing hospital building is very limited and do not examine the impacts of policy transformations on health architecture accurately.

3.2.7. Rise of the Modern Hospital, An Architectural History of Health, 1870-1940

The book entitled *Rise of the Modern Hospital, An Architectural History of Health and Healing* examines architectural developments in hospital design between the Civil War and the beginning of World War II in the USA. Jeanne Kisacky presents a detailed analysis of American hospitals based on existing literature written by hospital historians such as Charles Rosenberg, Rosemary Stevens, and particularly Annemarie Adams. Kisacky argued that there was no thorough historical analysis about the transformations that occurred in hospital building, shifting from a therapy itself to a tool developed based on medical and technological improvements in the period of 1870 to 1940.

In the mid-19th century, the hospital was expected to play a significant role in the healing process. It was a charitable low-rise pavilion considered as a "container of general care" (Kisacky 2017, p. 3). This therapeutic space provided inhabitants with natural light and fresh air in an orderly environment. In the mid-20th century, this belief changed to seeing the hospital as a tool that was developed through evolutions in medical science and technology. These two opinions around the role of the hospital in treatment were believed to be a debatable discussion between hospital designers and medical practitioners. On the one side, some medical and architectural historians argued that the progress of medicine called for the new type of hospital in the late-19th century (Henry E. Sigerist), or hospital plans were considered as "archaeological records of medical knowledge" (Lindsay Prior). However, other historians accepted the reverse explanation and mentioned the substantial impacts of hospital design on medical practices (Michel Foucault).

Kisacky proposed that understanding this shift in hospital design would be essential, firstly, in the process of building developments, deciding which hospital is worth saving and needing renovation. Secondly, the lack of studies about how and why American hospitals experienced this transformation, from decentralised pavilions to centralised high-rises, may lead to "distortions and even misunderstandings of relevant influences, essential chronologies, and critical sequences of change" (Kisacky 2017, p. 5). The main aim of this research was to address the dilemma of considering hospital design as a cure and an influence on medicine and culture or considering medical ideas and culture as an influence on hospital design. Of course, it was (and is) both. The nature of hospital design and medical science are bound to each other, which helps us understand the process of development in hospital design from 1870 to 1940. She also emphasised that this study is not important only because of telling the story from this viewpoint, but also to elucidate our role as architects in designing hospital buildings.

This study begins with the pavilion hospitals of the 1870s, designed by general architects and physicians. At that time, hospitals were generally considered unhealthy places and debates raged over whether to construct permanent hospitals or to build temporary ones to be obliterated in completely contaminated cases. In chapter two, the potential impacts of germ theory on hospital design are examined. By the end of the 1890s, pavilions were designed for specific functions and patients based on the new needs of asepsis and institutional efficiency. The architecture paid much attention to materiality such as finishes, internal structures and ventilation systems. Also, designers started thinking about new specialised spaces like operating and teaching rooms, and the site of new hospitals on an urban scale. Moreover, to promote the efficiency of hospitals, designers came up with the idea of nursing units to increase the performance of nurses by decreasing travel distance. Chapter five describe how hospital design was affected by World War I and economic challenges, which contributed to organising vertical and compact high-rise hospitals. The book ends with the efficient and flexible hospitals of the 1940s.

In a nutshell, this historical analysis of hospital design asks architects to understand "what kind of health is sought, and what role the physical surroundings are expected to play in its acquisition" (Kisacky 2017, p. 9). This is valuable research examining hospital design developments in terms of the built environment impacts on the healing process, and the inevitable effects of medical sciences on hospital design. However, the author did not consider all influential factors on hospital design, such as advancements in research, technology, meaning of health, social structures, and philosophy. The study is mostly restricted to limited case studies from the USA before the 1940s, and particularly hospitals that were examined in the existing literature. While the author also considered the European hospitals which affected them, this selectivity excluded many worthy hospitals located in other powerful and influential countries.

3.2.8. Medicine by Design, the Architect and the Modern Hospital, 1893–1943

Annmarie Adams published the book *Medicine by Design, the Architect and the Modern Hospital* in 2008. This study strives to locate the built environment and hospitals in the story of medical evolution. It sheds light on the interactive factors between medicine and architecture in hospital development from the late 19th to the first half of the 20th century. Adams highlighted that there is no accurate causal relationship between innovative moments in hospital design and advancements in medical sciences, instead stressing the direct or indirect impacts of them on each other. While medicine historians concur with the idea that hospitals are simply passive reflections of developments in medical sciences, some architectural historians propose that hospitals have acted as a catalyst in this evolution. To explore the links, Adams firstly selected Canadian hospitals in a 50-year period, based on her expertise and their significant impacts on the hospital history. Secondly, hospitals of the interwar period that experienced a fundamental revolution in their design were examined. She began the story with the construction of The Royal Victoria Hospital in Montreal (1893) and ended with the retirement of Edward Steven, a North American architect who was specialised in hospital design (1943).

Adams applied the case study approach to hospital buildings in the context of other building types to find out "how architecture and medicine intersected in the arrangement of the general hospital through affecting each other and how physicians and architects work together to modernize and develop the 20th century architecture?" (Adams 2008, p. 19). Notably, she focused on "The Montreal Royal Hospital" to track the impacts of huge social, technical and architectural shifts on hospital architecture and to examine relationships between architectural and medical advancements. The author's historical analysis is in five thematic essays. The analysis starts with setting the stage by explaining various architectural features of hospitals, particularly The Royal Victoria Hospital, such as wards, surgical theatres, light and air ventilation systems, to name just a few. Then, the users of the hospital are examined in terms of their social class, age and gender. The new architectural challenges of accommodating the emerging groups of patients in the 1920s and 1930s, including "paying patients, outpatients, pregnant women, and children", are discussed in chapter two. In the third part, the evolution in nurses' residences and stations within the hospital site reveal the changes in responsibilities and roles of women at home and their profession during the 50-year period. The fourth essay is about the emergence of hospital architects and hospital consultants as well as the rising tension between them and physicians in the design process. Last, architectural features in interwar hospitals are explored in the fifth chapter. Adams assumed that the modern hospital of Steven and other designers of his generation include flexible and functional plans in modern clothes to "smooth the effects of social and medical changes taking place within the walls" (Adams 2008, p. 25).

In sum, architects, designers, health providers and patients are believed to play key roles in creating and shaping the design of a complex, futuristic, hybrid and highly specialised building typology, called the hospital. Although most of the historical analyses are organised in a chronological or spatial format, this book is presented in five thematic essays to emphasise the social, political, and cultural challenges of the design process. While studying hospital history based on the "buildings as historical records in and of themselves", Kisacky asserted that "if the buildings (and drawings) are to speak for themselves, then it is essential to determine how it is they speak, and what it takes to prove that they are heard accurately in this study" (Kisacky 2010, p. 250). Moreover, as Adams tended to focus on hospitals designed by Stevens the story that she tells has clear limits. It is also highly contextualised, and therefore the results can hardly be generalised to the international hospital movements (Willis, Goad & Logan 2018).

3.2.9. 50 Years of Ideas in Healthcare Buildings

The Nuffield Provincial Hospitals Trust conducted surveys to find the main defects of hospital services in the early-1940s. These reports were published as the first Blue Books, considered as the main reason for the foundation of the NHS Act in 1946. The study, entitled *50 years of ideas in healthcare building,* was reported a year after the 50th anniversary of the NHS. The main aim was to revisit the history of NHS hospital buildings to identify the ideas that influenced them. These ideas had significant impacts on creating NHS healthcare buildings and the research provides architects with in-depth consideration of their roles, as well as understanding of interactions between theory and practice. The report categorises these ideas and their origin into four broad themes. The first is the practice of medicine, examining the impacts of antibiotic discovery, the emergence of drug-resistant bacteria, and advancements in organ transplantation on the architectural design of NHS hospitals. Secondly, ideas about architectural and technological developments in other building types, such as industrial production and prefabrication in Britain. Ideas around society and people to whom buildings belong shape the third theme, including consumer movement and expectations of convenience. The last source of ideas is the developments in healthcare policies and management in the NHS, such as official design standards.

The report starts with the impacts of research on designing HCFs. The first two chapters introduce the foundation of different research groups (such as "Hospital building Division" and "Medical architecture research unit") and the research conducted by them (like "studies in the function and design of hospitals"). Chapter three defines the systems, standards and standardisation of NHS hospitals over 50 years, such as the hospital Building Notes, Best Buy standard hospital, CAPRICODE, Standard Departments, Harness System, and Nucleus System hospital. Chapter four explains the interplay between theory and practice. Some theories like the balanced teaching hospital, tree hospital and low energy hospital are accompanied by their reflection in built hospitals. The report ends with a general description of ideas about the therapeutic environment, sustainability, and advancements in medical and information technologies.

This is the first and only study considering the impacts of such a broad range of factors on hospital evolution. It represents these in a table with four rows – named ideas in medicine, ideas in architecture and building, ideas in society and people, and ideas in healthcare policy and the NHS – along with the pictures of related case studies. of course, it only covers NHS hospitals and only between the 1940s and 1990s. It also does not include the impacts of research done in other fields, such as environmental psychology, and research conducted in other developed economies. Technological and medical developments were also largely overlooked. Altogether, this is a valuable study for realising the interplay between theory, the role of architects and society, and design practice.

3.2.10. Changing Hospital Architecture

The book *Changing Hospital Architecture* is the result of collaboration between nine researchers, architects, policymakers and managers in the field of healthcare design, published in 2008. Prasad (2008) argued that the design of hospital as a complex building type could not keep up with developments and progress in art and science. The authors saw hospitals as “background buildings” in mainstream architectural culture that were not of interest to designers, and believed there was a need for reinventing hospitals by developing a new paradigm. The prime aim of this book was therefore to provide a “tool” that highlights the issues and problems, shows exemplars, and identifies potential inaccuracies. In doing so, evidence provided by way of high quality designs and how they have been achieved.

This book contains eight chapters. The first section reviews the progress of hospital design, particularly the evolution of the NHS and hospitals in the UK. It examines the shift from the hospital to a deconstructed healthcare structure by considering the broader context of technological, sociopolitical and economic developments. The second chapter explains the importance of the pre-design phase and formulating the hospital brief. It is argued that hospital building design and organisational design should be integrated with value creation and address users’ expectations for better care. Next, changes in financing, procurement and design of hospitals are examined to find out potential ways of improving PFI processes. The first part is followed by four chapters exploring hospital design evolution and successful case studies in the UK, Europe, the US and Australia. The book ends with a discussion and prediction of the architectural form of the future hospital.

In sum, this book looks at hospital design evolution, from the 1940s to the early 20th century, and explains the need for a new paradigm. The historical overview explores the potential issues in the developed hospital type that eventually resulted in speculations on the architectural form of the future hospital. The book also examines a wide range of innovative hospital designs classified in relation to the building typology - showing how the four basic components, treatment areas (including theatres), wards (nursing units), outpatients (including diagnostics) and servicing are arranged.

3.2.11. Sustainable Healthcare Architecture

Guenther and Vittori (2013) published *Sustainable Healthcare Architecture* as a guide to sustainable design and environmental stewardship. The authors called for an urgent need for planning, development, design, and construction of restorative and regenerative healthcare facilities. They believed the healthcare industry must hold leaders in the construction industry to promote building designs that "do no harm" – human nor ecological harm (Guenther & Vittori 2013, p. 162). The main aims of this research were to represent the impacts of sustainable design on the economy, politics, human health and performance, as well as natural resources and environment, and to provide recent exemplars of how to put ecological design strategies into practice.

This book contains four main parts. The first part explains the adverse influences of human activities on the Earth's ecosystems, resulting in natural resource depletion, climate change, water pollution, etc. It stresses the need to change the principle of our stewardship of the earth to the idea of sustainable development. This chapter represents a solid foundation for sustainable development (green, ecological and living building design) by including essays on topics such as integrated design, the relationship between nature and healing, and commissioning. Part two, *Actualizing the Vision*, is made up of three chapters. Here, different metrics and tools for healthcare are explained, such as LEED, BREEAM, Green Star, and the Living Building Challenge, and their specific prerequisites are determined according to 13 key sustainability indicators. Further, concepts such as carbon neutrality, net-zero energy, healthy material and zero-waste in the design of hospitals are examined. A wide range of examples is also provided to demonstrate how these theoretical concepts can generate innovative designs. The next chapter focuses on the threefold benefits (social, environmental, and economic) of sustainability on individuals, buildings, communities and environment. The authors highlight the strengths of design that considers requirements both inside and outside the building.

Part three provides a wide range of case studies with descriptions of their design innovations related to sustainability indicators. In the last part, the authors explained the process of change in the design of healing environments with a shift from technology-focused to people-focused spaces by the early 21st century. Further, they highlighted the importance of bio-regionalist design language in shifting the hospital role to civic architecture. Sustainable design considerations are argued to impact hospital building typology for a more climate-responsive and place-centred hospital design. It is argued that these restorative and regenerative hospital designs are more resilient, transparent, connected to communities, supportive of health promotion, and most importantly, supportive of broader ecosystem services. They demonstrate a commitment to saving lives and improving health without undermining ecosystems or diminishing the world.

In sum, this book represents a thorough explanations of current ecological issues and innovative sustainable architectural designs in the healthcare industry. It provides a sound theoretical foundation for architects looking for ecological design innovations. However, as Cuddeback (2014) pointed out, many new environmental regulations (e.g., the Affordable Care Act) were legislated while the second edition of the book was being published, and therefore the significant impacts of these regulations on healthcare construction are not examined. While the book explored recent case studies applying sustainable considerations, it overlooked the evolution of healing environments.

3.3. Critical Discussion

The evolution of hospital building design is widely seen to be significantly slow, requiring the involvement of several factors, including the emergence of breakthrough technologies, innovations in medical practices, social transformations, new healthcare policies, etc. (Prasad 2008; Singha 2020; Verderber & Fine 2000). The gap between the initiation of ideas and their implications into practice has always been critical. As explained in the first section of this chapter, the gap between the ideation of thought, developing its application into hospital design, and finally construction often took a considerable amount of time. For instance, as Wagenaar et al. (2018) noted, the pavilion typology had been developed more than 40 years before the construction of the first pavilion hospital building (Hôpital Lariboisière (France, 1854)). Also, the Crimean War of the mid-1850s was the main reason for the construction of innovative field hospitals with separate barracks (an arrangement advocated by Florence Nightingale), and for their realisation in the Royal Herbert Military Hospital (the UK, 1871). However, the pivotal question here is why it takes so long between design innovation and its implementation in practice?

In the second section, the most significant texts with comprehensive historical analyses on hospital building evolution were reviewed to determine knowledge gaps. In this process, the arguments identified by the authors, their aims, the way they approached the problems and their strategies to represent the findings, besides the outcomes of each source, were explored. This section provides detailed reviews on the pivotal books and reports related to hospital design evolution. While other sources, particularly white reports and journal articles were studied thoroughly, they are not mentioned in this section.

In sum, critical review of the literature highlights the somewhat disjointed nature of the body of research and points to the need for a full description of the interconnections and interrelationships between the different contextual factors that have incrementally shaped innovation in hospital design. This gap of understanding includes lack of consideration of the whole modern era of hospital design evolution, from the 1920s to the present, encompassing the modern, late-modern, post-modern, and sustainable architectural styles. Moreover, while a few recent works have begun to fill the gaps, these have failed to elucidate how change triggers innovations across different locations because they have largely been geographically specific, and thus present only a small piece of a much larger picture.

Addressing these gaps in my study, existing historical analyses are combined to describe the evolution of hospital building design via holistic understanding of the full range of historical factors that have triggered innovation. The Mixed Grounded Theory (MGT) methodology was adopted to comprehend the phenomena and develop a context-based, explanatory innovation framework grounded on real data. All data sources (historical analyses) provided the information required for developing a framework that conceptualises the evolution of hospital building design via understanding of the main factors triggering innovative moments. In so doing, a table was first drawn to highlight the data provided by each document, with the references as rows and their information as the columns that also represents and defines the main categories in the process of GT analysis (see Appendix 9.3.1). Providing this table helped significantly to define the categories (parent and child) based on the data gathered from each document, as well as represent the related data sources for making decisions about reaching the saturation point. The next chapter explains the research design in detail and explains how the adoption of a novel multi-representational approach to MGT methodology helped me generate the final innovation framework.

04 The Research Design of Mixed Grounded Theory

This chapter describes the research design and methodology in detail. Given the many approaches to MGT methodology, the prime aim of this chapter is to justify my choices - *why* and *how* the proposed combination of different analysis techniques and methods facilitated the analysis process of this study. In the next chapter, a detailed reflection is provided of the analysis process in relation to the specific properties of the data collected through this study - *how* I applied those strategies and *what* resulted from each stage of the analysis.

This chapter starts with a brief description of the research design, indicating the choices of research paradigm, methodology and strategy. Next, the background of GT methodology is explained and a critical comparison between the three main schools of thought (Glaserian, Struassian, and Charmazian) is provided. Charmazian constructivist approach of GT was selected in accordance with the research objectives and the thesis philosophical stance. Having used the Charmazian steps for the iterative process of GT data analysis, the third section explains the issues I faced during the initial and focused coding in addressing the objectives. Thus, two different analysis methods were merged into the common process of focused coding. The next two sections examine how a set of creative diagrammatic representations as well as their associated analytical techniques can be employed to enhance the analytical and interpretive process of data analysis. This novel approach is explained in detail for studies employing the MGT methodology.

4.1. Research Design

This chapter starts with a brief description of the research methodology employed in the present study. According to Maxwell (2012) and Creswell and Creswell (2017, p. 5), designing research and selecting the methodology is subject to the nature of research problem, content consideration, as well as the assumptions made by the researcher regarding the problem and choices of procedures of inquiry with regards to:

1. *What knowledge claims are being made by the researcher?*
2. *What strategies of inquiry will inform the procedures?*
3. *What methods of data collection and analysis will be used?*

All the assumptions that have been chosen for these inquiries have defined the research paradigm, methodological choice, and strategy of the present study in an entirely iterative process (see Figure 4-1). The reasons behind these choices are articulated in the following three subsections – on the chosen research paradigm, methodological choice, and strategy.

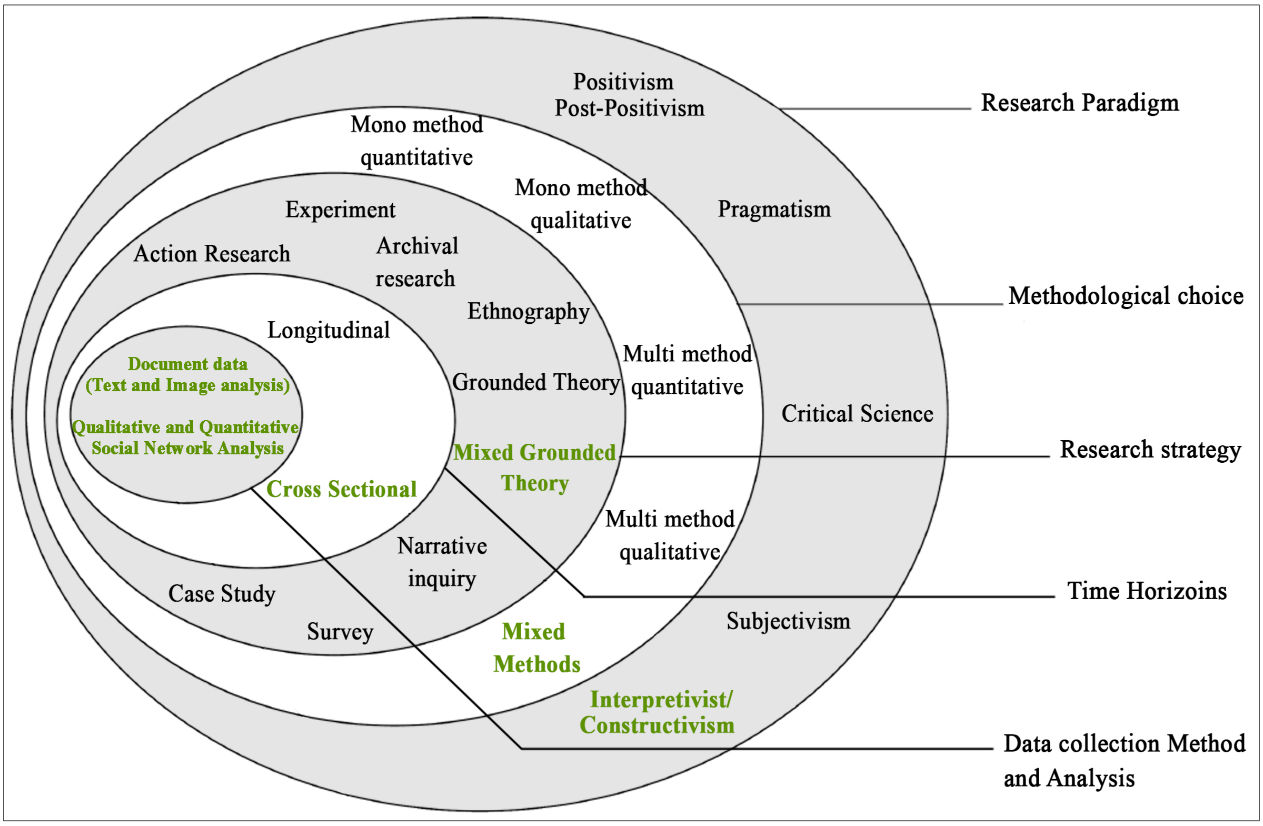


Figure 4-1: Research onion adapted from (Creswell & Creswell 2017; Guba & Lincoln 2005; Johnson & Walsh 2019; Melnikovas 2018; Saunders, Lewis & Thornhill 2019; Swanson & Holton 2005; Wingo 2015)

4.1.1. Research paradigm

A paradigm represents a philosophical viewpoint of a research inquiry that justifies the researcher's action (Guba 1990; Kuhn 2012). According to Guba (1990, p. 18), a research paradigm can be described based on the responses to the following questions:

Table 4-1: Philosophical elements of a paradigm (Guba 1990, p. 18)

Ontology	What is the nature of reality?
Epistemology	What is the nature of the relationship between the knower (the inquirer) & the known (or knowledge)?
Methodology	How should the inquirer go about finding out knowledge?

Studies have identified various research paradigms linked to different methodological choices (qualitative, quantitative, and mixed method). Research paradigms are classified into five pivotal groups: positivism and post-positivism, pragmatism, critical science, subjectivism, interpretivism and constructivism (Creswell & Creswell 2017; Guba & Lincoln 2005; Saunders, Lewis & Thornhill 2019; Swanson & Holton 2005). Table 4-2 provides the context to compare the different kinds of research paradigm.

Table 4-2: Paradigms for research (Creswell & Creswell 2017; Guba & Lincoln 2005; Saunders, Lewis & Thornhill 2019; Swanson & Holton 2005; Wingo 2015)

Paradigm	Ontology	Epistemology	Methodology
Positivism/ Post Positivism	There is a single reality of truth (more realist); Objective world that science can "mirror" with privileged knowledge without certainty	Reality can be measured; and hence the focus is on reliable and valid tools to obtain that. Uncover truth and facts as quantitatively specified relations among variables; Results are "probably" true	Includes both qualitative and quantitative methods: experiments; questionnaires; secondary data analysis; quantitatively coded documents
Interpretivism and Constructivism	Reality is created by individuals, with no single reality of truth. That is all truth is "constructed" by individuals in groups within a historical moment and social context. Multiple meanings of the same data exist.	Researchers and participants are linked and constructing knowledge together. The reality needs to be interpreted. Patterns of meaning are used to discover the underlying meaning of events and activities.	Generally qualitative; ethnography; participant observation; interview; conversational analysis; grounded theory development Case studies; conversational and textual analysis; expansion analysis
Pragmatism	Pragmatists may be less interested in what "truth" is and more interested in "what works"; Reality is constantly debated and interpreted based on its usefulness in new situations and conditions	The prime aim is to solve problems. Involves different perspectives and works to reconcile those viewpoints through pluralistic means	Works on a real-world problem with the most appropriate methods, and tends toward changes in practice; Mixed methods; design-based research; action research

Subjectivism	Reality is what we perceive to be real	All knowledge is purely a matter of perspective	Archaeology; genealogy; literary analysis; intertextuality
Critical Science	Realities are socially constructed entities that are under the constant internal influence	Uncover hidden interests; displace ideology with scientific insights; Concerned with the relationship between the the knower and the what became known	Collect data about the reality of human experiences in such a way to feel confident reality is captured Field research; historical analysis; dialectical analysis; deconstruction; textual analysis

Due to the assumptions that have been made for the research problem in section 1.1, the iterative process of selection, and the responses to the questions in Table 4-1, this study follows the interpretivism/constructivism paradigm. Moreover, much of my philosophical stance is drawn from the constructivist GT of Charmaz (2014). In the next two subsections, a brief critical comparison is provided between the most comprehensive, significant and frequently used research paradigms; traditional positivism and constructivism.

4.1.1.1. Positivism/Post-Positivism

Positivism assumes that there is only one true reality that could be understood objectively and in a completely independent way to the researcher. This epistemological stance reveals the significance of objectivity that clearly excludes values. Positivist researchers investigate the links and interactions between variables in the objective world. They mostly adopt quantitative methods to measure those variables, examine and verify hypotheses. Findings from a verifiable hypothesis, which is shown to be true regardless of the researcher's values, is to be generalised through careful sampling (Guba & Lincoln 2005; Haig 1995, p. 19). Creswell and Creswell (2017, p. 7) referred to this position as the "scientific method" or doing "science" research. Notably, the term *Post-Positivism* describes the thinking after positivism, which struggles with the traditional concept of the "absolute truth of knowledge".

4.1.1.2. Interpretivism/Constructivism

In sharp contrast to the positivism paradigm, the interpretivism paradigm is concerned with values and meanings related to individuals' interpretations of the world in which they live and work. Haig (1995, p. 19) pointed out that there is no objective knowledge regardless of the interpretations of events and settings by individuals and members. That is, the objective features of society and social actions (e.g., organisations, social classes, technology, and scientific facts) appear from, rest on, and are made up of the subjective meanings, intentions and beliefs of individuals in the social processes. The ontology of an interpretivist assumes that knowledge is understandable in relation to the appreciation of social interactions and the participants' views of the situation being studied.

The ontology, epistemology and methodology of the interpretivism paradigm fit with the subject of this study. In contrast with the positivist approach, the interpretive researcher tries not to force externally defined categories on social settings.

Swanson and Holton (2005, p. 20) identified "grounded theory developments" as research methods and types of analysis belonging to the "interpretivism" category. GT requires the intense engagement of the interpretivist researcher with the settings, interactions between variables, meanings and values. The concepts and categories emerging are underpinned by an in-depth examination of and exposure to the phenomenon of interest. Furthermore, studies applying interpretive methodologies like GT do not prove or disprove hypotheses. Rather, researchers aim to comprehend the phenomena through the meanings and values that people themselves assign to them, and to develop a theory explaining the phenomenon under investigation (Wingo 2015). Interpretivist research helps to answer the question *What is going on here?,* and to create policy from a more informed position (Charmaz 2006; Guba & Lincoln 2005).

4.1.2. Methodological choice

Generally, there are three major methodological choices: quantitative, qualitative, and mixed methods research (Johnson & Christensen 2008; Khaldi 2017; Melnikovas 2018). The quantitative methods focus on proving the validity of the links between variables, which can be measured and quantified for numerical analysis using statistical methods. This method solves the problem through a deductive process but struggles to do so without any bias. Qualitative studies aim to investigate the meanings of problems mainly through engaging individuals and social groups. In contrast with quantitative researchers, qualitative researchers adopt an inductive style with an emphasis on the participants' viewpoints. Last, mixed methods studies require the combination of quantitative and qualitative methods to provide the best understanding for solving the problem (Creswell & Creswell 2017, p. 18; Johnson & Christensen 2008). In a highly cited paper, Johnson, Onwuegbuzie and Turner (2007, p. 123) defined mixed methods as a methodological choice in which "a researcher or team of researchers mixes or combines qualitative and quantitative research philosophies/paradigms, methodologies, methods, techniques, methods, concepts, and/or language into a single research study or a set of closely related studies". Greene (2015) also highlighted that mixed methods research offers opportunities to combine research elements at multiple levels, such as method, methodology, and paradigm.

In the present study, mixed methods is an appropriate methodological choice that allows consideration of research objectives from different ways for better understanding of why and how the phenomenon occurs (Johnson, Onwuegbuzie & Turner 2007; Nissell-Tumbarello 2011; Schram 2006; Shank 2006). The mixed methods here provide a holistic approach to the study of phenomena by using qualitative methods to discover relevant contextual factors that later can be examined through quantitative forms of research.

4.1.3. Research strategy

Creswell and Creswell (2017, p. 13) highlighted that the strategies of inquiries "provide specific direction for procedures in research design and contribute to the overall research approach". The research strategy provides an outline indicating how a researcher is going to answer the research question. These strategies have been multiplied because of the fast pace of technological growth in pushing forward data analysis. Creswell and Creswell (2017, p. 13) categorised some of the main strategies according to three prime research strategies (see Table 4). It is suggested that research strategies support the research method and reflect the underlying research paradigm. In the present study, "Mixed Methods" with the research strategy of "Mixed Grounded Theory" works well to meet the research objectives. This research approach contains the construction of an explanatory framework using different types of data, analysis strategies, and logic of inquiry (Johnson & Walsh

2019). Notably, it takes elements and logic from both GT and mixed research traditions (Charmaz 2014; Johnson, Onwuegbuzie & Turner 2007).

Table 4-3: Strategies of inquiry (Creswell & Creswell 2017, p. 13; Johnson & Walsh 2019)

Quantitative	Qualitative	Mixed Methods
Experimental design Non-experimental design, such as survey	Narrative Phenomenology Ethnographies Grounded Theory Case Study	Sequential **Concurrent** **(Mixed Grounded Theory)** Transformative

While the GT methodology was originally considered as a broad research method suitable for both quantitative and qualitative data systems, it has become progressively seen as a qualitative method (Creswell & Creswell 2017; Glaser 1999; Howard-Payne 2016; Miller & Fredericks 1999). However, Johnson and Walsh (2019) highlighted in *The SAGE handbook of current developments in grounded theory* that taking the mixed method logic to GT results in the development of creative and useful designs of GT. The authors suggested six basic designs of MGT collected from the literature in relation to the sequential and concurrent methods of data collection. For instance, the exploratory sequential form of the qualitative method followed by the quantitative method.

The research paradigm, strategy, and method must be creatively combined on a "study-by-study basis" to provide the most informative, reach, and beneficial knowledge (Johnson & Walsh 2019, p. 8). Here, given the nature of GT research, a researcher is not supposed to develop the research at the beginning of the research. Indeed, the MGT approach evolves itself and becomes enriched through the iterative process of data analysis (Johnson & Walsh 2019). Thus, holding a broad perspective on the research aim, I started mixed methods GT research with the methodologies provided by Charmaz (2014). The need to address a complex phenomenon and deal with big data sets have then given rise to a "hybrid mixed grounded theory" research design, involving new methods of data collection, analysis and interpretation (Constantiou & Kallinikos 2015; Johnson & Walsh 2019, p. 13; Jones 2019).

4.1.4. Summary of research design

As discussed in the first chapter, the key research aim is to conceptualise the evolution of hospital design and identify the main factors and relationships among them triggering design innovations in this field. In so doing, four principal steps are determined:

1. Analysing the evolution of hospital design and exploring related contributing factors to design innovations;
2. Conceptualising how the contextual factors have triggered innovation in hospital building design;
3. Examining the structure of interactions and the hidden patterns in the design innovation ecosystem; and
4. Creating an explanatory framework that elucidates the nature of design innovation.

The assumptions about the study's problem definition and choices of procedures of inquiry for this research, through an iterative process, led to the identification of the research paradigm, method, and strategy of the present study. To achieve the research aim, the mixed methods strategy of GT with Charmaz's constructivist paradigm was employed.

As mentioned in section 1.7, four main reasons are behind this selection. First, this method is appropriate for exploring a contextualised domain without a dominant theory. In this research area, there is a lack of theory explaining the patterns of innovation in hospital design and the interconnections between incidents. Thus, through the interpretive methodology of GT, this study aims to comprehend the phenomena and develop a framework explaining it. Second, through GT methodology, the emerged framework is based on empirical data and fits entirely in the context and avoids imposing externally defined categories. Third, conducting a historical analysis and examining the interactions between different incidents requires specific strategies and intense engagement with the settings, interactions between factors, meanings and values. GT provides the best methodology to classify codes into categories, determine the concepts, and investigate the relationships for the development of the framework. Last, the MGT co-evolves with the analysis process and the acquired knowledge of the studied phenomenon. This research approach also encourages the creative use of both qualitative and/or quantitative methods of analysis to develop a holistic understanding of the phenomenon. Here, given the complexity of the innovation ecosystem, the adoption of MGT provides an opportunity to creatively construct the research design in relation to our understanding of the phenomenon.

The following subsections explain the background of GT and three main approaches to this methodology since its introduction in the late-1960s.

4.1.4.1. Charmazian approach of grounded theory

There are various approaches to GT methodology (see Figure 4-2), but the one chosen for this study is that of Charmaz (2014).

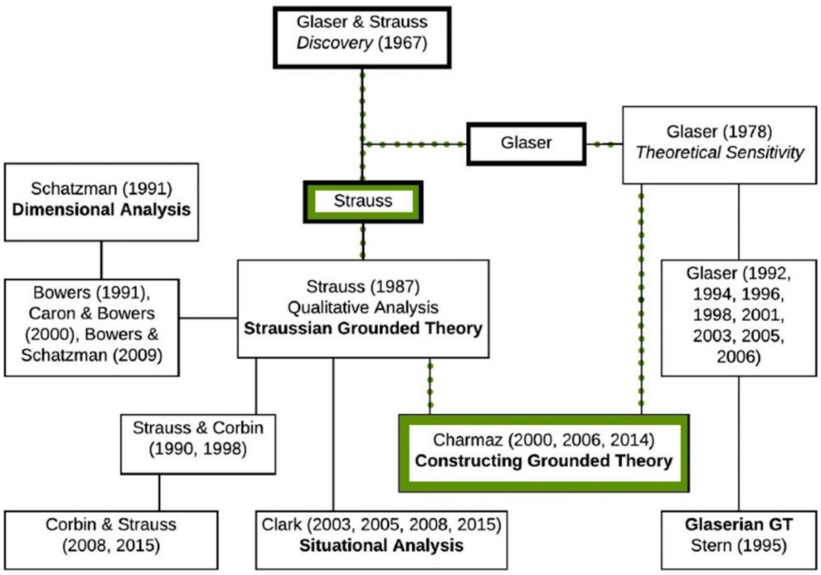


Figure 4-2: Genealogy of GT: Major Milestones (complied from (Clarke 2019; Morse et al. 2009; Wingo 2015))

The GT method was introduced by two sociologists, Anselm Strauss and Barney Glaser, in relation to their research on *death and dying.* The methodology became known as GT and was published in their book entitled "The Discovery of Grounded Theory". Here, GT was described as: a systematic generation of theory from data that has been empirically collected and analysed (Glaser & Strauss 1967).

Grounded theory is commonly believed to have one principal goal of creating a novel theory based on data gathered in the specific context of the phenomena (Haig 1995). Glaser and Strauss believed that theories can be identified as substantive, middle range, or formally derived from data; based on their application from specific to broad general applicability. While Glaser looked for a pattern of behaviour to develop a conceptual theory grounded in data, Strauss and Corbin adopted symbolic interactionism to help theory emerge by giving subjective meanings to objects (Chun Tie, Birks & Francis 2019). Charmaz (2014), as a student of both, expanded the theory as "abstract understanding, relationships of abstract concepts, and a way of understanding the world more comprehensively and abstractly" to explain or predict a phenomenon (Charmaz 2014, p. 230). She adopted a different philosophical perspective and argued that analysts need to construct meaning in accordance with the area of inquiry. Further, Clarke (2019) developed the GT methodology by integrating situational analysis in interpretive qualitative inquiry. As Zamani and Babaei (2021) highlighted, other researchers have also presented different approaches to GT: critical (realistic) grounded theory (Hadley 2019; Oliver 2012), transformational grounded theory (Redman-MacLaren & Mills 2015), perspectivist grounded theory (Flick 2018), informed grounded theory (Thornberg 2012), and feminist grounded theory (Wuest 1995).

Regardless of the commonly accepted main goal of GT, there are three different approaches and methodological genres to developing a theory (Chun Tie, Birks & Francis 2019). The differences in the process emerged because of dissimilarities in the philosophical backgrounds of GT scientists. In 1987, fundamental contradictions between Glaser and Strauss led to two distinct approaches: the Glaserian school of GT, and the school of GT supported by Strauss and Corbin. About 15 years later in 2000, Charmaz introduced constructivist GT as the third approach. The differences between the perspectives of Glaser, Strauss and Corbin, and Charmaz, as well as their different ways of analysing data and developing the theory, are discussed in the next section.

4.1.4.2. Varieties and commonalities in the analysis processes

Open or Initial Coding

The initial coding process is similar in the three GT approaches (Charmaz, 2014; Glaser, 1978; Strauss & Corbin, 1998). All these coding processes begin with fracturing data into smaller segments through word-by-word or line-by-line analysis methods. After that, the researcher should make groups and label these smaller pieces of data based on their properties and characteristics.

This process is named "open coding" by Glaser, Strauss and Corbin (Glaser, 1978; Strauss & Corbin, 1998) and "initial coding" by Charmaz (Charmaz, 2006). Glaser believed categories should emerge by "constant comparison" and not forced by pre-scripting bias on emerging theory. Strauss and Corbin tended to a more postpositivist approach and determined stages and strategies for doing the open coding phase. In contrast, Charmaz believed both approaches are too realistic as there is no interpretation. As a constructivist, she argued that the world is not "right", and so that we should construct it. Thereby, the meaning is not objectively pulled out of people, but it is co-structured in interactions. How you as a researcher interpret and construct things is just as important as how your respondents do. Charmaz (2013), in an interview discussing her ideas on GT, highlighted that there is always "interpretation between you and the data". At the end of this stage, basic concepts and primary categories from raw data are revealed (Singh & Estefan 2018).

Selective or Focused Coding

At this phase, three different methods were developed:

- Glaser (1978) proposed that making relationships between the core category and emerging concepts begins at the open coding stage and continues in the selective coding phase. That is, he promoted initial coding by comparing incidents with each other to make categories and trends emerge (Howard-Payne 2016). He applied selective coding to refine the core category and make it abstract to fit all data in it. Glaser assumed that "using constant comparison method gets the analyst to the desired conceptual power, quickly and with ease. Categories emerge upon comparison and properties emerge upon more comparison and that is all there is to it" (Glaser 1992, p. 43). Glaser's approach is much less formal, much freer and less of a recipe in comparison with Strauss and Corbin's approach (Kelle 2019). However, his approach highly relies on the researcher's "theoretical sensitivity", which means their ability to understand and interpret phenomena in theoretical terms (Kelle 2010, p. 191).

- Strauss and Corbin (1998) proposed an intermediate stage of "axial coding" between the open and selective coding phases. Axial coding helps researchers reassemble, synthesise and organise fractured data through the lens of a so-called "coding paradigm". This process brings data back together in a new coherent whole and explores the relationships between categories. To develop a paradigm, the researcher looks for "how phenomena construct processes (consequences) and structures (conditions)" or "the phenomenon, its conditions, framework and consequences which are the properties of each category" (Strauss & Corbin 1990, p. 99). Subsequently, in the selective coding stage, core concepts, abstract categories and subcategories all lead to the emergence of the final framework and theory.

- Charmaz (2014) posited that focused coding occurs simultaneously with synthesising and conceptualising segments of data after the initial coding and establishing some analytic directions. At this stage, the researcher selects relevant or dominant codes and determines their connection with others to bring data back together. Then, through theoretical coding, interactions between categories are created to explain the phenomenon.

Last, in all approaches, the theory is developed around a chosen "core category" that explains and accounts for all data (Singh & Estefan 2018). To develop the emerging theory, the researcher also needs to do theoretical sampling to collect more pertinent data to the core category. It is evident that while these different versions of GT are different in epistemological foundations, they have some significant common strategies such as: iterative data collection and analysis, constant comparison, writing memos and annotations, theoretical sampling, and theoretical saturation (Zamani & Babaei 2021). It is important to bear in mind that these steps are not prescriptive but indicative of the iterative process of GT data analysis (Bryant & Charmaz 2019).

In sum, all three prime GT approaches can effectively facilitate the process of conceptualisation and understanding a phenomenon, depending on researchers' philosophical inclinations (Apramian et al. 2017). However, it is critical to note that the Glasarian objective, inductive, passive approach would end up with a different GT process and outcome than would Straussian procedural approach or Charmazian constructivist approach. In this study, Charmaz's interpretive, constructivist approach is selected in relation to the research objectives. The different steps in this process – of constant data analysis and generating the theory – are described in the next sections.

4.2. Data Management and Analysis Process in Mixed Grounded Theory

Different analysis stages of GT methodology have been outlined in line with traditional research methods according to five main phases, namely "the initiation of research, the selection of appropriate data, data collection, data analysis, and the conclusion of the study" (Egan 2002, p. 280). In GT, however, synthesis occurs through a back-and-forth procedure between emerging analysis and data to address the need for adjustment. First, an area of inquiry (which might focus on a particular phenomenon, place or a specific context) and the corresponding method for the data collection must be selected. The analysis starts from the early stages of collecting data and continues throughout. Here, the researcher must remain open to changes in direction based on every single piece of data. Thereby, it may not be feasible to make a plan for sampling as decisions will be driven from the emerged concepts and categories (Haig 1995).

Corbin and Strauss (2014) and Charmaz (2014) recommended specific steps and strategies for researchers who, necessarily, have not an extensive background in the study's topic and need to strengthen their ability of theoretical sensitivity. These strategies can be classified as Straussian strategies or Charmazian strategies. While Strauss and Corbin suggested three main stages of GT called open coding, axial coding and selective coding, Charmaz posited initial coding and focused coding as the principal phases. In this study, the techniques and strategies suggested by Charmaz are applied to the process of data gathering and analysis. Notably, and as previously discussed, the term "grounded" is commonly applied to research adopting an inductive approach where findings are generated from data. However, there has always been a deductive approach complementing the process of analysis referring to the analyst's interpretation of concepts that arise as generalisations and abstractions over the data (Gorra 2019). Thus, there remains an iterative process between inductive and deductive approaches.

4.2.1. Data collection

In this study, the primary dataset consisted of a wide range of publications gathered across disciplines in English, which specifically deal with hospital building evolution and/or explicitly mention the key innovations in hospital building design. Here, the main databases for searching these sources were Scopus, Web of Science, Art & Architecture Source, Environment Complete, Avery Index to Architectural Periodicals, PsycINFO, and Google Scholar; and key research terms included hospital/healthcare, design/architecture/building, innovation/innovative, and evolution/architectural history. Notably, only studies exploring the historical evolution of hospitals in terms of architectural, service and organisational design were included and those focusing on medical and technological developments, in particular, were excluded. Also, due to similarities, in departmental structure and medical services, between university/teaching hospitals, specialty hospitals, and acute general hospitals (Wagenaar et al. 2018), research related to these three hospital typologies was considered. The literature on the wider range of healthcare facilities – e.g., ambulatory medical centres, highly specialised centres for quaternary care, transportable healthcare facilities, and palliative care facilities - were excluded given the considerable differences in the level and models of care, target population and organisational structures. As a result, 17 critical texts (mainly books) on the historical analysis of the evolution of hospital building design were determined (Adams 2008; Adams 2016; Francis et al. 1999; Guenther & Vittori 2013; Kisacky 2017; Prasad 2008; Risse 1999; Rivett 2017; Schrank & Ekici 2016; Singha 2020; Sloane & Sloane 2003; Thompson & Goldin 1975; Verderber 2010, 2015; Verderber & Fine 2000; Wagenaar 2006; Wagenaar et al. 2018; Willis, Goad & Logan 2018). Each source examined hospital design evolution in certain decades and from certain perspectives. In this study, the critical analysis of these references was used to elucidate how multiple contextual factors affected the translation of knowledge into episodes of innovation. Together these texts described the events and factors that influenced the evolution of hospitals to the present day from the first period of rapid change after WW1; covering particularly the context of developed economies: the USA, Canada, Australia, the UK, the Netherlands, France, Germany, Austria, Denmark, Switzerland, Norway, Sweden, and Finland.

In GT studies, selecting data is one of the most important steps in the process of data analysis and thus is collected throughout the analysis process. Data collection and analysis occur concurrently as fresh data are compared to existing data. Ultimately, GT requires enough data to achieve the point of saturation where no new theoretical insight or concept is emerging. In this case, because of the shared knowledge between the references, saturation was reached with 11 data sources.

4.2.2. Data analysis

Over the last two decades, the fast-paced growth of technology has widely altered the nature of research data and analytical methods. A plethora of well-established Computer Aided Qualitative Data AnalysiS (CAQDAS) software packages has considerably decreased the time-burden of data analysis while increasing the overall accuracy (Oswald 2019; Robins & Eisen 2017; Woods et al. 2016). This changing landscape has had a considerable impact on the highly data-driven nature of GT methodology (Bryant & Charmaz 2019). The increasingly growing impetus in addressing complex phenomena and dealing with big data sets have given rise to “hybrid mixed grounded theory” research designs, involving new methods of data collection, analysis and interpretation (Constantiou & Kallinikos 2015; Johnson & Walsh 2019, p. 13; Jones 2019).

As Bryant and Charmaz (2019) and Bryant (2017) highlighted, their explanations of multiple coding strategies are recommendations rather than rules and prescriptions. They highly recommended GT researchers employ a creative combination of strategies. It is also highlighted in *The SAGE handbook of current developments in grounded theory* (2019) that in this era of changing research environments, the prime issue is not “whether” to adopt analysis aiding tools, but “how” today's researchers can take advantage of them in facilitating and improving the process of theory development (Gilbert, Jackson & di Gregorio 2014; Gorra 2019, p. 327). Gorra (2019, p. 321) argued that technology can impact the way GT researchers interact with datasets, but this technology is not limited to CAQDAS software. She suggested that researchers “find their own way” of adopting technology in the analysis process.

In GT studies, diagramming is widely considered to actively facilitate the process of making sense of qualitative data and encapsulating fresh concepts (Birks & Mills 2015; Bryant & Charmaz 2019; Charmaz 2014; Gorra 2019; Lempert 2011). However, few researchers have explicitly examined the implementation of different diagrammatic modelling tools in GT analyses. Given the key role of diagramming in the analytical process and the contribution of digital tools in the quality of emerged theory, as well as the importance of transparency in explaining methodology, this chapter discusses the development of a multi-representational approach to improving the process of GT data analysis. In line with two previous studies, I argue that the strongest approach to yield effective results is to integrate the use of digital modelling tools with human analysis and interpretation abilities, instead of relying on machines for automated analysis (Barberis Canonico, McNeese & Duncan 2018; Baumer et al. 2017; Lipton 2018). The following sections explain the initial and focused coding used in this study to meet the research objectives.

4.2.2.1. Initial Literature Review

In GT research, the idea of engagement with existing literature before the dynamic interplay of data collection and analysis has widely been discussed from different perspectives by grounded theorists (Bruce 2007; Bryant & Charmaz 2011; Charmaz 2014; Dunne 2011; El Hussein, Kennedy & Oliver 2017; Glaser & Strauss 1967; Kelle 2007). Bryant and Charmaz (2011, p. 19), in the *Handbook of Grounded Theory,* adopted several grounded theorists' ideas to support the importance of developing researchers' reflexivity and accumulated theoretical knowledge through engaging with relevant literature. In this regard, Thornberg and Dunne (2019, p. 9) proposed three different phases of literature review, including: (1) an *initial literature review* that must be conducted before the process of data collection to help the researcher engage with the broader environment of a subject critically; (2) an *ongoing literature review* occurring during the iterative process of data collection and analysis; and (3) *the final literature review* that must be occurred towards the end of the research with the aim of contextualising the emerged theory in accordance with well-established theories.

While careful *analysis* of relevant literature and some "previously formulated categories" helps researchers build new knowledge, this preliminary reading does not mean defining or forcing the analysis process between data, categorisation and theory (Goldkuhl & Cronholm 2010, p. 12; Thornberg & Dunne 2019). This proposition is in line with the idea that "an open mind does not imply an empty head"; Dey (1999, p. chapter 8) believed experienced researchers have undoubtedly general familiarity with key topics and knowledge of a vast mass of literature leading to some preconceived ideas relevant to the research area. Thus, in this thesis, a literature review was conducted at the beginning of the analysis process to employ existing knowledge about contextual factors, concepts, interrelationships and different categorisations in the field of innovation in hospital building design. In the early stages of the analysis, a basic initial and focused coding examined all data sources according to the general idea of their chapters. As an ultimate goal, the links between the main categories and the prime sources were tabulated (see Appendix 9.3.1). In the next step, each data source was studied thoroughly, and information was coded through the initial and focused coding to generate the theoretical models.

4.2.2.2. Initial Coding

The process of analysis began with the *initial coding*, which included open coding. Immediately after the collection of the first dataset, data analysis started with "open coding" – breaking down data to find the related codes to different incidents having impacted design innovations, as well as conceptualising the segments to higher abstractions over those data. The specialised software NVivo was used to code the data and facilitate the coding process. Here, different stages of analysis were translated to a computer-assisted way following Charmazian strategies and Friese's suggestions published in *The SAGE Handbook of Current Developments in Grounded Theory* (Friese 2019). The main method used for the acquisition and construction of concepts was manual coding through line-by-line searches. Codes generated at this stage of the analysis were reconsidered for further exploration if they could be combined with other codes, risen to a higher level of conceptualisation, or simply eliminated. Data incidents were compared to other incidents to obtain word-phrase clusters and generate *concepts* as the prime units for further analysis and comparison. In the coding process, determining the degree of *generalisation* in the construction of abstract concepts becomes a crucial part of GT practice. The level of abstraction was reflected in coding data exactly as they appeared or moving from the particular to the more abstract codes.

Notably, codes should not be sorted for hierarchical structure at this phase (Charmaz 2014; Corbin & Strauss 2014; Friese 2019; Holton 2011, p. 277).

4.2.2.3. Focused Coding

In the *focused coding*, concurrently with data collection, emerging concepts were compared to more incidents to develop concepts by generating new theoretical properties (Chun Tie, Birks & Francis 2019; Holton 2011, p. 277). Following the generation of higher-level concepts in a back-and-forth process, vertical and horizontal analyses of concepts were conducted. At this point, it was important to stop coding whenever an idea is developed about a concept and start writing a memo. Memos could be either very short "jots" or long "proses" (Chun Tie, Birks & Francis 2019; Swanson & Holton 2005, p. 257).

Extracted concepts during content analysis were compared with each other across all data sources through *vertical analysis*. Under this constant comparison, concepts were classified into categories according to their common properties. In the classification process, concepts applied across different situations with more generic definitions were located at the upper levels in the hierarchy in comparison with those having a mere instance of a specific class. The conceptual labels were commonly generated from generalisations, rather than being taken directly from the data. Having a broader range of applicability arose from constant comparisons between the concepts with incidents and other concepts across different data sources. Notably, the generalisation could also be defined as the ability to cover the possible new data under the same concept.

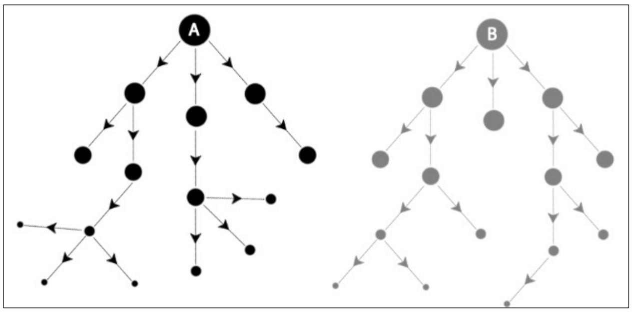


Figure 4-3: The vertical analysis of codes, resulting in hierarchical links between codes under each category

Horizontal or cross-sectional analysis was also conducted parallel to the vertical analysis of concepts to enhance the terminology and subcategory properties. That is, the result of focused coding was not a list of codes, but several relationships and memos describing the properties of categories were also created. This analysis aimed to compare the interrelatedness of context-specific concepts within and across categories, which were recognised as the influential factors impacting innovation in hospital building design. The horizontal study elucidated the way concepts were connected at different levels of abstraction and explored their value and strength with other links. At this point, recording how many times a code has been applied to different sections of data was used to examine the dominant codes and their connections to other codes. Together, these analyses provided the context for explaining the phenomenon under study (Gibbs 2010; Holton 2011).

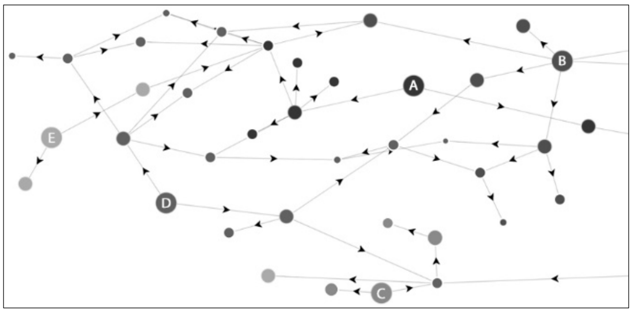


Figure 4-4: The horizontal analysis of codes, depicting the relationships between codes across the categories

Through the process of focused coding, the key concepts and causal relationships came to focus. At this phase, a single storyline was defined and all the interactions and interrelationships between codes were shaped around the specified storyline, which in this study is "*innovation triggers in hospital building design*" in relation to architectural, organisational and service designs (Birks & Mills 2019). The ongoing purposeful sampling and analysis determined the relevant concepts and their interactions, boundaries of the phenomenon and the needed level of abstraction (Morse & Clark 2019).

Having conducted the initial and focused coding analyses of the first two datasets using NVivo, a significant weaknesses became clear of the traditional GT procedure in addressing the complexity of research objectives. There were too many concepts and relationships to be analysed in a standard narrative way using analytical annotations and memos (in compliance with (Charmaz 2014)). Indeed, it was not possible to examine semantic relations by retrieving the attached annotations of codes. This situation was exacerbated after conducting equivalent analyses for the third dataset, which added more concepts via constant comparison between codes. Considering the importance and complicatedness of big data cross-sectional analysis, utilising an appropriate diagrammatic modelling tool could help me organise and make sense of concepts and their linked impacts on design innovations. Here, in line with the well-established role of diagramming as one of the most effective tools to enhance the analytical and interpretive process, the *network* function of NVivo was employed. Codes were connected manually based on the relationships discovered during the analysis to construct a network diagram. If there was a conceptual relationship between two codes, based on the relation, then an interconnecting line was drawn between the codes.

However, after conducting the analysis for the next dataset using the network graph provided by NVivo, it became evident that creating networks manually was not the most appropriate strategy to make sense of semantic relationships between a wide range of concepts (Brailas 2014; Solhi & Koshkaki 2016). Having used the network function of NVivo to depict interactions between various concepts classified in different categories, almost all codes were connected to one another. While a detailed and extensive set of concepts and relationships was necessary to explore and explain how and why a phenomenon occurs, the considerable number of codes made manual networking impossible for the relational data. Indeed, it was quite complicated for a human eye to identify any possible underlying structure in the way the codes were interconnected. Therefore, and in line with Charmaz' and Johnson's recommendations, two complementary analysis techniques and methods were used in this study to meet the research objectives, namely diagramming and social network analysis (SNA) (Charmaz 2014; Johnson & Walsh 2019).

4.2.3. Merging analysis techniques and methods to aid the GT analysis process

Having followed the MGT approach (Johnson & Walsh 2019), a novel combination of two analysis techniques and methods was added to the Chramaz GT methodology to resolve its weaknesses in addressing the specific research objectives of this study. Firstly, a set of creative and useful diagrammatic representations was selected to facilitate the process of ordering different concepts in correct relation to one another - both horizontally and vertically - and exploring and identifying semantic relations between different concepts through visual analysis. As discussed in section 2.4.2, a network-centric approach is commonly considered as a "systemic way of thinking" to deal with interrelationships, and as a "methodology" to truly understand the complexity of innovation ecosystems (Barile, Spohrer & Polese 2010, p. i; Vicsek, Kiraly & Konya 2016). Thus, a network diagram was constructed to depict interactions between influential factors, followed by the construction of an arc diagram to render the chronological order of relationships missed in the network diagrams. Secondly, the analytical framework of the network and arc diagrams, defined by their key characteristics and attributes, was adopted to enhance the analytical and interpretive process.

1. Diagramming

Visual thinking with interactive interfaces, in particular diagramming, is commonly considered to actively facilitate the process of inductive reasoning, encapsulating fresh concepts and adding different yet complementary value to the process of computer-aided analysis (Brailas 2014; Bryant & Charmaz 2011; Buckley & Waring 2013; Charmaz 2014; Gorra 2019; Lempert 2011). The approach developed in this study aids particularly with the examination of incidents within a wider relational composition, as stressed in the ontology and epistemology principles of the Charmaz (2014) interpretivism/constructivism paradigm. Constructivist GT researchers often adopt an analytical approach to break down data into its elemental parts and then reassemble, synthesise and organise fractured data to identify categories and patterns using CAQDAS tools. However, through this approach, researchers cannot easily explore the hidden relationships key to theory building between the different components of a system. Here, I described research evidencing a multi-representational approach to aid systematic thinking that complements the current analytical approach.

In this study, specific modelling tools, customised to fit with the data, aided the analysis process not only by visualising the data, but also by assisting the process of exploring semantic relations between different concepts and examining the possible underlying structure behind interrelationships (Brailas 2014; Solhi & Koshkaki 2016). Here, two distinct types of diagrams (network and arc diagrams) were constructed using Flourish plus Pajek (De Nooy, Mrvar & Batagelj 2018) and Observable respectively. The prime reason for this creative combination of CAQDAS (NVivo) and diagramming tools (web-based platforms and Pajek) is that while CAQDAS software packages offer a few diagramming tools with limited functions, they focus on organising data and exploring syntactic relations between theoretical concepts through textual analysis. However, using tools specifically designed for data visualisation (e.g., Pajek), I suggest, helps analysts explore and identify semantic relations through visual analysis and understand its constituent phenomenon as a coherent whole.

2. Machine Cognition: Social Network Analysis

The literature advocates the complementary effort between human and machine cognition as one of the most prominent methods to model highly complex phenomena (Barberis Canonico, McNeese & Duncan 2018; Baumer et al. 2017; Lipton 2018; Muller et al. 2016). The authors argued that a wise and creative integration of computational techniques provided by machine learning (such as network analysis) and human-centred analysis of concepts leads to effective results, as it follows inductive reasoning for complex problems. Indeed, machine learning is widely suggested as a complementary method to help grounded theorists make sense of highly complex and ever-increasing datasets. The literature to date has only employed the networked GT approach, focusing mainly on the quantitative techniques of SNA as a completely separate methodology in research design (e.g., (Brailas 2014; Guzek 2019; Lovrić & Lovrić 2018; Solhi & Koshkaki 2016; Sullivan et al. 2019)). In other words, the qualitative GT methodology has commonly been considered to be only a part of the main sequential mixed methods, whereby GT analysis is widely used to determine concepts and links and SNA is employed to develop categories and examine the structural properties of networks.

In this study, having researched the phenomenon systematically and acquired a deep knowledge of the empirical data, categories were developed during the focused coding, and relationships between concepts within and across categories were determined in a network diagram. Next, a set of techniques used for network analysis were employed to understand the patterns and better explain the phenomenon under study. In what follows, I elucidate the role of computer-aided analysis, the importance of diagramming in the process of data analysis, different types of diagrams and their potential value to GT studies, as well as the rationale for the inclusion of SNA as the most appropriate analysis technique to enhancing the analysis.

4.3. Diagramming in Mixed Grounded Theory

Due to the fast pace of technological change, big data analysis has gained considerable impetus in generating innovative theories and insights in academic research, and products/services in business communities (Günther et al. 2017; Jones 2019). However, the complex nature of big data is widely considered to challenge traditional methodologies and techniques in theory building and research design, giving rise to novel strategies and tools for the analysis process (Clark & Golder 2015; Constantiou & Kallinikos 2015; Günther et al. 2017; Jones 2019). The literature acknowledged the significant impacts of tools and strategies on the process of generating meaning from qualitative data (Miles & Huberman 2014; Ngulube 2015; Ryan & Bernard 2000; Suter 2012; Swanson & Holton 2005). Similarly, in qualitative GT studies, the adoption of a combination of analytical tools and strategies is widely suggested to creatively probe the data, increase researcher's sensitivity, and move away from descriptive summation to conceptual explanations of the phenomenon. In this respect, diagramming is known as one of the most effective tools to show the power, scope and direction of categories and their interactions, which can be created either by hand or by using newly established tools (Birks & Mills 2015; Bryant & Charmaz 2019; Charmaz 2014; Corbin & Strauss 2014; Glaser 2003; Stern 2007). Diagrams actively assist interpretive GT researchers to re-engage with data, gain "analytical distance" to encapsulate fresh concepts from the chaos of links and codes, and analyse relationships (Birks & Mills 2019; Buckley & Waring 2013, p. 152).

Three prime approaches to mapping led to the development of different types of diagrams used in GT studies, namely mind mapping, knowledge mapping, concept mapping, and cognitive mapping (Ligita et al. 2020; Silver & Lewins 2014). Mind mapping acts as a tool to illustrate the main idea(s) in relation to the thoughts/aspects reflecting them (Buzan 1995). Knowledge mapping aims to create novel and actionable knowledge through the manipulation/transformation of information (Hall & O'Donnell 1996). Concept mapping (as conceived by Novak, Gowin and Bob (1984)) and cognitive mapping (as conceived by Eden and Ackermann (1998)) involve several causal or directional links, resulting in more complex diagrams. Concept maps demonstrate meaningful relationships between developed concepts in the form of propositions, whereas cognitive maps model a theoretical approach to solve a difficult problem. Buckley and Waring (2013) represented a variety of diagrams used in GT studies that were developed from different mapping approaches. The authors argued that diagrams play distinct roles at different stages of GT research and proposed several types of diagrams: procedural clarification and articulation diagrams, diagrams to encapsulate emerging theories, draw and write diagrams, and emergent concept diagrams. Notwithstanding the potential of diagrams in the process of conceptualisation and communicating ideas, their implementation in the analysis process remains insufficient. This study suggests that this inconsistent use of diagramming mainly rests on the functional limitations of CAQDAS tools. The following sections explain these limitations and examine how different diagrammatic modelling tools can help researchers visualise and interpret data.

4.3.1. The use of digital tools to create and engage with diagrammatic representations

Different approaches to the use of technology in GT research have resulted in the development of two different sets of tools under CAQDAS software packages that serve distinct purposes in the analytical process: (1) tools that aim to complement the method by helping the researcher relate words and concepts for technical efficiency; and (2) tools that focus on visual representation to aid in-depth interpretations of data for theoretical efficiency (Bowleg et al. 2016). The frequently used CAQDAS programs (e.g., ATLAS.ti, MAXQDA, and NVivo) largely focus on the application of the first set of tools. Here, it is highly recommended that GT researchers use the analytic options offered by such software (e.g., code co-occurrences or proximity, code-document tables/matrixes, and frequency clouds) to help develop theories by linking emerged textual interpretations (Friese 2019; Olafson, Feucht & Marchand 2013; Silver & Lewins 2014). However, the diagramming tools offered – mind/concept maps and network view – vary little and can limit the capability for alternative interpretations of data.

Seven prime deficiencies are identified in relation to the use by researchers of these tools for GT analysis. Woods et al. (2016) found that researchers did not usually use diagrams in data analysis, and only about 10% of researchers used software to visually represent their analytical process and conclusions, indicating that network view and modelling tools do not add value to the process of theorising conceptual relationships. Second, diagrams generated by using tools such as NVivo and ATLAS.ti were in some cases ‘hybrid’ outputs adapted or converted from other software applications (Ligita et al. 2020; Woods et al. 2016). Third, representing a dense network of linkages for big data analysis requires a large format, yet available network diagrams remain impractical for analysts to consider the whole picture of the relational context (Bringer, Johnston & Brackenridge 2006; Friese 2016). Fourth, Buckley and Waring (2013) highlighted that while NVivo can aid researchers to make sense of data and create different visual representations, the Microsoft Office diagramming tool was commonly viewed as better. Fifth, Gorra (2019) and Ligita et al. (2020)

pointed out that the learning time and resources GT researchers need, as well as cost containment, have a substantial impact on their choice and use of tools. Sixth, CAQDAS representational tools provide researchers with only static diagrams, in which changes in different parts of the system do not impact the whole system. Last, the literature suggested the use of networks for manually visualising the links between concepts, which do not meet researchers' interpretive needs and are not 'yet living up to expectations' for big data analysis (Friese 2016; Friese 2019). They provide limited functionality for focusing on organising data and exploring syntactic relations between theoretical concepts through textual analysis.

The modelling gaps have led to the inconsistent application of diagrammatic modelling tools for analytics, interpretation and communication purposes by GT researchers. To enhance the GT research process, it is recommended that researchers adopt the increasingly diverse array of dissemination potentials (Buckley & Waring 2013; Woods et al. 2016). This thesis posits that the use of certain diagramming tools helps GT researchers: 1) represent the manually manipulated connections between concepts, 2) analyse interrelationships among concepts, 3) explore meaningful patterns via a tool-driven analysis and, 4) more importantly, interpret the models in an effective way. Here, the main characteristics and features of certain diagrams as well as the attributes of certain technological tools are explained in the next sections.

4.3.2. Different types and features of diagrams for grounded theory studies

The diagrammatical representation a researcher chooses needs to suit their data and research questions and enhance the simultaneous processes of analysis and interpretation. A set of appropriate diagrams can help GT researchers determine the representation pertinent to the context and data. Suggested in *From Data to Vis* (2021) is a decision tree based on input data (such as numeric variables, categorical variables, maps, network, and time series) (Figure 4-5). Given the data format of GT studies (codes, concepts and categories generated by one of the CAQDAS software packages), only diagrams classified in the categorical variables and network groups are examined in this thesis because these are commonly the focus of a GT analysis.

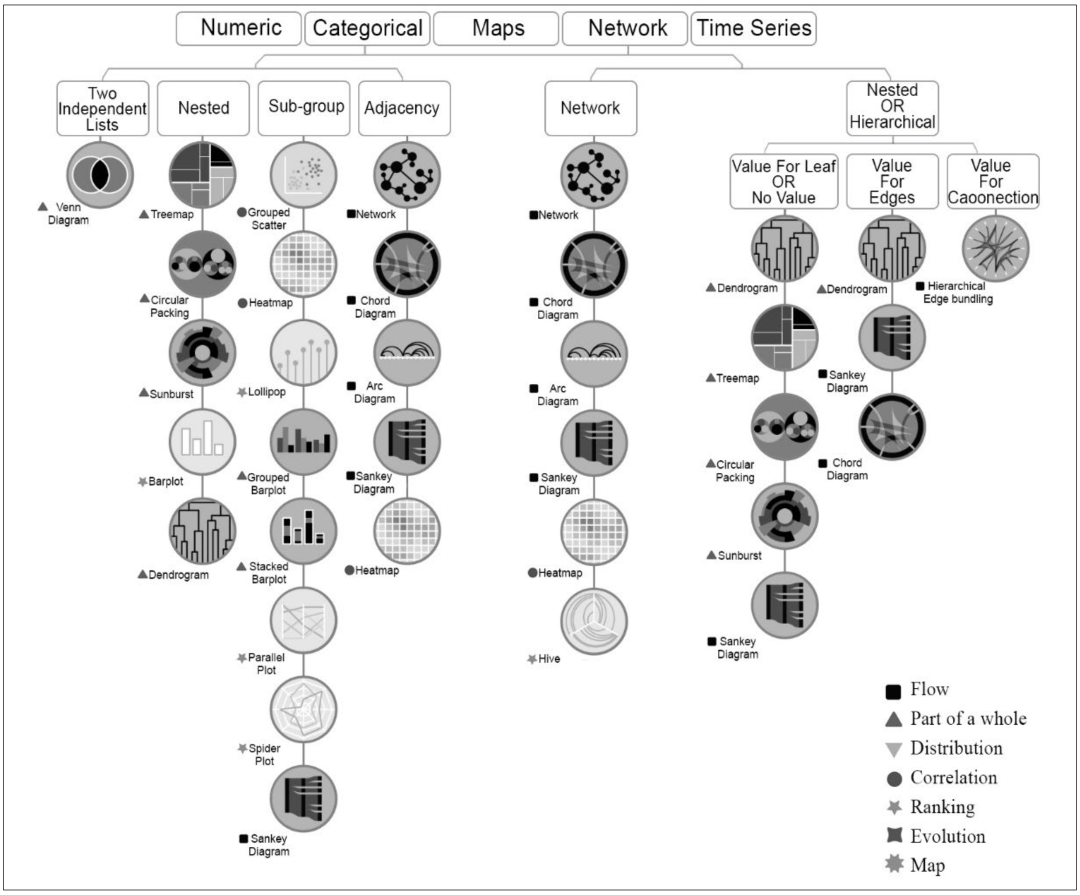


Figure 4-5: Different types of diagrams beneficial for GT analyses (revised version of From Data to Vis (2021))

The diagrams depicted in Figure 4-5 are grouped according to the different relationships they can represent, including distribution, correlation, ranking, part of a whole, evolution, map, and flow. In GT analyses, researchers can describe both hierarchical and non-hierarchical links (e.g., causal relationships) by using diagrams in “Flow” and “Part of a whole” categories, namely Tree-map, Circular Packing, Sunburst, Dendrogram, Sankey diagram, Network, Cord Diagram, Hierarchical Edge Bundling, and Arc Diagram. The main features of these diagrams are highlighted in Table 4-4.

Table 4-4: The main features of diagrams useful to GT research (Author (compiled from (From Data to Vis 2021; Observable ; RAWGraphs)))

Type of Diagram	Application	Benefits	Drawbacks
Treemap **Circular-Packing**	To Display the hierarchical organisation and the way each entity (higher levels) is divided into smaller parts (lower levels); The main nodes of the tree are depicted as sets of nested rectangles/circles, the size of which allow compare values	As treemaps make efficient use of space, it is appropriate for representing large datasets; Circular packing displays the hierarchical ordering better than treemaps	Treemaps are able to show less than three levels; The precise comparison between values of circles is not feasible
Dendrogram **Radial-Dendrogram**	Tree-like diagrams that represent the distribution of a hierarchical clustering that starts from one node spawning several nodes	Dendrograms illustrate the direct links between nodes in a hierarchical architecture; Radial variant show node-link diagrams with leaf nodes at equal depth is less compact	

		than tidy trees, but are useful for dendrograms, hierarchical clustering and phylogenetic trees	
Sunburst	Similar to treemap, it shows hierarchical structures, but in a radial layout; The main node locates at the centre of a circle with higher levels added as additional rings; numeric values can be included in each section		The comparison between sections of rings in relation to their size, particularly outer with inner parts, cannot be accurate; Adding labels to leaves and rotated sections is hard that make diagram hard to understand
Sankey Diagram **Alluvial Diagrams**	To display weighted flows and relationships between a wide range of variables (categorical dimensions); It is useful to depict different stages and links between variables from a start point to the end	The thickness of links and arcs is related to their value	
Network	Displaying the interrelationships between nodes	The thickness of links and the size of nodes is related to their value; The direction of links can be shown; Extra information can be added to each node	A layout algorithm is needed to determine the optimal position of each node
Arc Diagram	Displaying the interrelationships between nodes; A special kind of network graph in which nodes are located along a single axis	It shows the order between categories; There is enough space to show the label of each node; The thickness of arcs is related to their value	Do not provide the overall picture of relationships and nodes like networks
Cord Diagram	Displaying the interactions between several nodes by lines in a circular layout	The thickness of arcs is related to their value; Eye-catching representation	Not a good representation for large data as it gets cluttered
Hierarchical Edge Bundling	Displaying the interactions between several nodes by arcs in a circular layout; Using arcs instead of lines	Reducing the visual clutter by bundling the adjacency arcs; Useful for large data visualisation	

Over the last two decades, these diagrams have been widely adopted in various fields and considered in relation to both quantitative and qualitative approaches. In quantitatively driven analysis, researchers capture and examine the structural properties of diagrams using sophisticated mathematical techniques. Qualitative analysis, though, puts emphasis on the context and content of structures to better interpret different aspects of a phenomenon (Decuypere 2020; Venturini, Jacomy & Pereira 2015). The incorporation of these approaches has recently gained the attention of mixed method researchers, as it provides deeper understanding of the 'story' and the ideas behind structural properties to address many complex phenomena (Luxton & Sbicca 2020). Likewise, constructivist GT researchers looking for hidden patterns and the meanings of a phenomenon can employ these analyses to examine the interactions between variables within the wider relational composition (Charmaz 2014; Swanson & Holton 2005).

While all the eight aforementioned diagrams can be adopted in the process of GT analysis to visualise relational compositions and interpret the story, the key characteristics of 1) Network for representing the whole system, 2) Sankey for representing causal pathways, 3) Hierarchical Edge

Bundling for representing bundled adjacency links, and 4) Arc Diagrams for representing the sequence of concepts and links make them most applicable for the majority of GT studies. These diagrams can be analysed in terms of "why the user needs it, what data is shown, and how the idiom is designed" (Munzner 2014, p. 23). The analytical framework of each diagram, defined by their key characteristics and attributes, informs GT researchers in selecting the best diagram in accordance with their research objectives. The following section explains a well-established method for the analysis of network diagrams that is the most complex and significant type of diagrams used in this study.

4.4. Social Network Analysis in Mixed Grounded Theory

As explained in section 2.4.2.1, ANT was adopted as an approach with the aim of identifying the contextual factors (actors) involved and the interactions that formed possible stable networks supporting design innovations in hospital building design. Similar to the study conducted by Davey and Adamopoulos (2016), the data consisted of a very large block of historical text and the GT methodology was used to search for contextual factors and information about the interactions among them. Following the MGT research design, this study adopted specific methods to creatively analyse and interpret diagrams developed during the focused coding phase (Johnson & Walsh 2019). Particularly, to analyse the network diagram, qualitatively and quantitatively driven techniques provided by SNA were used. The main aim here was to understand complex interactions within the innovation ecosystem explored from the focused coding process (Telesford et al. 2011). This method has been widely applied to systematically describe and examine "all kinds of relationships" between entities and to explore the "patterns" apparent in those relationships (Scott 2017, p. 2).

Since the 1980s and its advancements in computer science, SNA gained a significant following in the analysis of complex networks with large data in a variety of fields such as anthropology, biology, economics, business, geography, history, information science, political science, public health, psychology, etc. (Cherifi et al. 2017). According to Borgatti, Everett and Johnson (2018, p. 40), while most studies investigate the interpersonal relationships between people, nodes can be "all kinds of entity" that has a direct impact on the kinds of relationships/ties. The commonly studied kinds of dyadic phenomena are co-occurrences (co-membership in groups, co-participation in events, physical distances), social relations (kinship relations, affective relations), interactions (transactions, activities), and flows (ideas, goods).

The SNA goes beyond the simple visualisation of relationships in a diagram to an examination and description of the structural features of the network and their impact on the final action (Scott 2017). In this study, both qualitative and quantitative techniques were used to combine the strengths of these methods in the analysis process (Domínguez & Hollstein 2014). As suggested by Huhtamäki et al. (2015) and Telesford et al. (2011), while it might be tempting for a GT researcher to summarise network behaviour in a few numerical values (using SNA), this evaluation must be followed by the qualitative analysis of relationships. Indeed, a GT researcher familiar with the context of the study needs to make sense of ties between concepts and relational patterns through an iterative and interpretive process. Due to the increasing growth of techniques provided by mathematicians and physicians for the SNA, the importance of "choice of measures" and "decisions on their application" to particular topics has been underscored (Borgatti, Everett & Johnson 2018; Scott 2017, p. 3). The wise selection of indicators and measurements is subject to our understanding of the concepts behind the structural properties of the networks. The following subsection describes the topological properties in relation to the research objectives and the most appropriate ways to compute them.

4.4.1. Analysis of structural properties

In this study, the network structure explained the nature of innovation in hospital building design by indicating the patterns of connection among concepts that were harvested from various data sources during the initial and focused coding. To understand the structural properties of this network in accordance with the research objectives, three prime variables of the network structure (*centrality measures*, *subgroup measures*, and *cohesion measures*) were computed. In parallel, the nature of ties was qualitatively examined based on the memos and annotations. The aim was to: 1) identify the contextual factors (nodes) most actively involved in relationships with other actors (at micro-level); 2) detect the presence of cohesive clusters, and interconnections between clusters (at meso-level); and 3) explore the cohesion and interconnectedness of actors within the whole network (at macro-level) (Blackstone 2018; Boccaletti et al. 2006; Bolíbar 2016; De Nooy, Mrvar & Batagelj 2018; Moody & Coleman 2015; Newman 2003; Russell et al. 2015; Scott 2017; Xu et al. 2020).

Table 4-5 describes three variables used to quantitatively characterise the innovation networks. The associated measurements and computation formula to each variable are also determined.

Table 4-5: Structural properties used for the analysis of innovation networks

Level of Analysis	Measurement/ Metric	Description
Micro-level	Centrality Measures an expression of how tightly the graph is organised around its most central points (Scott 2017)	
Number and Types of nodes (actors)		The size and composition of the network (innovation ecosystem) (Russell et al. 2015).
All and Average Degree Centrality Input/Output Degree Centrality		Degree Centrality of a node is its degree, identifying the most interconnected factors. This metric is a measure of *local centrality* indicating how well connected the nodes are with their neighbours (Scott 2017). While this metric indicates the most influential factors, it is crucial to consider the edge weight as well.
All Closeness Centrality Input/Output Closeness Centrality		Closeness centrality of a node is the number of other nodes divided by the sum of all distances between the node and all others. It is a way of detecting the most influential nodes in the whole graph, a *global centrality* measure. A node is globally central if it lies at short distances from many other points and has a strategic role in the overall structure of relations (Scott 2017). This metric can examine the extent to which a factor has freedom from the impacts of others in terms of triggering design innovation.
Betweenness Centrality		Betweenness centrality captures a node's position in the network with regards to the way the node links other nodes. The communication of two non-adjacent nodes depends on the nodes belonging to the paths connecting them. This metric, thus, was originally introduced to quantify the importance of an actor in a network (Boccaletti et al. 2006). Variables with high betweenness scores have the capacity to facilitate or limit interactions between the nodes they link (Basole 2016; Russell et al. 2015; Shipilov & Gawer 2020). Which actors were able to facilitate the generative relationships that support innovation? (Basole 2016; Russo & Rossi 2009) (Burt 1992; Russell et al. 2015).

Eigenvector Centrality		Eigenvector centrality assigns relative scores to each node in the network in reference to its connections to high-scoring nodes. That is, a connection to a high-scoring node contributes more to the score of the node in question than an equal connection to a low-scoring node. Thus, nodes with high eigenvector centrality tend to have many links to actors with several links (Basole 2016; Shipilov & Gawer 2020). It is a measure to identify the most powerful actors connected to other powerful actors in a network. This follows the idea that the centrality of a particular point cannot be assessed in isolation from the centrality of all the other points to which it is connected (Scott 2017).
Meso-level	Subgroup Measures	
Clustering		Given a graph G(N,L), a community (or cluster, or cohesive subgroup) is a subgraph G'(N',L'), whose nodes are tightly connected. Here, I adopted the Louvian method between the four main approaches to developing clusters in a network. Here, *modularity* measures how well a selected partition divides a network into communities. Cluster detection indicates the close interactions between different groups of nodes in the innovation network that determines which factors have been more related over time. Moreover, it indicates which connections bridge two distinct clusters, and which nodes reside at the intersection of different subgroups (Blondel et al. 2008; Boccaletti et al. 2006).
Macro-level	Cohesion Measures	
Density		The ratio of actual to the maximum possible number of network connections (its number of factual ties divided by the number of possible ties) (Fritsch & Kauffeld-Monz 2010). This metric describes the interconnectedness of actors in a network (Romero 2019) and how far the graph is from its state of completion (Scott 2017). It is suggested to consider the degree of each node when discussing the network density, as density is highly dependent on the size of the network (De Nooy, Mrvar & Batagelj 2018).
Degree Centralisation		Degree centralisation of a network is defined as the variation in the degrees of nodes divided by the maximum degree variation that is possible in a network of the same size, it is a value between 0 and 1. The idea is that determining the central and peripheral nodes in a star-network is more feasible than in a line-network with the same number of nodes and links. Thus, a network is more centralised if the nodes vary more with respect to their degree centrality.
Homophily		Homophily is a preference of nodes to attach to other nodes which are similar to them according to a categorical property, such as gender, race, or social class (De Nooy, Mrvar & Batagelj 2018; Hanneman & Riddle 2005). It reflects if a cohesive subgroup mainly contains nodes from similar categories or not.

Among all metrics and their computational techniques, selecting the most optimal clustering method (to measure clusters and reveal a possible underlying structure) is more challenging (Brailas 2014). According to Moody and Coleman (2015) and Borgatti, Everett and Johnson (2018), four main approaches are commonly used to manipulate the visual representation of networks and explore the clusters. The first deterministic approach considers the concept of k-cliques (a clique is a subset of nodes all of which are adjacent to each other, and such that no other nodes exist adjacent to all of them), and then count the number of shared cliques between nodes

(Boccaletti et al. 2006). This approach has been generalised by Palla et al. (2005) in the clique percolation method (CPM). The second algorithm cuts the graph by removing key edges until the graph is no longer connected (Borgatti, Everett & Johnson 2018; Girvan & Newman 2002). The third clustering approach focuses on using principal components or factor analysis to identify groups from interaction or nomination matrices (Bagwell et al. 2000). The fourth approach devises an algorithm that captures subgroup properties and then uses this to identify the groups (Newman 2004). The Louvain method, developed by Blondel et al. (2008), follows a similar approach to with the aim of optimisation of the modularity in a network. Here, the modularity is a scalar value between -1 and 1, an indication of the quality of the derived communities, measuring the density of the links inside the community in comparison with those between communities. Each cluster detection method corresponds to a particular subclass of problems and/or data types, and offers slightly different outputs (Pimentel 2014). This affects both quantitative and qualitative analyses, especially interpretations of the key clusters, the key bridging concepts, and possible structural holes in the network (Burt 2002). Thus, explaining the adopted approach is crucial to provide the necessary transparency to the GT study.

Given the potential clustering algorithms, the Louvain method of clustering was selected for the present study because of two prime reasons. First, the clValid package in R software is widely used for cluster validation by examining the internal validation indices (Connectivity, Dunn, and Silhouette) and the number of clusters for different clustering algorithms (Akbari 2015). Here, the clValid test, informed by Brock et al. (2011); Brock et al. (2020), determined *Walktrap analysis* (Pons & Latapy 2005), *Louvain analysis* (Blondel et al. 2008), and S*pin-Glass analysis* (Eaton & Mansbach 2012) as the most optimal algorithms based on the data provided in this study. Walktrap, Louvian and Spin-Glass algorithms detected 11, 9 and 10 clusters respectively, which could not support a theoretical meaning for the empirical data. Here, only the Louvian method allowed optimisation of the amount of modularity in the network, and thereby determination of the most appropriate number of clusters in relation to their theoretical knowledge of the phenomenon. Secondly, the wide application of Louvian algorithm for directed networks and its ability to apply the weight of links in the analysis made it a reliable method that creates valid partitions by assigning each node to exactly one cluster. Thus, the Louvian algorithm was considered as a force-driven algorithm designed to reach the best balance of constant interactions between forces of attraction and repulsion (Blondel et al. 2008; Newman 2004). It replaces communities with super nodes and links between communities as weighted ties to generate a smaller network. The passes are repeated iteratively until no increase of modularity is possible. The nodes are eventually grouped together in clusters based on the interconnections between them forming the overall graph structure. The detailed explanations of how this method was used to measure subgroups are provided in the next chapter (see section 5.3.1).

4.5. Data Interpretation in Mixed Grounded Theory

Whilst the preceding section offered some heuristic techniques from SNA to analyse and explore the form of network diagrams, the last step of this study focuses on the interpretation of innovation networks. Here, the quantitatively driven techniques of SNA allowed exploring who and what played a role in innovation networks, and what were the involved relationships, by focusing on the topology and structural properties of networks (Luxton & Sbicca 2020; Newman 2003). To complement understanding acquired from the statistical measurements, it was necessary to explore what happened when, and for what reasons, by focusing on chronology, intentions and explanations. This deeper understanding of the phenomenon being studied required the analysis of the arc diagrams, where the chronological order of concepts and interactions among them were captured.

Network visualisations are considered to possess both an "explorative function" (by which researchers scrutinise how a phenomenon is composed) and a "narrative function" (by which analysts construct particular narratives of the formed networks) (Decuypere 2020, p. 13; Segel & Heer 2010). In this study, I, as constructivist/interpretivist GT researcher, aimed to understand the "story" behind design innovations. To this end, after exploring the statistical properties of the innovation networks, the individual and collective impacts of the concepts were qualitatively interpreted to develop the final narrative and construct the innovation framework. Arc diagrams were also examined to complement the understanding of interactions and key patterns that triggered design innovations over time. Here, the theoretical models gained from the analysis process of initial and focused coding helped develop a narrative interpretation explaining the contextual factors and the content of ties, as well as elucidate why and how different nodes in a network occupy their position at certain points over the past 100 years.

4.6. The Interactive Model of Research Design

As Maxwell (2012) and Creswell and Creswell (2017) suggested, research design is a reflexive process that reshapes through different stages of a study. In other words, investigating the research problem, reviewing the literature, selecting the methodology, data collection, data analysis, and refocusing research questions, etc. impact one another in an iterative process. Providing an interactive model of/for research design can help to fully understand the relationships between the components of the research. As Maxwell (2012, p. 3) stressed in his model, researchers need to "assess", "construct" and "reconstruct" their qualitative research design through an interactive process between design components to achieve the main aim of the study. Here, five prime research components and the interrelationships between them constitute the research design model, namely goals, conceptual framework, research questions, method, and validity (Maxwell 2012; Robson 2011; Rudestam & Newton 2007). Figure 4-6 illustrates the interactive model of the research design that has been revised four times during this study.

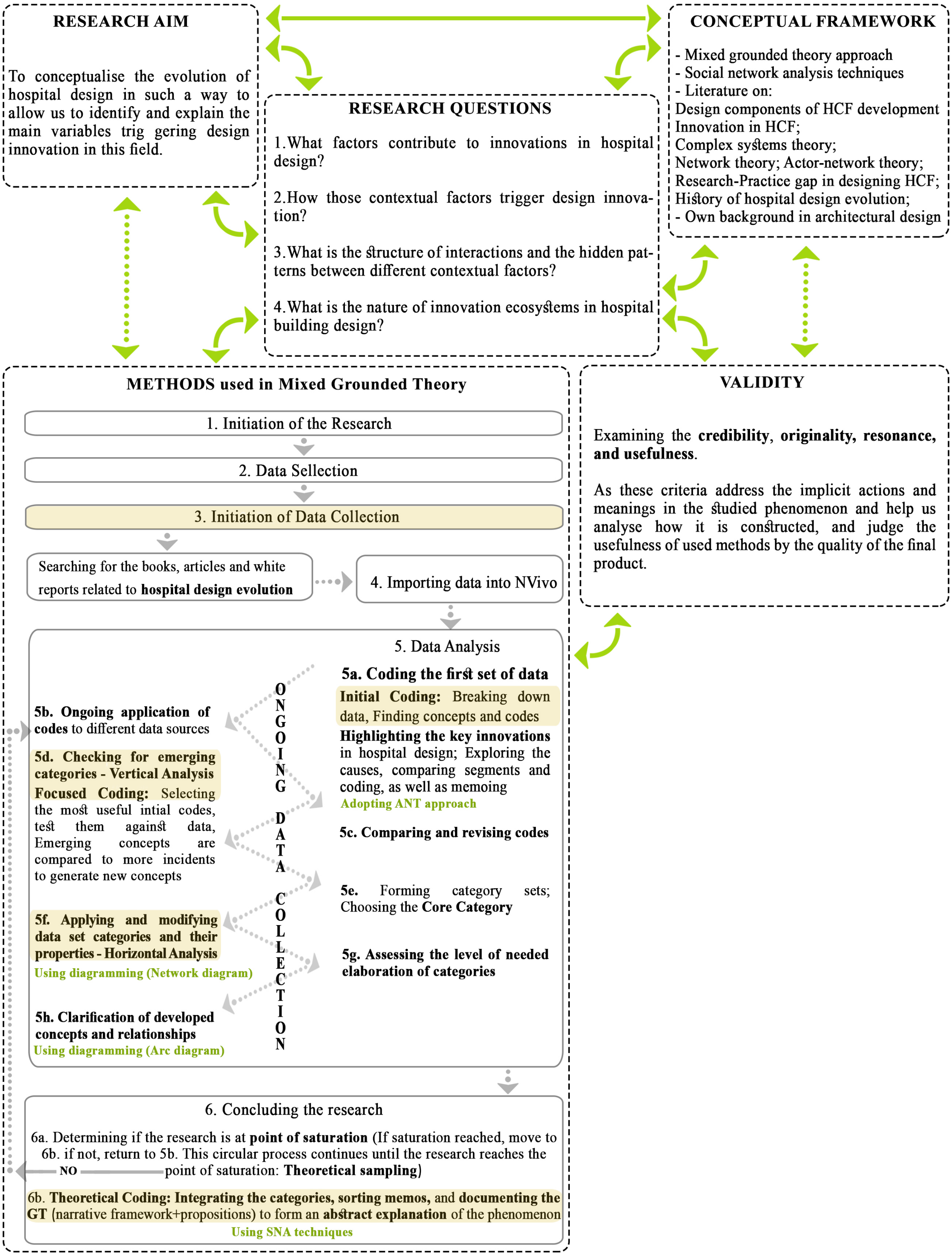


Figure 4-6: An adaptation of the Interactive Model of Research Design by the author (originally complied from Chun Tie, Birks and Francis (2019); Egan (2002); Maxwell (2012))

Interactions between the five research components and different steps of the analysis process depicted in Figure 4-6 were explained. Here, a summary of the five sections of this chapter is provided:

1) Reasons behind the identification of the research paradigm, methodological choice and strategy were explained in relation to the study's problem definition, research objectives, and

choices of procedures of inquiry (section 4.1). The mixed methods strategy of GT with Charmaz's constructivist paradigm was employed to achieve the research aim (section 4.1.4). Here, the MGT research design contained the use of different types of data, analysis strategies, and logic of inquiry to better understand why and how design innovations occurred.

2) Section 4.2 explained the techniques and strategies applied to the process of data gathering and analysing. The primary dataset consisted of a wide range of publications, which specifically deal with hospital building evolution and/or explicitly mention the key innovations in hospital building design (section 4.2.1). The back-and-forth procedure between data collection and analysis and how I, as a GT researcher, remained open to changes in direction based on emerging data were also explained.
   Data analysis in an MGT methodology (section 4.2.2) included three main stages (initial literature review, initial coding and focused coding). Here, the debate about GT researchers' engagement with existing literature prior to the dynamic interplay of data collection and analysis was discussed to explore the best starting point for this study (section 4.2.2.1). The methodological steps defined by the Charmaz (2014) interpretive GT were employed using NVivo (section 4.2.2.2 and 4.2.2.3). In the "focused coding", concurrently with data collection, the emerging concepts were compared with each other across all data sources through *vertical analysis* and were classified into categories according to their common properties. *Horizontal or cross-sectional analysis* was also conducted parallel to the vertical analysis to compare the interrelatedness of context-specific concepts within and across categories. However, the significant weaknesses became clear of the common GT procedure in addressing the complexity of research objectives. There were too many concepts and links to be analysed in a standard narrative way by retrieving the attached annotations and memos to codes.
   Section 4.2.2.3 provided explanations on why and how two complementary analysis techniques and methods were merged into Chramaz's suggestions for the focused coding. The new MGT design suggested the use of diagramming and associated analysis techniques:
   A) Considering the importance and complicatedness of big data cross-sectional analysis, a set of creative and useful diagrammatic representations was selected to facilitate the process of ordering different concepts in correct relation to one another - both horizontally and vertically - and exploring semantic relations between different concepts through visual analysis. As discussed in section 2.4.2, a network-centric approach is commonly considered as a *systemic way of thinking* to deal with interrelationships and a *methodology* to truly understand the complexity of innovation ecosystems. Thus, a network diagram was constructed to depict interactions between influential factors, followed by the construction of an arc diagram to render the chronological order of relationships missed in the network diagrams; and
   B) Different analysis techniques based on the prime characteristics of the network and arc diagrams were adopted to enhance the analytical and interpretive processes.

3) Section 4.3 discussed the well-established role of diagramming as one of the most effective tools to enhance the process of creatively probing the data, increasing researcher's scrutiny, and moving away from descriptive summation to conceptual explanations of the phenomenon. Notwithstanding the potential of diagrams in the process of conceptualisation and communicating ideas, their implementation in the analysis process remains insufficient. Section 4.3.1 suggests that this inconsistent use of diagramming mainly rests on seven

functional limitations of CAQDAS tools, limiting the capability for alternative interpretations of data. In section 4.3.2, eight types of diagrams useful to GT research, and explanations on their unique characteristics and properties, were provided. This study suggested that researchers adopt the increasingly diverse array of dissemination potentials to provide static and moving visual representations hyperlinked to texts to aid the process of data analysis. Here, the specific features of the network and arc diagrams made them applicable to the current GT study. The next chapter (section 5.1.3) illustrates how I attempted to construct and refine these two diagrammatic representations of data as an integral part of the constructivist GT.

4) Section 4.4 explained how the aforementioned diagrams could be creatively analysed and interpreted in relation to the research objectives, and presented the hidden values of using them in the analysis process. In particular, the qualitatively and quantitatively driven techniques, provided by SNA, were explained. The main aim was to understand the complex interactions within the innovation ecosystem, systematically describe and examine "all kinds of relationships" between entities and explore the "patterns" apparent in those relationships. Here, to understand the structural properties of the network, three prime variables of the network structure were computed. In parallel, the nature of ties was qualitatively examined based on the memos and annotations. The aim was to: 1) identify the contextual factors (nodes) most actively involved in relationships with other actors (at micro-level); 2) detect the presence of cohesive clusters, and interconnections between clusters (at meso-level); and 3) explore the cohesion and interconnectedness of actors within the whole network (at macro-level). In section 4.4.1, the metrics used in this study and their computational techniques, besides two reasons behind the selection of Louvian method as the most appropriate clustering algorithm, were represented.

5) Whilst the preceding sections offered some heuristic techniques from SNA to analyse and explore the form of network diagrams, section 4.5 focused on how these analyses could be interpreted to explain the nature of innovation in hospital building design. Here, the quantitatively driven techniques of SNA allowed me to explore who and what played a role in innovation networks and what were the involved relationships by focusing on the topology and structural properties of networks. To complement the understanding acquired from the statistical measurements, it was necessary to explore what happened when by focusing on chronology, intentions and explanations through the analysis of arc diagrams. Here, the theoretical models gained from initial and focused coding helped to develop a narrative interpretation explaining the contextual factors and the content of ties, as well as elucidating why and how different nodes in a network occupy their position at certain points in time.

To conclude, the main data sources identified through the initial literature search were iteratively analysed via initial and focused coding. Here, two complementary analysis techniques and methods were used to facilitate the process of focused coding. After reaching the saturation point and developing the final innovation framework, the complex nature of design innovation processes was explained in relation to the SNA outcomes. The next chapter reflects on the application of this methodology and represents the findings acquired from the process of initial and focused coding. Further, the process is explained of developing a taxonomy of concepts and a theoretical model elucidating the design innovation ecosystem. Next, chapter six reflects on the new knowledge extracted from these analyses, leading to the construction of an explanatory innovation framework.

05

The Construction and Analysis of Theoretical Models in Design Innovations

This chapter provides a reflection of the analysis process to demonstrate *how* I applied the strategies suggested in the previous chapter, and *what* resulted from each stage of the GT analysis process. It reports on the process of constructing and analysing the theoretical models explaining the process of innovation generation in hospital building design. The procedure is explained in detail of data analysing, coding and categorising during initial coding using NVivo, cross-sectional analysis during focused coding, as well as selecting and employing two analysis techniques and methods complementary to the focused coding. In the focused coding, the categories were developed, and the taxonomy of domain concepts was constructed through vertical analysis. Next, the horizontal relationships between codes were examined, resulting in a theoretical model comprised of a set of propositions explaining those interactions. Here, a set of diagrammatical representations (network and arc diagrams) in relation to their prime features and the study objectives were used to 1) represent interactions between a wide range of contextual factors, and 2) aid the cross-sectional analysis by using strategies and techniques of SNA. The final theoretical model represents the semantic interrelationships that triggered design innovation.

5.1. The Application of Mixed Grounded Theory

5.1.1. Starting point in the analysis process

As discussed in section 4.2.2.1, this thesis posits that it is important to employ existing knowledge about contextual factors, concepts, interrelationships and different categorisations in the field of innovation in hospital building design. Here, 17 critical texts on hospital design evolution were examined to explore the contextual factors and interactions between them that have mostly remained unrecognised and uncategorised. Among these existing studies, a report entitled "50 years of ideas in the NHS" published by Francis et al. (1999) has classified the prime ideas impacting the design and construction of NHS hospitals in four broad areas: (1) the practice of medicine, (2) the design and construction of different building typologies, (3) the society and people, and (4) the healthcare policies and management of the NHS. Here, the arguments identified by Francis et al. (1999) and their approach to the problem were close to those of this study. It gives broad insight into the links between different ideas indirectly related to the field of healthcare design in the UK over the second half of the 20th century. This classification and descriptions of prime factors provided the starting terminologies and categories that were the basis for the analysis process of this thesis.

In the early stages of the analysis, through basic initial and focused coding data sources were examined according to the general idea of their chapters. Here, the links between the main categories and the prime sources were tabulated (see Appendix 9.3.1). This table played a key role in identifying the saturation point since it indicated the related datasets for each category across the references. Next, the process of substantive coding was continued as described below and the subcategories were refined concurrently as the data collection progressed. Notably, each reference has a specific aim and provides information on the evolution of hospital building design and the contextual factors from a particular perspective. This study aimed to consider a wide range of approaches to explore the linked contextual factors to innovation in hospital building design.

5.1.2. Initial coding through content analysis

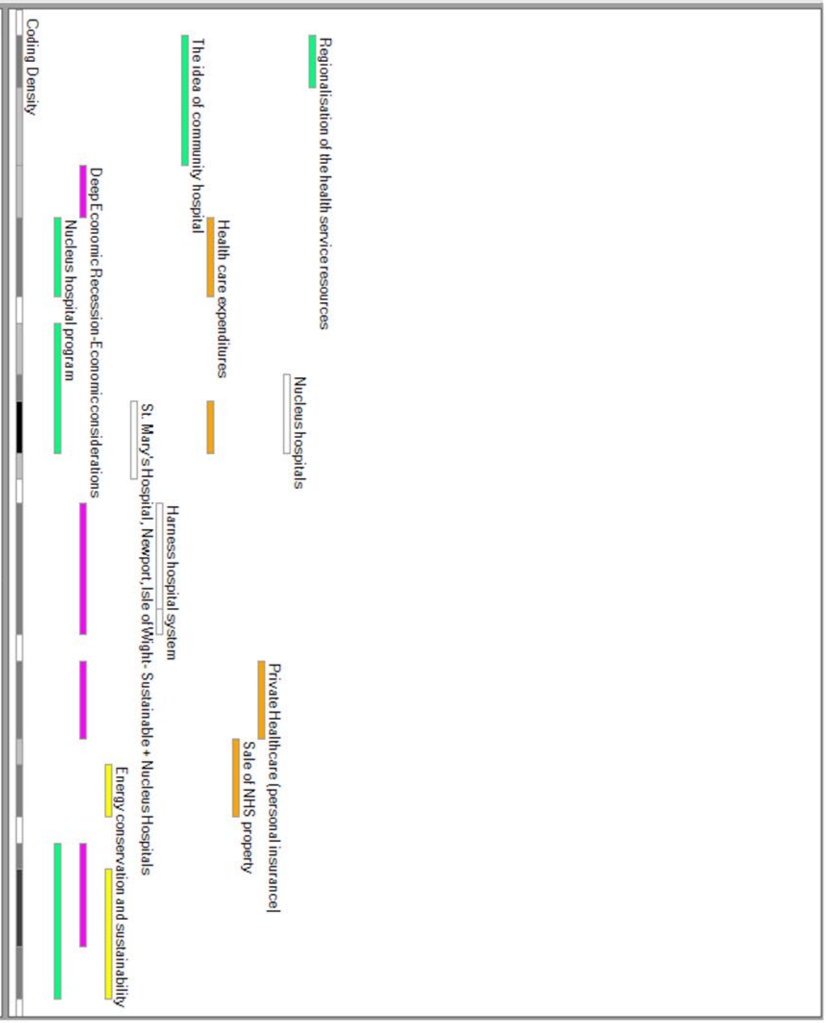
In this study, the selected raw data contain the actual incidents and events that occurred during hospital building design evolution since the 1920s. NVivo was utilised as a tool aiding the process of big data classification and analysis (CAQDAS-Computer Aided Qualitative Data AnalysiS). As discussed in section 4.2.2, the manual ways of GT analysis, which have widely been translated to a computer-assisted way, were employed in this analysis (Friese 2019; Gorra 2019). First, the raw data (selected texts from references) were imported into NVivo and classified according to the decade that events occurred in. Two decades were selected as the classification bracket because, across the overall period of study, twenty years would commonly see considerable innovation in hospital building design.

Initial open coding, to look for implicit and explicit meanings of incidents, started immediately after the collection of the first dataset (50 years of ideas in healthcare buildings (Francis et al. 1999)). The conceptualised codes were applied to data incidents (actions, happenings, and processes) using line-by-line analysis. Here, codes were determined according to the common terminologies used in the selected references (informant's terms in-vivo). In this instance, in-vivo is taken to represent a code based on a verbatim term uncovered in one or more data sources. These codes were compared to the fresh data incidents of each reference to generate abstract concepts that cover a broader range of incidents. Here, data analysis and coding were an *iterative process* that continued through subsequent data collection to examine and extend the provisional concepts across the whole study. In translating the Charmaz (2014) approach into NVivo, all the initial codes for each reference were recorded. Codes were integrated into a cumulative file, resulting in refinement and synthesis of the concepts in relation to new knowledge. It is noteworthy that initial coding was also conducted through recording ideas and writing memos about the links between codes using annotation in NVivo. Here, a few examples of the initial coding of the partial sections are provided (see Figure 5-1). Notably, as texts from different data sources focused on different periods of time, the order of the initial codes does not match with the order incidents occurred.

As is noticed from the samples of initial coding, a wide range of codes were assigned to the first dataset. Here, the following codes were constructed regardless of the links between them: Community Hospital, Healthcare Expenditure, Deep Economic Recession, Nucleus Hospital Program, Private Healthcare, Sale of NHS property, Hospital Building Note, Best Buy Hospital, Energy Conservation and Sustainability, CAPRICODE, Standardisation, Systematic Approach, Harness Hospital System, Hospital Service, Regionalisation of the Health Service Resources, the National Health Service Act, Changes in clinical Practice and new therapies, and Development of Antibiotic. At this point, codes resulting from the open coding process were not sorted for hierarchical structure. Notably, recording the number of data instances to code is important in this level to determine the frequency of occurrence for each code. The next section reports on the process of comparative analysis in focused coding and the development of initial concepts.

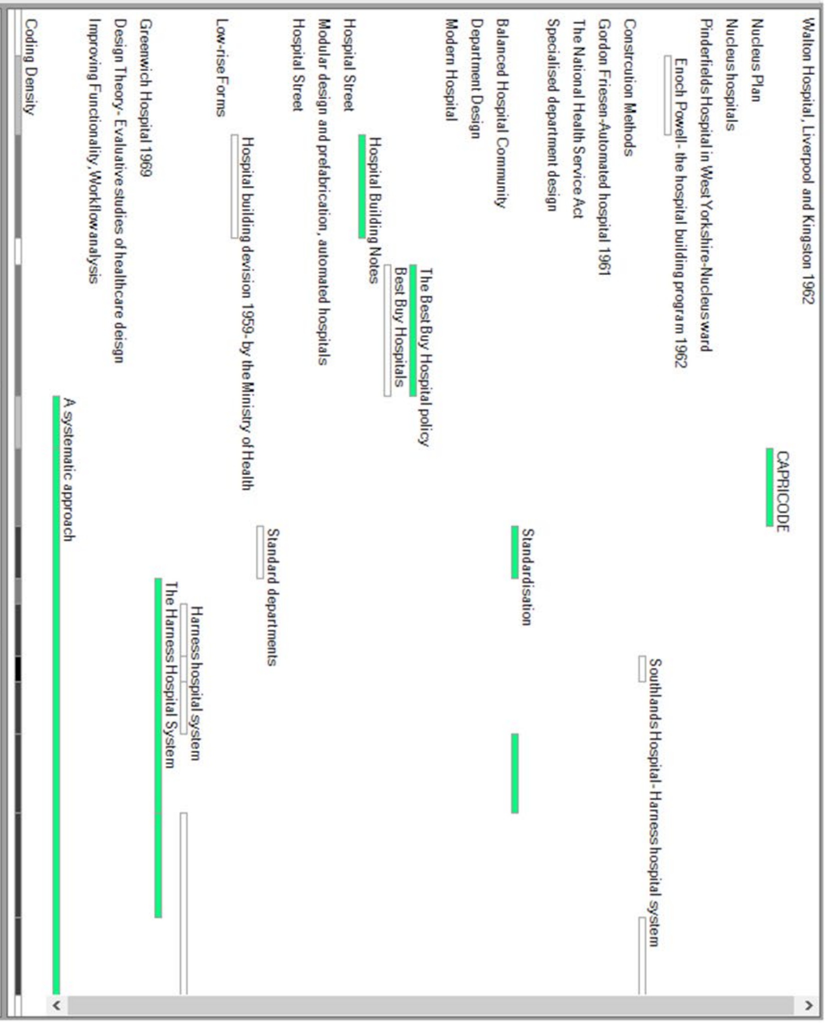
1970s-1980s

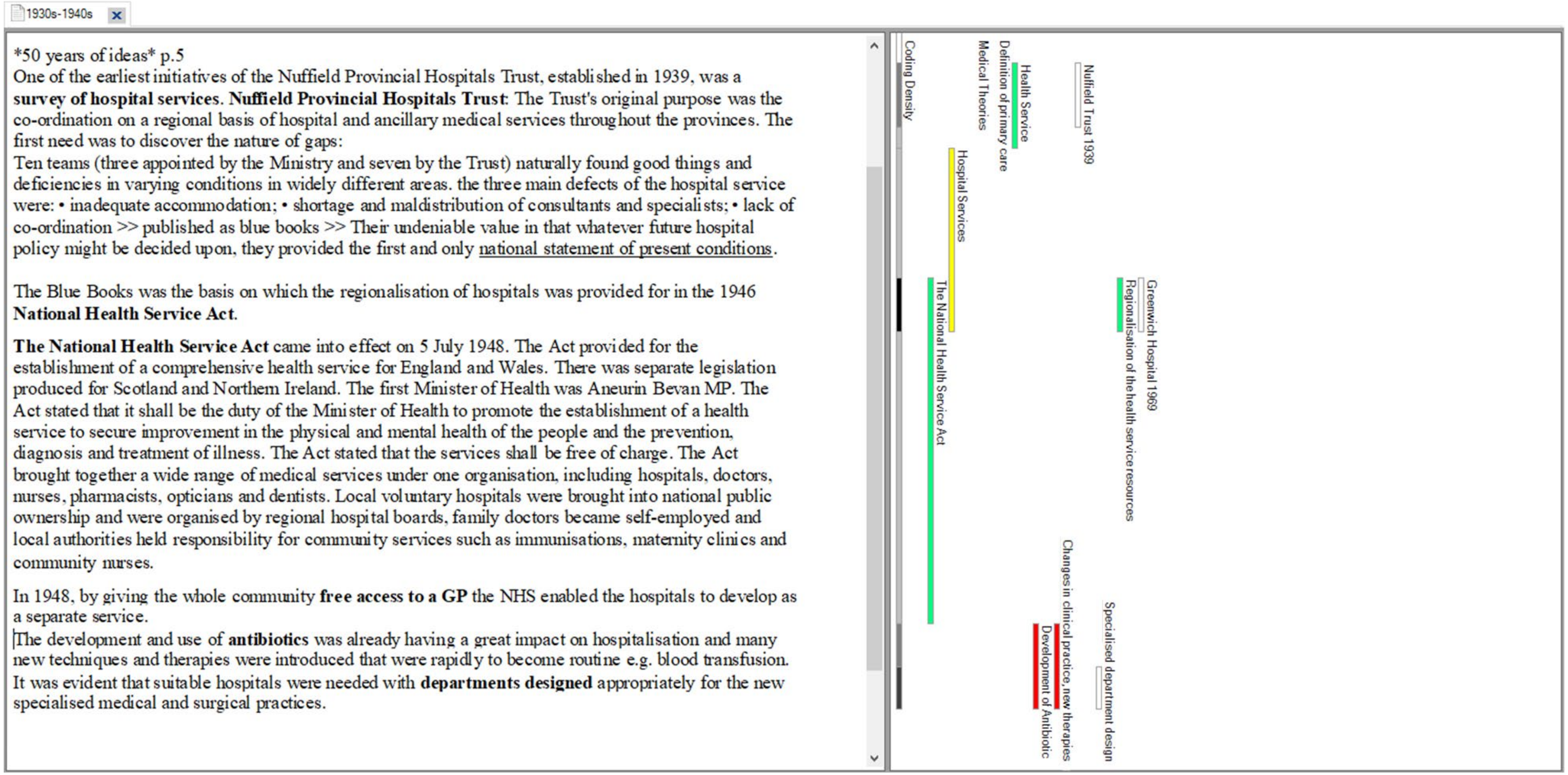
50 years of ideas p.20
An official report in 1969 broadly supported the idea of **the District General Hospital (DGH)**, on which the then heavily committed Hospital Plan was based. However, it recommended reducing the number of DGHs by enlarging their catchment population and by making provision within them for geriatric, psychiatric and mental subnormality services. In the early seventies the idea of the **Community Hospital** was introduced into official NHS thinking.
By the mid-seventies changing circumstances, of which **the oil crisis of 1973** was the most dramatic, began to eclipse Britain's post-war vision built on idealism and generosity. In a public statement in 1975, David Owen, the Secretary of State for Health, said that the hospital building programme was completely out of control and there was an over-riding need to control and **reduce expenditure** within the NHS. The **'Nucleus' hospital programme** was developed as a result of this.
p.48
Unless an exceptional gap in hospital services was identified all new developments and major extensions were to be restricted to a nucleus of departments costing no more than £6m (May 1975) but capable of expansion. Thus the modestly sized, low cost hospitals came into being as **the 'Nucleus' project.**
>> The Department's experts devised a standardised hospital briefing planning and design system with standard operational policies and standard department plans. There was a ready made plan for most hospital departments to fit into the fixed outline, together with operational policies.
p.50
The scale of the need to promote hospital developments, to set design standards, to achieve equity of provision and to monitor progress of developments meant that **the introduction of a systems and standards programme was inevitable**. Devising and implementing the process which moved from the identification of hospital service need to a successful development and design brief by codifying functional content and operational policies, was an important achievement.
p.20
Economic considerations continued to dominate the NHS during the eighties with some **political preference** for replacing the universal health service with private health care financed through personal insurance, with a low cost 'safety net' public service.
The report of 1982, Underused and Surplus Property in the NHS, led to the sale of NHS property, in order to release capital for new projects. To the same end Designing to Reduce Operating Costs (DROC) and Space Utilisation Studies were also promoted by the NHS during this period.
p.58
The low energy hospital study was commissioned in 1979 and made available in 1982. The 1973 fuel crisis had impact on building design and technology and on legislation. Since hospitals and other health care buildings consumed a significant amount of energy, and thus NHS revenue spending, the Department had astrong financial incentive to implement design measures to reduce energy consumption >> The study required a hospital to be designed that would consume only 50% of the energy used by a conventionally designed hospital delivering an identical service to the NHS.



1950s-1960s

50 years of ideas p.41
A planned framework for development was set eventually with the publication in 1962 of the Minister of Health's Hospital Plan for England and Wales >> resulted in the construction of a series of **District General Hospitals** of 600-800 beds.
The Ministry of Health approved the functional content, the design and the funding of capital projects. To meet the need for disseminating information, controlling standards, establishing need for capital investment and monitoring developments the Hospital Division established a programme to publish a series of **Hospital Building Notes in 1961** >> provided standards for all NHS hospital developments
p.42
But, **cost climbed + inflation after war**
>> The number of acute beds was reduced from about three to two per 1000 of population and a smaller complete DGH hospital design of 550 beds was introduced by the Department early in 1967 >> **the 'Best Buy Hospital'**>> as providing adequate facilities without being extravagant >> hospital policy and design for two storey buildings with simple construction methods + naturally ventilated.
A systematic approach towards all aspects of the hospital building programme: service planning, briefing, designing, building systems, building components, equipment, management and procurement.
CAPRICODE was the name for the Department of Health and Social Security Capital Projects Code which provided 'the mandatory procedural framework for managing and processing NHS capital building schemes'.
Towards the end of the sixties the Department of Health designed **standard hospital departments** for maternity units and psychiatric departments.
p.46
In 1969 the Department's Hospital Buildings Division was developing a new system in an attempt to obtain a synthesis of the best current ideas in hospital policies, planning, building technology, environmental services design and dimensional co-ordination. **Harness hospital system** >> This was **more flexible** than the standard whole Best Buy Hospital >> developments in a wide range of locations, with variable functional content and encouraged development control planning of hospitals.
Hospital building division: **a range of standard operational policies and designs for standard departments.** These had to conform with strict dimensional and modular co-ordination, with specified zones for structure and services.
Using the Harness system they could produce several development control plans with known viable departmental layouts and select a preferred one within two days, confident in the knowledge that their hospital could then be built to a very high standard in terms of both design and construction and with known costs.
Seventy major hospitals were being considered as Harness developments but with the economic recession following the oil crisis of 1973, all capital funding was severely restricted, and only two whole Harness Hospitals were built.





50 years of ideas p.5
One of the earliest initiatives of the Nuffield Provincial Hospitals Trust, established in 1939, was a **survey of hospital services**. **Nuffield Provincial Hospitals Trust**: The Trust's original purpose was the co-ordination on a regional basis of hospital and ancillary medical services throughout the provinces. The first need was to discover the nature of gaps:
Ten teams (three appointed by the Ministry and seven by the Trust) naturally found good things and deficiencies in varying conditions in widely different areas. the three main defects of the hospital service were: • inadequate accommodation; • shortage and maldistribution of consultants and specialists; • lack of co-ordination >> published as blue books >> Their undeniable value in that whatever future hospital policy might be decided upon, they provided the first and only national statement of present conditions.

The Blue Books was the basis on which the regionalisation of hospitals was provided for in the 1946 **National Health Service Act**.

The National Health Service Act came into effect on 5 July 1948. The Act provided for the establishment of a comprehensive health service for England and Wales. There was separate legislation produced for Scotland and Northern Ireland. The first Minister of Health was Aneurin Bevan MP. The Act stated that it shall be the duty of the Minister of Health to promote the establishment of a health service to secure improvement in the physical and mental health of the people and the prevention, diagnosis and treatment of illness. The Act stated that the services shall be free of charge. The Act brought together a wide range of medical services under one organisation, including hospitals, doctors, nurses, pharmacists, opticians and dentists. Local voluntary hospitals were brought into national public ownership and were organised by regional hospital boards, family doctors became self-employed and local authorities held responsibility for community services such as immunisations, maternity clinics and community nurses.

In 1948, by giving the whole community **free access to a GP** the NHS enabled the hospitals to develop as a separate service.
The development and use of **antibiotics** was already having a great impact on hospitalisation and many new techniques and therapies were introduced that were rapidly to become routine e.g. blood transfusion. It was evident that suitable hospitals were needed with **departments designed** appropriately for the new specialised medical and surgical practices.

Figure 5-1: Three samples of the initial coding process for the first dataset

5.1.3. Focused coding – adopting a multi-representational approach

Through focused coding, the most useful initial abstract codes were selected and examined against more incidents across different data sources to generate new theoretical properties of concepts. As higher-level concepts were generated, through *vertical and horizontal analyses,* categories and the links between concepts were developed incisively and completely (Charmaz 2006, p. 42; Holton 2011, p. 277). While the strategies suggested for these two analyses were represented in section 4.2.2.3, the reflection of those techniques in the present study is explained in this section.

In *vertical analysis*, codes with similar concepts and properties were categorised under the best fit conceptual label, leading to category development with specified relationships between codes. The vertical analysis aimed to classify higher- and lower-order codes based on their level of generality in a tree structure (Charmaz 2006, p. 91; Corbin & Strauss 2014). As such, a number of initial codes resulting from the coding analysis of the first dataset had common meaning and properties. These codes were selected and classified under one shared concept in NVivo. For instance, the generic concept identifying one of the categories is *Healthcare Policy* (i.e., the overall plans proposed by the government) (Figure 5-2). In the next step, codes and links under this concept were examined to develop more specific concepts that contain codes with particular properties. Thus, *Healthcare Policy* impacting hospital building design innovation is a general concept consisting of actions related to either *Healthcare Construction* or *Health Service*.

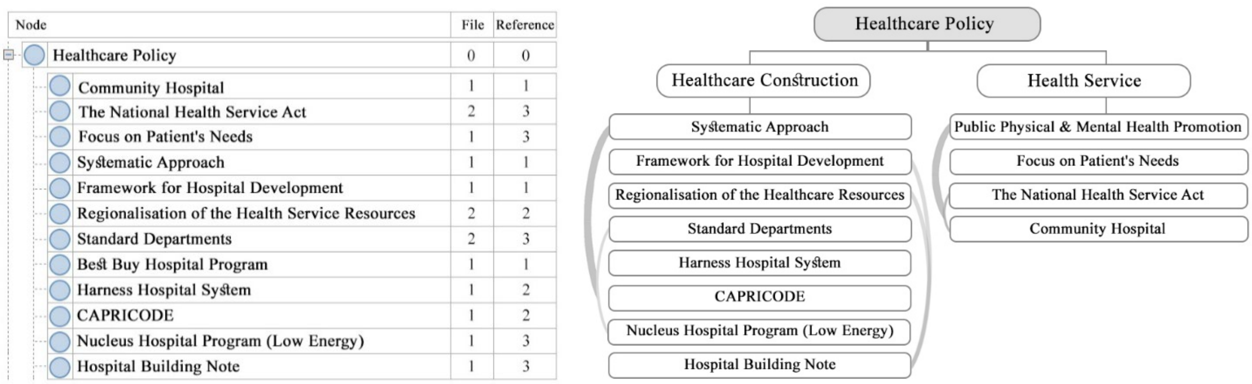


Figure 5-2: The vertical analysis of the codes resulted from the first dataset

Subsequently, codes under *Healthcare Construction* and *Health Service* were analysed to explore shared properties, resulting in the development of next degree subcategories. Here, the *Public Physical and Mental Health Promotion* (including the *National Health Service Act* and the idea of *Community Hospital*) and *Focus on Patient's Needs* constitute the two innovation triggers under the *Health Service*. Turning to *Healthcare Construction*, the planning of a *Framework for Hospital Development* was the first subcategory, which then led to the *Regionalisation of Health Service Resources* and subsequently to the establishment of the program for publishing *Hospital Building Notes*. Proposing the *Best Buy Hospital Policy*, and a *Systematic Approach* in the design of hospitals also played key roles in generating hospital architectural and organisational innovations. Establishing a *Systematic Approach* was followed by the developments of *Standard Departments*, *Harness Hospital System*, the introduction of *CAPICODE* and *Nucleus Hospital Program*.

This pattern of classification, going from the most general (topmost) to the most specific concepts, has been considered in the analysis of other categories. It is notable that the higher-level concepts were generalised in a way to include possible new data under the same concept. At this stage of vertical analysis, the code stripes in NVivo were utilised to aid the process of generalisation and constant comparison. Stripes represented the specific colours assigned to each category and its subsets that provide immediate feedback on the codes classified in the datasets.

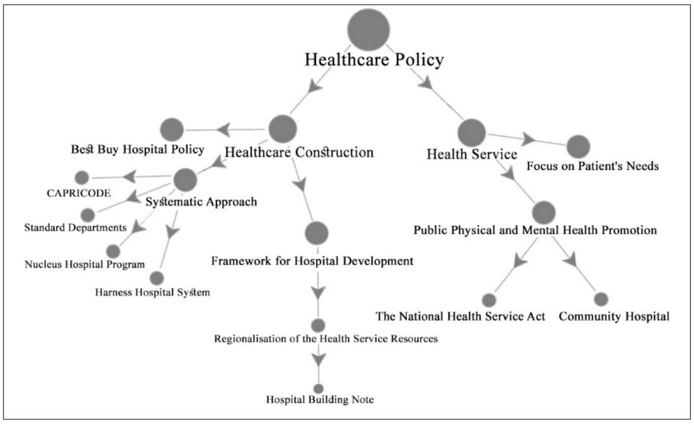


Figure 5-3: The hierarchical ordering of codes (resulting from the first dataset) under the Healthcare Policy category

Parallel to vertical analysis and categorisation of codes, the interrelatedness of context-specific codes was explored through *horizontal analysis*. At this point, several interactions between concepts within and across categories were added into the NVivo file. Here, the specific properties of categories and reasons behind the interconnections, elucidating the way concepts were connected at different levels of abstraction, were recorded as annotations to significant data sections. Further, specific design innovations (architectural, service and organisational design innovations) resulting from those interactions, as well as linked examples to each innovation, were added to the file. The main challenge here was to draw the most accurate interrelationships. This process required considerable attention to empirical data and previous knowledge on the subject. Next, the annotations and memos were sorted analytically to make a comparison between categories towards the theoretical integration of categories and the emergent ideation of theoretical codes (Charmaz 2014; Kelle 2007). However, as discussed in section 4.2, textual analysis was not adequate to describe the several relationships explored (in line with (Charmaz 2014)). Indeed, it was not possible to determine the hidden relational compositions by retrieving the attached annotations and memos for the first two datasets, (Francis et al. (1999) and). This situation was exacerbated after conducting equivalent analyses for the next datasets. Considering the importance and complicatedness of big data cross-sectional analysis, this study suggests the merger of two analysis strategies with the conventional focused coding process, adopting a multi-representational approach. The detailed explanations on the significant role of this analysis method and the potential value they add to an MGT study were highlighted in sections 4.3 and 4.4. The following subsections explain the reasons behind this selection in relation to different steps of the analysis process and represent the way these approaches and strategies were used in accordance with the aid of which tools.

5.1.3.1. Diagramming

Having 91 codes connected through 190 interrelationships, by conducting the vertical and horizontal analysis for the first two datasets using NVivo, I faced the main challenge of this study. As mentioned in section 4.2.2.3, it was evident that retrieving the connected codes and attached annotations in a textual format might not be the most appropriate technique for making sense of semantic relationships between concepts. Given the significant role of diagramming in the analysis process of GT, besides the complexity of innovation ecosystems and the heterogeneity of involved factors, a multi-representational approach was adopted to map the interrelationships acquired from the vertical and horizontal analysis. Here, following a systematic way of thinking to understand the complex innovation ecosystems, a network-centric approach was employed (Davey & Adamopoulos 2016; Poutanen, Soliman & Ståhle 2016; Pyka & Scharnhorst 2010; Vicsek, Kiraly & Konya 2016). In doing so, a network diagram was constructed to represent the interconnections between influential factors within and across categories.

1. The generation of a relational composition via a Network diagram

This study uses the Flourish Studio web tool to record in a network diagram the cross-sectional relationships between codes that were harvested from various data sources during the initial and focused coding. For this purpose, two sets of data had to be imported to Flourish Studio, including a table of "Points" that indicate codes, and a table of "Links" that indicate relationships between codes within and across categories. Here, the value of points illustrates the position of each code in the hierarchical ordering, where the higher levels of abstraction are linked to the higher-value points. By using mono-directional or bi-directional relationships, GT researchers can highlight the way codes have impacted one another. Figure 5-4 represents both concepts and relationships, indicated as links, to explain innovation triggers. Here, architectural, service and organisational design innovations related to contextual factors, and key information about each code (such as associated years, key players, examples, etc.) were determined in the table of "Points" using the pop-up option. Specific colours were assigned to each category to provide a better understanding of the interactions between factors across categories. Notably, descriptions of the connections between different factors were also recorded in the table of "Links" for further analysis (refer to the resultant network graph: https://public.flourish.studio/visualisation/8063689/).

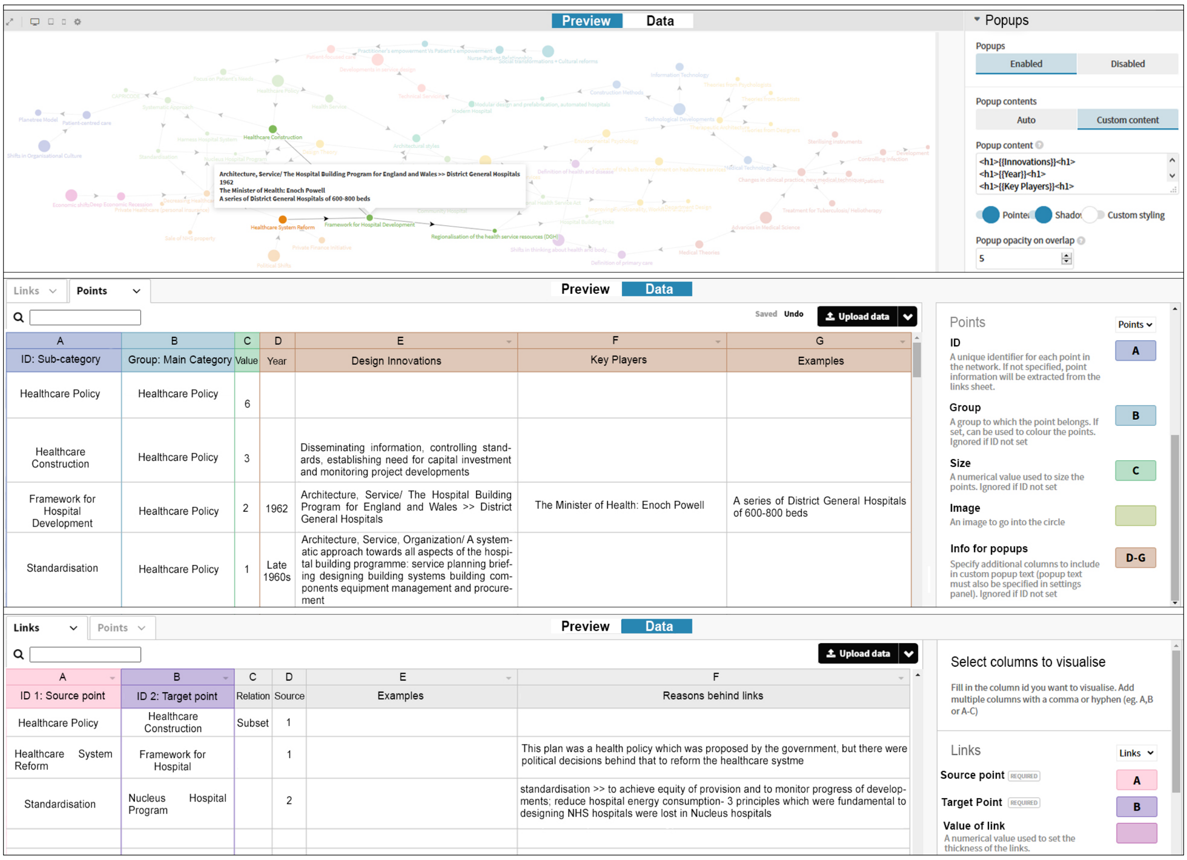


Figure 5-4: The process of creating a network diagram in Flourish Studio

Representing data in network diagrams led to the development of a relational composition that rendered all the interactions related to each code. Notably, as found by Miles and Huberman (2014), the detachment of this relational composition from chronological conceptions of time helped in the reading of multiple factors at the same time. However, it was also crucial to analyse the interplay between concepts within and across categories by considering the time order as the second variable. In this study, such classification of concepts has been achieved by constructing another type of graph (arc diagram) to capture trends in a time sequence.

2. The classification of concepts and links via an Arc diagram

One of the specific features of GT studies is to provide analysts with new perspectives during the process of data analysis. In the present study, analysing the first three datasets and developing the network diagram incrementally led to the generation of new ideas and questions for the study, such as the nature of the progression of these relationships over time. That is, the analysis process led to incremental increase in understanding of the nature of design innovation by offering different perspectives. Considering the importance of capturing trends based on time, arc diagram was selected.

Arc diagram was utilised to represent a wide picture of interactions between contextual factors within and across categories while indicating the sequence of innovation processes, which was essential in understanding the nature of design innovation. Moreover, it described the interactions between concepts with higher levels of generalisation (called parents) rather than focusing on individual codes (children). This diagram also contained both direct and indirect relationships between concepts, which offered a greater level of information presenting the full picture between larger categories. Arc diagram was generated in Observable, a web-first collaborative and computational notebook, using the R programming language (see Figure 5-5 - refer to the resultant arc graph: https://observablehq.com/@researcherhbd/arc-diagram).

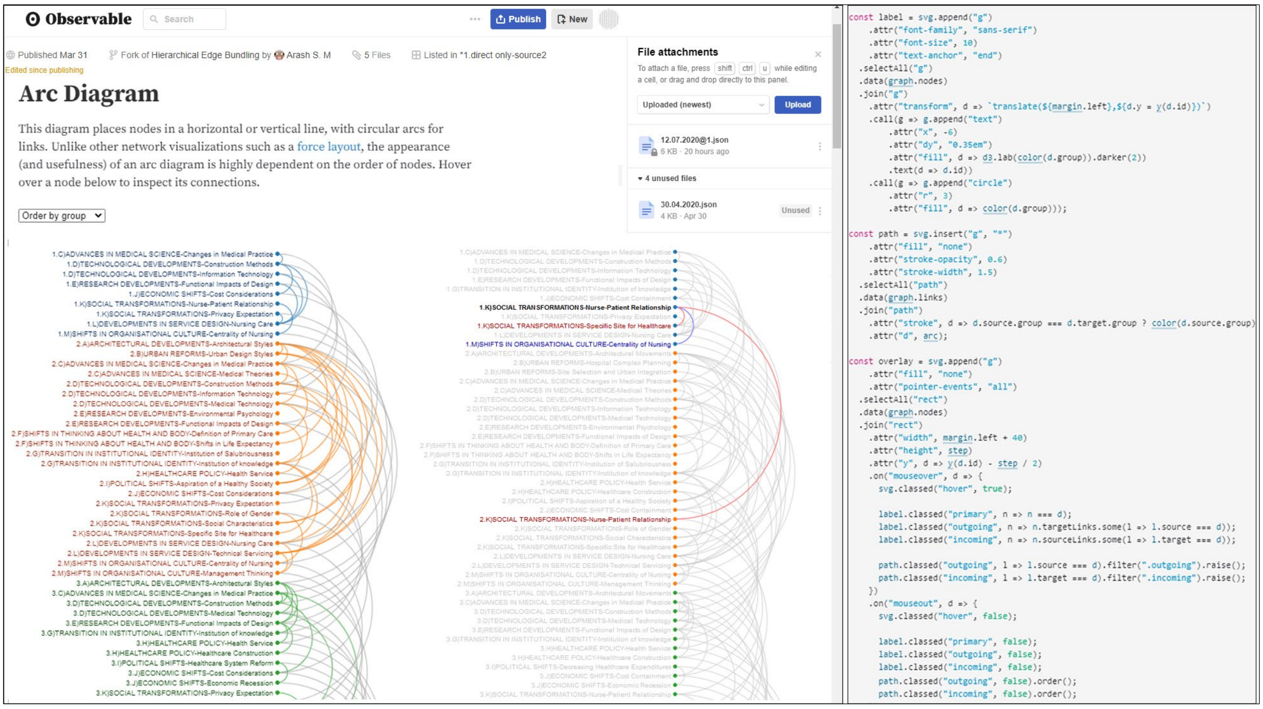


Figure 5-5: The process of creating an arc diagram in Observable

Like network diagrams, to create this diagram two main sets of data were required: nodes that indicate concepts, and links that represent relationships between concepts and categories. With respect to the research aim, analysts might import to the programming sheet either the first-degree linked codes of each category or all the links regardless of their level of generality. In this study, integrating similar links and moving to the higher-level concepts helped to simplify the interactions between a wide range of factors. I attached the input data in the file upload dialogue box that included two main datasets: 1) a tree structure defining nodes; and 2) an adjacency matrix indicating links between nodes of the tree. Here, it was of utmost importance to separate the relationships and concepts in accordance with the decade in which they triggered design innovation, as the main idea was to display grouped nodes in relation to time along a single axis. Also, related codes to each category were classified close to each other, which helped to detect clusters or groups of nodes. Furthermore, determining the direction of impact between codes was also important to explain the nature of innovation. Here, the role of each code was identified with outgoing and incoming links by a red or blue colour respectively. Thus, by clicking on each node, the hierarchical edge bundling diagram demonstrates if the factor impacted - or was impacted by - other nodes. Figure 5-5 represents two screenshots of how nodes are connected by blue and red arcs and the R programming sheet in Observable.

Analysts need to search in Observable for a sample of diagrams, as the programming sheets are exclusive to each diagram. Predefined codes and programs for diagrams such as hierarchical edge bundling, Arc, Force-Directed, Sun Burst, Maps, etc. are sorted in the library for forking, suggesting, and merging. Using samples, researchers can use the fork option to easily replace their data files with the pre-published ones on the site. Analysts can also adapt the programming sheet based on the research objective. For example, due to the importance of showing both direct and indirect connections between factors in this study, I modified the program of a sample arc diagram (the process of changing codes in the programming sheet is beyond the scope of this thesis, as analysts can use various commands for a particular action). Working with this platform might not seem straightforward in the beginning, but its capability for modification and adjustment makes it a suitable tool for most GT research.

3. The generalisation of interconnections via Hierarchical Edge Bundling diagram

As the study progressed, the relational composition facilitated the process of developing a more sophisticated diagram – the Hierarchical Edge Bundling diagram – to further understand and explain the nature of innovation in hospital building design. This diagram aimed to describe the interactions between parents with higher levels of generalisation rather than focusing on individual codes to provide the bigger picture of the studied phenomenon (see Figure 5-6 - refer to the resultant hierarchical edge bundling graph: https://observablehq.com/@asmoslehian/hierarchical-edge-bundling). Given the complexity of the network diagram, the idea here was to bundle the adjacency edges together to decrease the clutter. Moreover, the wider generalisation of impacts between contextual factors contained both direct and indirect relationships. However, after quantitative analysis of the network diagrams using techniques provided by SNA, it became clear that the knowledge acquired from this diagram could not add new values to the analysis. Therefore, while I created and analysed this diagram for the first four data sources, they were eliminated from the analysis process at this stage. Yet, in line with the principles of GT research, the first and fourth (last) hierarchical edge bundling diagrams are represented in Appendix 9.4.

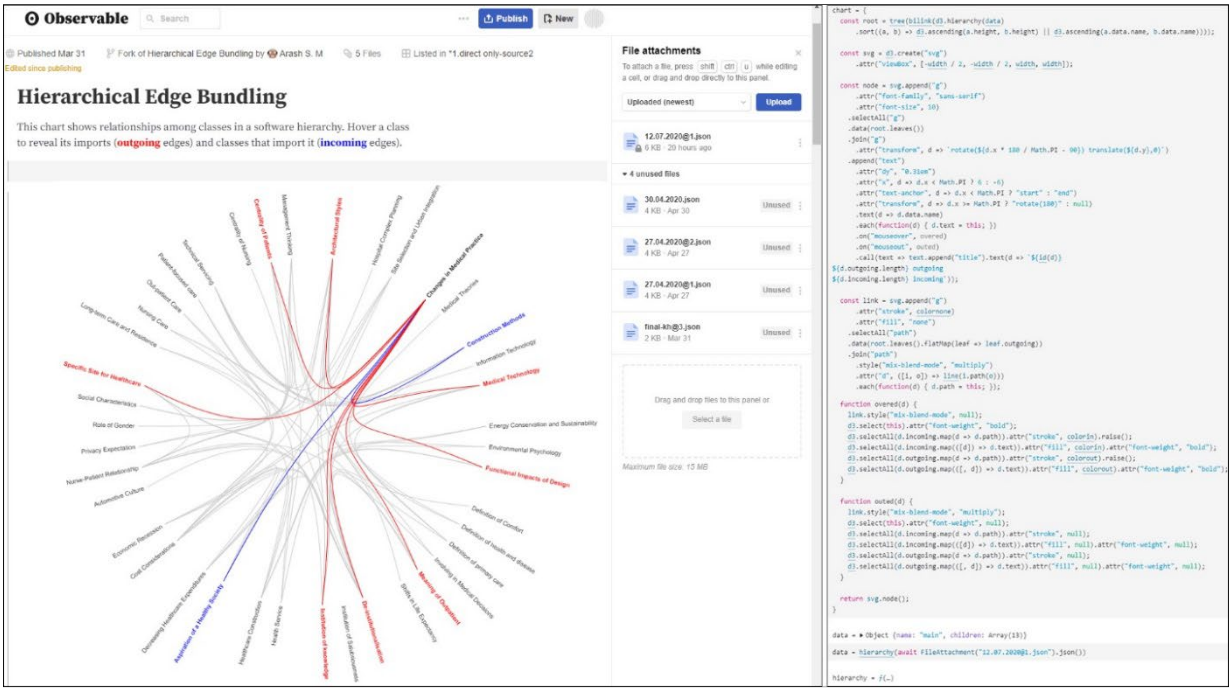


Figure 5-6: The process of creating a hierarchical edge bundling diagram in Observable

In sum, these two diagrams – Network and Arc – complemented each other in the process of data analysis. Here, the information acquired from an arc diagram could not be achieved from a network diagram as chronological ordering is not defined in networks. Moreover, it was not feasible to add value to the links in a network to classify codes in accordance with the date they occurred. Despite the significant ability of arc diagrams to depict sequence, arc diagrams could not be utilised instead of comprehensive networks because they do not effectively present the overall structure of the network. In other words, the relationships between ten interconnected codes can be mapped in a network, and the most influential code can be indicated in relation to the structural properties of the network. Yet, to understand the importance of each factor at certain times and the rationale between those relationships, it is necessary to depict the chronology of occurrences in an arc diagram. Thus, the relational understanding gained from the combined use of network and arc diagrams allowed me to interpret data at a level that would be impossible to describe without them.

5.1.3.2. Diagrammatic analysis

The prime aim of using diagrammatic representations, particularly the network diagram, was to aid rigorous interpretations of data. While in-depth knowledge of empirical data is essential for a GT researcher, utilising specific analysis techniques in relation to the characteristics of each diagram facilitates the process of exploring semantic relations and explaining the phenomenon. Here, to creatively analyse and interpret design innovation networks, and in line with the suggestions of grounded theorists, qualitatively and quantitatively driven techniques of SNA were employed (Brailas 2014; Guzek 2019; Lovrić & Lovrić 2018; Solhi & Koshkaki 2016). Moreover, web-based tools, such as Flourish, provide dynamic networks with non-deterministic force-directed layouts, resulting in different placement of similar codes and links via each run of the algorithm. This non-deterministic approach makes the qualitative analysis of the network topology unreliable. Thus, the network diagrams created in Flourish could not be used to qualitatively analyse the system behaviour. To solve this problem, I used professional tools for quantitative analyses. As highlighted in section 4.4, this level of analysis goes beyond the simple visualisation of relationships in a diagram to an understanding of the possible underlying structure and the complex interactions within the innovation ecosystem and examination of the role of various contextual factors in the whole picture (Scott 2017).

To conduct the quantitative analysis of the network topology, different software packages such as Pajek, UCINET, Gephi, R-Studio, and NodeXL, etc. are available (Decuypere 2020; Huhtamäki et al. 2015). Given the objectives of this study and the availability of tutorials for these packages, the Pajek software was selected for both visualisation and computation of structural properties (centrality, subgroup and cohesion measures). Pajek is open-source software for the visualisation and analysis of large networks using embedded analytic tools. Pajek also offers two- and three-dimensional visualisations to examine networks from various points of view (De Nooy, Mrvar & Batagelj 2018).

The *Files* menu has options to read, edit or sort data files to produce or import data into the program. Here, three datasets were needed: 1) a list of nodes and relations (network); 2) a list of nodes and associated categories (partition); and 3) a list of node values in relation to their level of abstraction in the category (vector). Using commands available from the *net* menu, networks can be transposed or reduced. The main SNA measurements are found under the *Info* > *Network* menu, where there are sub-menus for density, cohesion, centrality, clustering, and other various specialised procedures. There are several options under the *Draw* menu for the two-dimensional and three-dimensional drawing of network diagrams with the capability of being specifically coloured and labelled (De Nooy, Mrvar & Batagelj 2018; Scott 2017). The analysis and computational process used for each dataset are described in section 5.3 in detail.

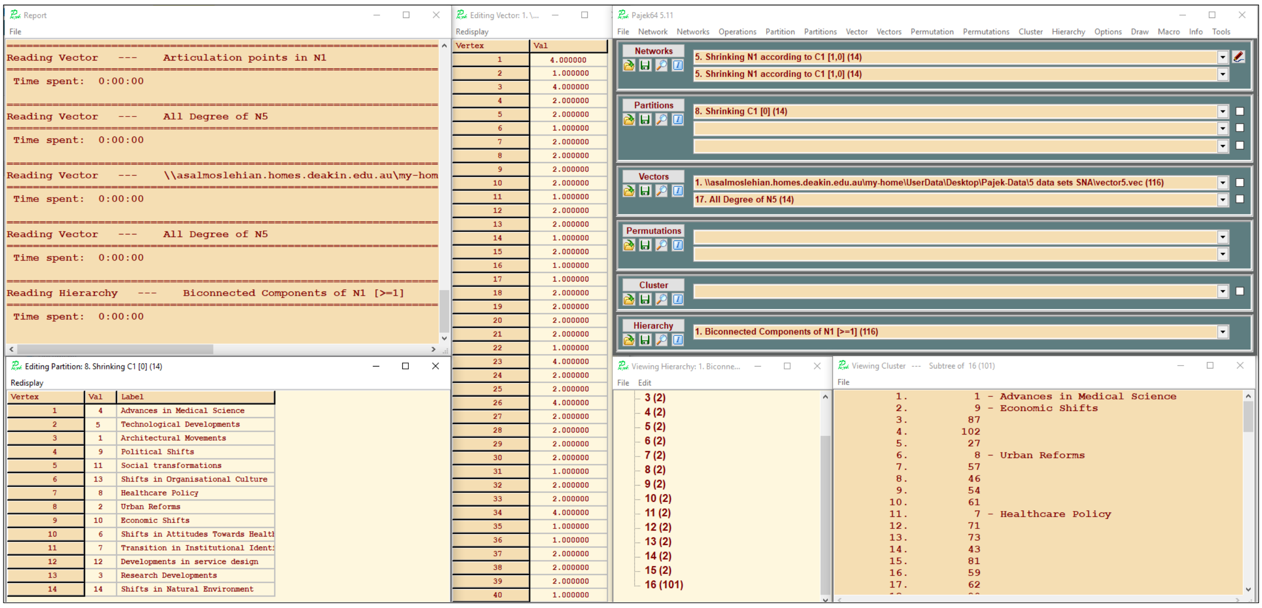


Figure 5-7: The process of creating network diagram in Pajek

Read together, the results of initial and focused coding led to: 1) the development of a *taxonomy of domain concepts* in the field of innovation in hospital building design that provides a common structure and shared set of descriptive terms; 2) the construction of a theoretical model that represents how codes are systematically related to one another in the context of hospital building design; and, eventually, 3) the development of an explanatory framework to understand the nature of innovation in hospital building design that contains a unified collection of concepts and verified relationships. The next section represents the process of achieving the saturation point, where no new theoretical insight or property was added through examining further raw data in the focused coding.

5.1.4. Reaching the saturation point

As noted above, the process of data analysis and data collection had been conducted concurrently until the categories were sufficiently saturated. The saturation point was recognised after the analysis of the eleventh data source, when the process of constant comparison yielded neither new properties/dimensions of each category nor new conceptual ideation (Holton 2011). Figure 5-8 illustrates all 11 data sources examined in this study and the time bracket each reference covers.

Having the data gathered from the ninth data source (Verderber & Fine 2000) coded and analysed, I noticed that most of the concepts and relationships had already been identified. Despite the importance of this source and its broad coverage of data on the evolution of hospital building design, the results of the analysis were mainly limited to verification and saturation of codes and categories, as well as minimisation of the possibility of missing an important concept or link. Further, at this point the diverse properties and categories became integrated with each other (Belgrave & Seide 2019). To ensure that all the events that occurred over the study's focus time were thoroughly examined, Kisacky's book (2017) on the history of the modern hospital was selected as the tenth data source to mainly explore codes and links related to the 1920s-40s. Here, the final taxonomy of concepts was double-checked to re-examine the terms used for each concept and the position of concepts in their hierarchy. Having the ninth relational composition developed and analysed in Pajek, it became apparent that codes related to sustainability ideas from the categories of *Architectural Movements, Healthcare Policy, Transition in Institutional Identity,* and *Shifts in Natural Environment* were not as interconnected as they were supposed to be, according to the recent research on the wider ecological role of the healthcare landscape. Thus, the eleventh data source (Guenther & Vittori 2013), focusing particularly on sustainability in healthcare architecture, was selected and new interactions between existing concepts were determined and analysed. At this stage of the study, the categories became theoretically saturated, and theoretical completeness was reached for my research questions.

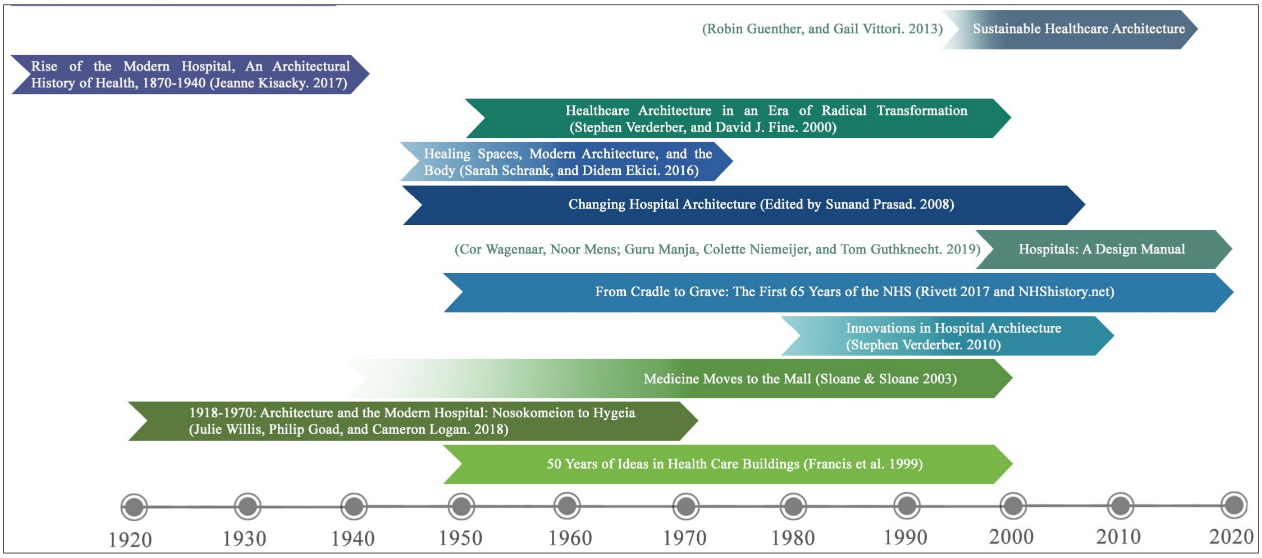


Figure 5-8: The pivotal data sources, and the time bracket each reference covers

The following sections describe the development processes of the final taxonomy of domain concepts and theoretical models after analysing each data source until the saturation point. In addition, the knowledge resulting from each level of analysis is explored and recorded to develop an understanding of the whole picture. Last, the interpretation of results acquired from the network and arc diagrams led to the development of an innovation framework.

5.2. Developing the Taxonomy of Concepts

Taxonomy is mostly concerned with the definition of concepts and the hierarchical relationships that hold them (Zarrad, Doggaz & Zagrouba 2012). In this study, the taxonomy is a representational vocabulary of hospital building design innovation that contains a set of related concepts and describable links between them (Gruber 1993). The taxonomy of domain terminologies created through an iterative process of initial and focused coding can be used for the explicit conceptualisation of innovation triggers in hospital building design.

Constant comparison of concepts during the vertical analyses was used to explore similarities and differences between codes and if they could be integrated into a higher level of conceptualisation. Table 5-3 represents the final taxonomy developed from the analysis of 11 key references. Notably, the process of developing the final taxonomy was recorded to examine the cumulative findings of the vertical analyses. However, due to the word limitations of the thesis, only the first, fifth and final taxonomy of concepts are provided as examples.

5.2.1. The first taxonomy of concepts

Regarding the first taxonomy of domain terminologies, 54 codes that resulted from the initial coding of the first dataset in NVivo were reconsidered to explore semantic relationships. According to the links between the contextual factors, 11 main concepts were developed, codes were classified under those concepts and categories were introduced. During the process of vertical analysis, codes within the main categories were also classified under new conceptual labels in accordance with certain shared properties and meanings. Table 5-1 represents the higher and lower order codes falling under each category. Here, most of the categories contain at least two subcategories that provide more specific codes to the generic concept.

Table 5-1: The first taxonomy of domain terminologies

No.	Main Category	Subcategory 1	Subcategory 2	Subcategory 3
1	Architectural Developments	Architectural styles	Modern Hospital	Modular design and prefabrication, automated hospitals
2	Advances in Medical Science	Changes in clinical practice, new therapies and medical techniques	Early ambulation for patients	
			Sterilising instruments	
			Controlling Infection	
			Treatment for Tuberculosis/ Heliotherapy	
			Development of Antibiotic	
		Medical Theories		
3	Technological Developments	Construction Methods		
		Information Technology		
		Medical Technology		
4	Research Developments	Impacts of built environment on the healthcare service	Improving Functionality, Workflow analysis	Department Design
		Energy conservation and Sustainability		
		Environmental Psychology	Therapeutic Architecture	Theories from Scientists
				Theories from Psychologists
				Theories from Designers
		Design Theory		
		Medical Services		
5	Shifts in thinking about health and body	Definition of health and disease		
		Definition of primary care		
6	Healthcare Policy	Health Service	Public Physical and Mental Health Promotion	The National Health Service Act
				Community Hospital
			Focus on Patient's Needs	
		Healthcare Construction	Framework for Hospital Development	Regionalisation of the health service resources (DGH)
			Systematic Approach	Standard Departments
				Harness Hospital System
				CAPRICODE
				Nucleus Hospital Program (Low Energy)
			The Best Buy Hospital policy	
7	Political Shifts	Healthcare System Reform	Private Healthcare (personal insurance)	
			Sale of NHS property	
			Decreasing Healthcare Expenditures	
			Private Finance Initiative	
8	Economic shifts	Deep Economic Recession		
9	Social transformations + Cultural reforms	Nurse-Patient Relationship	Practitioner's empowerment Vs Patient's empowerment	
10	Developments in service design	Technical Servicing	Mechanised Services and Application of Medical Machines	
		Patient-focused care		
11	Shifts in Organisational Culture	Patient-centred care	Planetree Model	

5.2.2. The fifth taxonomy of concepts

A total number of 117 fresh codes, which resulted from the initial coding of the fifth dataset in NVivo, were re-examined to explore semantic relationships between newly generated codes and those of the previous analysis. This process aimed to compare the emerged codes to more incidents to generate abstract concepts. Table 5-2 represents the higher and lower order codes falling under each category. Here, concepts were classified under 14 categories. Concurrently, the links between factors triggering design innovation were explored, resulting in the development of 279 prime relationships (without duplicates).

Table 5-2: The fifth taxonomy of domain terminologies

No.	Main Category	Subcategory 1	Subcategory 2	Subcategory 3
1	Architectural Movements	Modern Architectural Style	Functionalist and Rationalist Architecture	
			Modular Design and Prefabrication	
		Late-Modern Architectural Style	High-tech Architecture (Structural Expressionism)	
		Post-Modern Architectural Style	Green Architecture	
			Eco-human Design	
			Universal Design	
2	Urban Reforms	Urban Integration		
		Complex Planning	Landscape Perception	
3	Advances in Medical Science	Changes in Medical Practice	Specialised Medicine	
			External Therapies	
			Controlling Infection	Development of Antibiotic
		Medical Theories		
4	Technological Developments	Construction Methods	Structural Systems	
			Electrical Systems	
			Mechanical Systems	Air Conditioning
				Heating and Steam Supply
		Information Technology	Data Sorting	
			Call System	
			Virtual Reality	
		Medical Technology	Mobile and Adjustable Bed	
			Medical Machines	
5	Research Developments	Functional Impacts of design on healthcare service	Modern Hospital Practices	Theories from Hospital Specialists
		Energy conservation and Sustainability		
		Environmental Psychology	Therapeutic Architecture	Theories from Scientists
				Theories from Psychologists
				Theories from Designers
6	Shifts in Attitudes Towards Health	Definition of Comfort		
		Position of Primary Care	Preventative Medicine	
		Shifts in Life Expectancy		
		Definition of Health and Disease		
		Involving in Medical Decisions		
		Meaning of Outpatient		
7	Transition in Institutional Identity	Institution of Salubriousness		
		Institution of knowledge		
		De-institutionalisation and Trans-institutionalisation		

8	Healthcare Policy	Health Service	Community Hospital	
			Creating a Patient-led Health System	
		Healthcare Construction	Regionalisation of the health service resources (DGH)	Hospital Building Note
				The USPHS Plans
			The Best Buy Hospital policy	
			Systematic Approach	Standardisation
				CAPRICODE
				Harness Hospital System
			Private Finance Initiative	
9	Political Shifts	Framework for Hospital Development	New Town Designation	
		Decreasing Healthcare Expenditures	Shift the resources from NHS	
			Sale of NHS property	
			Personal Insurance	
		Public Physical and Mental Health Promotion		
		Commercialised Medical Landscape	Liberating the NHS	
		Redeveloping Outdated Facilities		
		Aspiration of a Healthy Society	Future military strength	
			Managed Care Organizations	
			The National Health Service Act	
10	Economic shifts	Deep Economic Recession		
		Cost Considerations		
		Economic growth		
11	Social transformations + Cultural reforms	Nurse-Patient Relationship	Practitioner's empowerment Vs Patient's empowerment	124
		Specific Site for Healthcare		
		Privacy Expectation		
		Social Characteristics and Cultural Traditions		
		Nursing Position-Role of Gender		
		Nurse-Patient Relationship	Patient's empowerment	
		Automotive Culture		
		Aging-in-place		
12	Developments in service design	Technical Servicing		
		Nursing Care		
		Long-term Care and Residence		
		Out-patient Care		
		One Stop Point-of-service		
13	Shifts in Organisational Culture	Shifts in Hospital Management Thinking	Time Management	
		Centrality of Patients	Plane-tree Model	
		Centrality of Nursing		
14	Shifts in Natural Environment	Natural Resource Depletion		
		Global Warming		
		Natural Disasters		

5.2.3. The final taxonomy of concepts

After conducting the initial and focused coding (including the diagrammatic analysis) of all datasets, the developed taxonomy of concepts was re-examined. Although the use of terms for the concepts and their position in the hierarchy were developed through the study, I reconsidered all codes and slightly changed a few ones based on the accumulated knowledge gained from the analysis of 11 data sources. Table 5-3 demonstrates the final taxonomy of design innovation concepts in hospital building design.

Table 5-3: The final taxonomy of domain terminologies

No.	Main Category	Subcategory 1	Subcategory 2	Subcategory 3
1	Architectural Movements	Modern Architectural Style	Functionalist and Rationalist Architecture	
			Modular Design and Prefabrication	
		Late-Modern Architectural Style	Brutalist Architecture	
			High-tech Architecture (Structural Expressionism)	
		Post-Modern Architectural Style	Critical Regionalist Architecture	
			Structuralist Architecture	
			Deconstructionist Architecture	
		Sustainable Architectural Style	Green Architecture	
			Restorative & Regenerative Architecture	Bioregionalist Design
2	Urban Reforms	Urban Redevelopment and Revitalisation	Site Selection and Master Planning	
		Urban Integration		
		Landscape Perception		
3	Research Developments	Design Functionalitv	Modern Hospital Practices	
		Therapeutic Built-Environment	Theories from Scientists	
			Theories from Psychologists	
			Theories from Designers	
		Energy conservation and Sustainability	Carbon Neutrality & Net-Zero Energy	
			Zero Waste	
4	Advances in Medical Science	Changes in Medical Practice	External Therapies	
		Specialised Medicine		
		Infection Control System	Development of Antibiotic	
		Cure for Pandemic		
5	Technological Developments	Construction Systems	Structural Systems	
			Electrical Systems	
			Mechanical Systems	Air Conditioning
				Heating and Steam Supply
		Medical Technology	Bed & Related Support Equipment	
			Diagnostic Machines	
			Treatment Machines	
		Information Technology	Construction Methods	
			Digitised Care Pathways	

			Communication Technology	Internet
				Virtual Reality
			Data Sorting	
			Call System	
6	Shifts in Attitudes Towards Health	Definition of Comfort		
		Preventative Care		
		Shifts in Life Expectancy		
		Definition of Health and Disease		
		Involving in Medical Decisions		
		Meaning of Outpatient		
		Role of Patient Room		
7	Transition in Institutional Identity	Social and Charity Institutions		
		Military Hospitals		
		Institution of Salubriousness		
		Institution of knowledge		
		De-institutionalised Facility	Out-patient Alternatives	
		Caring Network		
8	Healthcare Policy	Healthcare Service	Community Hospital	
			Creating a Patient-led Health System	
			Diagnosis-Related System	
			Prevention & Health Management	Managed Care Organizations/ Affordable Care Act
		Healthcare Construction	Framework for Hospital Development	The USPHS Plans
				Regionalisation of the Health Service Resources
			Systematic Approach/Standardisation	Hospital Building Note
				CAPRICODE
				Special Certificates
				The Best Buy Hospital policy
				Harness Hospital System
				Nucleus Hospital Program
			Private Finance Initiative	
			Outsourcing of Facilities	
			Sustainable Planning, Development and Design	Building Tools & Metrics
				Healthy Material

9	Political Shifts	Decreasing Healthcare Expenditures	High Operational Savings
			Shift the resources from NHS
			Personal Insurance
			Sale of NHS property
		Commercialised Medical Landscape	Market-Oriented Public Systems
			Liberating the NHS
		Public Physical and Mental Health Promotion	NHS Act | Medicaid & Medicare Programs
		Redeveloping Outdated Facilities	
10	Economic Shifts	Cost Containment	
		Economic Recession	
		Economic Growth	Frequent Funding
		Purchasing Power	
11	Social Transformations	Specific Site for Healthcare	
		Heightened Expectations	Privacy Expectation
		Social Characteristics and Cultural Traditions	
		Nursing Position	
		Nurse-Patient Relationship	
		Patient Empowerment	
		Automative Culture	
		Aging-in-place	
		Globalisation	
12	Developments in Health Service	Technical Servicing Rationales	Traffic Flow
		Care Pathway	Length-of-stay Reduction
		Nursing Practice	
		Patient-Centred Care	
		Out-Patient Care	
		Long-term Care and Residence	
		One Stop Point-of-service	
13	Shifts in Organisational Culture	Shifts in Business Models	Revenue-producing services
			Energy-Demand Reduction
		Centrality of Nursing	
		Patient-Focused System	Planetree Model
		Stakeholders Centrality	
14	Shifts in Natural Environment	Natural Resource Depletion	
		Climate Change	
		Natural Disasters	

5.3. Developing the Theoretical Models

Following the complexity-based approach, two diagrammatic representations of codes and links in parallel to the vertical and horizontal analyses of data assisted the process of developing the theoretical models of the innovation ecosystem. First, the network diagram was useful to develop a relational composition that depicted all the connections for each node individually and, thus, rendered the complete picture of dynamic interactions between factors triggering design innovations. Second, the arc diagram complemented this understanding by indicating the order of interactions and trends in a time sequence. Using specific colour for categories, size of points for the hierarchical organisation and value of directed relationships within categories facilitated the analysis process of these relational compositions.

The theoretical models constructed during the coding process needed to be analysed in relation to the prime characteristics of each diagram. The structural and topological properties of network and arc diagrams formed two analytical frameworks. The analytical frameworks were then used to explore the semantic relations between a wide range of concepts and to examine the trends (the analytical framework for the analysis of diagrammatic representations was explained in section 4.4.1). Notably, due to the general dependence of the behaviour of network structure on each node and its dynamic interactions with other nodes, it is necessary to consider the evolution process of the final model based on the different stable states of the innovation network. Considering the main scope of this study, the evolution of networks was examined in accordance with the knowledge provided by each dataset rather than the specific time and space zones in which events occurred. The final innovation network draws the complexity of the ecosystem identifying the constituent factors and interrelationships among them that triggered design innovations. In what follows, the process of creating the network and arc diagrams and the related analysis to each model are explained in detail.

5.3.1. Analysis of network diagrams

As discussed in section 4.4, both quantitatively and qualitatively driven strategies can be used to analyse network diagrams. Here, while the innovation processes captured in the network diagrams cannot be measured, it is widely considered to be impacted by the network structure (Ferraro, Iovanella & Pratesi 2016; Russell et al. 2015). To this end, through quantitative analysis, the structural properties of a network (such as centrality, clustering and cohesion variables) were measured (Newman 2003). This analysis was followed by qualitative strategies to focus on the forces shaping networks and the content of ties to explain why and how different codes in a network occupy their position (Decuypere 2020; Luxton & Sbicca 2020; Venturini, Jacomy & Pereira 2015).

To analyse the structure of a network it is essential to understand the working operations of its algorithm, as a network can be drawn in different ways each representing different structural features (De Nooy, Mrvar & Batagelj 2018). In this study, two force-directed algorithms were designed to reach the best balance of constant interactions between forces of attraction and repulsion, called *Kamada–Kawai* and *Fruchterman–Reingold* algorithms. The force-driven algorithms generated an optimal layout of the network that minimised visual cluttering, decreased the variation in the length of lines proportional to line value, and gave meaning to the disposition of nodes in the network diagram. The core principle was to attract densely interconnected nodes to each other and repel the less interconnected ones. Thus, the close position between nodes can be interpreted as they have either direct or indirect connection via linkage to the same set of nodes (Blondel et al. 2008; Newman 2004). This algorithm helps researchers identify key clusters, bridging nodes, and possible structural holes for further analysis (Burt 1992; Panetti et al. 2019). Notably, as suggested by De Nooy, Mrvar and Batagelj (2018), to reach the state of equilibrium for all of the network diagrams in this study I first used the Kamada–Kawai energy layout, and then the Fruchterman–Reingold energy layout.

After the networks were constructed using the force-driven algorithm, some of their statistical properties in relation to the research questions were examined. The metrics and measurements used in the network analysis (both quantitative and qualitative approaches) were classified at three levels according to the level of understanding they provided from the relational dynamics of node, cluster, and whole network (refer to section 4.4.1). Although these network dynamics are directly related to one another, they have different properties (Russell et al. 2015). In this study, networks were analysed using Pajek software through the computation of *centrality measures*, *subgroup measures*, and *cohesion measures*. These topological dimensions were then qualitatively analysed via an iterative process by retrieving their associated memos and annotations. It is worth mentioning that these two stages of analysis were conducted concurrently with the initial and focused coding for each data source.

As the properties related to the topological dimensions of a network are subject to the relationships between each node with its distant nodes, it is important to examine the evolution of the final network in relation to its different stable states. The following subsection represents the network diagrams constructed after the analysis of each data source. Here, the SNA was conducted for the first, third, fifth, seventh, and tenth relational compositions. However, to avoid repetition only the fifth and the tenth SNA are provided in the main text. This decision was made to avoid repetition and in relation to two main reasons: 1) the amount of data examined in the fifth SNA resulted in meaningful results; and 2) the results of the fifth and the tenth SNA saw a significant change. The following subsections explore the cumulative relational compositions developed after the analysis of each data source. Notably, all diagrams depicted in the following subsections are also represented in Appendix 9.1 at A3 landscape orientation for more legibility.

5.3.1.1. The first relational composition

The analysis of the first data source (Francis et al. (1999) determined 86 directed links across 59 contextual factors classified in 11 categories (Figure 5-9). The information collected from the first dataset was mostly used to determine the hierarchical order between concepts under each category rather than identifying the interactions across groups.

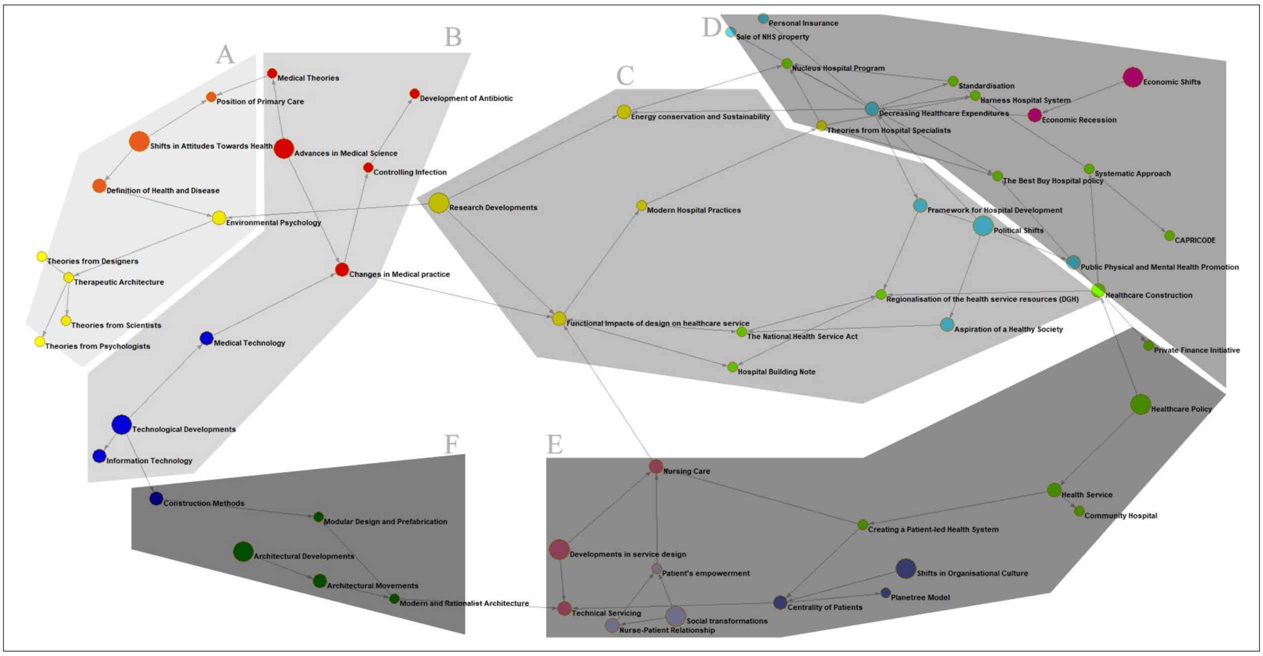


Figure 5-9: The first relational composition (with resolution 0.7, and modularity 0.71)

Having adopted the Louvian method of community detection, a resolution of 0.70 resulted in six clusters with modularity 0.71. Here, the lack of interrelationships between codes across different categories explains the impulsive forces across the network. While the visual analysis of the network at this stage could not explain the network behaviour, the prime categories, and a few identified relations between them, are represented to provide an overall idea of codes collected from the first dataset. In this network, the concepts of *Decreasing Healthcare Expenditures* (with all degree centrality of 10) and research on *Design Functionality* (7) had the highest number of interactions with other concepts resulting in design innovations. It was evident that *Changes in Medical Practices,* stemming from developments in *Medical Technology,* led to some incremental impacts on hospital building design by impacting the *Modern Architectural Style* (red, blue, and green points).

- In the 1920s and 30s, with the growing practice of early ambulation after surgeries for patients and the use of sterilising instruments by nurses, the typical ward design changed to provide adequate sanitary facilities and connection to central sterile supply departments (Musgrave Park Hospital, UK). Moreover, different methods in *Controlling Infection* had considerable impacts on architectural and service design, such as using natural light for reducing infection or the wide *Application of Antibiotic* leading to the innovative design of specialised departments (Larkfield Hospital, UK). The positive effects of sunlight in the treatment of tuberculosis also caused design innovations like south facing and balconied wards (Paimio Sanatorium, Finland).
- In the 1950s and 60s, there was a great need for flexibility and adaptation in building design because of rapid changes in medical practice. Here, the introduction of industrial production, prefabrication and modular co-ordination (in Construction Systems) resulted in the automated hospital concept with rigorously controlled functionalism. Greenwich Hospital (UK, 1967) and McMaster University Health Science Centre (Canada, 1969) are examples of a long-span warehouse-type structure with a universal structural grid of 7.2 m × 7.2 m and accessible interstitial space.

Similarly, research on *Design Functionality* connected codes under clusters B and D between the 1950s and 70s: *Architectural Developments, Advances in Medical Science* and *Technological Developments* with *Healthcare Policies, Economic Shifts* and *Political Shifts*.

- The introduction of *Medical Practice* highlighted *The Impacts of the Built Environment on Healthcare Services* (yellow points). Analysing the growing clinical practices and workflows aimed to enhance the functionality of healthcare practitioners through the emergence of innovative design solutions. In the 1960s, studies considering nurse's walking patterns, effects of colour, noise, natural and artificial lighting on the function and design of hospitals gave rise to the publication of the *Hospital Building Notes,* which at the same time was the result of the UK government *National Health Service Act* (Greenwich hospital, UK).
- During the 1960s, planning for district general hospitals according to the need for hospital developments made the *Standardisation* necessary for disseminating information to regional areas (green points). The Department of Health and Social Security's experts devised a standard hospital briefing plan and department plans by codifying functional content and operational policies. This was a significant accomplishment that resulted from incremental innovation (Outpatient, accident and emergency departments at Walton Hospital, UK). The *Standard Ward Design* caused restricted dimensional and modular co-ordination with

specified zones for structure and services. The progress in hospital construction was also limited to a *Nucleus of Departments* with the capability of future expansion. Meanwhile, *Design Theories* of the 1960s also played a major role in the evolution of hospital architecture, such as Indeterminate Architecture (using Hospital Streets to connect different outpatient and ancillary departments, as well as inpatient ward blocks and courtyards) and adoption of Low-Height Forms (Greenwich hospital, UK). The financial incentives accompanied by advancements in *Research on Energy Conservation and Sustainability* in the 1980s gave rise to innovative design measures for reducing the energy consumption to half that of conventional designs (yellow points).

- By the early 1970s, the deep *Economic Recession* that resulted from the oil crisis had significant influences on hospital construction and developed economies' post-war vision built on idealism (pink points). Economic considerations caused *Shifts in Political Preferences* leading to the *Healthcare System Reform* and a *Decrease in Healthcare Expenditure* (orange points). The reduction in capital expenditure needed for developing *Healthcare Constructions* contributed to various *Healthcare Policies* including *The Best Buy Hospital Program* and *The Systematic Approach* toward all aspects of the hospital building program (green points). *The Best Buy Hospital Program* aimed to provide adequate facilities without being extravagant, which led to a few architectural innovations such as modular forms pierced with internal courtyards for daylight and natural ventilation, and simple Construction Systems (Bury St Edmunds Hospital and Frimley Hospital, UK). Next, a *Systematic Approach* was proposed to control and manage the costs of hospital developments with the focus on organisational and planning operations, service planning, designing, building components and equipment. The hospital building division in the UK, for instance, developed the *Harness Hospital System,* which was a creative combination of pre-existing standard designs, Construction Systems, and operational policies, resulting in a development control plan with known viable departmental layouts (Southlands Hospital, UK).
- Two decades later, shifts in the *Definition of Health* gave rise to the wider evaluation of architecture and highlighted the importance of environmental design; leading to the establishment of the field of *Environmental Psychology* (purple and yellow points). Research on the physical and psychological impacts of hospital design called *Therapeutic Built Environment* generated considerable innovations in hospital building design.

5.3.1.2. The second relational composition

The analysis of the second data source (Francis et al. (1999), and Willis, Goad and Logan (2018)) indicated 190 directed links between 91 contextual factors classified across 13 categories (see Figure 5-10).

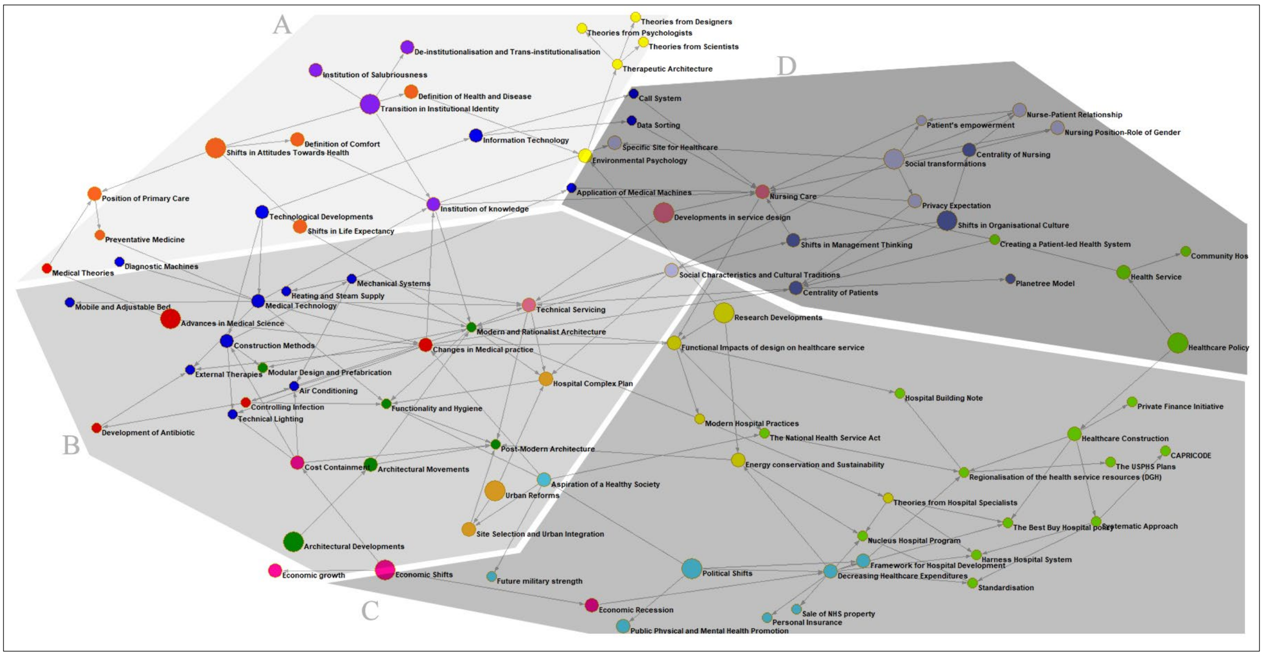


Figure 5-10: The second cumulative relational composition (with resolution 0.5, and modularity 0.67)

5.3.1.3. The third relational composition

The analysis of the third data source (Francis et al. (1999), Willis, Goad and Logan (2018), and Sloane and Sloane (2003)) indicated 222 directed links between 102 contextual factors classified across 13 categories (see Figure 5-11).

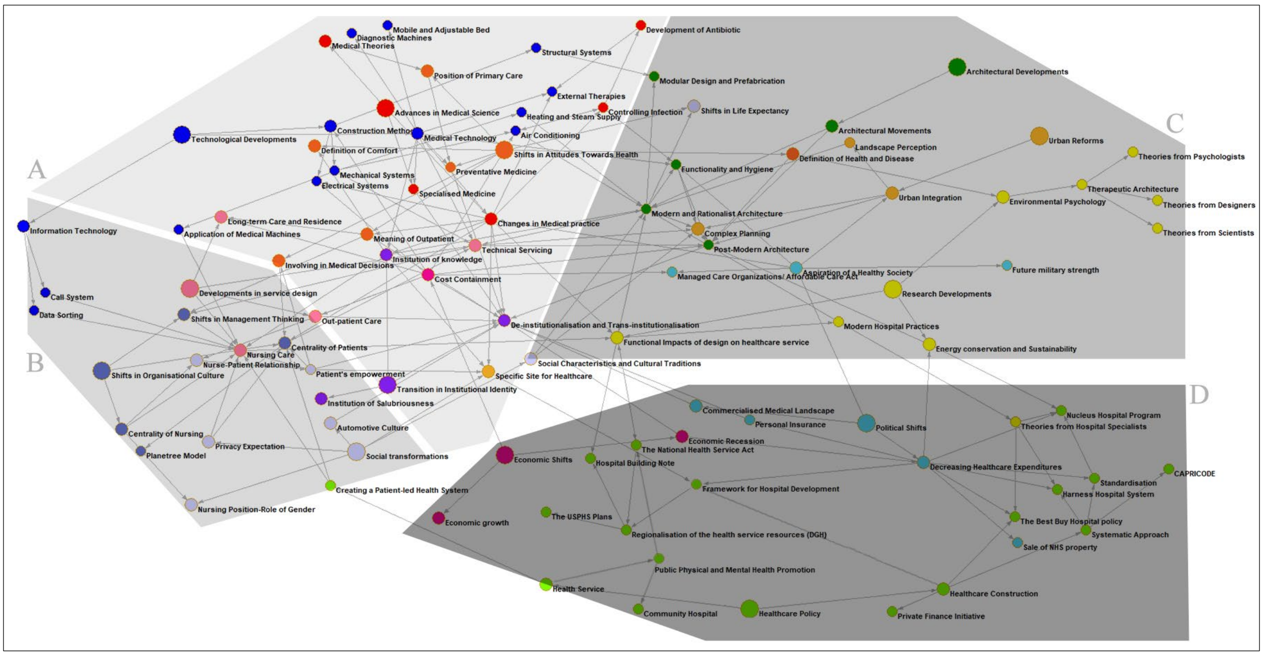


Figure 5-11: The third cumulative relational composition (with resolution 0.45, and modularity 0.66)

5.3.1.4. The fourth relational composition

The analysis of the fourth data source (Francis et al. (1999), Willis, Goad and Logan (2018), Sloane and Sloane (2003), and Verderber (2010)) indicated 272 directed links between 114 contextual factors classified across 14 categories (see Figure 5-12).

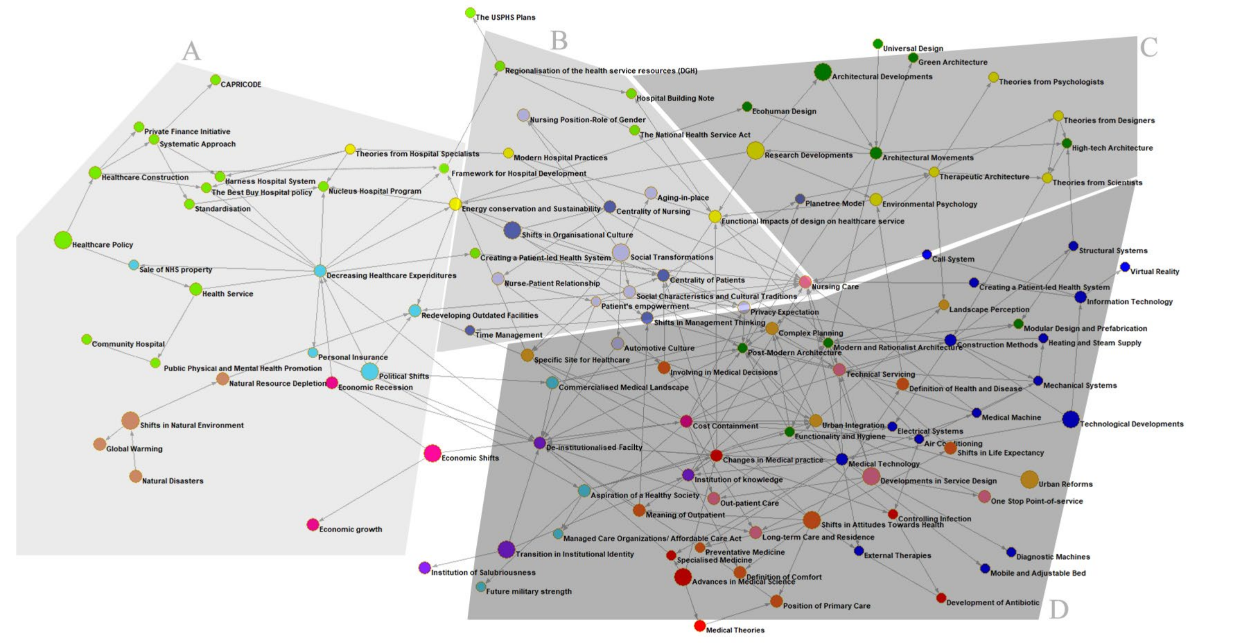


Figure 5-12: The fourth cumulative relational composition (with resolution 0.5, and modularity 0.61)

5.3.1.5. The SNA of the fifth relational composition

The analysis of the fifth data source (Francis et al. (1999), Willis, Goad and Logan (2018), Sloane and Sloane (2003), Verderber (2010), and Rivett (2017)) indicated 314 directed links between 116 contextual factors classified across 14 categories (see Figure 5-13). Eight structural properties of the network at this stage of analysis were examined through quantitative techniques of SNA using Pajek.

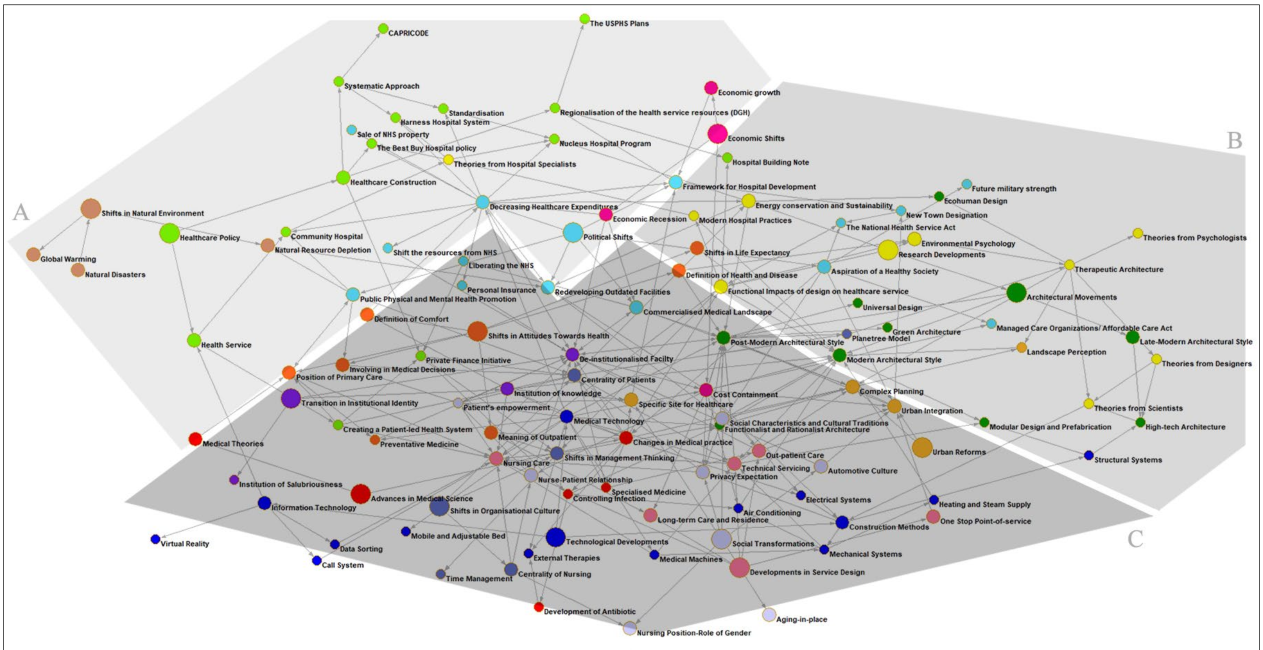


Figure 5-13: The fifth cumulative relational composition (with resolution 0.45, and modularity 0.61)

Considering the unequal distribution of codes at different abstraction levels of each category, it was essential to merge the codes under lower levels into the higher levels in the hierarchy for each category. To this end, a new network was formed with 65 nodes (including codes located at the first two levels of abstraction in each category) and 204 directed links among them. Here, the width of links demonstrates both the repetition of the relationship at different pairs of decades and the number of times lower-level codes were connected in the same way (see Figure 5-14).

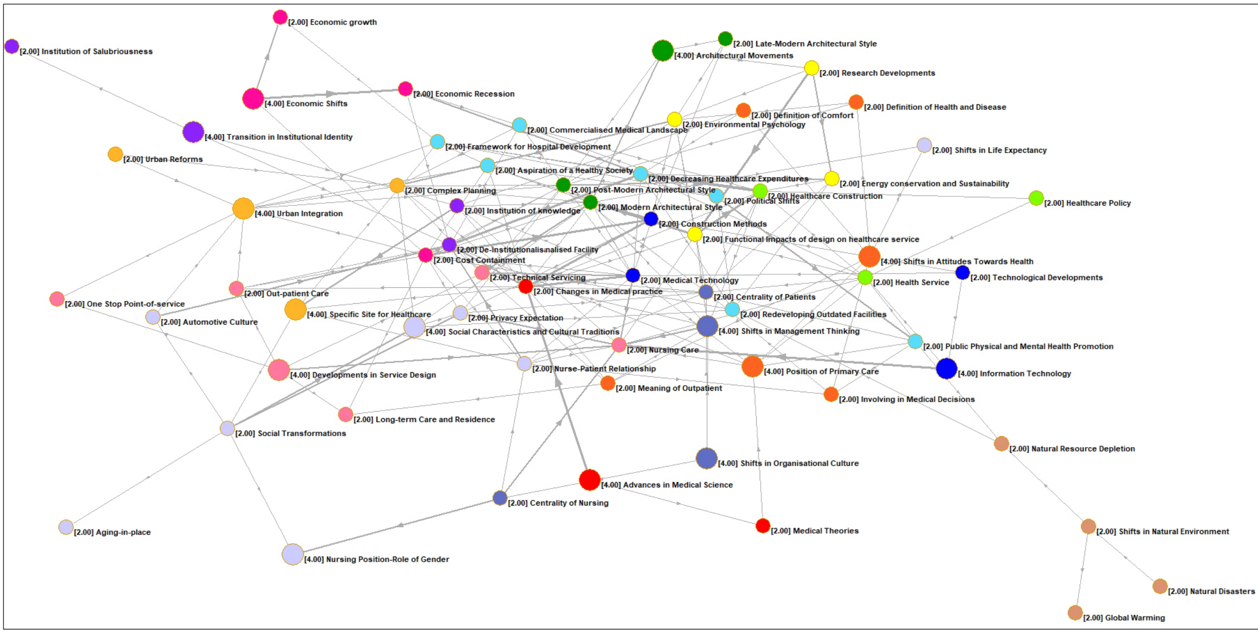


Figure 5-14: The fifth cumulative relational composition with the codes located at the first two levels of abstraction

The structural properties of the network were examined for these two networks (Figure 5-13 and Figure 5-14) with the consideration of required input data for each analysis. The merged network was used to compute centrality measures (degree and eigenvector). The remained properties were computed for the original version of the fifth network, as it helped to analyse and interpret the interactions in a more detailed way.

5.3.1.5.1. Centrality Measures (Micro-Level)

5.3.1.5.1.1 Degree Centrality

Degree centrality refers to the number of direct links a node has in a given network, measuring the *local centrality* (Freeman 1978; Kuznetcova 2018; Scott 2017). Here, the most interconnected factors (with the highest degree centrality) are more likely to be visible, or important, in the network. Figure 5-15 illustrates the "all degree centrality" for each node; that is the sum of input and output degrees, *De-institutionalised Facility*, *Modern Architectural Style* and *Changes in Medical Practice* with 17, 17 and 16 degree were the most interconnected nodes. Notably, the average degree for this network was about 6 (see Figure 5-15).

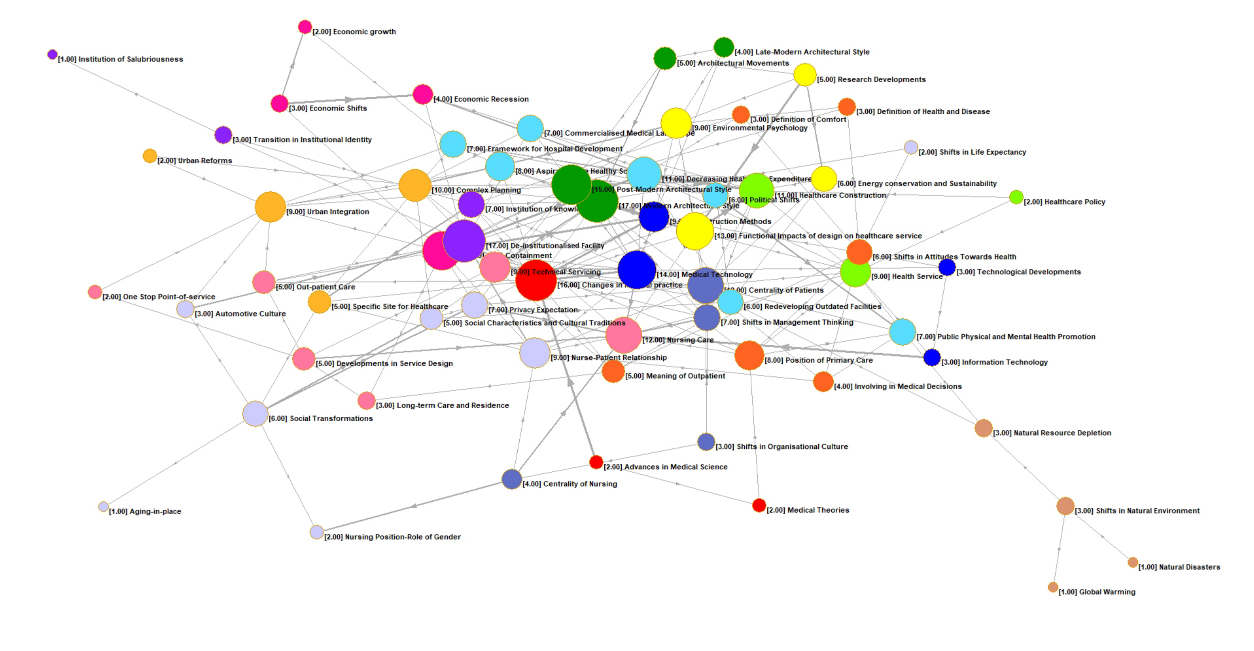


Figure 5-15: The fifth cumulative relational composition with the codes located at the first two levels of abstraction, representing the degree centrality of each node

Table 5-4 indicates concepts with the highest input degree centrality (the number of links a node receives). Evidently, a wide range of contextual factors impacted the *Architectural Movements* (particularly, *Modern Architectural* and *Post-Modern Architectural Styles*) and the development of the *De-institutionalised Facility*, resulting in innovations in hospital building design. The higher the in-degree centrality, the more popular and prominent the node is because other nodes want to connect with it.

Table 5-4: Nodes with Input Degree Centrality higher than 6

ID	Node Name	Input Degree Centrality
6	Centrality of Patients	9
9	Complex Planning	8
15	De-institutionalised Facility	12
23	Design Functionality	7
25	Healthcare Construction	8
34	Modern Architectural Style	12
38	Nursing Care	11
43	Post-Modern Architectural Style	13

Output degree centrality (the number of nodes the node links to) is identified for the eight concepts with the highest proportion in Table 5-5. The higher the out-degree centrality, the more influential the node is in disseminating impact in the network. Here, the role of factors such as developments in *Medical Technology*, *Cost Containment* and *Changes in Medical Practice* in impacting several factors in the generation of design innovation was significant.

Table 5-5: Nodes with Output Degree Centrality higher than 6

ID	Node Name	Output Degree Centrality
7	Changes in Medical practice	10
11	Cost Containment	11
12	Decreasing Healthcare Expenditures	6
23	Design Functionality	6
32	Medical Technology	13
41	Political Shifts	6

47	Shifts in Attitudes Towards Health	6
52	Social Transformations	6

5.3.1.5.1.2 Eigenvector Centrality (Hubs and Authorities)

Eigenvector centrality extends the measure of degree centrality by considering not only the number of adjacent nodes but also their value of centrality. Eigenvector centrality follows the idea that links to a high-scoring node contribute more to the score of the node in question than an equal number of links to a low-scoring node (Basole 2016; Bonacich 2007; Kuznetcova 2018; Shipilov & Gawer 2020). Pajek distinguishes between hubs, nodes that are important senders (connected with important authorities), and authorities (nodes that are important receivers (connected with important hubs)). Here, developments in *Medical Technology* (0.64) and advancements in research on *Design Functionality* (0.323) were the hubs representing the most influential factors to design innovation. This was followed by *Construction Systems* (0.26), *Cost Containment* (0.22), and *Changes in Medical practice* (0.23), meaning that the category of *Technological Developments* contains the most pivotal contextual factors (see Figure 5-16).

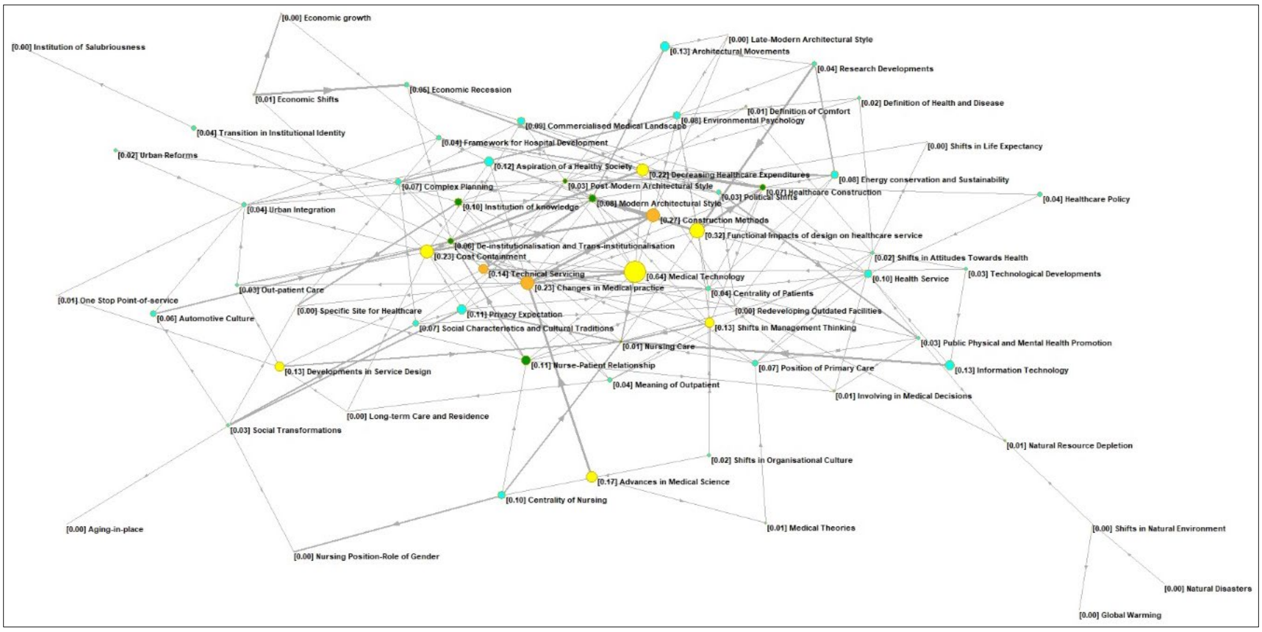


Figure 5-16: The fifth cumulative relational composition with the codes located at the first two levels of abstraction, representing the hub weight of each node

Turning to authorities, *Changes in Medical Practice* (0.49) and *Modern Architectural Style* (0.43) were the most impacted factors in relation to the aforementioned hubs. In addition, factors like *Nursing Care* (0.37) and *Technical Servicing* (0.31) from the category of *Developments in Service Design*, besides policies on the *Healthcare Construction* (0.28) were also important factors in this network, as they were considerably affected by developments in *Medical Technology*, *Shifts in Management Thinking*, and research on *Design Functionality*, as well as political decisions on *Decreasing Healthcare Expenditures* (see Figure 5-17).

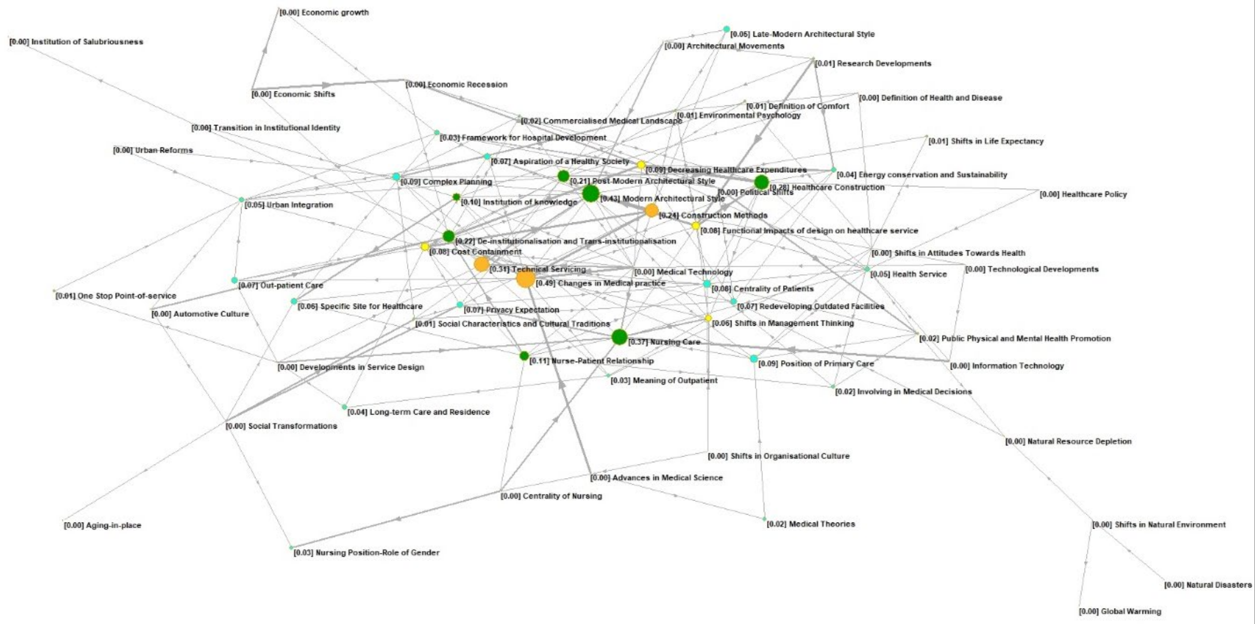


Figure 5-17: The fifth cumulative relational composition with the codes located at the first two levels of abstraction, representing the authority weight of each node

5.3.1.5.2. Subgroup Measures (Meso-Level)

5.3.1.5.2.1 Clustering

This metric helps to detect communities in which codes are tightly connected to one another. Communities indicate underlying concepts of actions and the way actors are operating in relation to each other. As previously mentioned, I adopted the Louvian method from the four main approaches of cluster development in a network (the reasons are explained in section 4.4.1). This method is critical in exploring unknown functional substructures by determining which categories are more interconnected with one another in a network. Moreover, the method indicates which connections bridge two distinct clusters, and which codes reside at the intersection of different clusters (Blondel et al. 2008; Boccaletti et al. 2006).

In the Louvian method of community detection, *modularity* measures the density of the links inside the community in comparison to those between communities, indicating how well a selected partition divides a network into communities. The *resolution coefficient* is used to adjust the modularity parameter. The larger this parameter, the larger the number of communities that we find, and so the smaller the communities are. By adjusting the resolution to 1.0 (default value), seven clusters with modularity 0.48 were detected in this network. While values over 0.4 for modularity can be considered satisfactory and meaningful, it is crucial to analytically examine the modularity parameter to the theoretical meaning for the empirical data (Blondel et al. 2008; Brailas 2014; Solhi & Koshkaki 2016). Thus, after testing different amounts, a resolution of 0.45 was selected as the best match in relation to both the amount of modularity (0.61) and the embedded meaning between codes within clusters (three clusters were detected) (see Figure 5-18).

As discussed earlier in this section, to get the state of equilibrium in the network representation, the Kamada–Kawai energy layout and then the Fruchterman–Reingold energy layout were used (De Nooy, Mrvar & Batagelj 2018). It is evident in Figure 5-18 that the communities detected through the computation of various parameters might not necessarily be represented as visually separated regions by using those force-directed algorithms (energy layouts). While it might be possible to qualitatively detect the overall position of communities in relation to the structural holes, employing a specific scientific method is particularly important to avoid bias from human visual perception in GT studies.

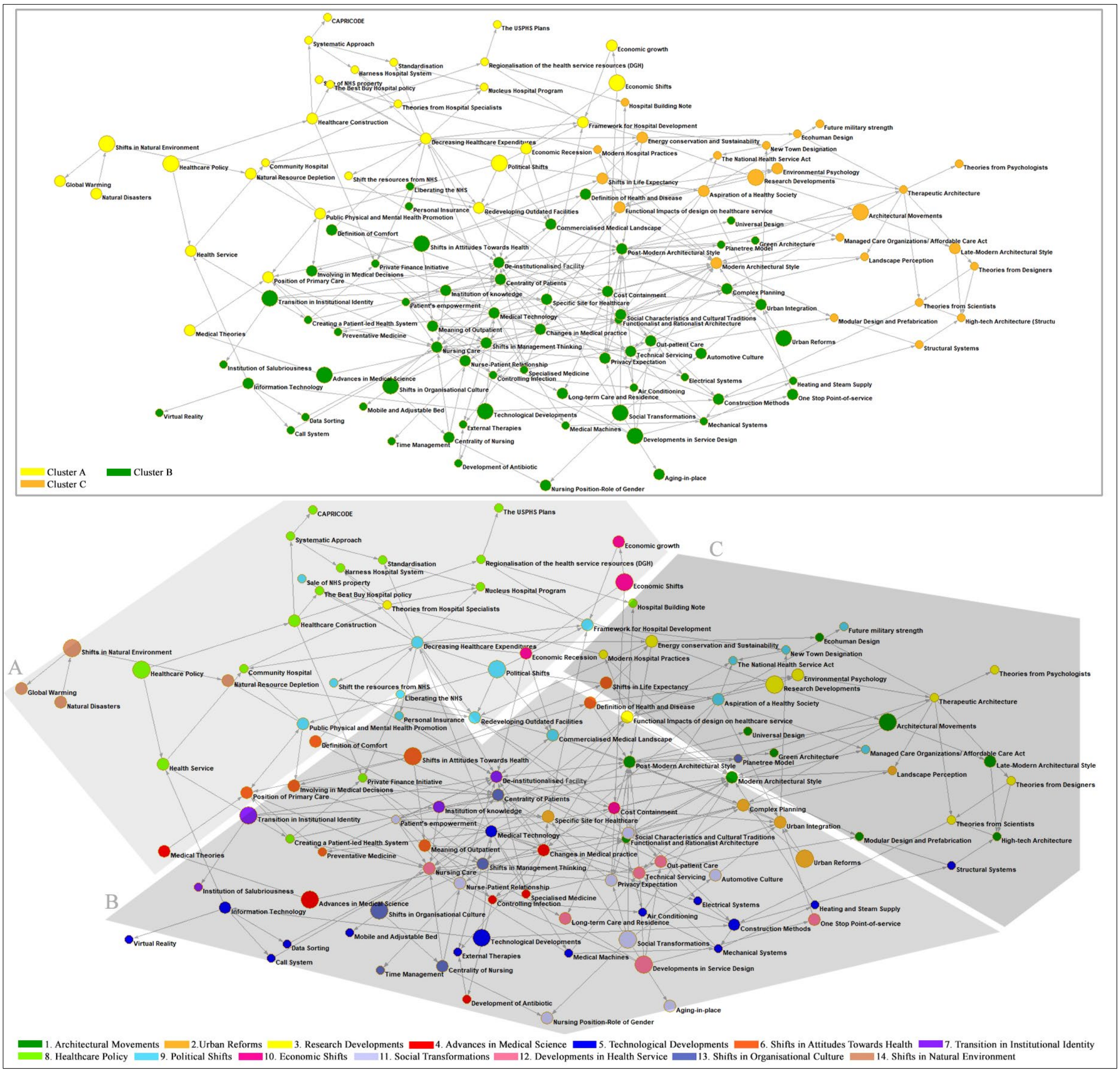


Figure 5-18: The fifth cumulative relational composition, representing three communities detected by Louvian method (with resolution 0.45, and modularity 0.61)

Using the Louvain method, three clusters of A, B and C were detected in relation to the nature of ties (existence, direction and strength) between contextual factors in the fifth innovation network. As Figure 5-18 shows, the concepts under the categories of *Political Shifts*, *Economic Shifts, Healthcare Policy*, and *Shifts in Natural Environment* comprised cluster A (yellow); *Urban Reforms, Advances in Medical Science, Technological Developments, Shifts in Attitudes Towards Health, Transition in Institutional Identity, Social Transformations, Developments in Service Design,* and *Shifts in Organisational Culture* were part of cluster B (green); and *Architectural Movements, Research Developments, Healthcare Policy,* and *Technological Developments* were in cluster C (orange).

Regarding the subclusters within the main cluster (cluster B contained about 60% of the contextual factors), the Louvain community detection analysis determined two less-distinct subgroups in cluster B. Here, by increasing the resolution coefficient to 0.5, the modularity decreased to 0.59 and four clusters were identified (see Figure 5-19). Here, cluster B_1 includes factors under the categories of *Urban Reforms*, *Advances in Medical Science*, *Technological Developments*, *Shifts in Attitudes Towards Health*, *Transition in Institutional Identity*, (Dark Green); and factors classified in *Developments in Service Design, Shifts in Organisational Culture, Social Transformations, Healthcare Policy,* and *Technological Developments* were part of cluster B_2 (Light Green).

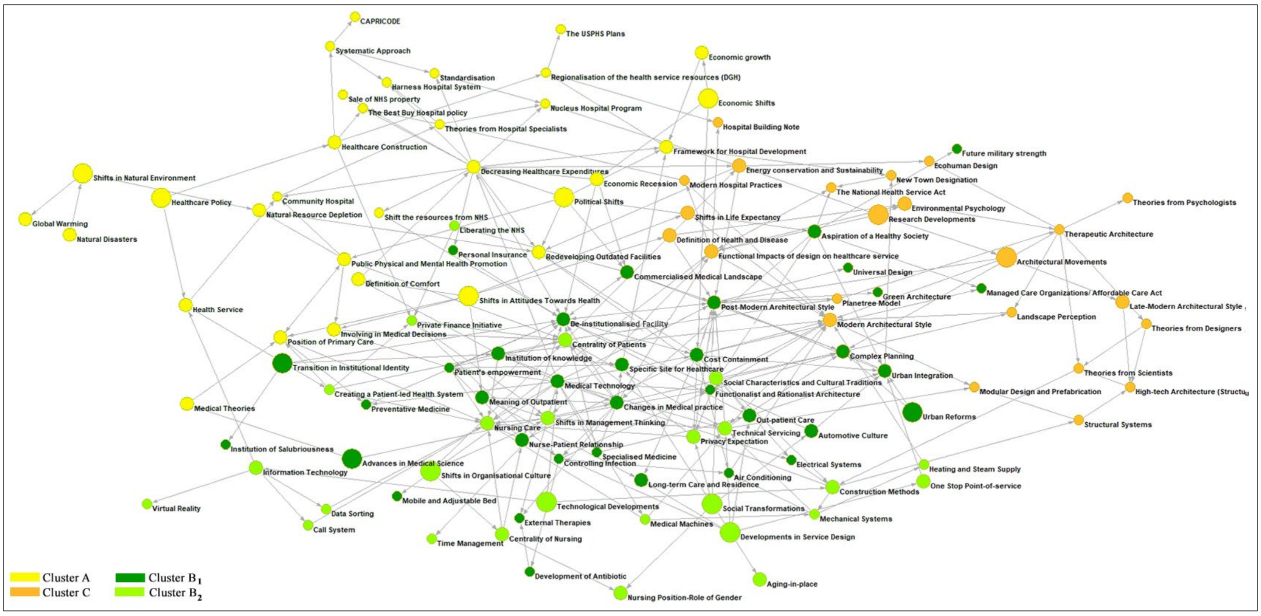


Figure 5-19: The fifth cumulative relational composition, representing four communities detected by Louvian method (with resolution 0.55, and modularity 0.59)

In addition to connections inside these three clusters, clustering of contextual factors may represent interactions according to their inherent nature. As Table 5-6 indicates, 81.8% (257) of relationships resulting in design innovation occurred within clusters and 18.2% (57) among clusters. On average, 65% of the links occurred between factors classified at the same cluster. Here, most of the factors in cluster B were interconnected to one another, with about 76% of the total number of links related to those factors. Notably, more than half (62%) of the interconnections between factors positioned in cluster A happened between factors of this cluster and clusters B and C. The ratio of links inside cluster C to links between cluster C and other clusters was approximately 1.16, where 54% of connections were inside the cluster.

Table 5-6: Percentage of interactions within and between clusters

	Number of links in each cluster				Percentage of links in each cluster	
	Number of links inside the cluster	Number of links between clusters		Total number of links related to factors in each cluster	Percentage of links inside the cluster	Percentage of links between cluster
cluster A	47	A-B B-A	22	76	61.8%	38.2%
cluster B	167	B-C C-B	29	218	76.6%	23.4%
cluster C	42	A-C C-A	7	78	53.8%	46.2%
Total	257	58			81.8%	
	314					

Here, cluster B is the densest region with most of the network nodes and edges. This cluster, whereby actors fill the space in a very even way, can thus be identified as the core cluster of this graph. The structural holes between clusters A, B and C are small, showing the clusters were slightly overlapped with a strong connection between them. Nodes in the bridging position, such as *Private Finance Initiatives* and *Position of Primary Care* (between A and B), *Decreasing Healthcare Expenditure, Aspiration of a Healthy Society,* and *Research on Energy Conservation and Sustainability* (A, B and C), as well as *Modern Architectural Style* (B and C), made regions permeable by impacting different innovations. In this study, the intense interactions between bridge nodes from distinct regions made different components of this network relatively integrated.

5.3.1.5.3. Cohesion Measures (Macro-Level)

5.3.1.5.3.1 Density

Density is defined as the ratio of actual to the maximum possible number of network connections (Fritsch & Kauffeld-Monz 2010). This metric describes the interconnectedness of actors in a network (Romero 2019) and how far the graph is from its state of completion (Scott 2017). A higher degree of vertices yields a denser network because vertices entertain more ties. Notably, due to the high dependency of the density formula to the size of the network, it is essential to consider the degree centrality of each node when discussing this metric (De Nooy, Mrvar & Batagelj 2018). Here, the density of the fifth undirected network was calculated at approximately 0.04, with an average degree of about 4.60. The density was close to zero, meaning that this network was not considered as a dense network with this number of nodes and links.

Table 5-7 indicates the number of codes classified at different levels of abstraction of each category. Here, *Technological Developments, Political Shifts,* and *Healthcare Policy* contained the greatest number of codes (15 times), followed by *Architectural Movements* and *Research Developments* with 10 times frequency.

Table 5-7: Frequency table of partitions for the fifth network

Cluster	Freq	Freq%	CumFreq	CumFreq%	Representative
1	10	8.6207	10	8.6207	Architectural Movements
2	5	4.3103	15	12.931	Urban Reforms
3	10	8.6207	25	21.5517	Research Developments
4	6	5.1724	31	26.7241	Advances in Medical Science
5	15	12.931	46	39.6552	Technological Developments
6	7	6.0345	53	45.6897	Shifts in Attitudes Towards Health
7	4	3.4483	57	49.1379	Transition in Institutional Identity
8	15	12.931	72	62.069	Healthcare Policy
9	15	12.931	87	75	Political Shifts
10	4	3.4483	91	78.4483	Economic Shifts
11	9	7.7586	100	86.2069	Social transformations
12	6	5.1724	106	91.3793	Developments in service design
13	6	5.1724	112	96.5517	Shifts in Organisational Culture
14	4	3.4483	116	100	Shifts in Natural Environment

5.3.1.5.3.2 Degree Centralisation

Degree centralisation compares network structure with a star-network structure with a fixed number of lines (and nodes). The idea is that determining the central and peripheral nodes in a star-network is more feasible than a line-network with the same number of nodes and links. Thus, a network is more centralised if its nodes vary more with respect to their degree centrality. The all degree centralisation for the fifth undirected network was about 0.10, meaning the difference between the central nodes and the peripheral nodes in this network was not clear. Thus, there was not one specific factor highly interacting with the other factors. In fact, it suggested that the fifth network was a line-network with different central codes, where factors were connected to one another without a high variation in the number of edges.

5.3.1.5.3.3 Homophily

Homophily measures the preference of nodes to attach to other similar nodes in term of categorical property (De Nooy, Mrvar & Batagelj 2018; Hanneman & Riddle 2005). In Pajek, this metric is usually measured using a numeric property known as the assortativity degree. The maximum value is 1, showing that nodes in a cohesive subgroup are mainly connected to nodes from similar categories. The minimum value of –1 indicates disassortativity, meaning that nodes from different categories prefer to be highly linked with one another. Here, the degree assortativity for the fifth network was calculated at close to 0.40, using the list of categories as a vector file and the main network file. Thus, while codes under each category were connected in a hierarchical order based on the abstraction level, the interactions between contextual factors from different categories were also considerable. That is, the impact of factors different in nature resulted in design innovation over time.

5.3.1.5.3.4 Shrinking the network based on categories

To provide a general idea of the whole picture, the fifth innovation relational composition was shrunk based on the main 14 categories. All the links between different concepts under each category were merged to develop this network. The width of links between categories demonstrates the number of interactions between concepts under associated categories. A total number of 196 out of 279 connections occurred between categories (through horizontal analysis). Here, *Architectural Movements* and *Political Shifts* reflected the highest degree centrality (19), followed by *Healthcare Policy* and *Shifts in Attitudes Towards Health* with the degree of 17. The positions of *Political Shifts* and *Research Developments* in relation to other categories had by far the highest amount of betweenness (0.26 and 0.11 respectively); highlighting its impact in the interactions leading to design innovation. Concerning the width of the relationships, *Technological Developments* had significant impacts on the *Developments in Service Design*, *Political Shifts* on *Healthcare Policy*, and *Research Developments* on *Architectural Movements*.

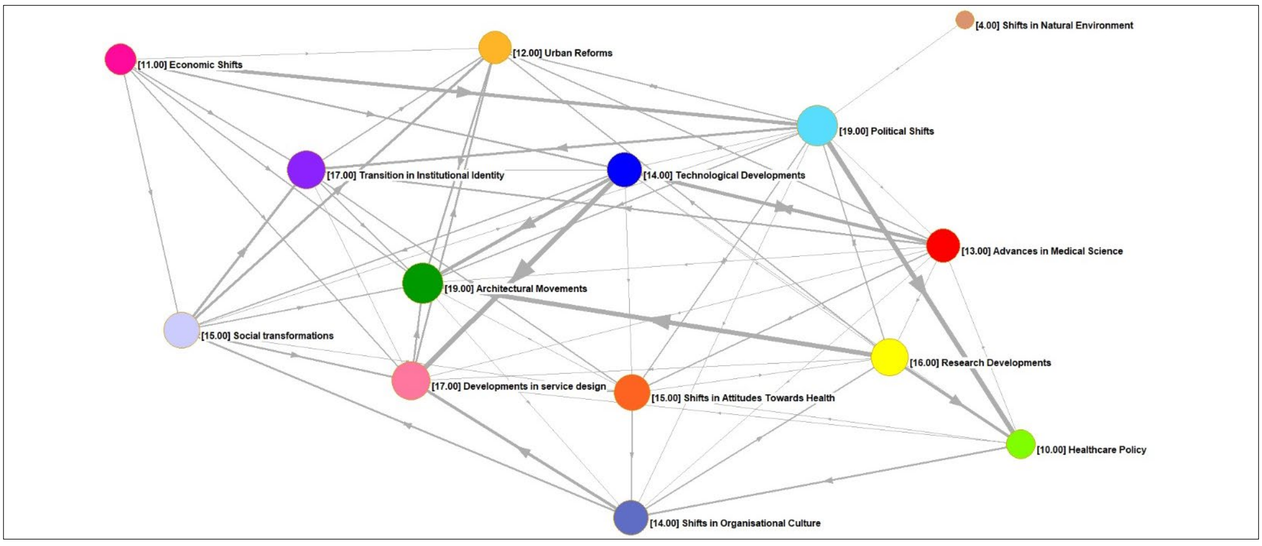


Figure 5-20: The shrunk version of the fifth network

5.3.1.6. The sixth relational composition

The analysis of the sixth data source (Francis et al. (1999), Willis, Goad and Logan (2018), Sloane and Sloane (2003), Verderber (2010), Rivett (2017), and Wagenaar et al. (2018)) indicated 416 directed links between 132 contextual factors classified across 14 categories (see Figure 5-21).

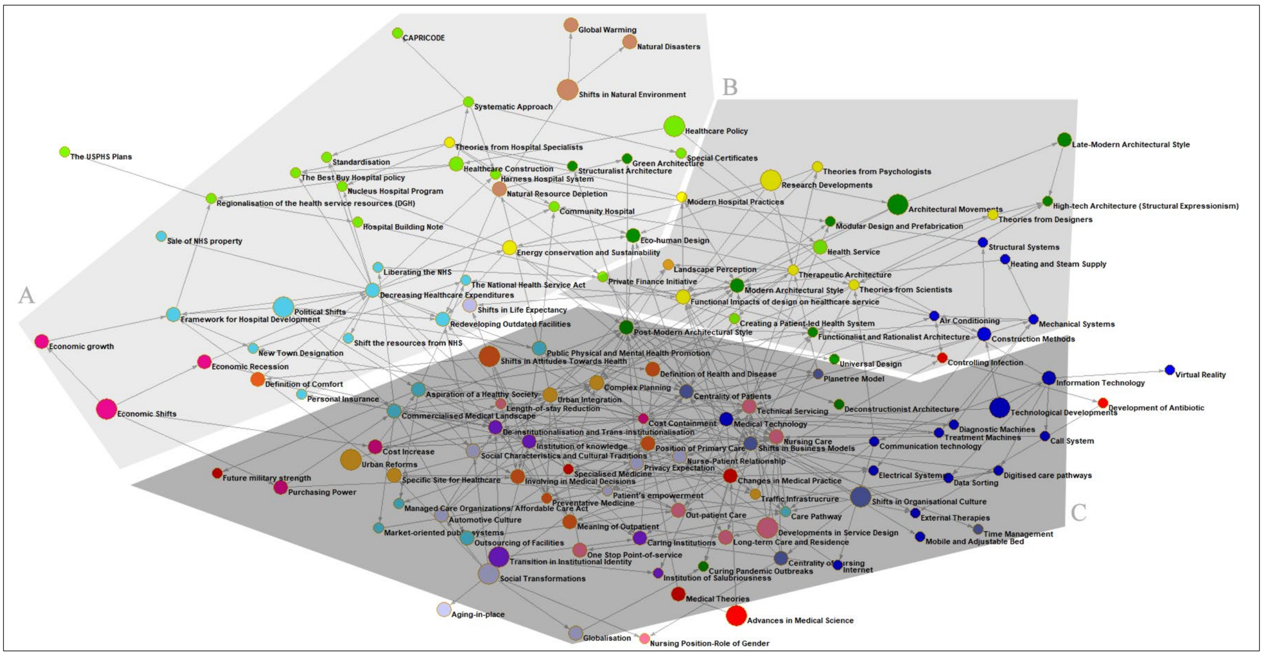


Figure 5-21: The sixth cumulative relational composition (with resolution 0.5, and modularity 0.58)

5.3.1.7. The seventh relational composition

The analysis of the seventh data source (Francis et al. (1999), Willis, Goad and Logan (2018), Sloane and Sloane (2003), Verderber (2010), Rivett (2017), Wagenaar et al. (2018), and Prasad (2008)) indicated 489 directed links between 136 contextual factors classified across 14 categories (see Figure 5-22).

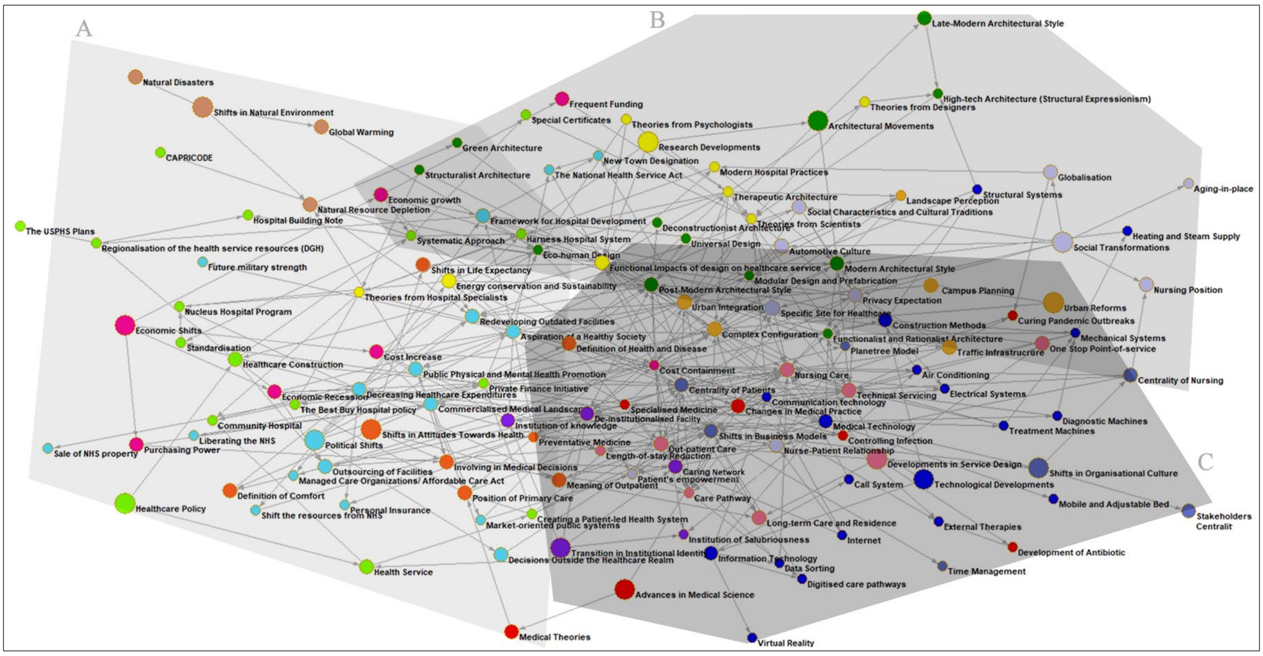


Figure 5-22: The seventh cumulative relational composition (with resolution 0.55, and modularity 0.5)

5.3.1.8. The eighth relational composition

The analysis of the eighth and ninth data sources (Francis et al. (1999), Willis, Goad and Logan (2018), Sloane and Sloane (2003), Verderber (2010), Rivett (2017), Wagenaar et al. (2018), Prasad (2008), Schrank and Ekici (2016), and Verderber and Fine (2000)) indicated 577 directed links between 147 contextual factors classified across 14 categories (see Figure 5-23).

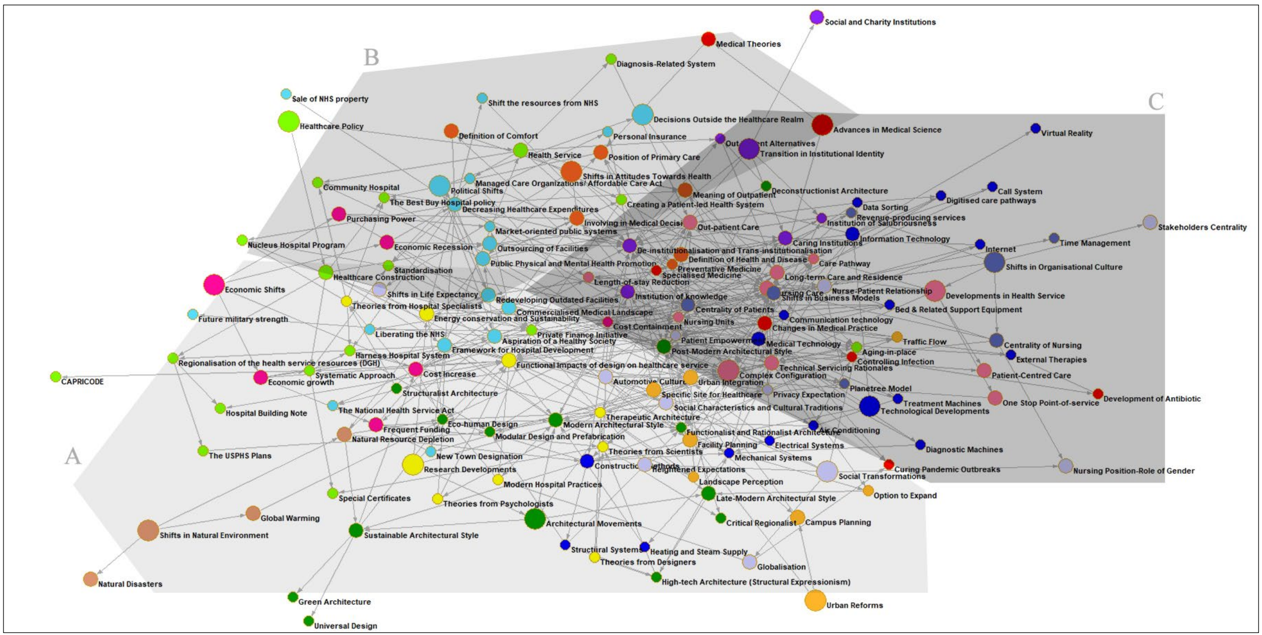


Figure 5-23: The eights cumulative relational composition (with resolution 0.6, and modularity 0.47)

5.3.1.9. The ninth relational composition

The analysis of the tenth data source (Francis et al. (1999), Willis, Goad and Logan (2018), Sloane and Sloane (2003), Verderber (2010), Rivett (2017), Wagenaar et al. (2018), Prasad (2008), Schrank and Ekici (2016), Verderber and Fine (2000), and Kisacky (2017)) indicated 565 directed links between 142 contextual factors classified across 14 categories (see Figure 5-24).

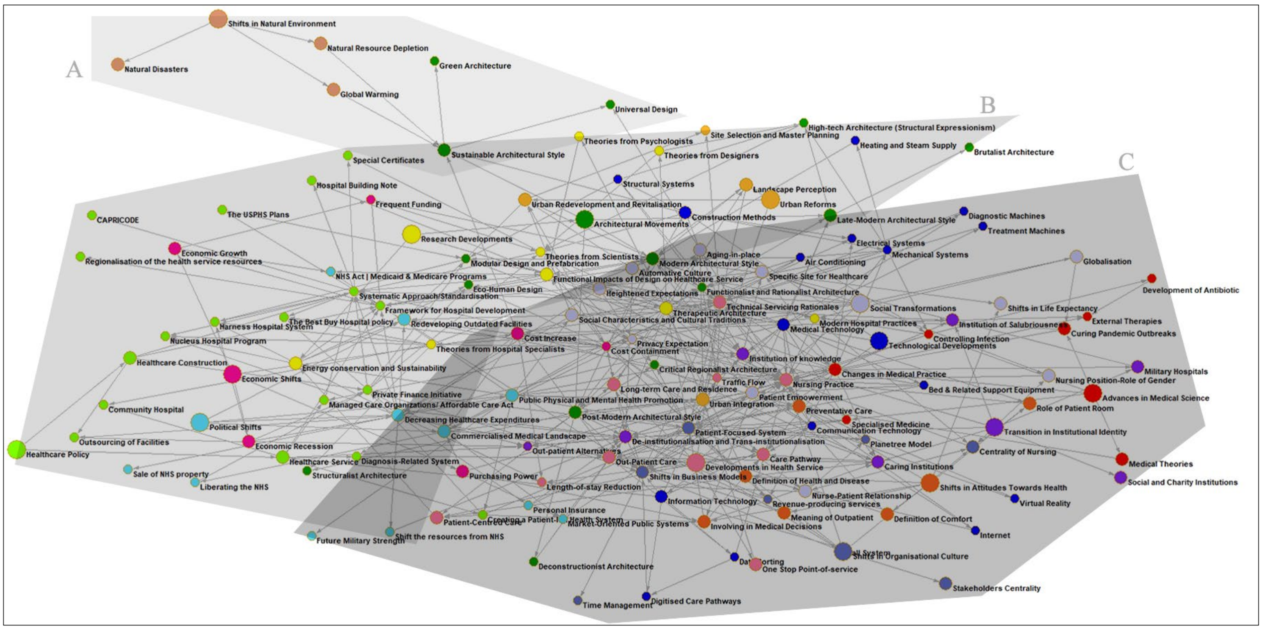


Figure 5-24: The ninth cumulative relational composition (with resolution 0.5, and modularity 0.53)

It is notable that after developing the ninth cumulative relational composition, I found out using the energy algorithm for the final layout in Pajek that there were nodes positioned at the peripheral parts of the network. It was necessary to understand if they did not convey significant information and must be removed from the network, or the links between those nodes and other factors had been missed. Here, factors such as *Time Management* and *Future Military Strength* were accumulated to their upper-level concepts because of their trivial influence on and relationship with other nodes. Also, the more accurate interactions between some of the factors from *Healthcare Policy, Political shifts, Architectural Movements,* and *Shifts in Natural Environment* were highlighted for examination in the next data source to ascertain if the data set was reaching saturation point.

5.3.1.10. The SNA of the tenth relational composition

The analysis of the eleventh data source (Francis et al. (1999), Willis, Goad and Logan (2018), Sloane and Sloane (2003), Verderber (2010), Rivett (2017), Wagenaar et al. (2018), Prasad (2008), Schrank and Ekici (2016), Verderber and Fine (2000), Kisacky (2017), and Guenther and Vittori (2013)) indicated 617 directed links between 146 contextual factors classified across 14 categories (see Figure 5-25). The data used for the analysis of the final relational composition is provided in Appendix 9.2.

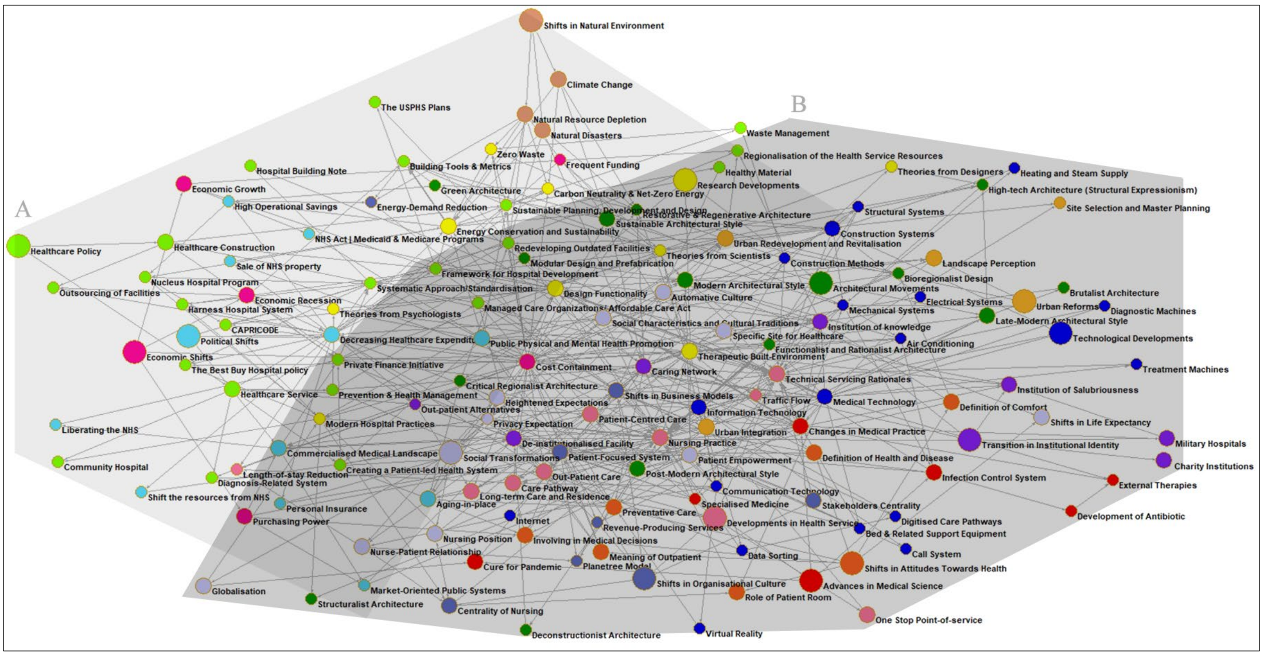


Figure 5-25: The tenth cumulative relational composition (with resolution 0.53, and modularity 0.51)

Figure 5-26 demonstrates the tenth cumulative relational composition with the codes merged into the first two levels of abstraction. This network consisted of 78 nodes and 381 unique directed links (540 links with duplicates) among them, where the width of links shows both the repetition of the relationship at different pairs of decades and the number of times lower-level codes were connected in the same way.

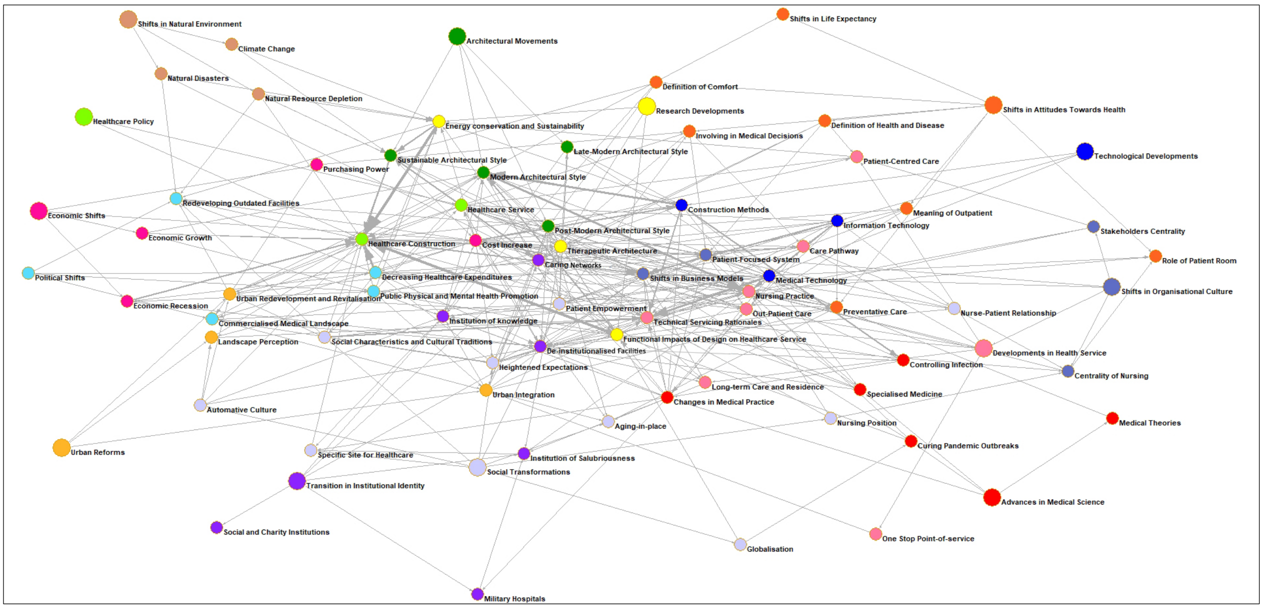


Figure 5-26: The tenth cumulative relational composition with the codes located at the first two levels of abstraction

Given the required input data for each analysis, the degree centrality and eigenvector metrics were computed using the merged network, while cohesion and subgroup measures were determined for the original version of the seventh network.

5.3.1.10.1. Centrality Measures (Micro-Level)

5.3.1.10.1.1 Degree Centrality

Figure 5-27 illustrates the "all degree centrality" for each node; *Cost Containment*, *Therapeutic Built environment,* policies on *Healthcare Construction, Nursing Practice,* and *Technical Servicing Rationales* with 33, 27, 27, 24, and 23 degree were the most interconnected nodes. In this network, the average degree centrality was about 9.7.

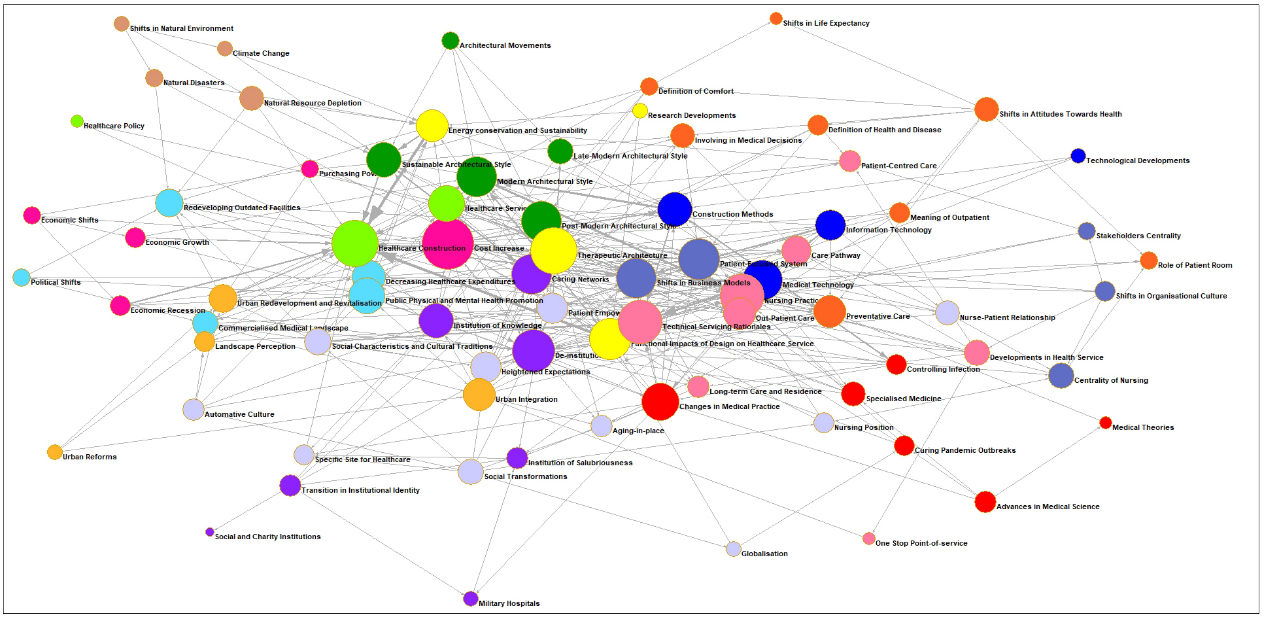


Figure 5-27: The tenth cumulative relational composition with the codes located at the first two levels of abstraction, representing the all degree centrality of each node

Table 5-8 indicates concepts with the highest input degree centrality. Evidently, a wide range of contextual factors impacted the service design, particularly *Nursing Care* and *Technical Servicing*

Rationales, the hospital identity (*De-institutionalised Facility*), and policies on *Healthcare Construction*; all resulting in innovations in hospital building design.

Table 5-8: Nodes with Input Degree Centrality higher than 13

ID	Node Name	Input Degree Centrality
17	De-institutionalised Facility	17
25	Healthcare Construction	21
45	Nursing Practice	23
50	Patient-Focused System	14
59	Shifts in Business Models	14
68	Technical Servicing Rationales	18

Output degree centrality is identified for the six concepts with the highest proportion in Table 5-9. Here, factors such as *Cost Containment*, developments in *Medical Technology,* Research on *Therapeutic Built Environment,* and *Changes in Medical Practice* significantly disseminated impact in the innovation network.

Table 5-9: Nodes with Output Degree Centrality higher than 10

ID	Node Name	Output Degree Centrality
7	Changes in Medical Practice	13
12	Cost Containment	25
27	Healthcare Service	10
29	Information Technology	11
37	Medical Technology	18
54	Public Physical and Mental Health Promotion	11
70	Therapeutic Built Environment	17

5.3.1.10.1.2 Eigenvector Centrality (Hubs and Authorities)

Figure 5-28 indicates hubs, nodes that are important senders. Here, research on *Design Functionality* (0.47), *Energy Conservation and Sustainability* (0.38), and *Decreasing Healthcare Expenditures* (0.33) were the hubs representing the most influential factors to design innovation, followed by *Cost Containment* (0.29), *Modern Architectural Style* (0.25), and research on *Therapeutic Built Environment* (0.22). The category of *Research Developments* contained the most pivotal contextual factors.

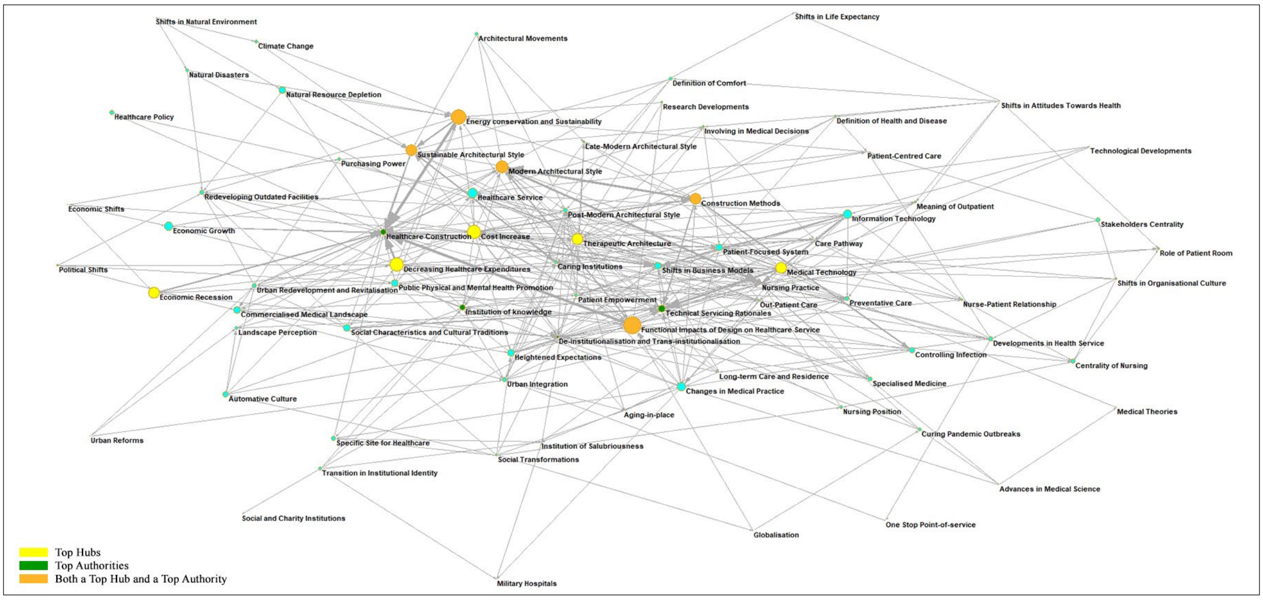


Figure 5-28: The tenth cumulative relational composition with the codes located at the first two levels of abstraction, representing the hub weight of each node

Figure 5-29 indicates authorities, nodes that are important receivers. Here, policies on *Healthcare Construction* (0.75), *Technical Servicing* (0.33), and *Nursing Practice* (0.30) from the category of *Developments in Service Design* and *Modern Architectural Style* (0.24) were the most impacted factors in relation to the aforementioned hubs. Further, factors such as *De-institutionalised Facility, Sustainable Architectural Style* from *Architectural Movements*, and research advancements on *Design Functionality* were important factors in this network, as they were considerably affected by *Economic Shifts*, and research advancements on *Functionality* and *Sustainability*, as well as political decisions on *Decreasing Healthcare Expenditures*.

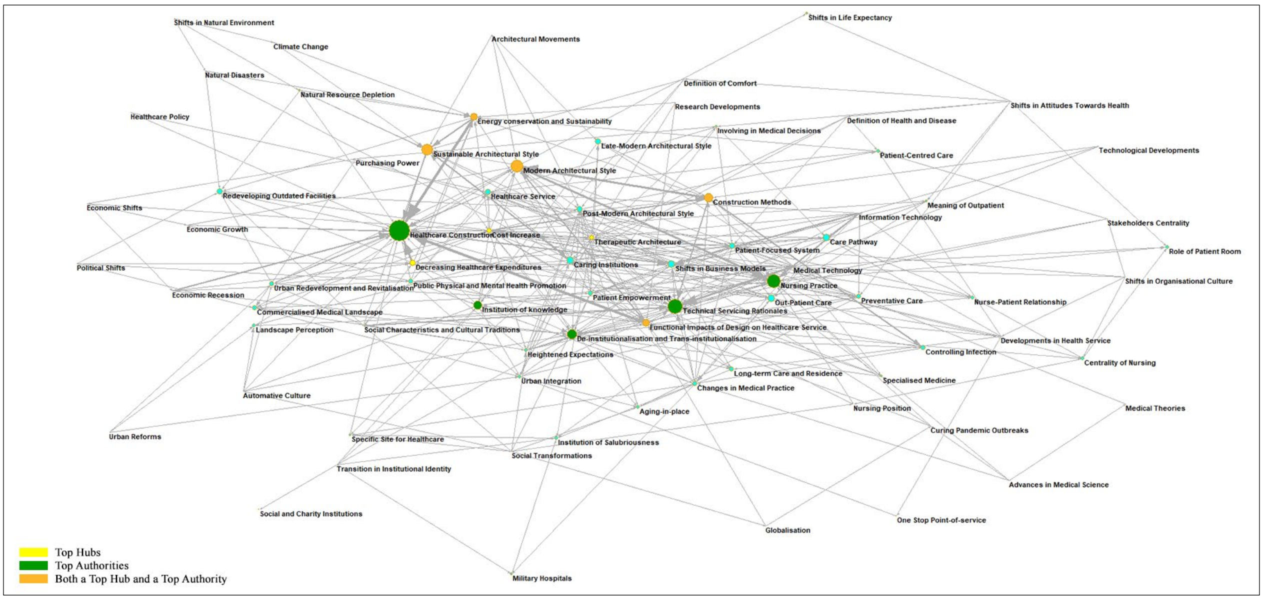


Figure 5-29: The tenth cumulative relational composition with the codes located at the first two levels of abstraction, representing the authority weight of each node

Here, two factors, research on *Design Functionality* and *Energy Conservation and Sustainability,* were classified as both a top hub and a top authority. These nodes were connected with both important hubs and authorities in the network and are therefore identified as playing considerable roles in triggering design innovations.

5.3.1.10.2. Subgroup Measures (Meso-Level)

5.3.1.10.2.1 Clustering

Having adopted the Louvian method of community detection, different amounts of resolution were tested to find the best match for this set of data. By adjusting the resolution to 1.0 (default value), seven clusters with modularity 0.37 were detected in this network. To achieve a value of more than 0.40 for modularity and a meaningful connection between codes within clusters, a resolution of 0.53 was selected resulting in three subgroups and modularity 0.51 in relation to the nature of ties (existence, direction and strength) (see Figure 5-30). It is evident here that the communities detected through the computation of various parameters might not necessarily be represented as visually separated regions by using the force-directed algorithms (energy layouts). Here, most factors in the categories of *Healthcare Policy*, *Political Shifts*, *Economic Shifts*, *Architectural Movements, Research Developments* and *Shifts in Natural Environment* were located in cluster A; and the rest of categories in cluster B. Some of the most important bridging factors between these two clusters were: *Cost Containment,* research on *Therapeutic Built Environment* and *Energy Conservation,* as well as the development of *De-institutionalised Facility*.

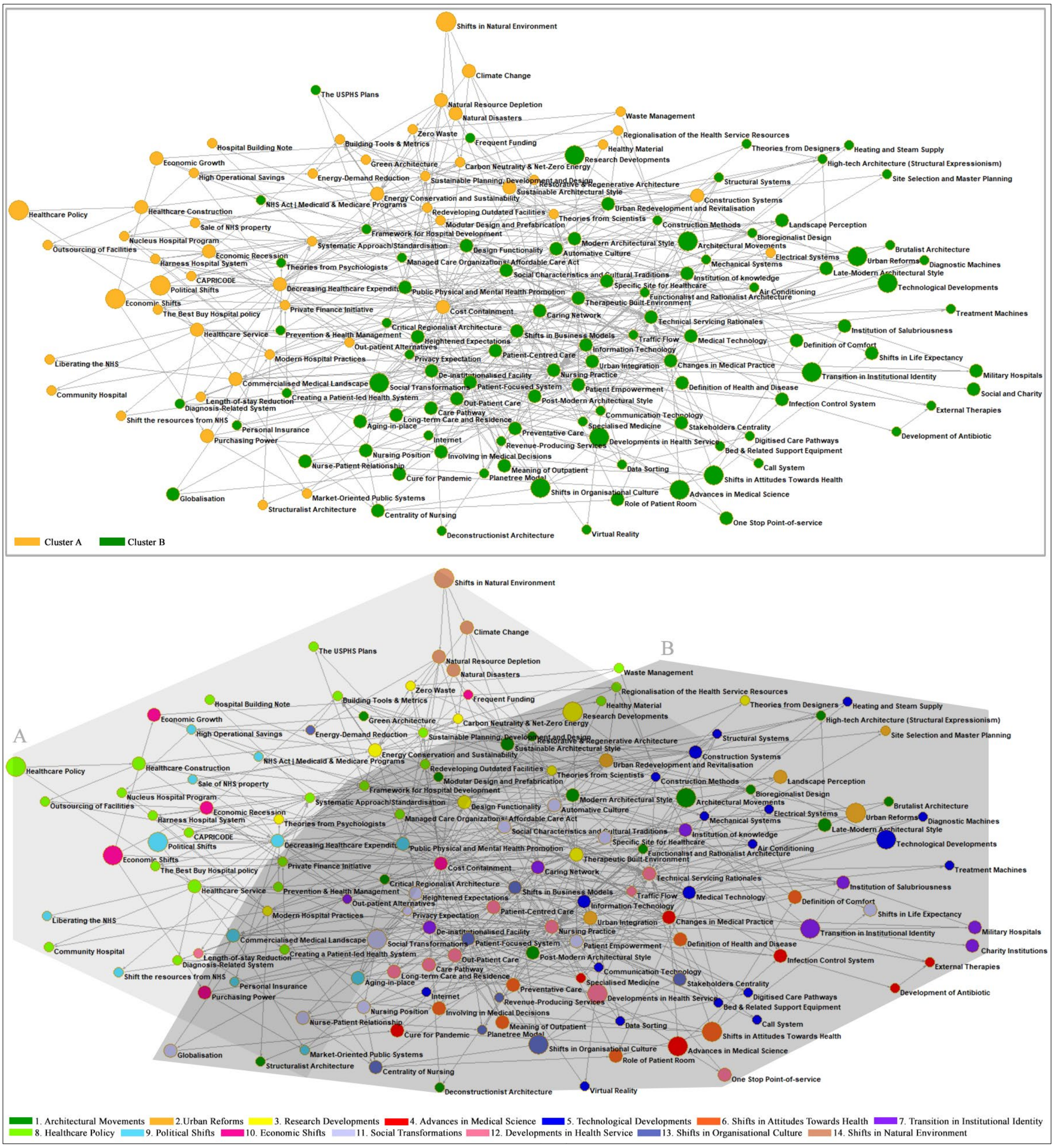


Figure 5-30: The tenth cumulative relational composition, representing two communities detected by Louvian method (with resolution 0.53, and modularity 0.51)

5.3.1.10.3. Cohesion Measures (Macro-Level)

5.3.1.10.3.1 Density

The density of the tenth undirected network was calculated at about 0.05, with average degree 7.40. The density was close to zero, meaning that this network was not considered as a dense network with this number of nodes and links. Table 5-10 indicates the frequency of codes classified at different levels of abstraction of each category. Here, *Healthcare Policy, Technological Developments,* and *Architectural Movements* contained the highest number of codes, followed by *Political Shifts*.

Table 5-10: Frequency table of partitions for the tenth network

Cluster	Freq	Freq%	CumFreq	CumFreq%	Representative
1	15	10.274	15	10.274	Architectural Movements
2	5	3.4247	20	13.6986	Urban Reforms
3	10	6.8493	30	20.5479	Research Developments
4	7	4.7945	37	25.3425	Advances in Medical Science
5	19	13.0137	56	38.3562	Technological Developments
6	7	4.7945	63	43.1507	Shifts in Attitudes Towards Health
7	8	5.4795	71	48.6301	Transition in Institutional Identity
8	24	16.4384	95	65.0685	Healthcare Policy
9	12	8.2192	107	73.2877	Political Shifts
10	6	4.1096	113	77.3973	Economic Shifts
11	11	7.5342	124	84.9315	Social Transformations
12	10	6.8493	134	91.7808	Developments in Service Design
13	8	5.4795	142	97.2603	Shifts in Organisational Culture
14	4	2.7397	146	100	Shifts in Natural Environment

5.3.1.10.3.2 Degree Centralisation

The all degree centralisation for the tenth undirected network was approximately 0.15, meaning the difference between the central nodes and the peripheral nodes in this network was not clear. Thus, there was not one specific factor highly interacting with the other factors. In fact, it suggested that the network was a line-network with different central codes, where factors were connected to one another without a high variation in the number of edges.

5.3.1.10.3.3 Homophily

The degree assortativity for the tenth network was calculated at close to 0.19, using the list of categories as a vector file and the original network file. Thus, while codes under each category were connected in a hierarchical order based on the abstraction level, the interactions between contextual factors from different categories were also considerable. That is, the impact of factors different in nature resulted in design innovation over time. Further, using the list of factors linked to their specific community (determined by Louvian method with resolution 0.55) as a vector file and the main network file, the degree assortativity for the tenth network was calculated at 0.48. This metric indicates that most factors were interconnected within the detected clusters and the number of relationships among clusters was considerable. Using the list of factors linked to their specific community (determined by Louvian method with resolution 0.5) as a vector file and the main network file, the degree assortativity for the tenth network was calculated at 0.58.

5.3.1.10.3.4 Shrinking the Network Based on Categories

To provide a general idea of the whole picture, the tenth innovation relational composition was shrunk based on 14 main categories. All the links between different concepts under each category were merged to develop this network. A total number of 477 out of 617 connections occurred between the categories (through horizontal analysis). Here, *Architectural Movements*, *Transition in Institutional Identity* and *Research Developments* reflected the highest degree centrality with 25, 24 and 24 respectively, followed by *Healthcare Policy* (23), and *Developments in Service Design and Organisational Design* (22). Moreover, the position of *Architectural Movements* in relation to other categories had by far the highest amount of betweenness at about 0.12; highlighting its impact in interactions leading to design innovation. As factors under the category of *Architectural Movements* lied on the path between their different non-adjacent nodes, they had the capacity to facilitate or limit interactions between the nodes they link. Concerning the width of the relationships, *Technological Developments* has a significant impact on the *Developments in Service Design* and on *Architectural Movements*; *Research Developments* on *Healthcare Policy* and *Architectural Movements*; and *Economic Shifts* on *Political Shifts*.

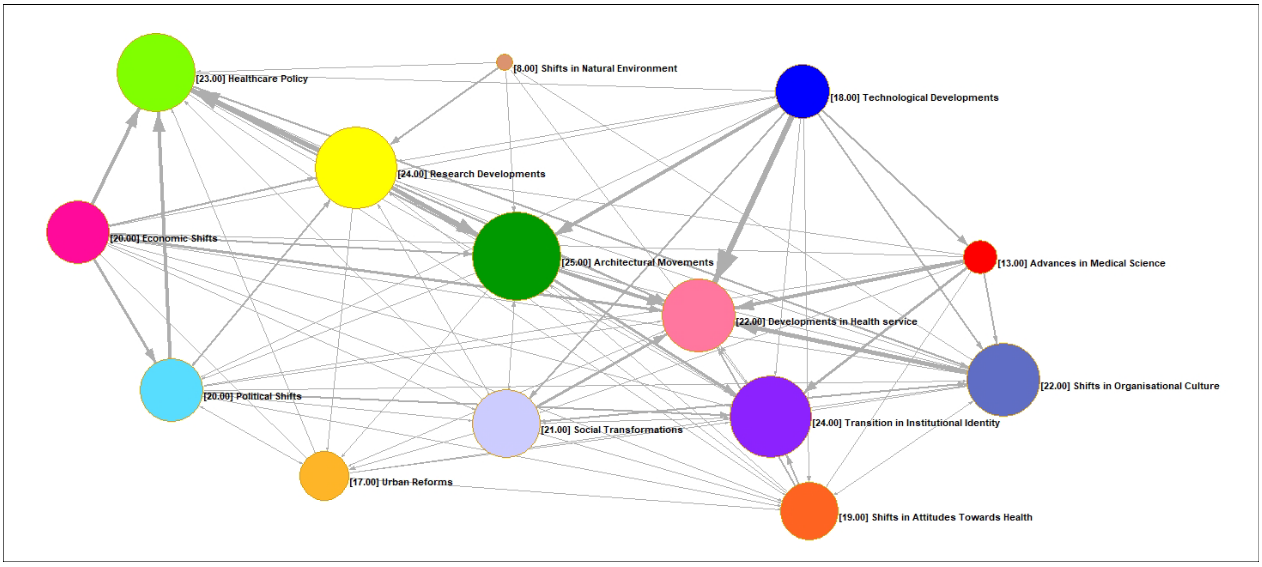


Figure 5-31: The shrunk version of the tenth network

Quantitative data presented here are widely seen to provide clear areas for further qualitative analyses (Crossley 2010; Gamper, Schönhuth & Kronenwett 2012; Guzek 2019; Luxton & Sbicca 2020). Next, time is examined as the second important variable in the analysis of interconnections between contextual factors generating design innovations. The combination of these two analyses provides the grounds for the development of the innovation framework.

5.3.2. Analysis of arc diagrams

Analysing the first three datasets and constructing the network diagrams resulted in an incremental change in our understanding of the phenomenon under study. Since capturing trends based on time made a significant contribution to understanding the nature of innovation in hospital building design, an arc diagram was employed in the analysis using Observable. Arc diagrams are generally classified in the network graph family where their specific feature is highly dependent on the order of nodes.

Arc diagrams elucidate relationships between contextual factors. The diagram can be analysed in terms of "why the user needs it, what data is shown, and how the idiom is designed" (Munzner 2014, p. 23). Here, the total number of arcs incoming to and outgoing from each code indicates the importance of that factor at each time bracket. The grey arcs connecting similar codes across different decades determine the constant impact of factors over a long period of time. The absence of grey arcs over the previous time brackets for each concept means that the concept emerged at that time. The emergence of new interactions between prior factors represents both the development of seemingly improbable interactions over time, and the focus of different data sources on specific subjects. Thus, categories with fewer links at the first steps of analysis do not necessarily reflect the insignificance of those concepts in relation to design innovation. In what follows, the evolution process of the final arc diagram is recorded in relation to the data analysed from each data source (refer to: https://observablehq.com/@researcherhbd/arc-diagram to explore the links). Nine graphs were constructed from the analysis of 11 data sources, five of which are represented here to demonstrate the development process. Notably, all diagrams depicted in the following subsections are also represented in Appendix 9.1 at A3 landscape orientation for more legibility.

5.3.2.1. The analysis of the first arc diagram

Figure 5-32 demonstrates the first arc diagram representing a wide picture of interactions between 32 unique concepts within and across categories while indicating the sequence of concepts. At this stage of analysis, to indicate the codes and categories related to each pair of decades, a total number of 77 concepts were classified into five categories. Here, the classification brackets used to capture hospital progression commenced in 1910s-20s and concluded in 1990s-2000s.

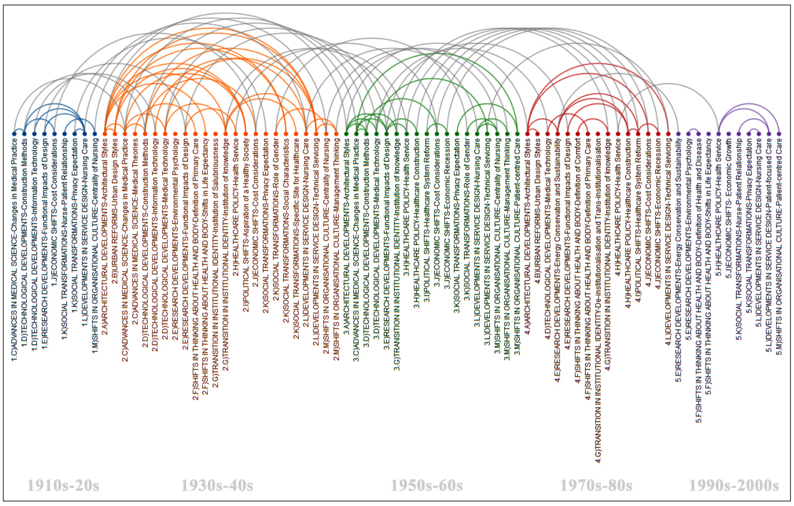


Figure 5-32: The first cumulative arc diagram

Regarding the most significant contextual factors, *Nursing Care* (with 3 incoming and 2 outgoing); the identity of hospital as *Institutions of Knowledge* (with 1 incoming and 4 outgoing) and Architectural styles (5 incoming and 3 outgoing); advancements in *Medical Technology* (1 incoming and 3 outgoing) and research on *Functionality* (3 incoming and 3 outgoing); and *Architectural styles* (5 incoming) played key roles in 1910s-20s, 1930s-40s, 1950s-60s, and 1970s-80s respectively. In the first two brackets, most of the architectural innovations were triggered by *Changes in Medical Practice* and the emergence of new treatments. In the 1940s, *Medical Technologies* and *Construction Systems* saw considerable improvements that resulted in different innovative hospital designs. *Social Transformations* came to affect the *Nursing Position* and *Privacy Expectations* of patients leading to service design innovation. In the 1950s and 1960s, *Advancements in Research* on enhancing the functionality of healthcare centres and *Shifts in Organisational Culture* impacted the rationality of spaces (*Technical Servicing*) and the *Nurse-Patient Relationship* leading to innovation in architectural and service designs.

The *Economic Crisis* of the 1970s and subsequent *Policies* and plans imposed by governments impacted innovation in hospital building design for nearly three decades. Furthermore, *Advancements in Medical Science* and *Technological Developments* significantly impacted design innovations over all time brackets while affecting one another. Evidently, shifts in *Healthcare Policy* and *Political Preferences* were related to *Advancements in Medical* Science and *Research* in the field of the built environment between the 1950s and 1980s. It is notable that mainstream

Architectural Styles impacting healthcare architecture were widely influenced by developments in *Technology, Medical Science, Service Design*, as well as *Social and Cultural Transformations* between the 1940s and 1980s.

5.3.2.2. The third arc diagram

Figure 5-33 demonstrates the third arc diagram representing a wide picture of interactions between 46 unique concepts within and across categories. To indicate the codes and categories related to each pair of decades, a total number of 119 concepts were classified into six categories.

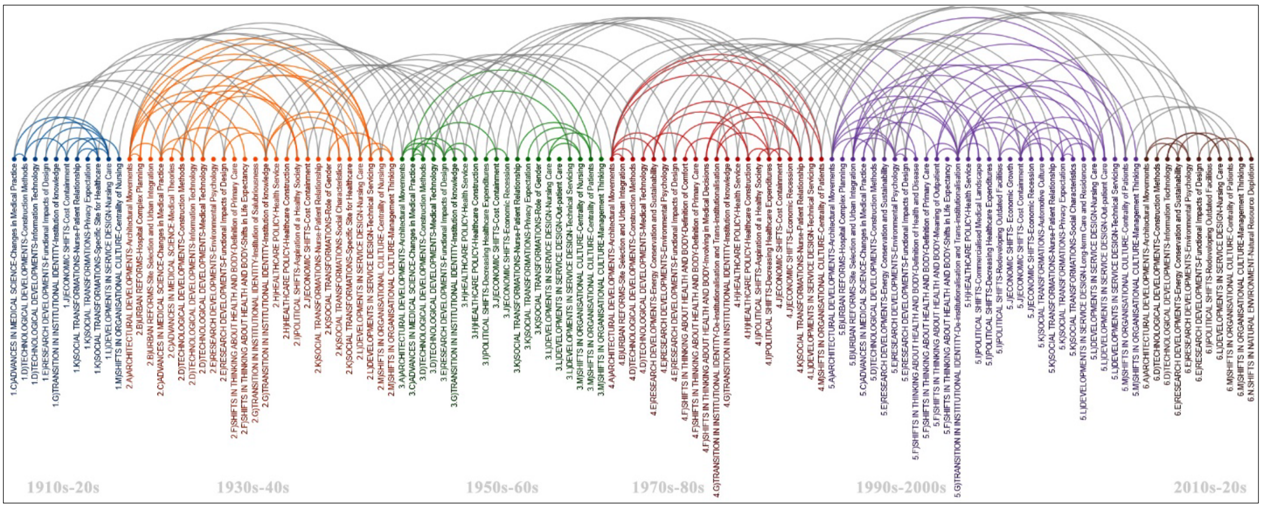


Figure 5-33: The third cumulative arc diagram

5.3.2.3. The fifth arc diagram

Figure 5-34 demonstrates the fifth arc diagram representing a wide picture of interactions between 53 unique concepts within and across categories. Here, a total number of 178 codes from 14 categories were classified into six pairs of decades. These codes were connected through approximately 349 links. Given the time focus of the data source, the links added (around 50) were mostly to the last two brackets.

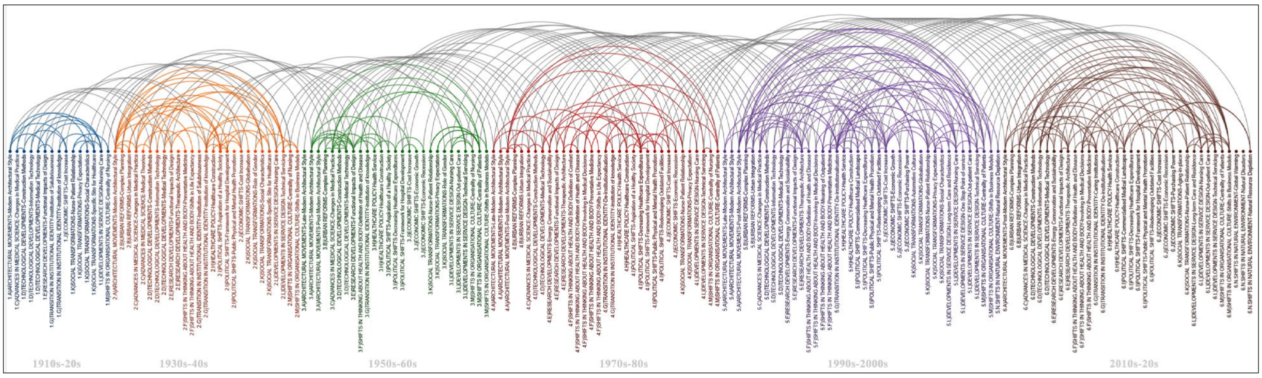


Figure 5-34: The fifth cumulative arc diagram

5.3.2.4. The seventh arc diagram

Figure 5-35 demonstrates the seventh arc diagram representing a wide picture of interactions between 71 unique concepts within and across categories. Here, 200 codes from 14 categories were classified into six pairs of decades. These codes were connected through approximately 467 links. Given the focus of the data source, about 70 links were added mostly into the brackets of 1970s-80s and 1990s-2000s.

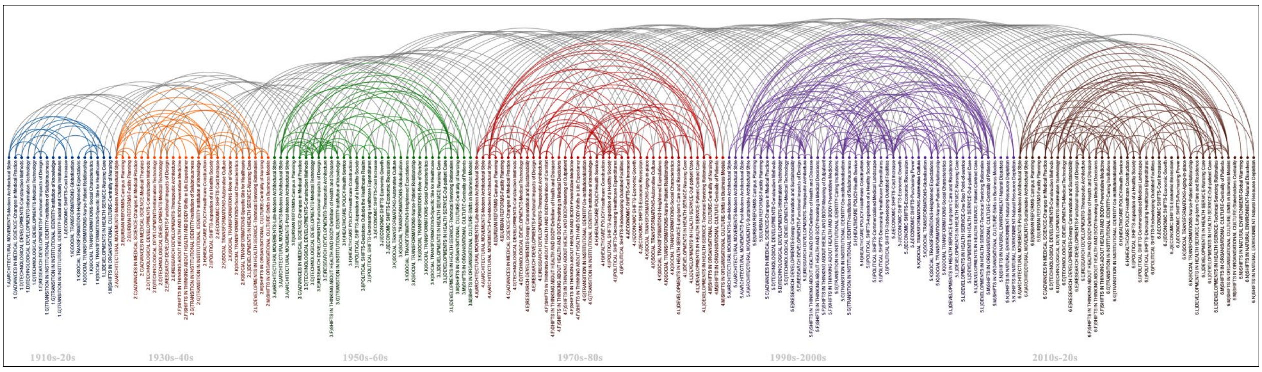


Figure 5-35: The seventh cumulative arc diagram

5.3.2.5. The analysis of the ninth arc diagram

Figure 5-36 demonstrates the ninth arc diagram representing interactions between 78 unique concepts within and across categories. Here, a total number of 230 codes from 14 categories were classified into six pairs of decades. These codes were connected through approximately 540 links. Given the focus of the last two data sources, about 70 links were added mostly into the first and last pairs of decades.

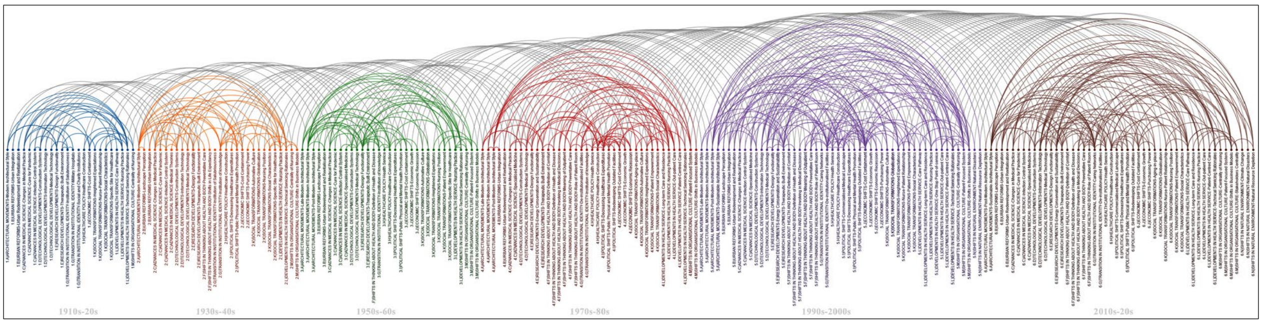


Figure 5-36: The ninth cumulative arc diagram

Regarding the most important concepts, developments in *Technical Servicing Rationales* (with 5 incoming and 4 outgoing); *Modern Architectural Style* (7 incoming and 5 outgoing) and changes in hospital identity as *Institutions of Knowledge* (5 incoming and 4 outgoing); research advancements on *Functional Impacts of Design* (7 incoming and 6 outgoing); *Post-Modern Architectural Style* (4 incoming and 7 outgoing), *Decreasing in Healthcare Expenditures* (6 incoming and 6 outgoing), and healthcare policies on *Healthcare Construction* (10 incoming and 1 outgoing); Cost Containment (4 incoming and 16 outgoing), Patient-Focused System (7 incoming and 5 outgoing), *De-institutionalised Facility* (15 incoming and 2 outgoing), and research developments on *Therapeutic Built Environment* (6 incoming and 4 outgoing); and *Sustainable Architecture Style* (10 incoming and 1 outgoing), Information Technology (9 incoming and 1 outgoing), changes in hospital identity as *Caring Network* (12 incoming and 4 outgoing), and *Shifts in Business Models* (10 incoming and 1 outgoing) saw the highest interrelationships with other concepts in 1910s-20s, 1930s-40s, 1950s-60s, 1970s-80s, 1990s-2000s, 2010s-20s respectively.

Some of the concepts had constant influence in successive decades. For instance, *Changes in Medical Practice (Medical Advancements)*, developments in *Medical Technology* and *Construction Systems,* and changes in health services such as *Nursing Care* considerably affected other factors from the 1910s to 1990s. *Modern Architectural Style (Architectural Movements)* was a constant factor triggering design innovation in 1920s-70s and *Post-Modern Architectural Style* in 1960s-2000s. Similarly, *Automotive Culture* and *Urban Redevelopment and Revitalisation* impacted a considerable number of factors from the 1950s to 2000s.

Turning to the emergence of new concepts through time, some political shifts such as *Commercialising Medical Landscape*, new interests in *Involving in Medical Decisions*, introduction of *Preventative Medicine* and advancements in *Information Technology* became key factors triggering design innovation since the 1990s. Further, some devastating *Natural Disasters*, the global attention to *Natural Resource Depletion,* and subsequent shifts to *Sustainable Architectural Style* and political decisions on *Redeveloping Outdated Facilities* resulted in innovation in hospital building design. Further, some shifts in *Business Models* for hospital organisational design based on social shifts and *Patient Empowerment*, as well as developments in *Patient-Focused Systems* emerged in 1980s-1990s to impact design innovation.

The influential factors and the interactions between them triggering design innovation in hospital building design increased significantly over time from 46 links in 1910s-20s to 195 in 1990s-2000s to 136 in 2010s-20s. Further, the interconnections between specific categories evolved over time, resulting in the development of interactions between prior factors. For example, while the concept of *De-institutionalised Facility* had been introduced in the late-1960s, more interactions between this code and other factors across different categories resulted in design innovations later in the 1990s.

5.4. Summary

This study, in line with the suggestion of Johnson and Walsh (2019), developed a novel hybrid research design to mixed grounded theory, which expands the possibility of alternative interpretations for big data and promotes systematic thinking. In this chapter, the reflection of strategies suggested in the previous chapter was explained thoroughly in relation to the specific properties of the data collected through this study. In so doing, the processes of developing the taxonomy of terminologies (conceptualising contextual factors triggering design innovations – section 5.2) and theoretical models (elucidating the semantic interrelationships between the factors – section 5.3) were represented.

After defining the starting point of the analysis process through the initial literature review, the methodological steps defined by the Charmaz (2014) interpretive GT (which have widely been translated to a computer-assisted way) were employed using NVivo. Through ongoing parallel analysis, codes were compared with new incidents and other codes to construct higher-level abstractions (section 5.1.2). Codes with similar properties were classified into categories through vertical and horizontal analysis. Due to the complexity of the innovation ecosystems, complicatedness of big data cross-sectional analysis and the limitations of the traditional GT methodology in addressing the research objectives, two complementary analysis techniques and methods were used to facilitate the process of ordering different concepts in correct relation to one another and exploring semantic relations between different concepts. Section 5.1.3 explained how the generation of a relational composition via a network diagram using Flourish web platform and Pajek, and the classification of concepts and links via an arc diagram using Observable web platform helped the analysis process.

Two diagrams – Network and Arc – complemented each other in the process of data analysis to achieve the prime goal of the study. Here, the information acquired from an arc diagram could not be achieved from a network diagram as chronological ordering is not defined in networks.

Moreover, it was not feasible to add value to the links in a network to classify codes in accordance with the date they occurred. Despite the significant ability of arc diagrams to depict sequence, arc diagrams could not be utilised instead of comprehensive networks because they do not effectively present the overall structure of the network. The relational understanding gained from the combined use of network and arc diagrams allowed me to interpret data at a level that would be impossible to describe without them.

In this study, 11 data sources were analysed to reach the saturation point, when the process of constant comparison yielded to neither new properties/dimensions of each category nor new conceptual ideation. Commencing with NVivo for open coding and then developing theoretical models made feasible the analysis of 617 interactions between 146 codes (section 5.3). Through the evolution of the theoretical models, the complex nature of design innovation processes and the limitations of the existing knowledge of this ecosystem became evident. In the next chapter, a narrative interpretation is provided of how the understanding was evolved through analysing each data source, and how different iterations added to the methodology facilitated new understanding of semantic relationships (section 6.1). Further, the nature of innovation in hospital building design is explicated through constructing an explanatory innovation framework (section 6.2).

06 Discussion - The Development of a Design Innovation Framework

This chapter represents a narrative interpretation of how my understanding of design innovation processes has evolved through the process of GT analysis, and how different methodological interventions facilitated new understanding of the semantic relationships between a wide range of contextual factors.

By illustrating the chronology of the theoretical models acquired from the process of focused coding and interpreting the structure and emerged patterns, the first section discusses the evolution of my understanding of design innovation and how the first three research objectives were met. This knowledge led to the construction of an explanatory innovation framework.

In the second section, the final framework is explained at three levels (micro-, meso-, and macro-level) by synthesising the behaviour of individual and combined actors using qualitative and quantitative analyses. This discussion elucidates the complex structure of interactions implemented by the different actors that triggered innovations in hospital building design over the last 100 years. The explanatory innovation framework is then explored based on the current issues and the predictions of the future of hospital designs provided by experts.

The fourth section explains how the proposed multi-representational approach has been instrumental in interpreting the behaviour of the innovation ecosystem in connection with its constituent phenomena, and addressing the research aim. Next, the quality of the findings is evaluated according to four criteria suggested by Charmaz: *credibility, originality, resonance, and usefulness*. Moreover, the knowledge acquired from the newly developed methodological strategies (merged to the common process of focused coding) are assessed in relation to the main data sources. This chapter ends by identifying the limitations of the study.

Notably, all diagrams depicted in this chapter are also represented in Appendix 9.1 at A3 landscape orientation for more legibility.

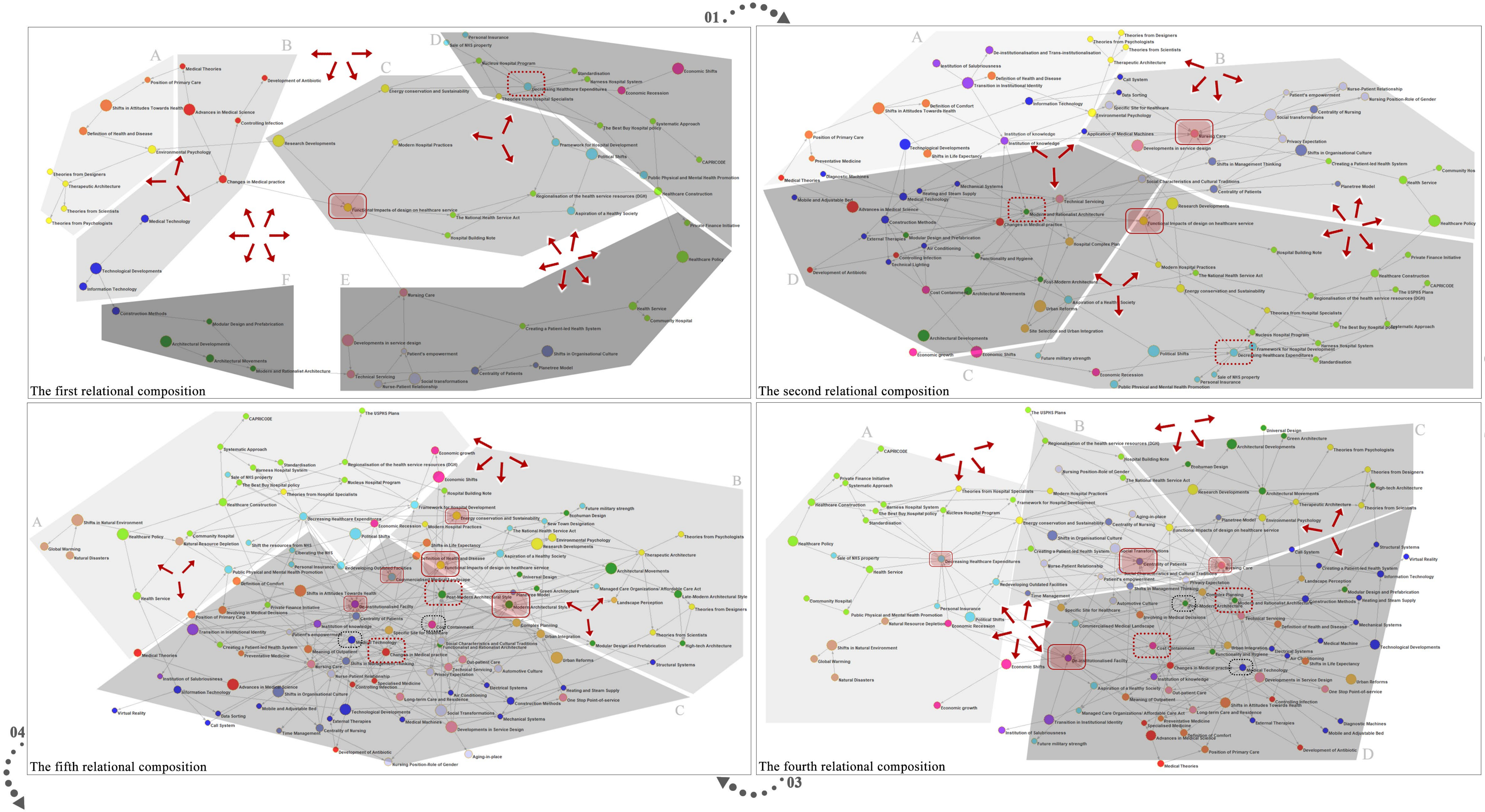
6.1. A Narrative Interpretation of Changes in Theoretical Models

This study aimed to conceptualise the evolution of hospital building design by identifying and explaining the main factors and relationships triggering design innovation in this field. The first three objectives were 1) to introduce the contextual factors contributing to design innovations, 2) to explore how design innovations were triggered from a holistic perspective, and 3) to examine the structure of interactions and the hidden patterns in design innovation ecosystems. Here, a novel approach to MGT methodology has been developed to address the complexity of the research problem. A multi-representational approach integral to the research design promotes systematic and systemic thinking and enhances the process of grounded theorising, which is both well-informed and analytically appropriate to Charmaz's methodological framework (Bryant & Charmaz 2011; Buckley & Waring 2013; Charmaz 2014; Gorra 2019).

In line with Barile, Spohrer and Polese (2010, p. i); Poutanen, Soliman and Ståhle (2016), network theory was used as both a systemic "way of thinking" to deal with interrelationships and a "methodology" to address the dynamic complexity of design innovation in hospital building design. Here, a hybrid approach, as suggested by Vicsek, Kiraly and Konya (2016) and Wickramasinghe and Bali (2011), was developed to use both the strengths of ANT as a rich theoretical lens and SNA as a technique to characterise the network topology. In so doing, a set of network and arc diagrams were used to represent the relational composition (between human and non-human actors) and the chronological order of incidents respectively. Next, those diagrams and their associated analytical techniques were employed as a tool to develop a new understanding of both individual and collective impacts of the factors triggering design innovations over the past 100 years.

As the accumulated knowledge of the nature of design innovation was revealed after the analysis of all data sources, it is critical to examine its process of evolution through this research. Innovation is considered as a systemic and evolutionary process that destabilises one state of the network and opens a new process of self-organisation leading to a new stable state. Thereby, as the analysis of each data source introduced new contextual factors and relationships (based on the main thesis of each book and their specific temporal and geographic scope), the structure of the innovation ecosystem as a whole changed, and in turn, our understanding of its nature evolved. Having examined all 10 relational compositions, I noticed five key moments of evolution in the structure of networks, namely from the first to the second, to the fourth, to the fifth, to the seventh, and to the tenth network. This section explains these five significant transformations between the theoretical models provided in section 5.3 with the aim of explaining how the GT has been developed.

The interpretation is highly dependent on my knowledge of the study and the research questions, resulting in a complex process that may not be classified into clear sub-steps (Decuypere 2020). As a constructivist/interpretivist GT researcher, I moved iteratively between the qualitative data (codes, categories, memos and annotations), network and arc diagrams, and the measurements of network structural properties to further explore the semantic relationships acquired from the initial and focused coding processes. Thus, understanding deducted from the diagrammatic analysis was built on top of the information obtained from reading each data source. As explained in section 5.3.1, networks constructed by the force-driven algorithm were analysed using Pajek software through the computation of *infrastructure and cohesion*, *interfaces and regions*, and *centrality measures* at three levels of *macro*, *meso*, and *micro* respectively. Here, these measurements and reasons behind the interactions between factors were employed to explain the evolution of the understanding of design innovation. Notably, as networks represent connections at specific times, which are “equally relationally enacted within the confines of the visual network”, the analysis of arc diagrams helped to make sense of interactions chronologically. A similar discussion might be held in relation to space, as constellations of actors in a network also generated specific sorts of spaces that “are not confined to physical and/or bounded understandings of spatiality” (Decuypere 2020, p. 86).



The first relational composition

The second relational composition

The fourth relational composition

The fifth relational composition

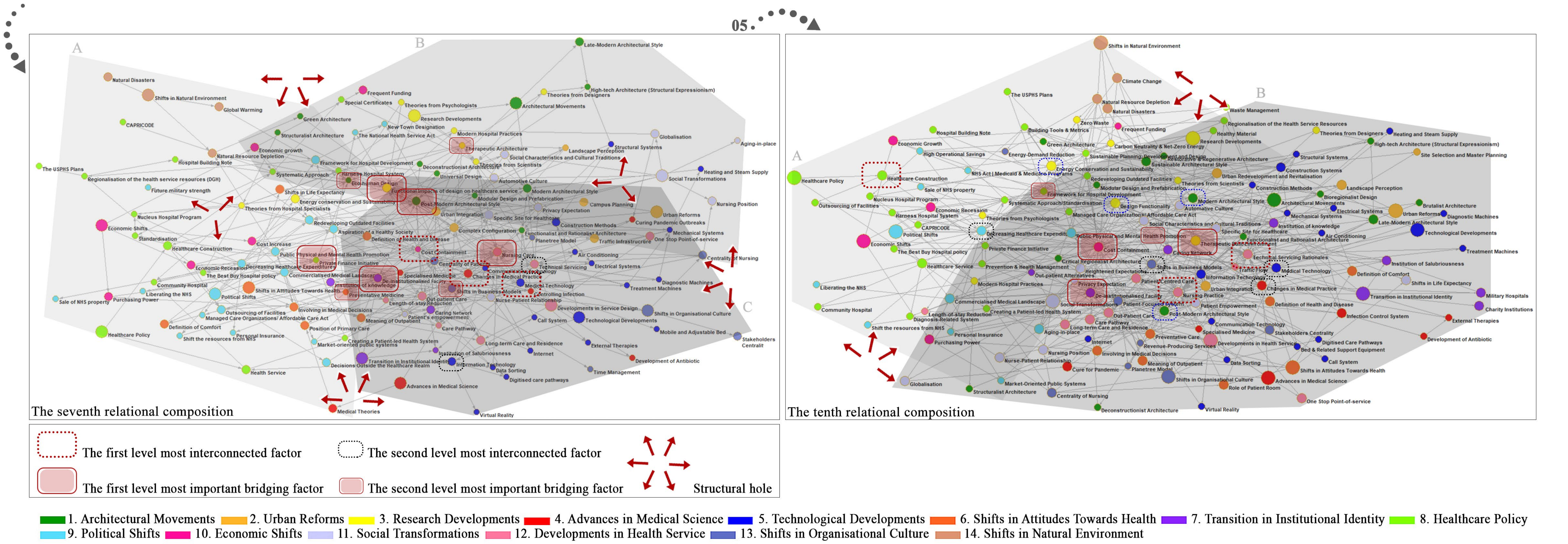


Figure 6-1: The chronology of relational compositions through the analysis process

6.1.1. Changes between the First and Second Models

The first transformation in the understanding of the design innovation ecosystem happened after the analysis of Francis et al. (1999) and Willis, Goad and Logan (2018):

Macro-level: While 11 categories were introduced in the first analysis, about half of them had less than two points (contextual factors classified under main concepts). The second analysis added to the understanding of design innovation by examining 104 new interactions between 91 concepts under 12 categories (mostly between the categories of *Architectural, Technological, Medical,* and *Service Developments*, while highlighting the impacts of *Organisational* and *Social Transformations*). Here, the categories of *Healthcare Policy, Technological Developments,* and *Research Developments* contained the highest number of codes. The second innovation network reflects the main approaches of these studies in explaining the evolution of hospital building design: 1) the significant impacts of research, medical advancements, and healthcare policies on design innovation in the UK after the establishment of the NHS (focusing on the interplay between theory and practice); and 2) the relationships between architectural, medical and technological developments in the Modern period.

Meso-level: The lack of interrelationships between codes across different categories and the existence of outstanding structural holes between clusters in the first network were significantly decreased in the second version. The analysis of the innovation ecosystem of the NHS hospital buildings illustrated a scattered whole, where the relationships between factors and key players of different fields in the network were insignificant and most categories accounted for distinct clusters. The clustering analysis of the second network indicated four functional clusters. Here, service design with the concepts of *Nursing Care* and *Technical Servicing* connected cluster B (with codes under *Architectural, Technological,* and *Medical Developments*) and cluster D (with codes under *Organisational* and *Social Transformations*). This structure demonstrates the critical role of *Nursing Care* in relation to a wide range of other contextual factors in triggering design innovation over different decades: how advancements in mechanical systems leading to centralised servicing freed nurses to participate in more specialised aspects of the medical process; how the introduction of call systems allowed accurate checks on personnel activities; how managers deployed nursing resources more carefully from the 1930s; how changes in medical practice and aseptic standards, as well as the introduction of diagnostic machines, required certain ward configurations; how mainstream modern architecture added aesthetic sophistication to hospital buildings in the 1940s; how organisational design and upheavals of social expectations impacted ward design and nursing practice in the 1950s by dividing patients into small groups and shaping nursing units; and how demands of private patients increased in the 1960s.

The structure of the network also reveals how advancements in research connected distinct clusters of the innovation ecosystem by interacting with different categories. In particular, research on *Functional* aspects of design was impacted by *Changes in Medical Practice*, and impacted *Nursing Practice* and some of the policies related to *Healthcare Construction* (generating design innovations based on the research which is itself based on new practices and treatment requirements to improve the provision of healthcare services); research on *Energy Conservation* was impacted by *Political* decisions; and research on *Environmental Psychology* was impacted by shifts in the *Definition of Health and Disease*. This finding strengthens how we might think about the relation between research and design practice in the health sector. Moreover, considering hospitals as

Institutions of Knowledge acted as a bridge between clusters A, B and D. The interactions between these bridge nodes made different components of this network relatively integrated. This understanding evidences how hospitals designed for a passive patient in the 1930s changed to highly specialised controlled built environments in the 1950s, and then to mobile places for the patients' needs based on research in the 1960s.

Micro-level: The most interconnected factors changed to 1) *Modern and Rationalist Architecture* and *Nursing Care,* which were impacted by a wide range of contextual factors, and 2) *Decreasing Healthcare Expenditures* (political decisions) and developments in *Medical Technology,* which impacted several factors generating design innovation. This is in line with the focus of the second data source, which is how modern hospital architecture impacted medical practice and was impacted by medical technological developments and mainstream modern architecture. Servicing a complex modern hospital and the impacts of research on department design were other influential factors highlighted as triggering design innovations. Notably, as the relational compositions were integrated into a cumulative one, including the knowledge acquired from the previous datasets, the concept of *Decreasing Healthcare Expenditures* shows the focus of the first study.

6.1.2. Changes between the Second and Fourth Models

The second transformation in the understanding of the ecosystem was developed from the analysis of Sloane and Sloane (2003) and Verderber (2010):

Macro-level: 24 new factors and 86 links were introduced to the network, particularly to the categories of *Architectural Movements, Research Developments, Social Transformations, Shifts in Organisational Culture, Political Shifts,* and the newly added category of *Shifts in Natural Environment*. The number of subsets in *Architectural* and *Technological Developments* significantly increased and yet these categories mainly populated the outer parts of the network and only a few codes are highly involved in the process. This distribution might indicate lack of information about the influence of these categories on design innovation.

A considerable change in the network infrastructure is the position of cluster B (including codes in *Social Transformations* and *Shifts in Organisational Culture*) at the core of the innovation ecosystem. Until this moment, these two categories were mainly positioned at peripheral parts of the network with much fewer connections to codes from other categories. While concepts such as *De-institutionalised Facility, Centrality of Patients,* and *Patient Empowerment* were added in the third network, the meaningful relationships between these factors and their significant influence on the structure of the innovation ecosystem became evident in the fourth network. The new set of central nodes reflects the key storyline of the books: how the place of medical practise shifted from healing machines with technology-centred medicine to modern hospitals to humanised post-modern mega hospitals to satellite clinics. These differences in the perception of hospitals impacted both the *Business Models* of hospitals (in a commercialised landscape) and *Service* design (for more patient-centred care) that, in turn, triggered significant innovations in hospital buildings.

Meso-level: Four clusters were detected in relation to the nature of ties, with four significant structural holes between the factors. Here, a comparison between the densest cluster (cluster D) in the second and fourth network shows how factors from different categories started interacting with one another more widely. Close connections are apparent between concepts in the categories of *Architectural Movements, Advances in Medical Science, Technological Developments, Shifts in*

Attitudes Towards Health, Service Developments, Urban Reforms, and *Transition in Institutional Identity.*

Four factors held the bridging position between distinct subgroups, namely *Nursing Care* and *Centrality of Patients* (between clusters B and D); *Decreasing Healthcare Expenditures* (A and B); and *De-institutionalised Facility* (A, B and D). The removal of these nodes, particularly *Nursing Care* and *De-institutionalised Facility* because of their position and links with other factors, will lead to a considerable shift in the structure in the form of bigger structural holes. For instance, interactions between *Nursing Care* and *Medical and Information Technologies* in the early-20th century resulted in design innovations such as decentralised, mobile workstations (within-room or room-adjacent) that are a safe, efficient and patient-friendly alternative to central nursing stations. Further, relationships between a shift in hospital identity to the *De-institutionalised Facility* and a wide range of other contextual factors in the 1980s-90s (*Post-Modern Architectural Style, Patient Empowerment, Nurse-Patient Relationships*, *Commercialised Medical Landscape, Automative Culture (Car-dominant Culture), Cost Containment, Personal Insurance, Preventative Care, Meaning of Outpatient,* and *Out-Patient Care*) resulted in significant design innovations. Post-modernism and residentialism in hospital design in the 1980s-90s spun off centralised institutions from its core (like a centrifuge) and reinserted them in different neighbourhood and community centres. The aim was to increase convenience and accessibility for routine and preventive health procedures, to draw paying patients, and to decrease costs by creating new revenue-producing services. Having followed shopping mall and airport design models, post-modern hospital buildings focused on orchestration instead of manufacturing, and gradually moved away from an overly institutional look and feel.

Micro-level: The most interconnected contextual factors changed to *Modern and Rationalist Architecture*, *De-institutionalised Facility,* and *Cost Containment,* followed by *Medical Technology, Post-Modern Architecture* and *Nursing Care*. Here, shifts in *Architectural Movements,* how health services (*Nursing Care*) were delivered, and the need for an efficient design (*Cost Containment*) are constant factors triggering design innovation over the past 100 years, whereas the concept of *De-institutionalised Facility* impacted design from the 1970s to 2000s. Given the temporal focus of the first set of data sources, this significant change in the most influential factors on design innovation was justifiable and predictable.

Moreover, the research concepts of *Functionality* and *Sustainability* are not only interconnected with factors in healthcare policies and politics, medical practice and modern architecture, but also with codes under *Organisational Culture* (*Shifts in Business Models* and *Patient-Focused Care Models*), service design and *Nursing Practice*, political decisions on *Redeveloping Outdated Facilities*, and the *Social Characteristics* of place. Considering the arc diagram, these new links resulted in design innovation that occurred after the 1980s, establishing a new position for research factors in the innovation ecosystem that strengthens the impacts of research in triggering design innovation.

6.1.3. Changes between the Fourth and Fifth Models

The third transformation in the understanding of the ecosystem was developed from the analysis of Rivett (2017):

Macro-level: about 50 new links were introduced to the network, particularly to the categories of *Political Shifts, Medical Advancements, Social Transformations* and *Shifts in Organisational Culture*. Indeed, points that already existed in the network became more connected.

One noticeable transformation in the network structure is how concepts under the categories of *Social Transformations* and *Shifts in Organisational Culture* became interconnected to factors in the densest part of the network and thus decreased the number of structural holes in the network. This change in understanding of the importance of certain factors is in line with the focus of the fifth data source: explaining the story of the NHS in terms of healthcare policies, financial and organisational models, clinical advancements, and social demands.

Meso-level: The clustering analysis indicated three functional subgroups such that factors in clusters B and D of the fourth network became merged. The emerged cluster illustrates close interconnections between the categories of *Advances in Medical Science*, *Technological Developments*, *Shifts in Attitudes Towards Health*, *Transition in Institutional Identity, Social Transformations,* and *Shifts in Organisational Culture*. In particular, between the concepts of: *Changes in Medical Practice* to more treatment and more consultants, need for efficiency and *Cost Containment* after the oil crisis, rising *Privacy Expectations* and *Patients Empowerment, Shifts in Business Models,* changes in *Social Characteristics*, and some political decisions on *Commercialising Medical Landscape* and related policies - such as *Creating a Patient-Led System* and *Private Finance Initiatives (PFI)* to meet the new needs. Indeed, the patients' voices were heeded and their choices prioritised through the creation of a new national body (Healthwatch, and local Healthwatch organisations).

The structural holes were minimised, and clusters started to slightly overlap. More than 80% of relationships resulting in design innovation occurred within clusters. Nodes in the bridging position made regions permeable by impacting different innovations: research on *Functional Impacts of Design* and *Sustainability* (between A, B and C); *Commercialising Medical Landscape*, *De-institutionalised Facilities* (A and C); and *Modern Architectural Style* (B and C) made regions permeable by impacting different innovations.

Micro-level: The most interconnected factors remained similar to the previous network with slight changes in the number of links associated with each node: 1) *Modern and Post-Modern Architectural Styles*, the development of *De-institutionalised Facility*, and *Nursing Care* and *Technical Servicing* that were impacted by a wide range of contextual factors, and 2) *Medical Technology*, research on *Functional Impacts of design, Cost Containment* and *Changes in Medical Practice* that impacted several factors in the generation of design innovations.

6.1.4. Changes between the Fifth and Seventh Models

The fourth transformation in understanding of the ecosystem was developed from the analysis of Wagenaar et al. (2018) and Prasad (2008):

Macro-level: 20 new factors and 175 links were introduced to the network, particularly to the categories of *Service Developments, Transition in Institutional Identity, Technological Developments, Economic Shifts, Political Shifts,* and *Healthcare Policy.* A considerable transformation in the network infrastructure here is significant increase in the density of the network core. In particular, this analysis led to intense interactions between the concepts of *Commercialised Medical Landscape, Public Physical and Mental Health Promotion, De-*

institutionalised Facility, Caring Networks, Post-Modern Architecture and Eco-Human Design, and *Shifts in Business Models*. The now tight core of the innovation ecosystem emphasises the close relationship between architectural, organisational, and service design for a better building design and therefore better care. These data sources examined a wide range of innovative hospital designs and explained how technological and sociopolitical developments, changes in financing and procurement (especially PFI processes), medical processes, and advancements in information technologies triggered design innovations over the past few decades.

The average number of links of each code nearly doubled from the fifth to the seventh network. Here, like the fifth network, *Technological Developments, Political Shifts,* and *Healthcare Policy* contained the highest number of codes with a slight increase in those numbers. Moreover, while the degree assortativity decreased to half of its amount in the fifth network, the number of links between factors from different categories is still considerable. It shows how the interplay between factors of different nature has resulted in design innovations.

Meso-level: Analysis indicated three completely overlapped clusters with the main structural holes at the boundaries. It is evident that 65% of relationships resulting in design innovation occurred within clusters, which saw a considerable decrease from 80% in the fifth network. Here, factors at the bridging position facilitated design innovation by linking clusters together. Notably, the number of bridging points almost doubled, these were: *De-institutionalisation, Private Finance Initiatives,* and *Preventative Medicine* (between A and C); Research on *Therapeutic Built Environment* (B and C); and *Post-Modern Architectural Style, Nursing Care,* and Research on *Functionality* (A, B and C). Further, as these books mainly focused on hospital design of the 21st century, factors at the bridging position indicate the recently extended collaboration between key players from different fields.

Until this moment of research, cluster A illustrated the close interconnections between the categories of *Healthcare Policy, Political* and *Economic Shifts*, and yet the impacts of factors under *Shifts in Attitudes Towards Health* and research on *Sustainability* had not been fully understood. Moreover, the impacts of factors under the category of *Social Transformation* (*Privacy Expectation, Automative Culture (Car-dominant Culture),* and specific *Social Characteristics*) on the mainstream *Architectural Styles* and in turn on innovative hospital building designs had been mostly overlooked.

Micro-level: The most interconnected factors saw a slight change to 1) *Post-Modern Architectural Styles*, and *Nursing Care* and *Technical Servicing* (from the category of developments in health service), which are impacted by a wide range of contextual factors, and 2) factors such as *Cost Containment*, *Changes in Medical Practice,* and *Medical* and *Information Technology,* which significantly disseminate impact over the innovation network.

Additionally, newly added concepts to the list of most significant contextual factors are Information Technology, Private Finance Initiative, Shifts in Business Models, Centrality of Patients, Privacy Expectations and Therapeutic Built Environment. These concepts started connecting to other concepts that already existed in the diagram. For example, the new critical relationships demonstrate how: Economic Recession, political decisions on Commercialising Medical Landscape and policies on Creating a Patient-led Health System resulted in the introduction of Private Finance Initiative (PFI) in the 1990s, and how this policy triggered design innovations by impacting research (Therapeutic Built Environment) on the layout, legibility and positioning of clinical activities, as well as on the psychological requirements for getting the best out of doctors and nurses - true whole life costing; by impacting Standardisation because of the new tendency to ever-larger hospitals; and by impacting Modular Design for the fast construction of larger buildings. It also shows how the development of the De-institutionalised Facility, the tendency to Urban Integration, and developments in Medicine and Technology influenced Business Models, and how different business models (customer-, product- and process-oriented models) and organisational designs directly generated design innovations. Similarly, how recent developments in Communication Technologies led to design innovations in relation to Patient Empowerment (by personalised digital health, entertainment and service environment), to Nursing Practice (by the provision of satellite workstations), to Care Pathway (by acting as a tool for improving the quality of healthcare), to Nurse-Patient Relationships (by creating an expert patient and reducing the gap between the two groups), and to Technical Servicing Rationales (by separating flows for supplies from that of staff and patients with mechanised distribution systems).

6.1.5. Changes between the Seventh and Tenth Models

The last critical transformation in the understanding of the design innovation ecosystem occurred after the analysis of Schrank and Ekici (2016), Verderber and Fine (2000), Kisacky (2017), and Guenther and Vittori (2013):

Macro-level: 9 new factors and 122 links were introduced to the network, particularly to the categories of *Architectural Movements, Shifts in Organisational Culture, Healthcare Policy, Research Developments, Shifts in Natural Environment,* and *Urban Reforms*. Most importantly, re-examining all the concepts and links after the analysis of the tenth data source led to the terms used for 27 codes being either slightly changed to cover a wider domain of concepts, or removed from the network because of their insignificance position in the ecosystem. The average number of links for each contextual factor remained constant. Also, *Healthcare Policy, Technological Developments,* and *Architectural Movements* contain the highest number of codes.

Notably, and as explained in section 5.1.4, the structural analysis of the ninth network indicated a considerable lack of interactions between the category of *Shifts in Natural Environment* and the rest of the concepts. The existing structural hole suggested a further consideration of the importance of the codes under the fourteenth category and selected data sources for the analysis. As a result, concepts of *Natural Resource Depletion* and *Climate Change* became connected to *research* advancements on *Sustainability* and healthcare construction policies on *Sustainable Planning, Development and Design.*

Eventually, the final transition in the network infrastructure is a significant increase in the density of the network, pushing the structural holes from the middle parts to the boundaries of the network. The intense interactions between most concepts make the innovation ecosystem resemble an integrated whole. In the final unified network, the degree of assortativity remained at the same level, where the number of interactions between factors from different categories with different nature is considerable.

Meso-level: Analysis indicated two completely overlapped clusters, where nearly half of the links occurred across the clusters. Here, most of the factors in the categories of *Healthcare Policy*, *Political Shifts*, *Economic Shifts*, *Architectural Movements, Research Developments* and *Shifts in Natural Environment* were located in cluster A, and the rest of the categories in cluster B. Some of the most important bridging factors between these two clusters are: *Cost Containment,* research on *Therapeutic Built Environment* and *Energy Conservation,* and the development of *De-institutionalised Facility*. It is evident that codes with various colours (from distinct categories) are distributed across different clusters.

Micro-level: The number of most interconnected factors increased significantly: 1) *Nursing Care* and *Technical Servicing* (from the category of developments in health service), the hospital identity (*De-institutionalised Facility*), and policies on *Healthcare Construction,* which are impacted by a wide range of contextual factors, and 2) factors such as *Cost Containment* and *Decreasing Healthcare Expenditures*, *Medical Technology*, research on *Therapeutic Built Environment,* and *Changes in Medical Practice,* which significantly disseminate impact over the innovation network. Moreover, factors such as research on *Design Functionality* and *Energy Conservation and Sustainability,* as well as *Modern* and *Po-Modern Architectural Styles,* play key roles in triggering design innovations by both impacting and being impacted by other factors.

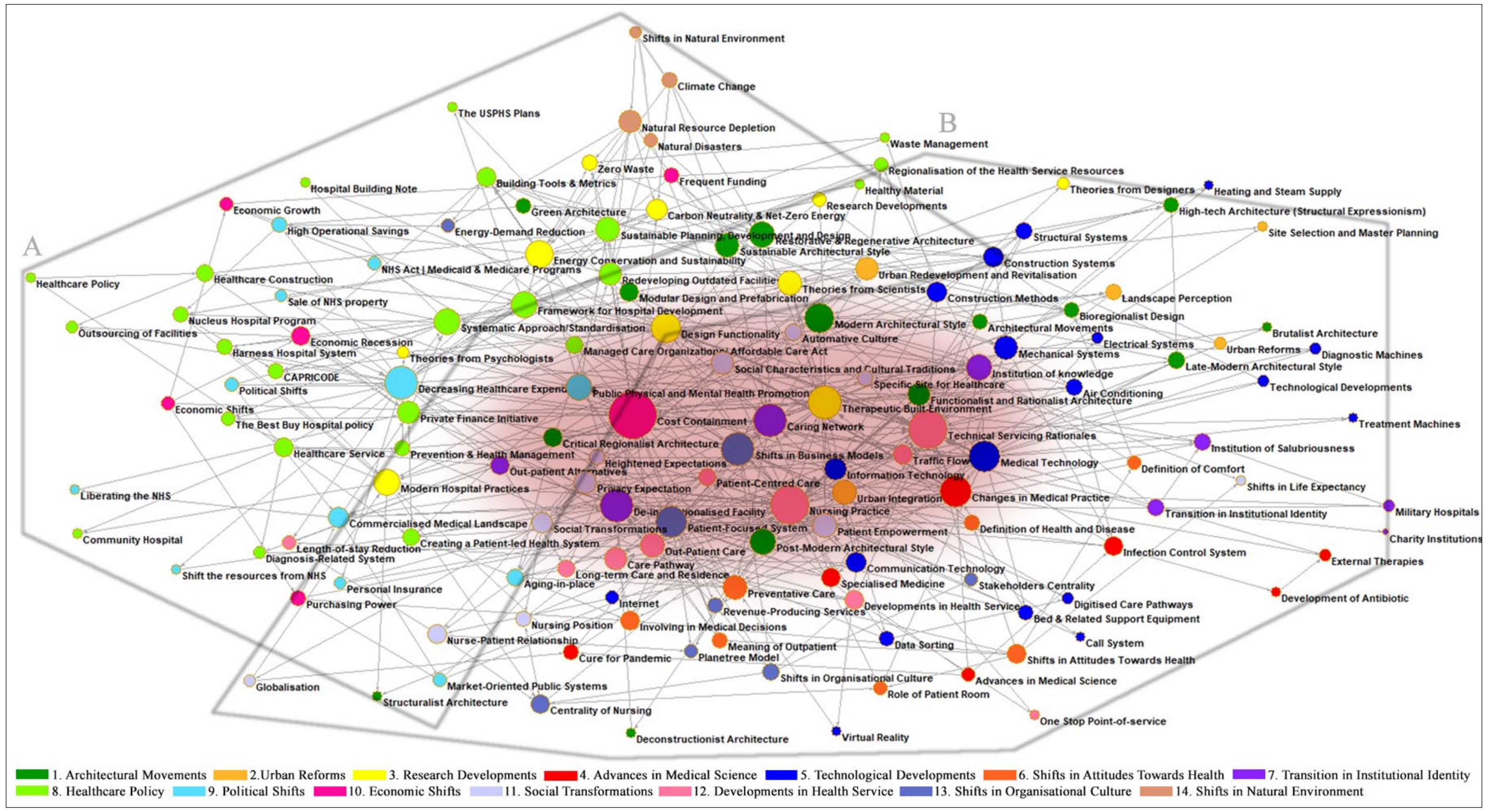
In sum, the chronology of transformations in the relational compositions through this study revealed how each data source focused on a certain set of contextual factors and interactions among them resulting in design innovations. For instance, new contextual factors were introduced into the network at different stages of the analysis that significantly changed the structural properties at meso- and macro-level. In some cases, new relationships were introduced to prior concepts that had seemed outliers until that moment. This explanation of the evolution of our understanding of the design innovation ecosystem highlights existing gaps in the literature. Each data source explains the impacts of certain factors, including changes in technology, socioeconomic climate, political and legal climate, and cultural and geographical contexts, on the generation of design innovations at certain points of time and in certain locations. It also highlights the importance of using GT methodology to accumulate an understanding of hospital building design evolution and its wider context.

This study posits an accumulated understanding of the nature of design innovation by analysing critical data sources focusing on the evolution of hospital building design from different perspectives. The knowledge elucidates the properties of multi-faceted processes triggering design innovations via an explanatory framework that spans ecosystems, as suggested by Valkokari (2015) and Xu et al. (2020) (see section 6.2). This approach provides a holistic view of the system detached from time and place, maps the many dynamic factors that constitute the design innovation ecosystem, explores the structural behaviour of the innovation network, and monitors its evolutionary trends. Notably, it might be argued that there is always the possibility of adding new concepts and links to the innovation ecosystem and therefore the possibility of significant changes in the structure of the network. However, this study claims to contain the most significant and influential contextual factors and associated connections in the final theoretical model, and to provide a transparent explanation of the analysis stages for future developments.

6.2. Exploring the Explanatory Innovation Framework

In this section, a final explanatory innovation framework is represented and analysed to address the fourth research objective: to elucidate the nature of innovation in hospital building design. Here, the discussion focuses on how different inhabitants (some of which were themselves innovations to different systems) of the innovation ecosystem located at different places triggered design innovations at new spatial forms within the networks. It conceptualises the complex structure of interactions implemented by different actors (both human and non-human). This is a vital step to acquiring "an integrated understanding of the *effects* that a relational composition generates" (Decuypere 2020, p. 74; Latour 2005).

The explanation addresses who and what played a key role in design innovations, how their interplay triggered design innovation and when the incidents occurred by considering the position of inhabitants of the innovation ecosystem, as well as intensity, direction, and the number of ties between them. Thus, the whole of the relational compositions of the network and arc diagrams shapes and enables understanding of how design innovations have occurred. Further, as Thornberg and Dunne (2019, p. 9) highlighted in *The SAGE handbook of current developments in grounded theory*, a final literature review was conducted during analysis of the innovation framework to locate the study "within or across disciplines". This new knowledge of design innovation is compared with the prior literature to complement and develop a holistic understanding of the complex innovation ecosystem, as well as explore new knowledge gaps in this field. The interpretation of the framework and associated arguments were structured in relation to three main levels of network analysis (macro-, meso-, and micro-level) to simplify this complexity.



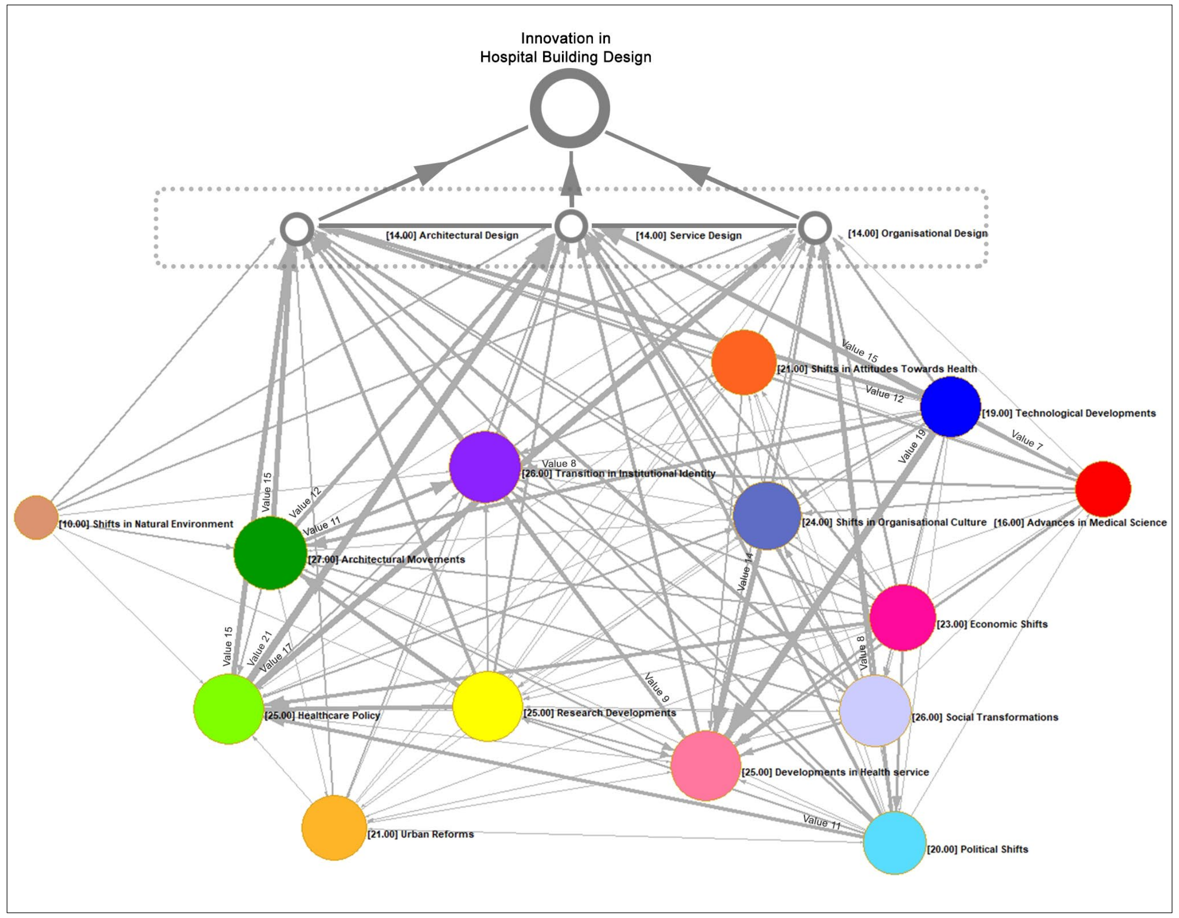


Figure 6-2: The explanatory innovation framework in hospital building design

Figure 6-3: The relationships between 14 categories and architectural, service and organisational design

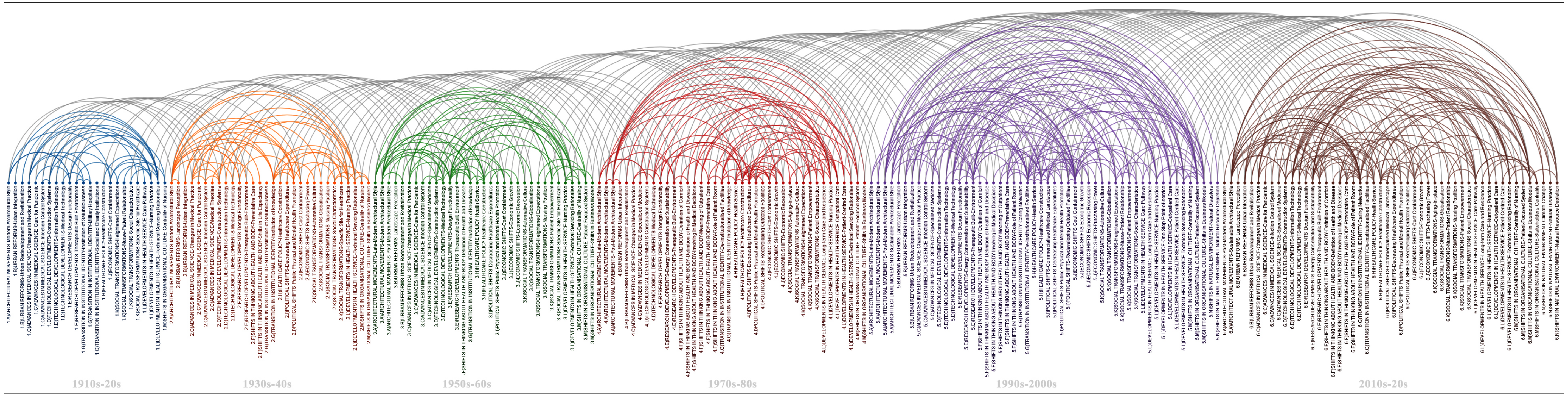


Figure 6-4: The final arc diagram

6.2.1. The main components of the innovation ecosystem

The interactions and patterns between a wide range of contextual factors triggered design innovations over the past 100 years. The present study classified these factors into the categories of: *Architectural Movements, Urban Reforms, Research Developments, Advances in Medical Science, Technological Developments, Shifts in Attitudes Towards Health, Transition in Institutional Identity, Healthcare Policy, Political Shifts, Economic Shifts, Social Transformations, Developments in Health Service, Shifts in Organisational Culture,* and *Shifts in Natural Environment*. This proposition is in line with the forces identified by Akenroye (2012) that drive the need for innovation in the health sector, namely: changing patient needs, technological changes, budgetary cuts, persistent and long-term health problems, social concerns, supply chain necessities, sustainability obligations. Moreover, Wagenaar et al. (2018) highlighted a similar set of factors impacting the process of planning and design of HCFs, namely: geography and sociopolitical context (geography, demography, government policies, pre-existing infrastructure, the available resources), medicine and care pathway, and operational logistics. Prasad (2008) also highlighted a similar set of factors related to the broader context, namely: technological developments (technology and model of care), sociopolitical developments (demographics, variability in demand) and economic developments (sustainability and regulations).

The well-known Donabedian conceptual framework (Donabedian 1966, 1988) and Carayon's developed model (Carayon et al. 2006) discussed the bidirectional connections between three main pillars (structure, process, and outcomes – SPO) for examining the quality of health care (Tossaint-Schoenmakers et al. 2021). As Donabedian pointed out, "A good structure increases the likelihood of good process, and good process increases the likelihood of good outcomes" (Donabedian 1988, p. 1745). This thesis posits that the proposed set of contextual factors triggering design innovation can be used as the indicators of structure (including human actors, organisations, technological tools and equipment, and environment) and process (actions done in giving/receiving care) to investigate the quality of care. Focusing on systems thinking and providing a view of the whole system, it does not imply that a change in one factor in the system leads to any specific patient, care provider, or organisational outcome. However, it provides a framework on how to think about the different inhabitants of an ecosystem, their interactions, and possible outcomes.

While most studies on hospital design evolution used certain sets of influential factors in their textual explanations, they have not considered relationships between those factors. The taxonomy of concepts (and framework) developed in this study goes beyond the simple identification of the main categories by examining the hierarchical relationships between factors with similar properties. The vertical connections between 146 contextual factors are indicated at four levels of subsets, whereby the higher levels in the hierarchy were assigned to more generic concepts. Here, the categories of *Healthcare Policy, Technological Developments,* and *Architectural Movements* contain the highest number of subsets, demonstrating the significant role of these categories and how distinct factors at certain points of time/place, but with similar meanings and properties, triggered design innovations. For instance, various healthcare policies in health service and healthcare construction, several technological developments in medicine, construction, and information systems, and different architectural movements under modern, late-modern, and post-modern architectural styles resulted in 23, 17 and 15 subsets respectively. However, the number of subsets is not always an appropriate criterion to examine the importance of a category. *Economic Shifts* and *Developments in Health Service*, for example, involved seven and 10 subsets respectively, whereas their vital role in triggering innovations is clear in their position and number of links. In fact, this shows that most of the historical books explaining the evolution of hospital building design lack comprehensive perspective when explaining all the influential factors in detail. Each data source covered specific incidents in relation to its overarching thesis and overlooked some of the factors and links impacting the design innovation processes. The taxonomy of concepts represented in this study provides policymakers, researchers and designers with more inclusive concepts impacting the innovation process, which broadens their perspective in exploring the potential of upcoming unexamined factors in this field.

Turning to the network infrastructure, the low density of the final innovation network indicated that the distribution of 617 links between 146 codes only covered one-twentieth of the maximum possible number of network connections. That is, design innovations generally occur through infrequent ways, highlighting the importance of understanding successful processes in the innovation ecosystem. Verderber (2010, p. 5) and Wagenaar et al. (2018, p. 11) stressed that history does "tend to repeat itself" and that significant changes in the hospital building designs have been "preceded by similar transitions in the past". As is argued in systems theory, sending positive and favourable feedbacks between actors can create patterns of organised interrelationships (Andriani 2011; Poutanen, Soliman & Ståhle 2016; Ramaprasad 1983). In other words, Innovation (A), which resulted from an interaction between specific contextual factors, can trigger Innovation (B) between the same actors. It is noteworthy that each feedback in the nonlinear innovation network might trigger different actions between the same set of actors depending upon the system. Here, this research represents and maps prior links between contextual factors in this inherently cyclic process.

The infrastructure also represents two completely different parts; a core zone with intense interconnections between factors (highlighted in red in Figure 6-2), and a peripheral zone enclosing the core with factors less interconnected to each other. Notably, despite considerably higher levels of density in the core zone, the contextual factors in the boundary position (such as *Climate Change, Natural Disasters, Urban Reforms, Shifts in Life Expectancy, Role of Patient Room, Nursing Position, Centrality of Nursing, Shifts in Organisational Culture, Market-Oriented Public System, Digitised Care Pathway, Healthcare Construction, Outsourcing of Facilities,* and *High Operational Savings*) cannot be eliminated from the network. These boundary factors mostly impacted design innovations either in the early-20th century or in very recent years. As hospital building design evolved gradually, even seemingly insignificant factors have had impacts on the structural formation of the network, and therefore are indispensable from the network.

6.2.2. The most influential factors in design innovation processes

In the final innovation ecosystem, some of the contextual factors uphold substantial links with other factors, as their introduction to or removal from the network significantly changes the overall structure of the network (factors with larger dots in Figure 6-2). There are strong interrelationships between factors at different parts of the network indicating the interdependency between concepts in providing impetus for design innovations regardless of time and place. Notably, the detachment of the relational composition from chronological conceptions of time and place facilitated the process of analysing multiple factors at the same time. Codes at the centre of these parts play an irreducible role within the innovation ecosystem. Given the importance of link direction in this network, some of the factors trigger design innovations by impacting other factors. For instance, factors such as *Cost Containment* and the political decision on *Decreasing Healthcare Expenditures*, research findings on *Therapeutic Built Environment*, advancements in *Medical Technology*, and *Changes in Medical Practice* significantly disseminate impact over the innovation network. Moreover, some factors facilitate the innovation process by being affected by a wide range of contextual factors. For instance, factors such as policies on *Healthcare Construction (e.g., Standardisation and PFI), Nursing Care* and *Technical Servicing* (from the category of developments in health service), and the development of *De-institutionalised Facility.* Notably, factors such as research on *Design Functionality* and *Energy Conservation and Sustainability,* as well as *Modern* and *Post-Modern Architectural Styles* play key roles in triggering design innovations by both impacting and being impacted by other factors. In a nutshell, the categories of *Developments in Health Service, Economic Shifts, Research Developments, Architectural Movements,* and *Healthcare Policy* contain the most pivotal contextual factors.

The importance of some of these contextual factors has been highlighted by hospital historians. Wagenaar et al. (2018, p. 11) considered a hospital as "a pattern of organized relationships" and explained the direct interaction between the organisational and architectural design of hospital buildings. The authors discussed the critical effects of a range of factors on sound business models, namely "the distribution of healthcare facilities in the region, variability in demand, the emergence of breakthrough technologies, drugs and devices, the appearance of new diseases, and improvements in care delivery processes". Prasad (2008, p. 109) noted the key role of five themes in generating innovative buildings that meet the needs of all users, namely "innovations in medical practices, the relationship with the city, therapeutic role of environment, and the rapid developments in technology, including IT". Kakkar (2021) argued that the planning and design of hospital buildings are widely influenced by three transformations: "changes in technology (including new diagnostics and health data), changes in the model of care (with more focus on multi-disciplinary and coordinated working), and finally changes in the service user (with the profile of a regular patient increasingly older, frailer and with more complex needs)". Guenther and Vittori (2013, p. 401) highlighted the impacts of four pivotal concepts in designing regenerative and restorative healthcare facilities, namely "prevention and health promotion, community connectivity, transparency, and resilience". Furthermore, Verderber (2010, p. 7) proposed the connection between three trends for a viable hospital building design: "human and ecological sustainability, functional deconstruction, and evidence-based research and design". Importantly, these references mainly discussed the most influential factors based on current issues in the healthcare industry. It is noteworthy, but unsurprising, that the literature focusing on specific periods of time also noted the relation between specific influential factors related to that specific time and place. For example, Willis, Goad and Logan (2018) highlighted the importance of modern architectural style, medical necessities in treatment, medical technology (diagnostic and treatment machines), and nursing practice on hospital design innovations of the 1920s-1950s.

Given the specific features of networks, the aforementioned concepts were determined as the most influential contextual factors regardless of temporal/physical understandings of spatiality. The following section looks at the most influential factors in each decade responsible for triggering radical and disruptive innovations. While both incremental and radical design innovations were examined in the generation of the theoretical models, factors having profound impacts on the evolution of hospital buildings are highlighted in this part. It is noteworthy that while some factors emerged at certain points, their significant impact on the innovation ecosystem only became evident a few decades later.

6.2.2.1. The most influential factors at each time bracket

The final theoretical models (network and arc diagrams) can be used to explain the history of hospital building design from a holistic point of view. While writing the chronological history of hospital buildings is beyond the scope of this thesis, a brief chronological explanation of hospital design evolution is provided to understand how the interplay between certain factors resulted in radical design innovation over the past 100 years.

The most influential factors in the 1910s-20s: *Changes in Medical Practice*, developments in *Technical Servicing Rationales*, and *Nursing Practice*.

The Flexner report of 1910 transformed the nature and process of medical education in the United States and globally, through the establishment of the biomedical model impacting the relationship between medical schools and hospitals (Carroll 2016a). This shift led to a unified medical school–hospital model functioning as a single institute that saw the study of medicine, and by extension the human body, primarily as an indivisible whole. In this typology, medical school and hospital became a fully coordinated facility, with a series of axial corridors aligning the laboratories directly with the wards (e.g., Vanderbilt University Medical Center (the USA, 1923)). Here, architectural design was impacted by the educational mission of medical schools and the scientific changes in medicine prompted that helped to define modern medicine.

Changes in hospital practices and medical technology resulted in striking differences in spatial requirements and ward design that came with a high price tag. Thus, designers looked for innovative solutions for the efficient provision of medical treatment. Recovery rooms to operating theatres and a central sterilising room were introduced because of the growing practice of early ambulation and the need to reduce personnel loads (e.g., Larkfield Hospital in Greenock (the UK, 1929), Musgrave Park Hospital in Belfast (the UK, 1920)). Research findings resulted in comprehensive circulation diagrams to decrease travel distances and manage traffic for aseptic reasons. To reduce the chances of cross-infection, Rigs wards were designed, in which partitions avoided contamination and nurses could take charge of groups of four beds. Further, the all-single-bed-room hospital was designed for the first time for medical efficiency (improved medical treatment, more efficient nursing service, and reduced cross-infections) (e.g., Presbyterian Hospital (the USA, 1925), and Beth Israel Hospital (the USA, 1929)). These design innovations aimed to create a place of medical production out of which health would flow and mostly affected the unit/ward design of hospitals.

1930s-40s: *Changes in Medical Practice*, *Modern Architectural Style*, changes in hospital identity as *Institutions of Knowledge,* developments in *Nursing Practice*, and technological advances in *Construction Systems*.

Following changes in medicine, a factory-oriented model of care was practised in many hospitals. In this new location for cutting-edge medicine, doctors asserted medical control of hospitals and nursing resources were deployed by managers to utilise their skills and specialties in narrower ways. Here, the increased need for efficiency favoured more compact hospital plans and pushed hospital facilities higher. The innovative high-rise hospital with a nearly square plan facilitated centralised services, shortened travel distances, simplified the addition of labour-saving technologies, and offered greater access to light in expensive and crowded urban sites (e.g., Cornell

Medical Centre in New York (the USA, 1933), Marine Hospital (the USA,1933), Hospital Beaujon (France, 1935), Prince Henry's Hospital (Australia, 1935), Westminster Hospital in London (the UK, 1936), Southern Hospital (Sweden, 1944)). Designers consciously planned vertical travel routes for the most efficient care service and increased exposure to light (e.g., in Allegheny General Hospital (the USA, 1931), where all elevators are grouped into one central area but with four lobbies to accommodate different kinds of circulation). The hospital typology of "matchbox on a muffin" was widely employed. Here, a few modernist architects such as Alvar Alto designed south-facing wards with long ribbon balconies and external sunshades to increase connection of the bed to the outside for the use of sunlight as a tuberculosis treatment (e.g., Paimio Sanatorium (Finland, 1932), Cincinnati General Hospital (the USA, 1937), and Meadowbrook Hospital in Long Island (the USA, 1935)).

Innovative structural systems reflected the ambition and economic power of the western developed economies (especially, the US). In the 1940s, hospitals were perceived as a kind of medical equipment: a powerful arrangement of technical services, subspecialties and diagnostic machinery. The Modernist preoccupation with functional zoning and efficient circulation also supported the idea of a hospital as a hygiene facility. Individual room unit air conditioner proved an extremely attractive solution to reduce the rate of cross-infection. In the mid-1940s, the emergence of shadow-free lighting systems for operating theatres and the widespread take-up of antibiotics significantly changed the link between building and the environment it provided for medical practice. The abandonment of aseptic interiors resulted in a balance between aseptic finishes and features, domestic comforts, and modern functional aesthetics (Little Traverse Hospital (the USA, 1939), Saint-Lo Hospital (France, 1948)). In sum, the modern architectural style, with its focus on functionality, made the interplay between medical technologies and new nursing practices possible.

In the USA, the Hospital Survey and Construction Act (Hill-Burton Act) of 1946 aimed to promote public physical and mental health by funding the construction of hospitals mostly in rural and regional areas. The framework for hospital construction led to the development of different guidelines for more efficient and fast design processes. Similarly, in the UK, European countries and Australia, the notion of the public hospital (where an attempt is made to provide on a limited budget a decent standard of hospitalisation for all) emerged. The establishment of the National Health Service (NHS) in 1948 changed how people could obtain and pay for care.

1950s-60s: Developments in *Medical Technology*, research advancements on *Design Functionality, Modern Architectural Style*, and *Policy on Healthcare Construction,* changes in hospital identity as *Institutions of Knowledge,* and developments in *Nursing Practice.*

Significant changes in medical practice and technology resulting in a more machine-based medicine required design innovations to meet the new rigorous functional and economic challenges of an automated hospital. Architecture decoupled from therapy and helio-therapeutical ideals were overshadowed by drug therapy and technologically enabled diagnostic regimes. Following advancements in air conditioning and deep-span frame structures in the 1950s, efficiency replaced light and air as a foundational requirement for hospital design, and this complex schema was designed in very deep "muffins" (one to five floors assigned only to technical services, ancillary, diagnostic and outpatient facilities) in striking resemblance to office skyscrapers. Increased governmental funding for hospital construction (for district general hospitals) engendered a new research-based mentality in design. Research aimed to understand how physical circumstances were helping or hindering the provision of healthcare services (functional rationales behind the design). Specific hospital departments were designed based on workflow, working practices and function. As a result, some standards and guidelines were developed, such as the *Hospital Building Notes*, USPHS plans, and later the CAPRICODE. The impact of these factors was seen in hospitals constructed in the next pair of decades.

Gradually, hospitals became completely sealed to enable a controlled indoor environment, resulting in architects focusing on the aesthetic effect of windows in their designs. The efficient accommodation of processes, rather than creating places, was the main concern of designers. Having been influenced by functionalist and rationalist modern architecture, hospital designers used different footprints (X, Y, Z, H, and T types) to plan different functional zones. Here, different ward design typologies impacted and were significantly impacted by nursing practice and medical technology. The double-loaded corridor mandated by the Hill-Burton guidelines was developed as the race-track ward design with a core containing several support amenities (e.g., St. Joseph's Hospital in Burbank (the USA, 1962)). Due to the migration of many nursing staff from the UK, a compact hospital with the first multi-level street was designed (e.g., Greenwich District Hospital (the UK, 1967)). To increase efficiency via direct visual contact with patients from the nurses' station, the radial plan (Lorain Community Hospital (the USA, 1965)), and three linked polygons with nurses' stations at the centre point of each were developed (e.g., Sandringham and District Hospital (Australia, 1957)). Last, to decrease walking distance and increase the efficiency of nursing staff, the Yale index research developed triangulation ward design. This was a highly efficient, effective configuration from the standpoint of nursing staff, as well as offering economical sizing of service core areas and low construction cost in comparison with radial plans (e.g., Lane Pavilion (the USA, 1964), Central Kansas Medical Center (Kansas, 1964), and St. Mark's Hospital (Utah, 1971)).

By the late 1960s, machine-driven medical centres and their surrounding services constituted small cities in themselves. Although health outcomes improved, patients' blind faith in the power of the hospital to cure their ailments began to diminish. The definition of health and disease changed, and new research on the therapeutic and healing impacts of the built environment heightened expectations. Through the emergence of counter-cultural criticism, the authoritarian approach to medicine characterising the high-rise hospital was accused of ignoring the identity of inhabitants. There was a strong demand for a more patient-focused organisation and structuralism in architecture. The failures of modern minimalism led to new additions to existing buildings without destroying their core legibility and scale, such as multicoloured bands on floors and bold supergraphics for wayfinding. However, these incremental design innovations could not meet all aspects of occupants' needs. This significant transformation in cultural and social demands led to the reappearance of the low-rise type that enabled access to the outdoor environment (e.g., Slough District General Hospital (the UK, 1965), American Oncologic Hospital (the USA, 1968), where rooms were provided for family members to stay overnight, and open, wooded sites were considered a therapeutic adjunct to the care provided within.

1970s-80s: The impacts of *Economic Recession* and *Cost Containment*, political decisions on *Decreasing Healthcare Expenditures*, the introduction of healthcare policies (such as *Nucleus Hospital Program* and *Standardisation*), *Post-Modern Architectural Style, Out-Patient Care,* and the development of the *De-institutionalised Facility*.

The funds assigned to post-war programs led to the construction of several new hospitals. The size, layout configuration, form and appearance of hospitals were significantly impacted by the limits of these allocated funds. In the late-1960s in the UK, standardisation was seen as the only means of achieving economy in the construction of adequate healthcare facilities without being extravagant. The Department of Health and Social Security (DHSS) aimed to obtain a synthesis of the best current ideas in hospital policies, planning, building technology, and environmental services design with the principles of modernist functionalism. However, after the oil crisis of the 1970s, overlarge and daunting hospital buildings with unsustainably high operating costs were rejected for future models (e.g., Northwick Park (the UK, 1969) and Greenwich (the UK, 1966)). Financing the hospital building programme was becoming out of control and there was an overriding need to reduce capital expenditure within the NHS. Research informed the reduction of hospital energy consumption with the use of innovative technologies and construction of only the nucleus of new hospitals with extension plans (in reality, the first nucleus hospital was not built until 1983).

Cost containment, failure of functionalist architecture, market competition, and third-party payer policy dictated that the accepted formula for success was changing. Criticism grew of the "servo-system", an innovative strategy to meet future functional needs that was used in low-rise mega hospitals (which had a machine aesthetic) (e.g., McMaster University Health Science Centre (Canada, 1972). Hospital designers were looking for innovative ideas to create friendlier and less machine-like architecture to provide patient-centred care with a positive impact on the bottom line. The post-modern architectural style, together with the concept of critical regionalism, promoted significant cultural meaning and authenticity in hospital design via ideas of urban integration. In the mid-1980s, managed care organisations and the "diagnosis-related groups" system provided incentives for a hospital to minimise the length of hospital stays, and to avoid unnecessary services. Medical centres met these challenges either by relocating certain services off-site to their newly built, less costly outpatient centres or by relocating and consolidating them in a single on-site centre for ambulatory care with revenue-producing services. The developed economic model of de-institutionaliation and reduced duplication supported a more patient-focused system with less cost (Lathrop 1993). These revolutions were supported by advancements in diagnosis machines transforming the notion of health promotion and preventative care.

Regarding design innovations at unit and space levels, in the late-1960s optimisation of staff and patient flow diagrams emphasised the team organisation model of care, where patients were divided into small groups of 9–13. This resulted in the single most significant innovation of the 1970s, called the cluster-bed concept for nursing units (e.g., Somerville Hospital (the USA, 1974-77)). This innovative ward design was widely used in the 1980s when hospitals large and small sought new ways to reconfigure their nursing units to avoid shutting them down outright. Moreover, the design of transformational rooms changed attitudes toward the traditional patient room. Transformational rooms were used to combine elements of residentialism with the tectonics of the hospital environment (e.g., transformational labour, delivery, and recovery room in the 1980s). In the same vein, a new design movement exploring the impacts of the built environment on the health and experience of occupants was introduced in the 1980s in the US. This evidence-based design aimed to enhance medical outcomes by learning and examining different aspects of spatial design (Ulrich 1984).

It is worth mentioning that by the 1970s, the term "patient-centred medicine" introduced to contrast with "illness-oriented medicine" led to the development of a new holistic patient-centred approach to medical care (Balint 1969). Patient-Centred Care was described as "treating the patient as a unique individual" (Redman 2004, p. 11). This model of care was about considering the patient's point of view and circumstances in the decision-making process (McWhinney 1985; Ponte et al. 2003). Patient-centredness also involved a new style of doctor–patient relationships characterised by responsiveness to patient needs and preferences (Levenstein et al. 1986; Stewart et al. 1995). While by the early 1980s the patient-centred care movement advanced further, its impact on hospital building design was not recognisable before the 1990s (Gusmano, Maschke & Solomon 2019).

1990s-2000s: *Cost Containment,* research developments on *Therapeutic Built Environment*, *Post-Modern and Sustainable Architectural Styles, Medical Technology, Policy on Healthcare Construction*, *De-institutionalised Facility, Patient-Focused System,* and *shifts in Business Model*.

Health services needed to respond to changing needs like an ageing population, along with upward pressure on health expenditure as expensive new medical techniques and equipment raised costs and increased demand. In the late-1980s, critics argued that the growth in the NHS budget was not enough to match growing demand and planned improvements in services. The NHS and Community Act of 1990 created a split between purchaser and provider bodies resulting in an internal market in healthcare and self-governing hospitals. PFI was seen to create financial incentives too, and competition between the new hospital trusts, resulting in hospital designs for better efficiency and improved performance (e.g., Norfolk and Norwich University Hospital (the UK, 2001), Hexham General Hospital (the UK, 2008)). However, it is widely argued that despite many potentially innovative designs aiming to enhanced healing process, many schemes failed to proceed because of initial capital costs.

Changes in medical practice and new care pathways climbed the rate of ambulatory care and the number of outpatients. Reduced length of stay was believed to increase efficiency when outpatients had become a prime source for hospital service and reimbursement. Along with the inexorable forces of cost containment and heightened expectations, the notion of pluralism emerged from post-modern philosophy, leading to the functional deconstruction of hospitals and the redefinition of outpatient health centres. Ambulatory care facilities were built and maintained for less expense than hospitals, and offered yet more flexibility, accessibility, sense of normality over institutionalism, and placemaking potential especially for preventive health procedures (e.g., St Olave's University Hospital (Norway, 2006), Dartmouth Hitchcock Medical Centre (the USA, 1992), and Mount Sinai Medical Centre (the USA, 1992)).

Given steadily rising costs and employee and customer dissatisfaction, hospital business models shifted from technical aspects to an emphasis on relationships to develop an innovative non-academic hospital shaped around patients (e.g., Isala Clinics at Zwolle (the Netherlands, 1998)). Hospitals became more patient-focused via a "product-line management approach" that worked with efficiency and cost-reduction measures (Braithwaite 1995). Different organisational models for distinct departments based on their properties and needs resulted in building design innovation. The ideals of patient-focused care (gaining ground in the 1980s) led to the emergence of the Planetree concept, aiming to focus on patients rather than on medical processes for improved service performance and reduced hospital operating costs (Lathrop 1993). This economic model of decentralisation offered patients and staff a non-institutional, informal environment, whereby patients had direct access to medical staff, customised information, and facilities (e.g., Pacific Presbyterian Medical Centre (the USA, 1985), Juliana Children's Hospital (the Netherlands, 2015), and Whipps Cross Hospital (the UK, 1997)). By the 1990s, computerised systems, which empowered patient choice (even offering environmental control in patient bedrooms) and informed some medical decisions, began to support the patient-focused system. More mobile medical equipment and devices, as well as hotel-quality furniture, changed the role of patient bedrooms technically and spatially (e.g., Randall Children's Hospital, 2010). A few central nursing stations with decentralised bedside and individual monitoring stations impacted nursing practice and led to environments that were more human-centred, making more efficient use of the time of staff who now enjoyed working (Southwest Washington Medical Centre (the USA, 2007)).

Considering the advances in medical and information technology, the application of patient-focused organisational mode, and increased competition between facilities, the patient-centred care developed in the late 1970s started to impact the hospital design significantly. A patient-centred care setting aimed to increase the empowerment of the patient by making the patient more informed, and providing reassurance, support, comfort, acceptance, legitimacy and confidence (Fulford, Ersser & Hope 1995; Pelzang 2010). For delivery suits, for example, it called for the room/suite to be homelike or residentialist one moment and hospitalist the next (e.g., Center for Women's Birth at Cottonwood Hospital (Utah, 1986)). By the mid-1990s, "person-nature transactions" had become a sub-movement within the larger umbrella of patient-centred design, with research on this topic including reassessment of the therapeutic benefits of gardens in true, whole life costing and sustainability. Several special certificates and international policies and guidelines have as a result been created for hospitals that incorporate evidence-based principles. Through the first decade of the 21st century, a proliferation of tools, best-practice procedures, and policy frameworks emerged to support the evolution of sustainable planning, development, design, and construction. Further, some devastating natural disasters, global attention to natural resource depletion, and subsequent shifts to sustainable architecture, and political decisions on redeveloping outdated facilities, resulted in innovation in hospital building design (e.g., Martini Hospital, Groningen (the Netherlands, 2004), Dell Children's Medical Centre of Central Texas (the USA, 2007), and Circle Bath hospital (the UK, 2009)); (e.g., Charity Hospital, RMJM Hillier (the USA, 2008), Milstein Family Heart Centre-Presbyterian Hospital (the USA, 2010), Kiowa County Memorial Hospital Greensburg (the USA, 2010)).

2010s-20s: *Sustainable Architecture Style,* changes in hospital identity to *Caring Network, Shifts in Business Models,* advancements in *Information Technology,* Research on *Energy Conservation and Sustainability, Care Pathway,* and inexorable *Cost Containment*.

With advancements in medical science and technology (e.g., the increasing use of local anaesthesia), the design of new parts of hospitals (such as the operating room and laboratory department as strategically important treatment facilities) is becoming an important factor impacting patients' experience. Unit configurations have been rethought in terms of their logistical (to facilitate mechanised distribution systems and translational cooperation between clinicians), economic, social (to invite patients to take responsibility and support family care) and hygiene aspects (e.g., Erasmus MC Hospital and Education Centre (The Netherlands, 2017)). Moreover, increasing research on both the therapeutic impacts of the built environment on the healing process and building energy performance has informed design innovations (e.g., New Karolinska Solna University Hospital (Sweden, 2017)). Carbon neutrality, zero waste, energy independence and net-zero energy aims inspired pragmatic and transformational policies and programs in hospitals that emerged as the aspirational benchmarks of 21st century green buildings (e.g., St. Mary's Hospital Sechelt Expansion Sechelt, British Columbia (Canada, 2012)). Being attentive to sustainability, wellness, resource consumption and environmental stewardship has resulted in hospital design innovations (living hospitals) that have claimed impact on individuals, society, and the planet. The adverse impacts of natural disasters and the inability of hospital buildings to respond to these needs inspired decentralised innovative designs that are resilient to many natural disasters and other infrastructure challenges.

Today, if saving money is a big concern, then an increasingly relevant area where architects can now contribute is the design of sustainable buildings for healthcare. The complement of sustainability standards provides a clear indication of a marketplace increasingly defined by rigorous performance bars that recognise a carbon-challenged era. Healthcare organisations are devising creative ways to find incremental capital to invest in strategies that deliver long-term high operational savings. In the European Union, for example, innovative energy systems with a fifteen-year payback are implemented. Acute-care hospitals in the United States, generally designed for fifty-year-plus life spans, are primarily owner-occupied; hence, hospital owners should be receptive to longer payback periods on design elements that reduce energy consumption (e.g., Gundersen LaCrosse Hospital (the USA, 2015), Swedish Medical Centre (the USA, 2011)). Bioregional and climatic design solutions are emerging as important indicators of the future of healthcare typologies (e.g., Thunder Bay Regional Health Sciences Centre (Canada, 2004), and Seattle Children's Bellevue Clinic (the USA, 2010).

Good cooperation between architectural considerations and organisational management is essential to ensure successful long-term results (e.g., energy reduction plans). Indeed, while good architecture is both essential for and conducive to a sound business model and improved operational performance, the contribution of architecture to better health service is subject to a sound business model. Today, different business models, as well as process and workflow designs, are assigned to different departments of a hospital, resulting in distinct building types for the hospital complex (such as hotel, laboratory, airport lounge, business centre, shopping centre, etc.). Here, only the core hospital with specific functional requirements and standards must be tailor-made. There is no doubt that global business has entered an era in which it must both meet and go beyond the demands of current processes and logistics to create generic, adaptable and versatile design solutions. Further, the way digital technology, particularly the Internet, facilitates communication between patients and medical practitioners decreases the gap between the two groups; creating expert patients and providing care out of hospital settings that is more patient-focused and efficient. The Internet, with significant amounts of medical record data, helps the analysis of patient flows and practice care pathways to improve the quality of the care delivered in specialised centres of excellence. Vast accessibility to this data also enables hospitals to function as networks of distributed facilities, where the hospital is part of the city and the city part of the hospital. Reintegrating HCFs into urban settings is of utmost importance, as it might facilitate the process of breaking down physical, mental and functional obstacles between the medical machine and its users to further accommodate services providing disease prevention and community care.

Having examined the interplay between the most significant factors at each time bracket, it is evident, as would be expected, that the number of influential factors and the interactions between them triggering innovation in hospital building design has significantly increased over time, from

46 links in 1910-20s to 195 in 1990s-2000s to 136 in 2010s-20s. Most interactions resulting in design innovations took place between the 1970s and 2000s, showing the increasingly growing number of influential factors in hospital design and reflecting the significant role of emerged contextual factors. Although it is important to study the emergence of new concepts and their influence on the innovation processes, some factors (repeated in the explanations of different time brackets) have had constant impacts over history. The following section explores those incidents.

6.2.2.2. The constant themes repeating at different decades

While all 14 categories played a significant role in innovation generation, some of them impacted this process more significantly at different points in time. Figure 6-3 demonstrates the cumulative numbers of links between categories. The main interactions occurred and began from factors classified as 1) *Technological Developments* to *Developments in Health Service* and *Advances in Medical Science;* 2) *Advances in Medical Science* to *Developments in Health Service and Transition in Institutional Identity*; 3) *Political Shifts* to *Healthcare Policy* and *Economic Shifts* to both; 4) *Research Developments* to *Architectural Movements*; and 5) *Architectural Movements* to *Transition in Institutional Identity*. Certain contextual factors in these categories have also had constant influence in consecutive decades.

- *Changes in Medical Practice*, developments in *Medical Technology* and *Construction Systems,* and changes in health service such as *Nursing Practice* have been considerably interconnected with other factors since the 1920s. Other influential contextual factors have been added to this list through time, without undermining the role of these constant categories in the ecosystem.
- *Cost Containment* considerations and demand for the most efficient designs have always triggered design innovations. However, the economic recession of the 1970s resulted in several political decisions and policies on healthcare construction resulting in design innovations. It is noteworthy that despite the long-term preventative impacts of cost containments on design innovations between the 1970s and 1990s, this factor created substantial values in different aspects of hospital building design by affecting other contextual factors.
- The functionalist *Modern Architectural Style* was a constant factor triggering design innovations in the 1920s-60s (especially tower, and podium & slab typologies), and the *Post-Modern Architectural Style* in the period of 1960s-90s. Notably, given the incoming and outgoing links to these architectural movements, and in line with Guenther and Vittori (2013), it is evident that hospital building design in the last four decades has evolved independently of broader architectural styles but in relation to many other factors.
- Research on *Design Functionality* has widely impacted design innovations in the period of 1950s-70s; and research on *Therapeutic Built Environment* as well as *Energy Conservation and Sustainability* in the period of 1990s-2020s. These research findings have led to policies on *Healthcare Constructions*.
- Demographic growth and shifts in *Social Characteristics*, and the pervasive impacts of *Automotive Culture*, and *Heightened Expectations,* as well as evolution in health promotion and *Preventative Medicine* and *Urban Redevelopment and Revitalisation,* impacted a considerable number of factors in the periods of 1950s-80s and 1970-2010s respectively.

The interconnections between specific categories evolved over time, resulting in the development of interactions between prior factors. For instance, while the concept of the *De-institutionalised Facility* had been introduced in the late-1960s, more interactions between this code and other factors across different categories resulted in design innovations later in the 1990s. Similarly, while the notion of a *Patient-Focused System* and *Patient-Centred Care* (changes in the role of the patient room and involving patients in the medical decisions) emerged in the 1970s, their critical influence on *Care Pathways* (coordination between the various actors in the diagnostic and treatment processes), and therefore on service and architectural design innovations, occurred in the 1990s. Furthermore, while organisational management impacted hospital building design since the 1940s, certain hospital business models emerging in the 1980s widely triggered design innovation in the early-21st century.

As Singha (2020) highlighted, there are five *constants* recurring globally in developing the vision/concept of hospital building design: attachment (emotional concepts), money (financial), risks (structural), silos (operational), and reorganisation (organisational). I argue that design innovation occurs at the interactions of different contextual factors; when new visions in these constants are addressed. Here, advancements in medical practice, different technological developments (medical, construction and information technology), economic shifts, and research developments have had constant influence on design innovation processes. Disruptive innovations in the most influential contextual factors determined in this study might make hospital design considerably vulnerable. However, as Rechel et al. (2009) and Guenther and Vittori (2013) pointed out, the need for hospitals to be adaptable to those changes is also a key driver of design innovation. Moreover, given the theory of culture lag, Singha (2020, p. 19) argued that changes in “value” are normally incremental, whereas transformations in “material culture” are likely to happen radically and fast. I believe the slow and evolutionary process of change induced by factors in the categories of *Social Transformations, Transition in Institutional Identity,* and *Shifts in Attitude Towards Health* are comparable with those fast and revolutionary interactions caused by *Technological Advances, Architectural Movements, Medical Advances, Economic* and *Political Shifts*. While it might be challenging to predict the direction of radical innovations, it is of utmost importance for hospital designers to consider the force of former sets of factors while embracing technological changes to generate design innovations.

6.2.3. The most interrelated contextual factors in design innovation processes

Using the Louvian algorithm of cluster detection, the concepts and interactions were divided into two main clusters (Figure 6-2). Given the significant difference in the density of clusters, cluster B is considered as the main functional subgroup and the landmark of analysis. This cluster contains connections between a wide range of factors from twelve categories. The analysis indicates factors from different categories are more likely to interconnect one another in the core zone (highlighted in red). While all the factors in the core zone are interrelated to one another and the whole network, the close relationships between two specific sets of factors are noticeable. Here, the sets of highly interrelated factors are:

1) *Research on Design Functionality, Changes in Medical Practice, Medical Technology, Technical Servicing Rationales, Cost Containment, Nursing Practice, Construction Systems, Modern Architectural Style, Centrality of Nursing, Institution of Knowledge, Communication Technology,* and *Policies on Healthcare Construction*; and

2) *Research on Therapeutic Built Environment, Caring Network, Post-Modern Architectural Style, Shifts in Business Models, Patient-Focused System, De-institutionalised Facility, Privacy*

Expectation, Patient Empowerment, and *Nursing Practice, Social Characteristics, Out-Patient Care*.

Turning to cluster A, it mostly reflects the interactions between factors from the categories of *Research Developments, Political Shifts, Healthcare Policy, Economic Shifts,* and *Shifts in Natural Environment* that triggered design innovations after the oil crisis of the 1970s. These interconnections started with the impacts of *Economic Recession*, political decisions on financial priorities - *Decreasing Healthcare Expenditures* - on the introduction of certain healthcare policies - such as *The Best Buy Hospital Policy, Nucleus Hospital Program* and *Standardisation*. Next, indications of *Natural Resource Depletion* and *Climate Change,* as well as the significant increase in the *Cost* of healthcare construction, resulted in political decisions on *Commercialising Medical Landscape* and investment in strategies that support *High Operational Savings.* These factors led to new policies for more *Sustainable Planning, Development & Design* and the introduction of *Building tools & Metrics* that are also impacted by developments in research on *Energy Conservation & Sustainability*, and developments in the mainstream *Sustainable Architectural Style*. The individual and combined impacts of these factors have resulted in several design innovations over the past few decades. In this respect, Kisacky (2021) has recently highlighted the significant impact of 1) advances in prevention practice, antibiotics and the decrease in contagious disease incidence, 2) mechanical ventilation technologies, and 3) federal funding and associated healthcare construction policies and regulations on the innovative designs of isolation rooms. She has argued that the prevalence of the new antibiotic-resistant, contagious diseases (Covid-19) has raised the need to reconsider research priorities, codes and minimum standards – specifically for the design of isolation facilities. She highlighted that this process requires federal funding and time investment, such as that experienced over the second half of the 20th century. This explanation supports the close relationships between factors in this cluster and highlights the importance of *Change in Medical Practice* (*Cure for Pandemic*) and *Medical Technology* (as critical bridging points between clusters A and B) in generating design innovations.

Despite the close interplay between factors at each cluster, approximately one-fifth of the links occurred within clusters A and B. This highlights the significant role of contextual factors in the bridging position that make regions of the network permeable. These factors bring the clusters into union by connecting different innovation processes. In this network, some of the most important bridging factors are *Cost Containment,* research on *Therapeutic Built Environment* and *Sustainability,* and the development of *De-institutionalised Facility*. Moreover, factors in the categories of *Research Developments* and *Medical Technology* colonised different parts of the network. These concepts stretched over the network and interacted with factors residing at both clusters. Notably, the positions of subsets in relation to other contextual factors are quite justifiable; for example, research on *Therapeutic Built Environment* is at the intersection of *Post-Modern Architectural Style, Patient-Centred Care* and *Caring Networks*, and the factor of *Communication Technology* is at the intersection of *De-institutionalised Facility, Involving in Medical Decisions, Nursing Practice* and *Care Pathway*. This study interprets research in the field of the built environment, technological developments, and architectural movements as elastic; impacting and impacted by several factors in the process of design innovation. Moreover, this study posits that there is no correspondence between the typology (indicating the vertical analysis and categorisations) and topology (indicating the horizontal analysis and the particular form) of the design innovation network. It suggests that the generation of the innovation ecosystem is subject to links between factors of various natures.

Regarding the position of factors in creating the most stable state of the innovation ecosystem, the categories of *Technological Developments, Shifts in Organisational Culture,* and *Transition in Institutional Identity* are mainly located at boundaries with other factors positioned in the core zone. This demonstrates both the critical role of these three categories and their constant influence on the structural formation of the process. Notably, small nodes positioned at the boundary, such as *Digitised Care Pathway, Globalisation, Virtual Reality,* and *Pandemic Outbreaks*, might in the future become more interconnected to other factors. It is also noteworthy that concepts classified in one category might be interrelated to different factors from distinct categories in generating design innovations. This distinction generally lies behind the focus of the relationships on different aspects of hospital building design or the certain time and place that relationships occurred. For instance, *Institution of Knowledge* and *Caring Networks* are interconnected to completely different sets of factors mainly because of their distinct inherent nature and the time they were introduced to the ecosystem. Similarly, research on *Energy Conservation & Sustainability* and *Therapeutic Built Environment* are interconnected to dissimilar factors resulting in design innovations, as they influence different aspects of building design.

Overall, this study suggests that radical design innovation processes occur as a result of interactions between various contextual factors targeting different aspects of hospital building design. Despite substantial interconnections between certain sets of factors (determined as clusters here), the significant role of bridging actors cannot be overemphasised. A substantial interdependency is evident between most involved factors in the ecosystem, whereby the introduction or removal of each factor and its connections to other elements influence the emergence of changes in the main system. This proposition supports the complexity of innovation ecosystems and the critical role of diverse exogenous elements in ecosystem function as widely discussed in the literature (Klerkx, Aarts & Leeuwis 2010; Long & Li 2014; Shayan et al. 2018; Valkokari 2015; Xu et al. 2020). Most importantly, my accumulated understanding of the design innovation ecosystem revealed how different sets of contextual factors are strongly interrelated to one another and highlighted the impossibility of assigning distinct meaningful subgroups to the network. In this study, a design innovation ecosystem is argued to comprise different forms of interaction between heterogeneous factors that are not mutually exclusive.

The importance of the interplay between a wide range of contextual factors in the value creation of hospital building design can address several questions raised in the literature relating to: the R-P gap, lack of design innovation, and hospital evolution. For instance, Wagenaar et al. (2018) probed into the reasons behind a 40-year period between the design of a pavilion-type hospital and its implementation into practice in the construction of innovative military hospital buildings. Verderber and Fine (2000) discussed the failure of the building design of the Walter C. MacKenzie Health Sciences Centre (1984, Alberta-Canada) in value creation, despite the exploitation of the latest technologies and research by its designers. Prasad (2008) highlighted the failure and obsolescence of hospital designs despite refinements in planning special arrangements, considerations of the operational costs and new models of care. Similarly, Kisacky (2017, p. 7) questioned the causes since the 1950s of a serious gap between "design intentions and lived realities". These issues can be explained by considering the significant role of different contextual factors in hindering and facilitating design innovations in hospital building design. Here, I complement the model proposed by Verderber (2010, p. 7) that considers the fourth condition at the intersection of "human and ecological sustainability", "formal and aesthetic advances", and "evidence-based research and design" as holding the most promise for the future viability hospitals. Figure 6-5 illustrates such a condition at the centre accommodating all influential factors and forces in triggering design innovations by adopting a multidimensional outlook of the innovation ecosystem in hospital building design.

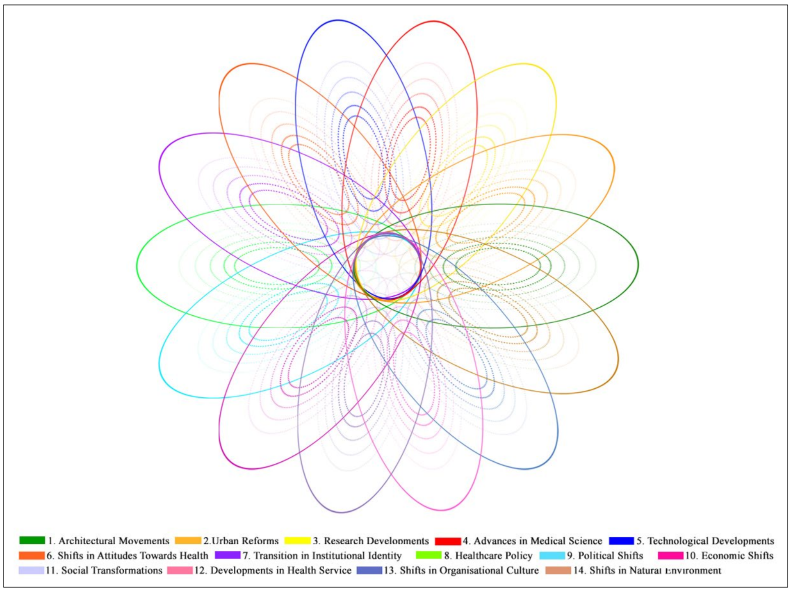


Figure 6-5: A schematic model of the condition accommodating all influential factors and forces

6.2.4. Relationship between design types and the role of hospital designers

Figure 6-3 demonstrates the cumulative number of links between categories, the relationships between them, and architectural, service and organisational design. Here, *Architectural Movements, Social Transformations* and *Transition in Institutional Identity* contain the most interconnected factors, followed by *Developments in Health Service, Healthcare Policy* and *Research Developments* in the field of the built environment. Notably, factors classified in the category of *Architectural Movements* are the most critical actors in the interactions (routes) between other categories, followed by *Social Transformations, Economic Shifts,* and *Research Developments*. However, the slight differences between the total number of links associated with the contextual factors emphasise the meaningful role of interactions between all factors in triggering design innovations. As Wagenaar et al. (2018, p. 41) acknowledged, while we must appreciate the role of partnership with evidence-based design, there are "many other factors in play" in hospital building design.

This study argues that innovation in hospital building design has been triggered by the influence of interactions between 14 pivotal contextual factors. As explained in previous sections, while some of these factors have had more constant or stronger influences on the innovation process, the influence of other factors on those incidents cannot be overemphasised. Kisacky (2017, p. 344) stressed the importance of understanding the history of hospital design as both and more than a "product" of medicine and a "confining structure" on scientific medicine and future possibilities. The present study goes beyond this proposition by adopting an ANT lens. Not only do I confirm the reciprocal relationships between architecture and medical advancements, but also highlight the mutual impacts of 12 more factors on architectural element, care processes and the organisational structure of hospitals, as value creation in a hospital building design gets meaning at the intersection of these aspects. In examining design innovations, I considered both the impacts of *contextual factors* triggering design innovations (reflecting sociopolitical and environmental transformations) and the *role of researchers and designers* in changing the experience of hospital inhabitants and society by creating a caring environment (reflecting designers' control and purpose). This approach also advocates the explanation by Wagenaar et al. (2018, p. 41) of the architect's role in flourishing innovative hospital designs. This knowledge helps architects understand both their systemic impact on the ecosystem (by creating design concepts) and the crucial act of other factors on their decisions.

The relationships between the 14 pivotal contextual factors revealed a close interplay between architectural, service, and organisational design in the process of design innovation. As the degree closeness for these three design-spheres and 14 contextual factors is similar, their position in relation to contextual factors shows a comparable level of importance. However, the analysis showed a considerable difference between the impacts of the 14 factors on the three types of design that resulted in innovations. Here, organisational design experienced the lowest number of connections with the 14 contextual factors. It can be argued that the interplay of organisational culture, hospital business models, structures of medical practice, and the role of patients with other contextual factors in design innovation processes have been less considered in the literature. Wagenaar et al. (2018, p. 52) stressed the increasing number of specialties in hospitals, and the lack of design approaches "conducive to interdisciplinary cooperation". Similarly, Pinzone, Lettieri and Masella (2012) pointed out that there is a lack of research on the interplay between elements of architectural and organisational design in hospitals and highlighted existing misalignments as a significant factor in the failure and obsolescence of several projects. Melo (2018) also noted a paucity of studies considering the interactions between hospital building and organisational processes when examining the design and quality of healthcare services. Further, Halawa et al. (2020) highlighted low levels of collaboration between disciplines as reflecting knowledge gaps on the links between architectural, service and organisational design in the field of healthcare. The authors believed there is a significant need for interdisciplinary and integrated approaches involving various disciplines across science, technology and research. Indeed, dimensions of everyday life are increasingly interrelated and require different key players to work collaboratively with shared vision on multiple fronts (Bernhardt et al. 2021; Bhavnani et al. 2017; Singh & Singh 2017). The interplay between organisational, service and architectural design in hospitals is vital in generating design innovations for better care.

This study complements the literature on hospital design evolution but also provides a unique, holistic insight into all contextual factors triggering design innovation over the past 100 years. The importance is appreciated for hospital historians to focus on limited periods of time and the interactions between specific factors to provide the thorough explanations of incidents. However, it is also critical to consider the individual and combined impacts of all factors more widely on the design innovation ecosystem. This knowledge helps to fully understand the strength of interdependent yet distinct factors, and to explore the potential collaborations between key players in generating innovation processes that ultimately improve design.

6.3. The Framework Based on the Current Issues

The developed framework explains the nature of design innovation in hospital building design based on incidents that occurred over the past 100 years. This framework further delineates the properties of multi-faceted processes triggering design innovations. However, as the inclusion/exclusion of each contextual factor and its interconnection with other factors have been seen to be critical to the network formation, it is predicted that significant changes might happen in the future in different components of the innovation ecosystem. These transformations, though, are inherent in design innovation, meaning the knowledge of the innovation ecosystems will not be changed but adapted based on newly added inhabitants. The current issues and predictions of future developments explained in five critical texts (Gillen et al. 2021; Guenther & Vittori 2013; Singha 2020; Verderber 2010; Wagenaar et al. 2018) were re-examined to explore the potential influential contextual factors in hospital building design. Unsurprisingly, almost all of the factors and key players identified in these five texts have already inhabited the innovation ecosystem. For instance, the impacts of pandemic outbreaks, changes in medical practice and the development of certain cures, technological developments in medicine and building construction, nursing shortage, development of functional standards, etc. on the hospital building design evolution have all been previously identified. However, it would appear that their position and importance will significantly transform, and therefore the actors playing in the core will be changed.

The literature has brought advances in communication technology into sharp focus as triggering significant innovations in hospital building design. Information technology might fundamentally distort current physical relationships and impact several factors such as electronic health recording, patient empowerment (personalisation, wayfinding and security), the role of healthcare professionals, operational efficiencies (resource management), care delivery (telemedicine and virtual care), and digital therapeutics and care pathways (personalised care) etc., and therefore the required spaces for these needs. The digitisation of healthcare has already been experienced to be safer, quicker and more comfortable in certain circumstances and for certain community groups, but it is predicted to become more pervasive through care delivery innovations. Moreover, the emergence of infectious diseases, growing lifestyle-related chronic diseases and complex comorbidities, and ageing population are seen to increase the need for disease prevention and health promotion. The demand for a wellness revolution will promote the re-urbanisation of the hospital and regenerate the concept of hospital as part of the city with medical, educational, and social roles. The substantial impacts of the environmental degradation and issues related to climate change are other factors that will have considerable influence on hospital building design. Research developments on sustainable energy and water systems, reduction in carbon footprint, efficient operational systems, etc. and subsequent policies can trigger significant design innovations by addressing financial and ecological issues without reducing quality of care.

In sum, as Singha (2020, p. 182) stresses, the “only constant” in hospital building design has always been “change”. While hospital buildings are vulnerable to disruptive innovations in the aforementioned factors, they at the same time provide hospital designers with the chance of generating design innovations to increase efficiency, satisfaction, performance, as well as enhance healing processes (to name just a few). It seems advisable that potential threats to the system have always resulted in hospital design innovations. Here, this research contributes to the understanding of potential interactions between contextual factors in this complex adaptive ecosystem before they became a threat to the healthcare system.

The next section discusses how the proposed multi-representational approach aided systematic thinking and developed my reflexibility as a constructivist GT researcher. The approach has been instrumental in interpreting the behaviour of the system in connection with its constituent phenomena, as stressed in the ontology and epistemology principles of the Charmaz (2014) interpretivism/constructivism paradigm.

6.4. Diagramming to Advance the Analytical Process of GT Research

While GT methodology offers a set of well-structured guidelines, it is of utmost importance to be creative in choosing where to look and how to indicate relationships among concepts in the analytical process. The literature on GT methodology has widely considered the use of diagrammatic modelling tools as a creative and effective approach to big data analysis that helps GT researchers interact with data, interpret relationships, make the research process increasingly transparent, and enhance the validity of the final theory/framework (Bryant & Charmaz 2019; Buckley & Waring 2013; Charmaz 2014; Gorra 2019). This study, in line with the suggestion of Johnson and Walsh (2019), developed a novel hybrid research design to *mixed grounded theory*, which expands the possibility of alternative interpretations for big data by using diagrammatic representations and analyses.

Given the wide variety of possible visualisation idioms and different ways of creating and interacting with visual representations (Munzner 2014), I have explained a novel multi-representational approach to understanding the complexity of the innovation ecosystem. Here, a set of systematic interventions were introduced at different stages of the analysis. It is argued that the strongest approach to yield effective results is to augment the use of digital modelling tools with human analysis and interpretation abilities, instead of relying on machines for automated analysis (Barberis Canonico, McNeese & Duncan 2018; Baumer et al. 2017; Lipton 2018). This methodology can be followed both to further explore different dynamics of this complex phenomenon (for long-term use in an explanatory analysis) and, more importantly, to support the growing use of big data in developing theories and insights in other GT studies.

This study suggests that newly established open web tools support cross-sectional analysis by visually representing concepts and relationships in different ways. A diverse array of dissemination possibilities in GT methodology has been proposed, although never examined in full, by GT scientists (Bryant & Charmaz 2019; Buckley & Waring 2013; Friese 2016). As textual analysis might not be adequate to explain hidden links, creating in-motion and unfixed diagrams such as network and arc diagrams can be adopted to enhance the analytical and interpretive process. Indeed, diagrammatic representations and their associated analytical techniques proved to be useful in developing new understanding of both the individual and collective impacts of different factors. The specific properties of network and arc diagrams enhanced the analysis process of this study in the following ways:

- *Network diagrams*
    1. Networks represent codes/concepts as well as vertical and horizontal links related to each code and provide a two-dimensional layout of the overall structure regardless of chronological patterns. Indeed, connections are demonstrated at specific sorts of times/places that are not confined to temporal/physical understandings of spatiality. This feature helped to develop a relational composition that goes beyond the simple identification of the main categories by examining hierarchical relationships between factors with similar properties and the importance of categories in relation to the number of subsets.

2. This diagrammatic representation describes the wider picture by using a force-driven algorithm designed to reach the best balance of constant interactions between forces of attraction and repulsion between nodes. Exploring the overall structure of the ecosystem in detail can help to address certain queries (especially finding patterns) that might not be possible through the summation of factors and links.
3. The qualitatively and quantitatively driven techniques provided by SNA helped analyse and explore the form and structural properties of networks at three levels (micro-, meso-, and macro-level): 1) the most influential factors in the design innovation process were identified; 2) the most interrelated contextual factors were detected, and correspondence between the typology and topology of the innovation network was indicated; and 3) the cohesion and density of the whole network was explored, helping to understand the system behaviour.
4. This process eventually addressed who and what play a role in the design innovation ecosystem, and what were the involved relationships by focusing on the topology and structural properties of networks, as well as the nature of ties. My experience proved the use of two functions of Network diagrams defined by Decuypere (2020, p. 13): an "explorative function" (by which researchers scrutinise how a phenomenon is composed), and a "narrative function" (by which researchers construct particular narratives of the formed networks).

- *Arc diagrams*

1. Arc diagrams represent the interplay between codes/concepts within and across categories by considering chronology as the second variable. Their use demonstrated both the most influential contextual factors at each decade and the critical role of some factors with constant influence on the structural formation of the process. The aim was to explore what happened when focusing on chronology, intentions and explanations through the analysis of Arc diagrams. I suggest the use of this graph for studies aiming to capture trends chronologically.
2. Researchers might use this diagram to display the interplay between parents with higher levels of generalisation rather than focusing on individual nodes. In this study, I used this specific feature to reduce the inevitable clutter generated in the networks and examine the interplay between more abstract concepts.
3. An interactivity changing display provided by most web-based tools facilitates the analysis of big datasets. The GT researcher can interact with the visualisation idiom to change the view to explore different aspects and levels of the dataset (from very detailed information to the structural overview of relationships). In the arc diagrams, for example, putting the cursor on each concept highlighted all the links related to that node (refer to: https://observablehq.com/@researcherhbd/arc-diagram).

In sum, and in line with Decuypere (2020), I argue that adopting diagrammatic modelling tools to visualise and analyse data helps researchers both explore hidden relationships and interpret the nature of ties through the development of narratives. However, as Venturini, Jacomy and Pereira (2015) highlighted, this understanding is impossible without the intense engagement of the interpretivist researcher with the data and settings, meanings and values of the phenomenon being studied. Although it might be tempting for a GT researcher to summarise the network behaviour in a few numerical values (using SNA), this evaluation must be followed by the qualitative analysis of relationships.

While there has recently been a slight growth in studies investigating digital agency and automation for GT analysis (Nelson 2020), in this approach the researcher has greater agency in the development of concepts, inclusion/exclusion of codes, the hierarchical positioning of codes within categories, and making horizontal connections between codes across categories. Moreover, unlike the existing literature employing quantitatively driven techniques of SNA to detect categories and functional concepts, the network diagram can be used to represent the interrelationships and categories already developed through the initial and focused coding process, and to compute the structural properties of the final network to explain and interpret hidden patterns. In this, as Gorra (2019); Paulus et al. (2017) argued, it is critical to consider the significant position of research methodology over software functionality, even in the analysis of big data. The aim should be to address complex phenomena and leverage big data analysis through the development of a human-centred approach that bridges the limitations of computer capacities, human perceptual and cognitive capabilities, and display capacities by keeping both human and computational decision-making methods in the analysis loop (Barberis Canonico, McNeese & Duncan 2018; Munzner 2014).

6.5. Evaluating the Quality of Findings

In a highly cited paper, March and Smith (1995) determined four types of products for design science: constructs, models, methods, and instantiations. They recommended that researchers must properly conceptualise real problems, construct appropriate techniques for responses and develop appropriate criteria to assess and implement their solutions scientifically. The present study proposes: a *taxonomy* of the influential components/constructs in design innovations, two *theoretical models* depicting the contextual factors and interactions between them that trigger design innovations, and an *explanatory framework* explaining the nature of innovation in hospital building design. Notably, evaluation and justification of non-mathematically represented artifacts (outputs) usually follows methodologies to develop metrics and evaluate the performance of constructs, models, methods, and instantiations for particular goals.

Evaluation of *constructs* entails the "completeness, simplicity, elegance, understandability, and ease of use"; *models* are assessed in accordance with "their fidelity with real-world phenomena, completeness, level of detail, robustness, and internal consistency"; and the appraisal of *instantiations* includes "the efficiency and effectiveness of the artifact and its impacts on the environment and its users" (March & Smith 1995, p. 261). Because frameworks and theories imply explaining why and how the constructs, models, methods and instantiations work, its knowledge contribution should be judged based on the *novelty* of the artefact, the *persuasiveness* of the claims, as well as the *significant improvements* it makes (Johnson & Christensen 2017; Kivunja 2018; Wacker 1998). Thus, in this study, after developing the final explanatory framework using the MGT methodology, it is of paramount significance to explore the issue of "quality" in the process.

The framework that emerged from a GT methodology does not need a validity test since it has resulted from a constant comparison of concepts and interrelationships collected from empirical data. Ideally, after the completion of the study, the emerged framework is "comprehensive, defensible, rich in its explanatory power, insightful, useful, and broad in scope" (Morse & Clark 2019, p. 165). GT scientists have defined a number of criteria to assess the quality of both the GT method and final product (Charmaz 2014; Corbin & Strauss 2014; Glaser 1978). Here, Glaser (1978) proposed four principles for evaluating the theory-building process in the GT: *fit, generality, relevance, and modifiability*.

However, Charmaz (2014, p. 337) argued that these factors are only useful for "thinking about how the constructed theory renders the data". She strongly emphasised the untapped versatility and potential of a GT study and suggested examining GT studies with the criteria of *credibility, originality, resonance,* and *usefulness*. Charmaz believed that while the lines between the process and results might become blurred for the readers, these criteria "address the implicit actions and meanings" in the studied phenomenon and help them analyse "how it is constructed" and assess the usefulness of used methods by "the quality of the final product". The detailed questions examining these criteria are listed in Table 6-1.

Table 6-1: Main criteria to assessing a GT study adopting Charmaz (2014) approach

Credibility
• Has your research achieved intimate familiarity with the setting or topic? • Are the data sufficient to merit your claims? Consider the range, number, and depth of observations contained in the data? • Have you made systematic comparisons between observations and between categories? • Do the categories cover a wide range of empirical observations? • Are there strong logical links between the gathered data and your argument and analysis? • Has your research provided enough evidence for your claims to allow the reader to form an independent assessment – and agree with your claims?
Originality
• Are your categories fresh? Do they offer new insights? • Does your analysis provide a new conceptual rendering of the data? • What is the social and theoretical significance of this work?
Resonance
• Do the categories portray the fullness of the studied experience? • Have you revealed both liminal and unstable taken for granted meanings? • Have you drawn links between larger collectives or institutions and individual lives, when the data so indicate? • Does your GT make sense to your participants or people who share their circumstances? Does your analysis offer them deeper insights about their lives and morals?
Usefulness
• Does your analysis offer interpretations that people can use in their everyday world? • Do your analytic categories suggested any generic processes? • If so, have you explained these generic processes for tacit implications? • Can the analysis spark further research and other substantive areas? • How does your work contribute to knowledge? How does it contribute to making a better world?

According to Charmaz (2014), a successful combination of originality and credibility has a direct relation with resonance and usefulness that increases the value of the knowledge contribution of the study. The descriptions of how these four criteria have been achieved in this study are provided to elucidate the high quality of the final innovation framework. Here, the abovementioned questions assisted me to examine different aspects of the analysis process and findings.

Credibility/trustworthiness has been achieved through adherence to the prime steps of Chamarzian's GT methodology. The methodological steps that have widely been translated to a computer-assisted way were employed to efficiently facilitate the initial and focused coding using NVivo (Friese 2019; Gorra 2019). Two complimentary analysis techniques and methods were also merged into the conventional focused coding to address the complexity of the phenomenon under study. Here, two types of diagrams (network and arc diagrams) were selected in accordance with the research objectives. Then, their analytical frameworks, defined by their key characteristics and attributes, were adopted to enhance the analytical and interpretive process. The aim was to develop my "own way" of adopting the most appropriate analytical tools and techniques in the analysis process to best meet the research objectives (Gorra 2019, p. 316).

While codes were being assigned to data, they were being grouped into categories to form hierarchies of concepts, and were becoming interconnected within and across categories using the constant comparative method. All of this information was also recorded in the network and arc diagrams for each dataset. Using diagramming tools gave rigour to the research process as it helped to systematically re-engage with data, creatively probe the data and move away from descriptive summation to conceptual explanations of the phenomenon (Buckley & Waring 2013, p. 152; Lempert 2011). Most importantly, employing quantitatively driven techniques of network analysis significantly decreased the level of bias involved in a typical GT study. Notably, memos were also used from the early and evolving stages of analysis to trace the development of ideas and to provide several detailed descriptions supporting the final narrative interpretation.

Using multiple data sources (11 references focusing on the history of hospital design evolution from different perspectives) provided triangulation, constant comparison between new data and the body of analysis, and thus supported credibility (Corbin & Strauss 2014; Oktay 2012; Wingo 2015). The use of memoing and comparative analysis had dual purpose of "being part of data analysis and also in countering subjectivity", as this assisted to check if the memos fitted into the emerging framework (Lazenbatt & Elliott 2005, p. 52). Last, I spent a "prolonged time in the field" and developed an understanding of the phenomenon, which decreased the *bias* I might bring into the study and ultimately enhanced the likelihood of producing accurate research findings (Watt 2007, p. 92).

The second aspect, *originality*, refers to the fresh insights and new conceptual rendering of existing data. This study took a completely novel approach in depicting the complex picture of innovation in hospital building design. It is posited that the explanatory innovation framework constructed in this study has an original knowledge contribution to the field of hospital building design. Furthermore, the novel combination of visual analysis techniques/tools and methods at different analytical stages of this study indicates the study's original model of MGT methodology. This methodology provides GT researchers with a novel approach to addressing specific research objectives.

Third, the *resonance* of this research is indicated in the fullness of the study in accordance with the in-depth investigation of the key triggers and the interrelationships between influential factors over the last 100 years. The innovation framework fits well into the substantive data on innovations in hospital building design. That is, it has the ability of "theoretical transference" by being applicable beyond the context and situation in which it was first identified (Morse & Clark 2019, p. 265). The fourth criterion for evaluating GT studies is the *usefulness* of the findings. This study provides an explicit understanding of the nature of design innovation by exploring and examining the contextual factors triggering innovations in hospital building design. This framework can help policymakers, healthcare developers, hospital designers, practitioners, managers and decision-makers understand and analyse the strength of all influential components when formulating future innovations or intending to promote an existing one.

Last, it is important to highlight that in the present study two different analysis methods were merged to the process of focused coding and a novel MGT methodology was developed. Here, to further assess the validity of the employed diagramming tools and analysis techniques, the process of change in the results acquired by the analysis of each data source was examined. By comparing the knowledge built by analysing each data source with the prime thesis provided by the authors of that reference, the validity of techniques employed in the analysis was double-checked. This checking also explained how the knowledge was built and complemented by analysing different data sources focusing on the evolution of hospital building design from different perspectives until the saturation point was reached (see section 6.1).

In sum, it seems advisable that the results of the analysis of each relational composition are in line with the key thesis of the data source argued by the authors. Notably, the authors of each data source explained the evolutionary process of hospital building design using a narrative interpretation. Yet, finding the codes and concepts and mapping them in the relational compositions allowed me to develop as complete and accurate a picture of the whole story as possible within the limitations of the available data. Also, new semantic relationships were explored between knowledge gained from different data sources to provide an accurate understanding of the nature of innovation in hospital building design. Thus, it is argued that the use of diagrammatic modelling tools and specific analysis techniques can be considered as an appropriate way of representing data and exploring prime themes.

6.6. Limitations of Study

This study has the following limitations:

- A holistic lens was adopted aiming to explore and map all the contextual factors triggering design innovations since the 1920s in the developed economies. Given the considerably wide scope of the research and the complexity of hospital building design, I could not provide a comprehensive survey of all hospital buildings designed and constructed over the last 100 years. This study was limited to the existing literature on hospital design evolution and did not look for unexamined incidents. It is a first attempt to examine a broad variety of design innovations (both radical and incremental) in hospital buildings to explore hidden patterns and semantic relationships.
- I examined the impacts of contextual factors on design innovations in hospital building design. However, hospital design evolution has also had considerable influences on some of

those contextual factors. The interplay between hospital design and contextual factors needs more investigation.

- Hospital building design has different phases, namely strategic definition, preparing and briefing, concept design, spatial coordination, and technical design, before manufacturing, construction, and handover (Singha 2020). The contextual factors examined in this study might trigger innovations and create value at these different stages. However, the framework does not provide information on the impact of interactions that occurred at certain stages of hospital building design.
- While the developed innovation framework renders the wider context of hospital building design in most modern economies, all contextual factors may not necessarily apply equally to different contexts. The underlying reason might be that the country-specific policies and innovation adoption and absorption are different when it comes to research-practice issues. This limitation of the study may provide ground for future research investigating country-specific healthcare policies, economic circumstances, and political decisions, and thereby healthcare innovations.
- Regarding the developed MGT methodology, following this representational approach is limited to the relational data containing one type of relationship between codes. In my study, for instance, the causalities between contextual factors were demonstrated via directional links.
- Given the wide range of datasets, diagrammatic representations, and analytical approaches, it might not be feasible for GT researchers to select the best diagramming tools in relation to their research objectives by only reading studies with a similar approach. While the full transparency of the methodology is provided in this thesis, researchers might need further investigation of visualisation idioms to effectively conduct their studies.

07 Conclusion and Recommendations

This final chapter summarises the two prime contributions of this study: 1) developing a taxonomy of concepts and an explanatory innovation framework that elucidates the nature of design innovation in hospital building design; and 2) developing a novel approach to MGT methodology. A detailed assessment is provided of the contribution and impact of the research in the field of hospital building design. This study culminates in recommendations for future research and a short reflective section on my PhD journey.

7.1. Concluding Remarks

The biannual Consensus Construction Forecast (2021) by the American Institute of Architects has prognosticated for 2022 a significant growth in construction spending related to healthcare facilities. However, the design and construction of healthcare facilities, especially the most complex form of healthcare building – the hospital – offers fundamental and unique design challenges. The crucial role of hospital building design innovation has been widely posited to enhance the quality of care, promote the healing process and overcome past inaccuracies and inefficiencies, to name just a few (Innovation and Science Australia 2017). Despite the steady increase of research in this field, it is suggested that few innovations are generated from this research and the process of change is too slow. The research to date has put emphasis on the R-P gap as the prime obstacle to innovation and aimed to inform further innovation in hospital design by explaining and bridging the R-P gap. However, this study argues that an oversimplification of the wider context of the evidence base for the design of hospital buildings, and focusing on one object for innovation, have been a prime obstacle to design innovation. Indeed, innovation in hospital building design is a complex ecosystem with various dimensions and the R-P gap is only a small part of a more complex picture. Overlooking this complexity and therefore insufficient understanding of the nature of innovation in hospital building design has been one of the critical factors in the shortage of timely design innovations in this field. Further, the global dimension of innovation ecosystems and the impacts of facilitated exchange and diffusion of knowledge and technology worldwide has yet to be examined. This research posits that conceptualising the nature of and possibly bridging the R-P gap is subject to our understanding of the nature of innovation ecosystems in this context. However, identifying the dynamic interrelationships between actors within overlapped ecosystems and exploring the semantic relationships among them from a systemic perspective involved a new method of analysis of a great deal of data.

The main achievements of this study are: 1) a taxonomy of concepts and theoretical models leading to an explanatory innovation framework that elucidates the nature of innovation in hospital building design; and 2) an exploratory expanded approach to MGT methodology. In other words, the knowledge contribution is twofold: theoretical and methodological. On the *theoretical side*, this dissertation contributes to a deeper understanding of the strength of different contextual factors and interactions among them triggering innovation in hospital building design. Understanding the relatedness of these influential factors not only allows us to revisit key concepts affecting the R-P gap, but also offers a basis for further studies. On the *methodological side*, GT studies using both qualitative and quantitative data analysis are extremely rare, particularly in examining complex phenomena requiring big data analysis. Due to the commonly acknowledged challenges of traditional GT research design, this study used a novel set of analysis techniques and methods to generate meaning from qualitative data. The following subsections summarise the main findings and provide a synthesis of arguments associated with each contribution.

7.1.1. An Explanatory Innovation Framework in Hospital Building Design

An inherently systemic innovation ecosystem in hospital building design is composed of interdependent components that co-evolve in an unpredictable and non-linear process to enable the co-creation of one, or a number of, key values underpinning hospitals (such as the quality of healing process, care services, and organisational efficiency - to name just a few). Here, innovation is a process in the structure formation of a heterogeneous network, which destabilises one state of the network and opens a new process of self-organisation leading to a new stable state. While the research to date has focused on certain interconnections between some of the contributing factors of design innovation, an adequate explanation is yet to be developed of how the interrelationships between different factors have triggered a collective impact on the design innovation ecosystem. In this study, lack of a holistic understanding of the complex innovation ecosystem involved an interpretive GT analysis of the critical texts explaining hospital building evolution over the last 100 years. Notably, while the analysis was limited to certain countries, due to the availability of literature on the evolution of hospital building design, the proposed higher-level concepts and interrelationships portray the wider context of hospital building design in most modern economies.

The complex innovation ecosystem involves several dynamic actors and multi-faceted processes with both individual and collective impacts on innovations in hospital building design. This thesis suggests 14 prime categories when considering the wide range of contextual factors: *Architectural Movements, Urban Reforms, Research Developments, Advances in Medical Science, Technological Developments, Shifts in Attitudes Towards Health, Transition in Institutional Identity, Healthcare Policy, Political Shifts, Economic Shifts, Social Transformations, Developments in Health Service, Shifts in Organisational Culture, and Shifts in Natural Environment*. These concepts comprise different contextual factors with common properties and meaning, each of which might also include less-generic factors - up to two lower levels of generalisation. This taxonomy of concepts is proposed to act as a tool for policymakers, researchers, and designers to further explore the potential role of less-examined factors in this field.

The explanatory innovation framework developed in this study revealed that design innovations generally occur through infrequent ways. However, significant changes in hospital building design are widely seen to repeat themselves through similar processes, and therefore the knowledge provided in this study of successful processes and prior interactions in the innovation ecosystem is argued to be beneficial for further developments of the system. Further, due to the accelerated, complex, competitive nature of the health sector, decision-makers were constantly driven by contextual factors analysed in the present thesis. Here, the patterns of organised interrelationships and network effect, particularly between North American and European countries, have been further developed since the 1990s as the information age came to dominate. Thus, it seems advisable that the developed framework reflects all influential factors and links in most modern economies, whereby different design innovations at different times and places accelerated and/or triggered innovations in other contexts (with similar characteristics). Yet, it is noteworthy that in the nonlinear innovation network, different processes might be triggered between the same set of actors depending upon the system.

It is important to stress that not all the factors in the framework uphold a similar position and importance in generating innovation processes. The introduction/removal of certain factors has significantly transformed the structural properties of the innovation ecosystem due to their critical interactions with other factors. Notably, the emergence of some factors into the system might need a significant amount of time, policies/regulations, and funding before inducing significant impacts on the innovation ecosystem. Figure 7-1 demonstrates the most influential contextual factors regardless of time and place, factors in each decade responsible for triggering radical innovations, and factors with constant influence in consecutive decades. This thesis posits that *Advancements in Medical Practice*, different *Technological Developments* (medical, construction and information technology), *Economic Shifts*, and *Research Developments* have had constant influences on design innovation processes. It is also suggested that fast and revolutionary interactions induced by these factors are as influential as the slow and evolutionary process of change caused by factors in the categories of *Social Transformations, Transition in Institutional Identity, and Shifts in Attitude Towards Health*. This study highly recommends that hospital designers consider the force of the latter set of factors while embracing the technological changes in generating design innovations.

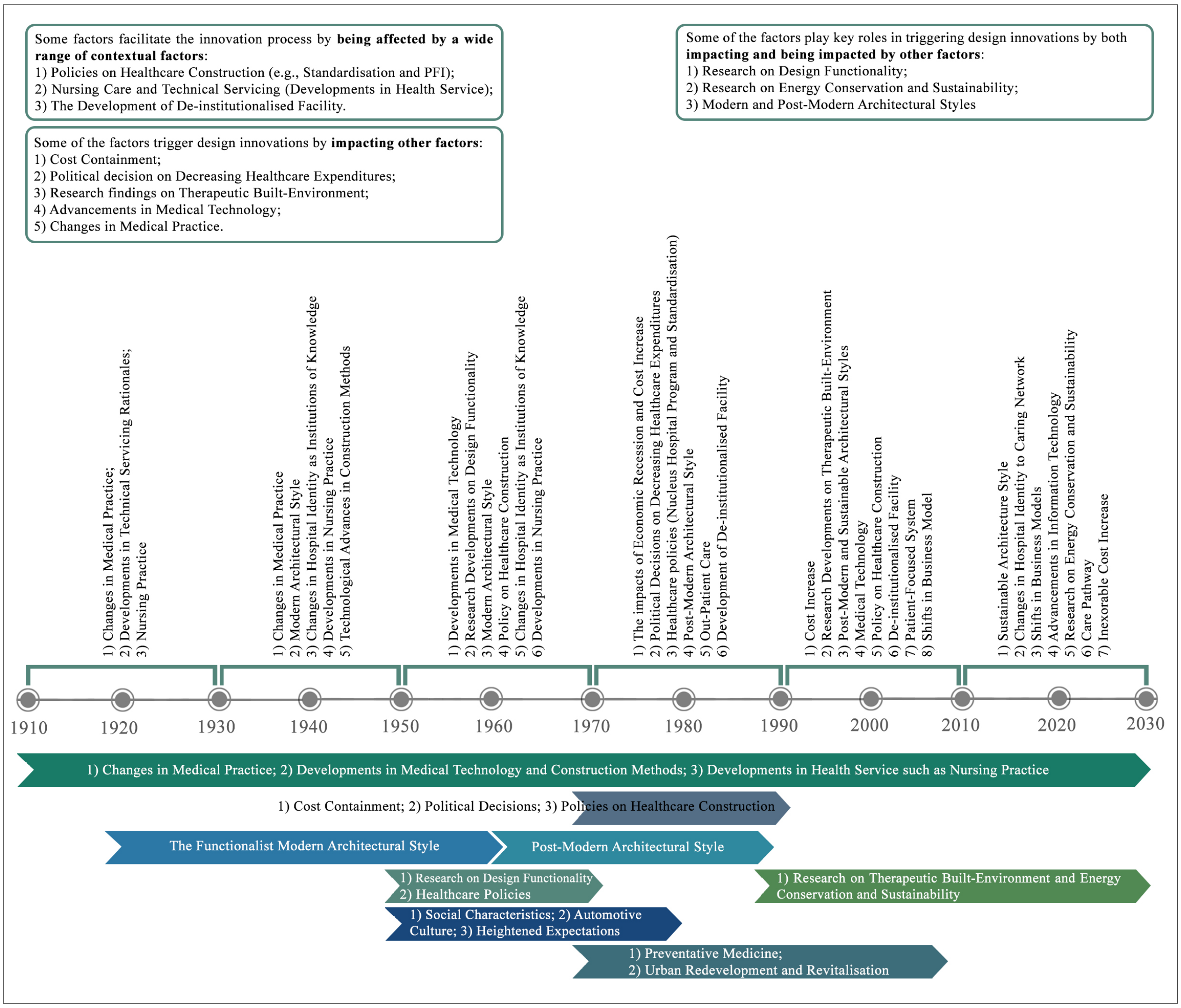


Figure 7-1: The most influential contextual factors regardless of time and place, the most influential factors in each decade, and factors with constant influence in consecutive decades

The highly overlapped functional subgroups of the design innovation network suggest that design innovation processes generally happen because of interactions between contextual factors of different natures. Further, the significant number of links between the detected clusters highlights the key role of bridging factors connecting different innovation processes, such as *Cost Containment,* research on *Therapeutic Built Environments* and *Sustainability,* and the development of *De-institutionalised Facilities*. Factors in the categories of *Research Developments* and *Medical Technology* also colonised different parts of the network, stretching over the network and interacting with factors residing at either cluster A or B. Evidently, the interdependent factors of distinct natures have impacted different fields of research at certain times in relation to sociotechnical priorities. Specifically, research on *Design Functionality* has been affected by: *Architectural Movements, Developments in Health Service, Shifts in Organisational Culture, Healthcare Policy, Advances in Medical Science, Economic Shifts, Technological Developments,* and *Transition in Institution Identity;* research on *Therapeutic Built Environment*: *Social Transformations, Architectural Movements, Attitudes Towards Health, Urban Reforms, Shifts in Organisational Culture,* and *Transition in Institution Identity*; and *Energy Conservation and Sustainability*: *Healthcare Policy, Political Shifts, Architectural Movements,* and *Natural Disasters*. As a result of these interactions, research outcomes have been translated into design practice effectively that generated design innovations in hospital building design. This study argues that value can be created in hospital building design through different forms of interaction between heterogeneous factors that are not mutually exclusive. Thus, policymakers should adopt this multidimensional outlook of the innovation ecosystem and consider the strength of interdependent yet distinct factors facilitating/hindering design innovations. This knowledge allows them to identify potential collaborations between key players on multiple fronts in generating innovation processes.

Value creation in a hospital building design is stressed to become meaningful at the intersection of three interconnected design types (architectural, service and organisational) for integral enhancements in architecture and spatial perception, care processes and the organisational structure of the hospital. Yet, the framework showed a considerably fewer number of links between contextual factors triggering innovative organisational design in relation to service and architectural design. This study recommends the development of further interdisciplinary research, especially on the links of organisational design with architectural and service design. The innovation framework revealed a considerable gap between *Political Shifts* and *Healthcare Policies* with factors under the categories of *Development in Health Service* and *Shifts in Organisational Culture*. It seems that the deconstruction of a fully centralised and integrated health and social care service system and the emergence of independent entities for healthcare facility planning might have impacted hospital building design negatively. In fact, despite the constructive effects of commercialising the medical landscape and empowering individual hospitals for financing and constructing buildings, the lack of central departments with an integrated knowledge of the mutual links between different design types takes its toll on innovation processes, and thus as well, it might be inferred on the quality of care. This study suggests that a central department/organisation (over for-profit, non-profit, and government healthcare systems and independent entities) might develop healthcare construction policies, guidelines, and standards based on the integrated knowledge of all influential factors, and help researchers re-formulate research questions for innovation and greater impact through transdisciplinary approaches. It is predicted that this systemic knowledge will help decrease the widely highlighted frequent errors in building design and its subsequent cost burden.

This knowledge of the nature of innovation in hospital building design acquired from the explanatory innovation framework might change by the introduction of new factors in time. Indeed, the only constant in hospital building design is commonly seen to be *change*, and thus transformations in the structure of the innovation ecosystem reflect this nature. However, analysing the most recent texts on hospital building design evolution indicated that most factors predicted to trigger design innovation (such as advances in communication technologies, the emergence of infectious diseases (like COVID-19), growing lifestyle-related chronic diseases, growing need for disease prevention and health promotion, environmental degradation and issues related to climate change) have already inhabited the innovation ecosystem. Thus, it is advisable that only the position and importance of factors may change, meaning the actors playing in the core are likely to be transformed. It is noteworthy that radical transformations in the level and models of care, target population and organisational structures may raise questions on the nature and identity of general acute/university/specialty hospitals, evolution of which examined in this study. This potential change might shift several contextual factors to the peripheral positions in the ecosystem. Yet, this inevitable adjustment is the prime driver of design innovation. In fact, while disruptive innovations in these concepts might make the designs of hospitals noticeably vulnerable, they have also been the key drivers of design innovation throughout history.

Mapping the impacts of contextual factors is not to usurp the designer's role, but rather help them understand the complexity of innovation processes from a wider system approach. The knowledge presented in this thesis helps architects understand both their systemic impact on the ecosystem and the crucial act of other factors on their decisions by characterising and portraying the contribution of the factors to innovation potential. This study highlights the role of architecture in the innovation ecosystem as a dependant factor vibrating in relation to changes on all other components within the whole system. Moreover, by embracing the crucial impact of disruptive innovations in certain fields on hospital building design, the widely acknowledged role of building users (patients and their families, as well as healthcare providers) in value creation is highlighted. Apart from innovations generated by hospital designers, the active user providing feedback on their experience changes and innovations in different aspects of hospital design (bringing new potentials and set of needs) might also create a new space or adapt an existing one with new meanings. The present study, therefore, highlights design flexibility and adaptability in relation to developments in medical and information technology, preventative medicine, and an ecological and sustainable healthcare system; all of which impact patient and staff experiences. Hospital designers must appreciate that addressing a complex design problem without divergent thinking embracing all the contextual factors is doomed to failure. Additionally, appreciating the design innovation ecosystem and its inhabitants might inform the creation of interdisciplinary courses and programs in architecture schools, perhaps in the form of continuing professional development (CPD), to bridge different planning and design disciplines and, more importantly, prepare students and practicing architects for evolving real-world design problems. This new, systems thinking would not focus on distinct components of the system but consider the individual and combined impacts of different parts on the system behaviour. Given the significant influences of globalisation and communication technologies, it seems collaboration between different actors is more considerably simplified than at any time in history. However, in reality, there is still an urgent need for multidisciplinary collaborations in this field.

Conclusively, and in line with Singha (2020, p. VIII), "lack of intent" has never been the main reason for shortcomings in hospital building design, but rather a lack of a "holistic approach" and inability to fully understand the involved factors and align different forces that add value to the system. This study developed an explanatory innovation framework that delineates the nature of innovation processes by mapping the involved actors and interactions among them. Due to the critical and leadership role of the healthcare industry, the knowledge of the nature of innovation in hospital building design will not only enhance healing processes, improve occupants experience, promote sustainability, and increase organisational efficiency, but also will inform stakeholders in other construction industries leading to further innovation and value creation. Considering the increasingly growing demand for *health for all*, design innovation in different building types will bring unprecedented opportunities to the health and wellbeing of human/society and environment/ecology. The existing gap between factors resulting in knowledge and regulations aiming to improve the performance of buildings and a wide range of other factors impacting the user experience and health-promoting services require reconsideration. Collaboration is necessary between researchers from different fields – hospital architectural, service and organisational designers – and policymakers for better care services. Understanding the impacts of different contextual factors and the process of knowledge transition to practice is a key to timely design innovations. This study highlights the importance of considering different areas of research and spanning knowledge across different domains to contribute to innovation in this field.

7.1.2. A Multi-Representational Approach to MGT Methodology

Diagrammatic visualisations facilitate thinking in non-linear ways, promote researcher scrutiny and aid the analysis process by precisely and concisely representing what GT researchers do and do not know. While the GT methodology has considerably evolved in the past decade, the use of diagrammatical representations remains an area of unexplored potential for the development of theory. This thesis proposed a multi-representational approach to MGT methodology that enables the human GT researcher to use digital tools to transcend the limitations of each side, resulting in enhanced visualisation, creativity, enriched interpretation and emergence of transparency. The use of solely computational decision-making methods (such as statistics and machine learning) in GT research with poorly defined questions is doomed to failure as the human researcher is out of the analysis loop to explore the best way of approaching the problem. Also, the limitations of the human perceptual and cognitive capacities make the manual creation of diagrams (either by hand or CAQDAS programs) strongly unlikely to represent different aspects and levels of data, as well as facilitate a holistic analysis of real-world datasets. Here, the development of a human-centred approach to research design can be considered as a way of overcoming the constraints of conventional GT methodology to address complex phenomena.

In this study, creating visual analytical tools in web-based platforms (Flourish studio and Observable) and using an analytical software program (Pajek) to quantitatively analyse the structural properties of the networks highlighted nine key contributions to GT analysis. Some of them are associated with visual analysis in general, and some are directly related to certain types of diagrams and their analytical framework. The contributions to this GT study are:

1. Going beyond the limitations of GT researchers' cognition and memory;
2. Assisting the GT researcher to explore the best way of approaching complex research problems;
3. Accessing large datasets; and increasing the possibility of searching and selecting certain components;
4. Creating moving diagrams with interactivity options for researchers that provides different views of the data for different levels of analysis (without being overwhelmed by visual clutter);
5. Representing both the overall structure of the system to explore patterns and the links related to individual nodes without summarisation;
6. Providing quantitative analysis strategies to examine the structural properties of systems for a holistic understanding of the studied phenomenon, and increasing the replicability of the study;

7. Serving different analyses and addressing different queries (different diagrams for exactly the same dataset);
8. Making long-term analysis possible for exploratory studies; and
9. Providing a proper way to communicate with team members during the analysis process, as well as communicate findings with broader audience.

Due to the various advantages of the diagrammatic representations discussed, GT researchers need to wisely select the most appropriate type of diagram, or a combination of graphs, to the research objectives to enhance the analytical and interpretive capabilities necessary to conduct sound qualitative research. Notably, diagrams need to be built on one another to complement each other during the process of data analysis. To increase the replicability of the study, transparency in the proposed methodology (particularly in the introduced systematic interventions at different stages of analysis) was fulfilled. However, as research design is commonly seen to be a reflexive process of reshaping through different stages of a qualitative study, GT researchers are strongly encouraged to build upon and extend the research designs I have provided based on their specific research objectives. Moreover, this new approach to GT analysis supports the need for advancing qualitative research methodology in relation to the growing use of big data.

7.2. Recommendations for Future Research

Regarding the proposed MGT methodology, future research might examine the process of GT analysis using a combination of other diagrammatical representations related to specific research objectives. Moreover, as this thesis discussed in its preliminary stages, a diagrammatic modelling tool that concurrently explores different relationships in one diagram might be developed.

Turning to the innovation framework, it might be argued that there is always the possibility of adding new concepts and links to the innovation ecosystem and therefore the possibility of significant changes in the structure of the network. While this study claims to contain the most significant and influential contextual factors and associated connections in the final theoretical model, a transparent explanation of the analysis stages is provided for the future development of the proposed framework (section 5.1 and 5.3). Moreover, I have made the data sets I used for the construction of the framework publicly available to provide the basis for further analysis in this field. Future work might further explore different dynamics of this complex phenomenon by analysing and adding contextual factors explained from the perspective of historians from different fields (rather than hospital architects and designers) aiming to provide a more holistic perspective.

I would like to stress that the aim of this study was not to directly enhance the design practice of hospital buildings in relation to current issues, but rather to develop a more complete understanding of how the complex innovation ecosystem works in this context from a holistic perspective. Within the context of the R-P gap, developing such an informative innovation framework was viable through the theoretical analysis of the practical data (real-world incidents over time). Here, developing and using a hybrid approach to the MGT methodology increased the credibility and viability of the final framework, as this methodology is grounded in real data to minimise researchers' bias. However, this study examined a complex issue that could benefit from a multidisciplinary research team (involving researchers from sociology and management, urbanism, and biomedical engineering, as well as medical practitioners and hospital building designers). Future research may develop this framework via consultations with both practitioners from the sector and researchers from other fields.

Future research may also focus on the flow of interactions between contextual factors to explore the role of certain contextual factors in triggering design innovations through history. For example, to investigate the role of architecture in the innovation ecosystem, the interactions between this code and other contextual factors can be examined by showing the direction and weight of links between possible intermediate steps. It would be beneficial to understand when a certain factor had a central role in an innovation process and when it was a peripheral factor. It might also be interesting to examine the impacts of contextual factors on different phases of the design process of hospitals. Additionally, due to the highlighted knowledge gaps in the existing critical texts explaining hospital building design evolution, the final innovation framework might provide researchers with a tool to construct a history of hospital building design from a holistic point of view.

7.3. Reflections on Challenges and PhD Learning

Working on a complex real-world problem for three years brought many new aspects of research to my attention. Apart from the prime knowledge contributions of this thesis, I learnt a lot about how to critically think about a subject, approach and define a problem, support and relate my ideas within the existing literature, develop new skills along the way, communicate and discuss the findings of my research, and manage my time during a long journey. Before writing this section, I reviewed all records of my PhD meetings with my supervisors and thought carefully about different stages of my study. It seems at the early stages of this journey, I thought in three years it would be both necessary and achievable to address many knowledge gaps! From where I stand today, I know the required depth of knowledge for making a small but impactful difference. I understand there is no one correct solution to a certain problem, but there might be a correct way of thinking to approach that problem. Indeed, this has been the main complexity of developing my researcher identity. I learnt that the concern is not to solve the biggest issue possible, but to find the best way of addressing that problem in a way that overcomes knowledge blocks gradually.

When I started the historical analysis of design innovations in hospitals using the GT method, I expected to come up with a number of factors repetitively impacting hospital design evolution. However, there was a wide range of incidents that occurred through interactions between several factors. Via analysing each data set, a considerable number of factors and links were added to the picture; though, it was critical to find out and integrate the similar incidents and factors described from different perspectives without missing any links. This process was not straightforward at the beginning and I had to repeat the initial and focused coding of the first four data sources three times! It was important to consider every factor and link as seemingly unimportant ones could become influential in the later stages of the analysis when all their relationships were mapped. For this study, the common GT methodology, and other recommended strategies, were not sufficient to make sense of the very wide range of factors and relationships explored in this study. Given the ever-expanding pallet of digital tools available to analyse complex phenomena and big data sets, I thought that today's unaddressed research problems require novel thinking approaches and a new set of strategies and techniques. However, without programming knowledge and skills, I was not able to turn these thoughts into reality. While I was lucky to get help via my brother's programming skills, I believe some seemingly unimportant issues might completely change a researcher's way of conducting a study. The importance of cost issues associated with software programs and required time for developing skills to effectively use them cannot be overemphasised. In my study, the open accessibility of web-based platforms, and the availability of online tutorials to conduct

SNA in professional programs, such as Pajek, were some of the main reasons for selecting that set of tools among a vast variety. The implication for my future as a researcher would be to carry out the most appropriate method and not necessarily the best possible one to reach the best outcome.

Addressing novel research problems sometimes involves using different theories and analytical frameworks from different philosophical backgrounds. While researchers critically review the literature and examine similar studies to justify their knowledge contribution, it is essential to get feedback from experts on that specific topic. In this study, I contacted two A/professors from the department of social sciences to ensure that my understanding of the network approach to complex systems was correct and the proposed way of adopting related concepts and techniques made sense from their perspective. One of the main challenges here was to explain the research problem and method in a way that was both comprehensible for them with a different educational background and not too simplified. It is worth mentioning that participating in a few PhD competitions, such as 3MT and VYT, helped me develop a storyline and explain my study concisely and precisely to a lay audience without compromising its value.

Constantly focusing on only one subject for three years is a great opportunity to innovatively address a gap in knowledge. I had enough time to develop different skills to think and write critically. However, I also found working as a casual research assistant on projects slightly different to my PhD study very helpful. The gap between thinking about my study and those projects, usually over a few weeks, helped me refresh my mind and come up with new ideas. Additionally, I could achieve some short-term goals that significantly enhanced my motivation. Regarding the thesis writing process, the importance became clear of developing an outline before going into details, as well as constantly stepping back and considering the subject from a wider perspective. In this way, I could find out the potentially defective parts and/or come up with new ideas. I understood it is crucial to have consistency and further develop the research. In my experience, different stages of developing the knowledge did not necessarily occur in the same order presented in this thesis.

Last, while I could meet the planned deadlines, the mental impact of the Covid-19 lock-downs, working in isolation, and having virtual supervisory meetings was considerable. I hardly explained my research to peers for feedback and bouncing ideas off each other. Despite these negative impacts, Covid-19 changed my daily routine and helped me establish a more meaningful PhD life by adding exercise and painting to my schedule! I learnt that a few small additions to my daily routine can even save me time by enhancing my performance. In a nutshell, I have had the privilege to become fully engaged in my PhD research and learn many unspoken skills expected from a researcher from my supervisory team. I hope to employ the knowledge and skills gained in these three years in my next journey and have the chance to further develop this version of myself!

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09

Appendix

This section is uploaded into *figshare* (please refer to https://figshare.com/s/11cf5f185832a377602c to access the data).

9.1. Diagrams Represented in the Thesis

9.1.1. Relational Compositions (Network Diagrams)

9.1.2. Arc Diagrams

9.1.3. Changes in Theoretical Models

9.1.4. Explanatory Innovation Framework

9.2. Data Supporting the Final Network Diagram

9.2.1. Table of Points

9.2.2. Table of Links

9.3. Initial Historical Analysis

9.3.1. Categories Acquired from the Initial Literature Review

9.3.2. Summary of the Main Published Standards and Guidelines in Hospital Design

9.3.3. Summary of the Main Research Findings in Architecture and Environmental Sciences

9.4. Analysis of Hierarchical Edge Bundling Diagrams

9.4.1. The First Hierarchical Edge Bundling Diagram

9.4.2. The Fourth Hierarchical Edge Bundling Diagram