Hospital nursing staff productivity - the role of layout and people circulation

This item was submitted to Loughborough University's Institutional Repository by the/an author.

Additional Information:

- A Doctoral Thesis. Submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy of Loughborough University.

Metadata Record: [https://dspace.lboro.ac.uk/2134/14932](https://dspace.lboro.ac.uk/2134/14932)

Publisher: © Masoumeh Nazarian

Please cite the published version.
This item was submitted to Loughborough University as a PhD thesis by the author and is made available in the Institutional Repository (https://dspace.lboro.ac.uk/) under the following Creative Commons Licence conditions.

For the full text of this licence, please go to: http://creativecommons.org/licenses/by-nc-nd/2.5/
Hospital Nursing Staff Productivity
The role of layout and people circulation

by

Masoumeh Nazarian

Doctoral Thesis

Submitted in partial fulfilment of the requirements
for the award of
Doctor of Philosophy of Loughborough University

18/11/2013

© by Masoumeh Nazarian 2013
Abstract
Abstract

As a facility that offers an important service to its users, a hospital can be considered as a ‘production unit’; a unit that provides health-care service. Therefore, a range of factors that facilitate this service (i.e. healthcare) need to be considered when speaking of improving the productivity in a hospital ward. Evidence suggests that one of the main factors that affect the productivity level of a hospital ward is how the design of the hospital deals with access and circulation of the people inside the ward (e.g. Joseph and Ulrich, 2007). A productivity-oriented circulation system will need to improve staff performance; enhance patients’ safety, privacy and rate of recovery; minimise the risk of cross-infection; reduce the delay time of external service delivery; create a more welcoming environment for visitors; and reduce the evacuation time in emergency situations. Thus, the need to design ward layouts that benefit from the most effective circulation system cannot be over-emphasised.

The study presented in this thesis focused on finding a method for identifying different systems of access and people circulation in hospital wards and how they could affect nursing staff productivity. The study comprised five main phases. The first phase involved a literature review of existing healthcare environments to identify different types of access and people circulation requirements. In the second phase, data on nursing staff’s movements were collected from a case study. The third phase focused on categorising and modelling the existing approaches and layout design systems. Phase four provided a comparative study of different categories of people circulation designs and contrasted their advantages and disadvantages to improve access and people circulation. In the fifth and final phase, the study concluded with proposing guidelines for choosing between different layout options in the design of new hospital wards or the refurbishment of the existing ones.

Findings of the study included: further empirical and analytical support for the impact of the ward design on nursing staff’s performance; a ranking of the suitability of different design layouts for minimising staff’s unnecessary walking in wards similar to the case study; the importance of considering different staff members’ needs in such analyses; and a ranking of the criticality of different routes within a ward.

Keywords: ward design, circulation, access, people flow, productivity, nursing staff, Atieh Hospital, archetypal models
Acknowledgments
There have been so many people who have contributed to the accomplishment of this study that it would be impossible to name all of them on this page. I would like to offer my wholehearted gratitude to all of them even if their names are not mentioned here.

This thesis would not have been possible without the momentous support and patience of my supervisors, Prof. Andrew Price and Dr. Peter Demian, to whom I am extremely grateful.

My sincere thanks go to Prof. Khalil Alizadeh and his wonderful team at Atieh Hospital, particularly Mr. Vahidian and Saba Ward staff. They have all been enormously compassionate and supportive over the period of my data collection.

I am also very thankful to Prof. Jacqui Glass for her valuable guidance and suggestions, especially during the final phases of this thesis.

I would like to express my appreciation for the spiritual and unequivocal support of my beloved family and friends particularly Mrs. Khadijeh Abedini, Mrs. Laila Monibi, Dr. Bahareh Kaveh and Dr. Zahra Zolmajd who smoothed the difficulties of my journey and encouraged me on my way.

I will forever be thankful to my dear mother for her unconditional and eternal love and attention. I am, and will be, indebted to her for all my life.

Furthermore, I would like to thank my husband, Masoud, for his wise and intelligent recommendations and unremitting and trustworthy love during different steps of this work.

Last, but by no means least, my very special thanks go to my adorable angels, Mehraban and Mundanny, for being such considerate and extremely thoughtful children throughout my tough journey.
Contents
Abstract ............................................................................................................................. 2
Acknowledgments ............................................................................................................ 4
Contents ............................................................................................................................ 6
List of figures ................................................................................................................... 14
List of tables .................................................................................................................... 18
1 Introduction ............................................................................................................ 20
  1.1 Background ...................................................................................................... 21
  1.2 Motivation for the research ............................................................................. 22
  1.3 Research questions .......................................................................................... 23
  1.4 Aim ................................................................................................................... 24
  1.5 Research objectives .......................................................................................... 24
  1.6 Research plan ................................................................................................... 24
  1.7 Outline research method ................................................................................. 25
  1.8 Thesis structure ............................................................................................... 25
  1.9 Summary .......................................................................................................... 27
2 Methodology ........................................................................................................... 28
  2.1 Introduction ..................................................................................................... 29
  2.2 Justification for current study .......................................................................... 29
  2.3 Research framework ........................................................................................ 30
    2.3.1 Ontological considerations ....................................................................... 30
    2.3.2 Epistemological positions ......................................................................... 31
    2.3.3 Multi-methodology ................................................................................... 31
    2.3.4 Mixed-methods research and paradigm .................................................. 32
  2.4 Research design ............................................................................................... 33
  2.5 Research ethical considerations ........................................................................ 34
    2.5.1 Informed consent...................................................................................... 35
2.5.2 Confidentiality ................................................................................................. 36
2.6 Employed methods ............................................................................................. 37
  2.6.1 Literature Review .......................................................................................... 37
  2.6.2 Case study ..................................................................................................... 37
  2.6.3 Interviews ........................................................................................................ 38
  2.6.4 Developing guidelines for productivity-oriented ward design .................. 39
2.7 Summary ............................................................................................................. 40
3 Literature review – Hospital nurse productivity .................................................... 41
  3.1 Introduction ....................................................................................................... 42
  3.2 Efficiency, effectiveness, performance and productivity ..................................... 42
  3.3 The concept of productivity ............................................................................... 43
    3.3.1 Productivity vs. quality ............................................................................... 44
    3.3.2 Productivity vs. staff morale ....................................................................... 44
    3.3.3 A definition for productivity ....................................................................... 46
  3.4 Nursing staff productivity .................................................................................... 47
  3.5 Impact of ward design on service quality ......................................................... 48
    3.5.1 Cross infections ............................................................................................ 48
    3.5.2 Medical errors .............................................................................................. 49
    3.5.3 Patient physical wellbeing ............................................................................ 50
    3.5.4 Patient mental and social wellbeing ............................................................ 51
    3.5.5 Way finding ................................................................................................ 54
  3.6 Impact of ward design on staff morale .............................................................. 54
    3.6.1 Staff stress .................................................................................................... 55
    3.6.2 Staff satisfaction ........................................................................................... 55
  3.7 Impact of ward design on resources ................................................................... 56
    3.7.1 Patient transfers .......................................................................................... 56
3.7.2 Length of patient stay ................................................................. 56
3.7.3 Staff injuries ............................................................................. 57
3.7.4 Staff work flow ........................................................................ 57
3.8 Summary ..................................................................................... 58

4 Literature review - Hospital productivity in the current UK context .......... 59
4.1 Introduction .................................................................................. 60
4.2 Incorporating productivity in hospital design .................................... 60
    4.2.1 Activity DataBase (ADB) ......................................................... 60
    4.2.2 Achieving Excellence in Design Evaluation Toolkit (AEDET) and AEDET Evolution ................................................................. 62
    4.2.3 British Standards and British Standard Codes of Practice .......... 62
    4.2.4 Health Technical Memoranda (HTMs) ...................................... 63
    4.2.5 Health Building Notes (HBNs) ................................................. 63
    4.2.6 Health Facility Notes (HFNs) .................................................... 64
    4.2.7 Other NHS Estates guidance .................................................. 64
4.3 Hospital productivity assessment ..................................................... 64
    4.3.1 NHS Environmental Assessment Tool (NEAT) ......................... 64
    4.3.2 Patient Environmental Action Team (PEAT) ............................. 64
    4.3.3 Patient-Led Assessments of Care Environment (PLACE) ........ 65
    4.3.4 Premises Assurance Model (PAM) .......................................... 65
4.4 Improving hospital productivity ...................................................... 65
    4.4.1 Lean ....................................................................................... 65
    4.4.2 Productive Ward - Releasing Time to Care ............................... 66
4.5 Summary ..................................................................................... 66

5 Literature review - Approaches towards hospital ward design .................. 68
5.1 Introduction .................................................................................. 69
6.3.4 Data collection ........................................................................................................ 96
6.4 Archetypal models ...................................................................................................... 103
   6.4.1 Corridor design .................................................................................................. 103
   6.4.2 Nuffield design ................................................................................................ 104
   6.4.3 Racetrack design ............................................................................................ 104
   6.4.4 Radial design .................................................................................................. 105
6.5 Summary .................................................................................................................. 106
7 Comparative analysis of the archetypal models .......................................................... 107
   7.1 Introduction ......................................................................................................... 108
   7.2 Analysis of the journey frequency data from the case study .............................. 110
      7.2.1 Method ...................................................................................................... 110
      7.2.2 Overall analysis and frequency levels ........................................................ 112
      7.2.3 Analysis by staff type ............................................................................... 117
   7.3 Analysis of the journey distance data from archetypal models .......................... 121
      7.3.1 Method ...................................................................................................... 121
      7.3.2 Journey distances in archetypal models .................................................... 122
   7.4 Comparative analysis of the archetypal models .................................................. 126
      7.4.1 Results ...................................................................................................... 126
      7.4.2 Sensitivity analysis .................................................................................... 129
   7.5 Summary .............................................................................................................. 133
8 Guidelines for improving hospital staff productivity and circulation ...................... 135
   8.1 Introduction ........................................................................................................ 136
   8.2 Definition of a high-productivity ward ............................................................... 136
   8.3 Method ............................................................................................................... 137
      8.3.1 Journey frequency data ............................................................................ 139
      8.3.2 Journey distance data ............................................................................. 142
8.3.3 Comparative analysis of the models based on the walking distance of the nursing team .............................................................. 143

8.4 Design recommendations for high-productivity wards .................. 144

8.4.1 Nurse Station ............................................................................. 144
8.4.2 Treatment Room ......................................................................... 144
8.4.3 Staff Room .................................................................................. 145
8.4.4 Ward Entrance ......................................................................... 145
8.4.5 Patient rooms ............................................................................... 146
8.4.6 Proximity matrix .......................................................................... 146

8.5 Summary ........................................................................................ 147

9 Conclusions, recommendations and further work .......................... 148

9.1 Introduction .................................................................................. 149

9.2 Conclusions of the objectives ........................................................ 149

9.2.1 Objective One ........................................................................... 149
9.2.2 Objective Two ........................................................................... 150
9.2.3 Objective Three ......................................................................... 151
9.2.4 Objective Four ........................................................................... 151
9.2.5 Objective Five ........................................................................... 152
9.2.6 Objective Six ............................................................................... 152

9.3 Findings ........................................................................................ 153

9.3.1 Importance of good access and circulation in hospital wards ....... 153
9.3.2 Staff circulation in different hospital ward designs ...................... 153
9.3.3 Variance by staff type ................................................................. 154
9.3.4 Critical routes ........................................................................... 154

9.4 Contribution to knowledge and practice ...................................... 155

9.4.1 Literature review ........................................................................ 155
List of figures
Figure 2-1 Research methodology .......................................................... 35
Figure 2-2 The connection between different research phases and thesis chapters .... 36
Figure 3-1 Factors influencing productivity .................................................. 47
Figure 5-1 Nightingale ward, St. Thomas Hospital, London (James and Tatton-Brown, 1986) ............................................................................................................................... 70
Figure 5-2 St. Thomas Hospital, London (James and Tatton-Brown, 1986) ............ 71
Figure 5-3 Radial ward design (Morelli, 2007) ................................................... 72
Figure 5-4 Radial ward, Henry Saxon Snell 1880s (Goode et al, 2009) .............. 72
Figure 5-5 An example of Subdivided ward type, early 20th century (NHS Estates, 1997) ............................................................................................................................... 73
Figure 5-6 Nuffield ward, 1950s (NHS Estates, 1997) ........................................ 73
Figure 5-7 Nuffield ward, 1950s, (NHS Estates, 1997) ........................................ 74
Figure 5-8 Nuffield ward, Larkfield Hospital, UK (James and Tatton-Brown, 1986) ...... 74
Figure 5-9 Racetrack ward, High Wycombe Hospital, Buckinghamshire, UK (James and Tatton-Brown, 1986) ......................................................................................................... 75
Figure 5-10 1960s Falkirk ward (NHS Estates, 1997) ........................................ 75
Figure 5-11 Courtyard ward, Acute Psychiatric Department, Norway (Burt-O.Dea, 2005) ................................................................................................................................. 76
Figure 5-12 Cluster layout, Istanbul Medicine Faculty, Istanbul, Turkey (Unlu et al, 2005) ................................................................................................................................. 77
Figure 5-13 Cruciform Cluster ward, Weston General Hospital, Weston-super-Mare, UK (James and Tatton-Brown, 1986) ......................................................................................................... 77
Figure 5-14 Nucleus ward, a pair of 24-bed wards (NHS Estates, 1997) ............. 77
Figure 5-15 Nucleus ward, a six-bed room and a single-bed room (NHS Estates, 1997)................................................................................................................................. 78
Figure 6-1 Re-categorising ward designs ...................................................... 86
Figure 6-2 Final ward selection ..................................................................... 86
Figure 6-3 Atieh Hospital urban accessibility (Atieh Hospital, 2013) ................. 88
Figure 6-4 Atieh Hospital, Tehran, Iran (TBY, 2011) ........................................ 89
Figure 6-5 Saba ward, Atieh Hospital (Atieh Hospital 2013) ........................... 90
Figure 6-6 Nurse Station is the starting point and destination for all nurses’ journeys. 93
Figure 6-7 Location of Nurse Station relative to all areas of the ward is of crucial importance .......................................................................................................................... 93
Figure 6-8  In locating Nurse Station, factors such as visual access to some rooms is also important. ................................................................. 93
Figure 6-9  Communal parts of the ward also need to be visible from the Nurse Station. ................................................................. 93
Figure 6-10  For a short while (during shift handover), the number of staff is doubled. ................................................................. 93
Figure 6-11  Most of the non-walking time of nurses is spent for documentation at Station. ................................................................. 93
Figure 6-12 Single-bed Room ................................................................. 94
Figure 6-13 Double-bed Room ................................................................. 94
Figure 6-14 Isolation-adaptable Room ................................................................. 94
Figure 6-15 Isolation-adaptable Room ................................................................. 94
Figure 6-16 Single-bed Room en suite bathroom ................................................................. 94
Figure 6-17 Isolation-adaptable Room bathroom ................................................................. 94
Figure 6-18 Corridors provide quick and safe access to different parts of the ward. ................................................................. 95
Figure 6-19 Staff Room accommodates nurses’ break times as well as admin activities. ................................................................. 95
Figure 6-20 Treatment Room is the destination for most nurses’ journeys. ................................................................. 95
Figure 6-21 Treatment Room provides space for medical equipment and in-house cleaning. ................................................................. 95
Figure 6-22 current patients’ daily records are kept and accessed in the Nurse Station. ................................................................. 95
Figure 6-23 Storage of restricted access drugs is one of the other functions of Treatment Room. ................................................................. 95
Figure 6-24 Nurse data collection sample form ................................................................. 99
Figure 6-25 Head Nurse data collection sample form ................................................................. 100
Figure 6-26 Nurse Assistant data collection sample form ................................................................. 100
Figure 6-27 Origins and destinations of journeys in the ward ................................................................. 101
Figure 6-28 An example of data collection sheet in observation stage ................................................................. 103
Figure 6-29 Corridor archetypal model ................................................................. 103
Figure 7-1 First few rows of the case study journey frequency data (full table in Appendix C - Journey frequency data for staff types) ................................................................. 111
List of tables
Table 1-1 Research objectives vs. methodologies .......................................................... 25
Table 6-1 Number of ward staff per shift ..................................................................... 90
Table 6-2 Data collection diary ................................................................................... 96
Table 6-3 List of daily activities per staff type .............................................................. 97
Table 7-1 Shortlisted journey routes ........................................................................... 113
Table 7-2 Share in daily journey frequency per level ................................................... 116
Table 7-3 Journey distances of active routes per model .............................................. 125
Table 8-1 Journey frequency data vs. journey distance data ....................................... 139
Table 8-2 Ward spaces proximity matrix ...................................................................... 146
1 Introduction
1.1 Background
A preliminary scoping study showed that previous research had linked the quality of care, patient health and wellbeing with the physical attributes of the healthcare environment (Yang and Price, 2006). Gesler et al (2004) identified that physical, social and symbolic design of a hospital defines how its environment can contribute to the healing of patients. The need for the contribution of the environment to the healing process of the patients has been generally appreciated (Francis et al, 1999), but the details of the interactions between the environment and the healing process are not fully understood (Canter and Canter, 1979).

Interventions in the healthcare environment and their impact on the health outcomes of the patients have been the focus of a vast body of research in the last few decades. Most of such studies cover maintenance, refurbishment or relocation practices, during which the health outcomes of the patients are measured before and after each intervention. Some offer a comparison between different healthcare environments with different qualities to conclude qualities that contribute to the health outcomes. An investigation on these studies leaves no doubt in the significant share of healthcare environment on patients’ wellbeing and healing process. Such evidence suggest that, for example, interventions in the built environment of healthcare buildings may contribute to a 9% reduction in patient stay time in a hospital (Ulrich, 1984), a 22% reduction in patients’ feeling of pain (Lawson and Phiri, 2003), a decline of 67% in medication errors (Hendrich et al, 2004), 17.3% reduction in patients’ fall accidents (Brandis, 1999), 70% reduction in patient psychological distress (Lawson and Phiri, 2003) and may even result in total eradication of hospital acquired infections (Oren et al, 2001).

There are many factors that could contribute to the design of a more effective hospital. It is understandable that supportive built environments with good internal layouts, accessibility, and circulation can create an overall inviting, calming, engaging, and more hygienic and productive healthcare environment for staff, patients and their relatives. Trying to improve productivity in hospitals is not a new idea. Kuhn (2000) introduces Henry Ford, founder of Ford motor company, as one of the pioneers of transferring the concept of productivity from automotive industry into healthcare. When designing a
hospital for his staff, he is quoted to have said that “in a normal hospital, nurses are forced to make many unnecessary steps. Hence they spend more time walking around than nursing the patients” (Kuhn, 2000). This seems to still be a challenge, even now, in the 21st century. A study showed that nurses spend close to one-third of their time walking in the unit between patient rooms, the nursing unit core and the nurses’ station, which, in turn, results in fatigue (Joseph and Ulrich, 2007).

There have been many studies into the effects of the workplace on employees (Armstrong et al, 2004). Within the healthcare setting, there has been much work completed on the effect of the environment on patients (for example Lawson and Phiri, 2003), yet little attention has been given specifically to the effect that the hospital environment has on the staff (Armstrong et al, 2004).

Many efforts have been made to improve the performance of the medical staff by changes in the layout of their workspace. Some studies have investigated the impact of the unit layout on the amount of time spent walking (e.g. Shepley, 2002; Shepley and Davies, 2003; Sturdavant, 1960; Trites et al, 1970). A review of these studies by Nazarian (2011) showed that time saved walking was translated into more time spent on patient-care activities and interaction with family members.

1.2 Motivation for the research

The on-going increase in population in addition to the increase in average age of the populace means that the need for expanding public healthcare services will probably never end. This expansion is normally sought through one of these three approaches:

- construction of new hospitals;
- physical extension of existing hospitals; and
- optimising the productivity of existing hospitals.

Hospitals are among the most expensive building projects used by members of the public on a daily basis. The extent of the financial means needed for building new hospitals or extending the old ones as well as the need for constant and uninterrupted access to these facilities has led health authorities to put more emphasis on improving the productivity of existing facilities through less intrusive and less expensive methods.
There are general guidelines as to how these methods apply to specific types of healthcare facilities, such as those published by the National Health Service (NHS) under the title ‘Enhancing the Healing Environment’ (e.g. Waller and Finn, 2004). These guidelines are usually based on the experience of the staff and patients rather than an analytic evidence base to support their advantages.

The same applies to the guidelines available for designing new hospitals. The design of the hospital is, principally, shaped around the architect’s ideas based on user needs and available funds. There are very broad suggestions about the criteria that a design should meet (e.g. DH, 2007b), but the need for establishing robust methodologies to determine the requirements of these guidelines and get the highest performance from a hospital as a production unit is still a missing link. The present study intends to establish these robust methodologies for evaluating the productivity of hospital ward arrangement options, whether in the design stage, during its use or in the process of renovation. Completing of this study offers: a framework for understanding the relationship between different spaces within a ward and nurse movement requirements as imposed by these relationships; solutions for optimising spatial arrangement of hospital wards in terms of reducing time wasted due to unnecessary movement of the staff between different spaces; and a method for deciding between different designs for a ward according to staff productivity.

1.3 Research questions

The questions that shape the general concept of this research can be summarised as follows.

- What are the impacts of the access and people circulation on staff productivity?
- How do access and people circulation impact on patient experience?
- What are the current United Kingdom (UK) good practices in regards to a good quality access and people circulation design?
- What new health promoting theories and design strategies can be developed from knowledge of the impacts of the good access and people circulation on hospital staff productivity?
1.4 Aim
With consideration of Sections 1.1 and 1.2, the main aim of the research is defined as follows.

‘to improve the productivity of hospital nursing staff through better people circulation and layout’

1.5 Research objectives
The research will consider the design of new and redesign of existing facilities and, through that, will develop new knowledge and guidelines on how the built environment adds value to healthcare delivery and will improve understanding of how a well-designed access and circulation system affects patient care, safety, privacy, clinical recovery, staff effectiveness and operational efficiency. Therefore, the main objectives of this research are to:

• explore and demonstrate the importance of good access and circulation in hospitals;
• articulate current knowledge on hospital staff productivity and its relationship with layout design;
• review and compare application of current UK design standards and guidelines and hospital productivity audit and planning tools, in order to identify the hospital productivity in the current UK context;
• identify most common types of hospital ward designs and their characteristics;
• analyse nursing staff’s circulation in the most common types of hospital design; and
• develop guidelines for improving hospital nursing staff productivity and circulation.

1.6 Research plan
The research comprises five core phases as summarised below.

Phase 1: Literature review of people circulation layout planning in order to establish a knowledge base of current UK practice.
Phase 2: Collect data on journeys of the nursing staff within ward.
Phase 3: Design archetypal models to represent different ward design types.
Phase 4: Compare design types by analysing walking distances in archetypal models.
Phase 5: Develop guidelines that comprise:
• a theoretical basis for defining what is expected from a high productivity ward;
- a design selection method for hospital wards; and
- design recommendations for hospital wards in order to improve productivity.

### 1.7 Outline research method

To achieve the objectives mentioned earlier, a combination of different research methods will be used during the course of this study. These methods have been mapped against the objectives in Table 1-1 and discussed in full detail in Chapter 2.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explore and demonstrate the importance of good access and circulation in hospitals</td>
<td>Literature review</td>
</tr>
<tr>
<td>Articulate current knowledge on hospital staff productivity and its relationship with layout design</td>
<td>Literature review</td>
</tr>
<tr>
<td>Review and compare application of current UK design standards and guidelines and hospital productivity audit and planning tools, in order to identify the hospital productivity in the current UK context</td>
<td>Literature review Preliminary interviews</td>
</tr>
<tr>
<td>Identify most common types of hospital ward designs and their characteristics</td>
<td>Literature review Desk study</td>
</tr>
<tr>
<td>Analyse nursing staff’s circulation in the most common types of hospital design</td>
<td>Case study selection Data collection Create archetypal models Result analysis</td>
</tr>
<tr>
<td>Develop guidelines for improving hospital nursing staff productivity and circulation</td>
<td>Desk study</td>
</tr>
</tbody>
</table>

### 1.8 Thesis structure

This thesis comprises nine main chapters plus appendices and listings. The present chapter provided a background of the topic and why such a study is needed. This led to an explanation of the aim and objectives of the study and a brief description of the methods employed for accomplishing them. These methods are discussed in further detail in the following chapter (Chapter 2) after a discussion on the study’s academic and ethical frameworks.
The multi-disciplinary nature of the research calls for a comprehensive knowledge of the matter from different points of views. The extensive literature review presented in the next three chapters of this thesis (Chapters 3 to 5) provides the knowledge base needed for this study. Chapter 3 investigates the matter of productivity and, specifically, hospital nurse productivity. The first phase of the chapter involves an attempt to disambiguate the term ‘productivity’ and create a definition that fits the purpose of this study. The second phase gathers all the evidence pointing to how the design of a hospital can affect its productivity in different ways.

Chapter 4 provides a review of national design briefing, operational audit and strategic planning guidelines and tools related to people circulation towards gaining specific background knowledge on hospital productivity in the present UK setting. It describes how different matters relating to productivity are dealt with in the UK healthcare system. It investigates many different practices tended to either designing new productive hospitals or assessing and improving the productivity of existing hospitals. The former category of these practices (those tending to incorporate productivity in the original design of a hospital) is further discussed in the next chapter.

Chapter 5 explores the design needs of a hospital, trends in meeting such needs by designers and resulting approaches in hospital design and specifically the design of wards in a hospital.

Chapter 6 describes the importance of selecting and observing at least one case study and building archetypal models for layout types described in the previous chapter.

Chapter 7 analyses the productivity of selected ward categories using the collected data and comparing the circulation systems of archetypal models.

Lessons learnt from this analysis are then presented as a set of guidelines, proposed to maximise productivity in hospital wards in Chapter 8. This chapter also presents a definition for highly productive design systems and a method for measuring the potential of an existing design for productivity improvement.

This brings the thesis to its conclusion (Chapter 9), which comprises of discussions on the findings of the research and how they contribute to academia and practice. The
conclusion chapter also discusses limitations of the research and makes suggestions for further enhancement of the results of this study through future research.

1.9 Summary
In this chapter, a background was provided on why a new study is necessary to establish methods for improving the productivity of hospitals (and specifically, hospital wards) and how establishing such a method is feasible. This led to the statement of the aim and the six objectives of the research and an explanation on how different methods applied through different chapters of the thesis meet each of the objectives. The relationship between methods and objectives will be further investigated in the following chapter (Chapter 2), where the methodological stance of the research is explained and methods designed to accomplish the aim are discussed.
2 Methodology
2.1 Introduction
This chapter presents the research design and the methodology adopted to meet the aim and objectives set out in Chapter 1. The research aim and objectives are initially restated and followed by a discussion of the philosophical considerations in relation to the research. Methods of data analysis are described in relation to the propositions derived from the aim and objectives.

2.2 Justification for current study
Chapter 3 demonstrates that physical environment of a ward has been shown to have a significant effect on a variety of productivity-related outcomes, such as service quality, resources and staff morale. Given that hospital wards are unique in their complex and dynamic work environment as well as the sensitivity and vitality of timely and efficient performance of their users, this indeed demands high levels of productivity of medical staff, especially nurses, if they are to be successful in providing more effective care. However, few productivity studies have been undertaken in the context of the hospital ward domain, and the question of how circulation and people flow affects nursing staffs’ performance in their daily work still remains unclear.

As a direct response to the underlying impact of circulation design on nursing staff productivity, the research aim was established as ‘to improve the productivity of hospital nursing staff through better people circulation and layout’. To fulfil this aim, it is first necessary to understand: how nursing staffs’ productivity is relevant to circulation design; why productivity is important to healthcare services; and how physical environment affects nursing staffs’ performance. This forms the research objectives listed below.

• Explore and demonstrate the importance of good access and circulation in hospitals.
• Articulate current knowledge on hospital staff productivity and its relationship with layout design.
• Review and compare application of current uk design standards and guidelines and hospital productivity audit and planning tools, in order to identify the hospital productivity in the current uk context.
• Identify the most common types of hospital ward designs and their characteristics.
• Analyse nursing staff’s circulation in the most common types of hospital design.
• Develop guidelines for improving hospital nursing staff productivity and circulation.

2.3 Research framework

Crotty (1998) stated that it is customary for every research project to consider four areas before conducting the research: ontology, epistemology, methodology and method. Ontology is defined (for example by Jupp, 2006) as “a study on the existence of and relationship between different aspects of society, such as social actors, cultural norms and social structures”. Likewise, Bryman and Bell (2003) defined epistemology to be a study on the question of what is (or should be) regarded as acceptable knowledge in a discipline. Methodology refers to the philosophical stance or worldview that underlies and informs a style of research (Jupp, 2006). Finally, method refers to the techniques capable of delivering the objectives of the study (e.g. data collection and analysis). The following sections address these four areas.

2.3.1 Ontological considerations

“What is the nature of reality?” This is the central question of ontology as described by Creswell and Plano Clark (2006). The reality under the study of this research is productivity and, therefore, this question will apply to the current research in the following form.

What is the nature of productivity?

This thesis presents a comprehensive review on the nature of productivity as seen by different researchers. It is discussed in Chapter 3 that the definition adopted as the result of this review is as follows:

“Productivity is the extent to which resources available to a production unit are exploited, so that staff can consistently provide the highest amount of high quality goods/services for the clients”.

This definition is, then, further discussed to describe productivity as a function of service quality, resources and staff morale. Based on this definition, productivity can be seen as a social phenomenon, the meaning of which has an existence that is
independent or separate from social actors. Bryman and Bell (2003) described the study of such a phenomenon to be of an objectivist ontological position.

2.3.2 Epistemological positions
“What is the relationship between researcher and that being researched?” This is the perspective, from which epistemology defines a study (Creswell and Plano Clark, 2006). From this perspective, this research formulates its problems and accomplishes its objectives by the use of both positivism and interpretivism. These two may seem far from each other or even in contrast to each other. Interpretivism, being of the nature of phenomenology, is usually considered at an exact opposite stance to positivism. However, as Hussy and Hussey (1997) argue, between these two ends there is a continuum of ontological and epistemological assumptions; and in practice, research investigations can be placed on this continuum between these two extreme approaches. On this basis, the epistemological positions used to lead this study will comprise the following.

- **Positivism** is “an epistemological position that advocates the application of the methods of the natural sciences to the study of social reality and beyond” (Bryman and Bell, 2003). Positivism is often associated with quantitative approaches (Creswell, 2007).

- **Interpretivism** is a contrasting epistemological position to positivism, which subsumes the views of writers who have been critical of the application of the scientific model to the study of the social world and who have been influenced by different intellectual traditions. It is predicated upon the differences between people and the objects of the nature of science and therefore, requires, the social scientist to grasp the subjective meaning of the social action (Bryman and Bell, 2003). Interpretivists endeavour to describe, interpret, and understand a situation from the perspective of the scientist (Creswell, 2007).

2.3.3 Multi-methodology
Many previous productivity research studies have been conducted in one paradigm either by qualitative or quantitative methodology. It has been widely accepted that the paradigm used will shape the way in which the researcher perceives the world (Jackson, 2003). Although there is a controversy about whether research should be
conducted in a single paradigm or in a specific way of combining different paradigms together, Mingers and Brookesby (1997) argued that no one paradigm could capture the richness of real-world situation. In support of this argument, he further explained that the real-world problem situations are highly complex and multidimensional.

Different paradigms each focus attention on different aspects of the situation, thus adopting only one paradigm is inevitably gaining only a limited view of a particular intervention or research situation. In contrast to one paradigm, multi-methodology, which refers to combining together more than one methodology (in whole or part) within a particular intervention, is deemed to be more effective to deal with the real world situation. This argument makes multi-methodology attractive to this research.

In addition, the reason for using a multi-methodological research design in this research is that it is in line with the context of the current study. As alluded to earlier, this study explores the productivity levels of nursing teams and finds ways to enhance nursing teams’ productivity through different design solutions, such as optimising the routes taken by nurses, in hospital wards. This requires researching three different areas: service quality, resources and staff morale. Thus, only looking at any single aspect, either from minimising resources or maximising the morale, would not have led to a full understanding of the research situations in which the problems are based. It requires using different methods to accomplish the aim and objectives through various stages. In addition, these research stages pose different tasks and problems, as such combining different methods together will provide a comprehensive understanding of the research questions and yield a better result. As a result, a multi-methodological research design is deemed the most suitable research approach to be utilised in the current study; and a mixed-methods research, combining both quantitative and qualitative methods for data analysis in different research stages, is chosen as a suitable design to use in addressing the research questions, which were identified in Chapter 1.

2.3.4 Mixed-methods research and paradigm
Mixed-methods research defined by Creswell (2003) is a research design with philosophical assumptions as well as methods of inquiry research. In other words, this method studies a combination of qualitative and quantitative data where none of the
two sets provides a complete understanding of the problem. Pragmatism is the most commonly used paradigm associated with mixed-methods research (Jupp, 2006). Pragmatism rejects the traditional view which suggests that the paradigms underlying quantitative and qualitative approaches (positivism and constructivism respectively) are essentially incompatible and in conflict (Jupp, 2006). Instead, it focuses on the consequences of research; and on the primary importance of the questions asked rather than multiple methods of data collection to inform the problems under study (Creswell and Plano Clark, 2006; Rossman and Wilson, 1985). Thus, it is pluralistic and oriented toward “what works” and practice (Patton, 1990). Hence, a pragmatic mixed-methods approach is taken to be the most appropriate in this research.

When it comes to the procedure of how to conduct mixed-methods research, three general strategies are addressed in the literature; these being sequential procedures, concurrent procedures, and transformative procedures (Creswell, 2003). The present study follows sequential procedures, whereby the quantitative data collection and analysis is undertaken first, followed by a qualitative data analysis (or vice versa). In line with this principle, this study begins with an exploratory qualitative research with experts in order to explore the role of circulation design in nursing staff productivity; and this is followed by computer-aided analyses with the purpose of examining the extent to which different circulation systems contribute to nurses’ productivity. These will form the basis of recommendations for how circulation system in hospital wards can be enhanced to promote nursing staff productivity in an attempt to identify the potential factors that might nurture productivity in a positive way.

2.4 Research design

Having established the ontological and epistemological perspectives for the research, a research design was devised to ensure that the data collection and analysis were conducted in a logical and structured manner that accomplished the research aim and objectives. Effective research design shows how the research questions are aligned to the relevant data sources and research methods (Jupp, 2006), and as such, the current research design comprised five research phases aligned with the objectives.

In phase one, a comprehensive literature review was needed to establish:
• the definition of hospital staff productivity,
• hospital productivity in the current UK context; and
• different hospital/ward layout systems

This was done through desk studies as well as interviews with healthcare policy makers, planners and designers.

In phase two, a case study was selected and the nursing staff movements during their working shifts were monitored. Typical characteristics of each system were modelled in form of a hypothetical simplified layout design as part of phase three. Using the results of data analysis, a comparison between different layout systems was conducted in phase four based on the criteria derived from the literature review. Results of the data analysis provided the foundation for a set of guidelines for designing access and people circulation for high-productivity hospital wards in phase five.

Obviously this process would be more comprehensive if the experience and feeling of the actual users of the space (i.e. staff and patients) is also considered. This would add to the qualitative validation of the study results but the experience of staff and patients may be influenced by other factors than layout design of the ward. One might have an overall positive or negative experience of a ward as a result of so many different factors regardless of the design of that ward. This study focuses on subjective experience of ward staff (i.e. the physical experience of walking) and their other experiences could be used in the validation phase which is one of the thesis future research suggestions.

Figure 2-1 and Figure 2-2 present the research methodology employed in this study and the connection between different phases of research and the thesis chapters.

2.5 Research ethical considerations

This research needed to comply with the ethical procedures of both Loughborough University and the case study provider. To achieve this, certain ethical concerns had to be raised and given enough consideration before carrying out the research to ensure its credibility. Some of these concerns are discussed below.
2.5.1 Informed consent
All participants, regardless of the degree of their contributions, age or status were fully informed of the purpose and procedure of this research, including the expected duration of interviews and group discussions. No form of deception or coercion was employed in order to gain the co-operation of participants. A well-informed oral
consent was employed and all participants in this study had a clear picture of the subject purpose, as well as their role and position in it, before taking part in the research. Furthermore, they were given a copy of written “Participant Information Sheet” (Appendix B) to read. A summary of findings of this study was also given to those participants who showed interest.

2.5.2 Confidentiality
During the quantitative and qualitative data collection, participants were under no obligation to continue if they felt the urge to withdraw their participation. The information provided by participants was treated in strict confidentiality and the findings were used only for research purposes. In addition, anonymity was granted to all participants.
2.6 Employed methods
A multi-methodological research design was employed in order to deliver richer and fuller meanings for the research questions and achieve the research aim and objectives. In addition, a mixed-methods research, combining both quantitative and qualitative approaches for data collection was developed. The current research design contains different stages in which the research questions are completely explored.

2.6.1 Literature Review
As mentioned above, the ultimate goal of the literature review in this study was to establish the background knowledge in these three fields.

➢ Theories of hospital staff productivity
In order to gain an understanding of the nature and importance of productivity in the context of hospital ward as well as how it is influenced by the ward layout design, a review of the literature on the concept of productivity (and in specific, hospital nurse productivity) was carried out. Also, the evidence on the impact of hospital environment on different indicators of productivity was studied.

➢ Hospital productivity in the current UK context
The literature review explored existing guidance on incorporating productivity in the design of hospital ward by studying different documents published by the NHS and the Department of Health (DH). Also, tools used for evaluating and assessing productivity in hospital designs were studied and some of the procedures intending to improve productivity in hospital wards were reviewed.

➢ Different hospital layout systems
Although different categorising approaches exists to classify hospital designs, a more specific approach needed to be established to address the requirements of this study. In order to achieve this, common examples of today hospitals in the UK were examined and relevant classification of design layouts in regards to circulation systems was concluded.

2.6.2 Case study
Case study analysis forms a major part of the quantitative approaches taken by this research to identify the layout systems most suitable in terms of staff productivity. A
case study investigation suitable for the purpose of this research was carried out on a hospital through a set of data collections and observation of the movements of the nursing staff in the ward. This data was then used to build the archetypal models needed for the comparative study.

➤ **Targets**
To make different categories of circulation systems comparable to each other, all distinctive characteristics of each category had to be integrated in one simplified model. This hypothetical model needed to represent those features of the hospitals in its category that made their access and circulation different from other categories. It also had to eliminate all other factors that were not relevant to the concern of this research (e.g. size of the building, number of staff, management, etc.). Consequently, the selection of a case study was vital to make the design of the hypothetical models possible. The case study would define all characteristics of different hypothetical models such as the number of rooms, beds and staff, but the circulation routes which would be created by the definition of that type of ward would be derived from literature review.

➤ **Process**
The data gathered from the case study were applied equally to all of the representative models. The outputs extracted after data analysis stage were a set of values for factors relevant to staff productivity as defined by the criteria from the literature review.

➤ **Results**
The outputs of the analysis procedure provided a metric to assess the performance of the circulation systems in comparison to each of the criteria introduced for staff productivity. The overall staff productivity of each system is defined by applying appropriate weights to each criterion. The ultimate result of the data analysis process was presented in the form of a ranking of different systems regarding staff productivity.

2.6.3 **Interviews**
A combination of qualitative and quantitative data was achieved by conducting interviews with specialists.
➢ **Targets**
Interviews were mainly targeted at hospital planners, designers and managers and looked into the experiences of each of these groups with staff productivity in different systems of circulation design.

➢ **Process**
Ten interviews were conducted in this research (Appendix A) focusing on the matters around productivity in general and methods to measure and evaluate it and also ways to apply it in hospital design. These included seven short interviews (between 30 minutes to 1 hour) with researchers actively involved in studying issues concerning planning, designing and managing healthcare facilities. One interview was carried out with a member of the NHS’s Productive Ward project who is a clinical improvement facilitator. This interview provided an insight to the issue of staff productivity from a practical point of view. The remaining two interviews focused on how hospitals are planned and designed and how staff productivity ideas could be reflected throughout design process. These interviewees included two architects, a hospital planner and a space analyst with the experience in analysing healthcare facilities.

➢ **Results**
The results of interviews contributed to the research by providing a better understanding of productivity in general and methods to measure and evaluate it, as well as ways to apply it in hospital design. They also influenced the direction of the literature review by providing a set of keywords for further investigation. Some of these keywords that were later studied in Chapters 3 to 5 are presented in Figure 2-3. An analysis of the interviews and lessons learnt from them is presented in Appendix A.

2.6.4 **Developing guidelines for productivity-oriented ward design**
Based on the comparative analysis and the design types studied in the course of the study, guidelines were drawn to improve existing hospitals and to design future hospitals with the view of maximum staff productivity. These guidelines can be beneficial to policy makers, planners, designers, managers and users of hospitals.
2.7 Summary

This chapter outlines the research methodology and research design adopted in the current research. A methodology was formulated along with five phases that derived from the aims and objectives of the study. The current research was discussed to be unique in that it studies nursing staffs’ productivity in three different but interrelated areas (service quality, resources and staff morale). Different research stages required using different methodologies to achieve research propositions. As a result, a multi-methodological research design was utilised in an attempt to provide richer and fuller meanings for the research questions. In addition, a mixed-methods research, combining both quantitative and qualitative approaches for data collection was devised in line with the research aims and objectives. The current research design encompasses different stages in which the research questions are fully explored.
3 Literature review – Hospital nurse productivity
3.1 Introduction

This chapter is the first of three literature review chapters that establish the background knowledge of the study. This chapter presents available literature on:

- productivity and, in particular, hospital nurse productivity; and
- how the design of a hospital can affect its productivity in different ways.

In this chapter, the conceptual relationship between efficiency, effectiveness, performance and productivity is discussed. Then a more focussed section on productivity is presented which leads to a definition for staff productivity in hospitals. Finally, the impacts of the ward design on different indicators of productivity are investigated.

3.2 Efficiency, effectiveness, performance and productivity

When talking about productivity, it is inevitable to touch the definitions of “efficiency”, “effectiveness” and “performance”. This will help to get a better understanding of “productivity” and draw a better picture of how all of these terms are connected to each other.

There is no consensus on the definitions of the above terms. Many different, and sometimes contradictory, definitions have been given for each of them. In many occasions, these terms have been used interchangeably. For example, Tangen (2004) lists fourteen different definitions for productivity, some of which use elements of “value”, “efficiency” or “effectiveness” in calculating productivity. However, it seems that most of these definitions are variations of the classic equation given by Chew (1988) who defined productivity as:

\[ P = \frac{\text{Units of output}}{\text{Units of input}} \]  

Equation 3.1

This defines improving productivity as either offering more output from consumption of same amount of input or consuming a lesser amount of input for production of same amount of output.

When it comes to performance, Equation 3.1 encompasses a much wider range of outputs. In assessing the performance of a unit, factors such as profitability, flexibility, dependability and quality are also considered to be adding to the performance level of
the unit (Tangen, 2004). This gives weight to success and failure indicators in the calculation of the outputs of a system. By this definition, performance gets a broader meaning compared to productivity, at least in regards to the nature of outputs it considers.

Efficiency and effectiveness are two complementing terms that together define performance of a unit from a different perspective. Sink and Tuttle (1989) describe effectiveness in simple words as “doing the right things” and efficiency as “doing things right”. These simple descriptions prove that effectiveness is more concerned about achievements and outputs, while efficiency is more about managing the resources and inputs. This has been reflected in the methods suggested for calculating efficiency and effectiveness (e.g. by Sink and Tuttle, 1989).

The present research considers the rearrangement of the spaces within a hospital ward (in order to reduce the journey distance of the nurses in corridors) to be an effective factor in reducing time as one of the inputs of the caring activities of the nurses. This is seen to also have a positive effect on performance and efficiency of the nursing services through input management. The time saved this way can be utilised for increasing the output of the system, which is to provide care for patients. This means that these rearrangements can also increase the effectiveness of the wards.

3.3 The concept of productivity

Roll and Moran (1984) define productivity as “the extent to which resources available to a system are exploited in order to achieve its goals”. In other words, productivity is the relationship between the output and input of a system. Input generally refers to resources such as labour, capital, energy, materials and time spent by the system. These resources are transformed into outputs, which can be goods or services.

The concept of productivity has been debated in different fields. However, “Regardless of the type of production, economic or political system, the definition of productivity remains the same. Thus, though productivity may mean different things to different people, the basic concept is always the relationship between the quantity and quality of goods or services produced and the quantity of resources used to produce them” (Prokopenko, 1987).
Productivity of a system is, therefore, measured as the ratio between the outputs of the system and its inputs (Lim, 1996). Neither of these two factors is always easy to measure (Eilon et al, 1976; McLaughlin and Coffey, 1990; Lim, 1996; Linna et al, 2010). However, despite all the difficulties, the need for measuring productivity as a comparable, and therefore improvable, metric is generally accepted to be essential to many businesses. Productivity measurements concepts in manufacturing have been introduced decades ago, but in service sector, they are still under research. Biege et al (2011) mentioned that measurement concepts from manufacturing cannot simply be transferred due to the “service peculiarities”.

### 3.3.1 Productivity vs. quality

The above discussion of productivity can be, wrongly, interpreted as “producing more sellable goods or services using less resources”. This interpretation is incorrect and could lead to the belief that any attempt in increasing the quality of the goods or services provided by the system will impose the need for more resources (capital, human resources or time) and, so, reduce the system’s productivity. Therefore, it is essential to realise that simply producing ‘more’ is not enough to guarantee higher productivity and, instead, producing ‘more and better’ is what is expected from a highly productive unit. High quality work will result in better output, fewer rejects, less rework, less wastage, more clients and, hence, higher productivity (Lim, 1996). Thus, quality and productivity complement each other.

It might be thought that quality and productivity are only relevant to production activities and the manufacturing sector. Many case studies of successful companies, however, show that quality and productivity improvement are equally important in other sectors of the economy, such as in finance, service sector and construction (e.g. Triplett and Bosworth, 2000). Later in this chapter, the importance of these factors in healthcare sector will be highlighted.

### 3.3.2 Productivity vs. staff morale

Based on what was discussed above, the image of a highly productive unit might be seen as a unit with a low number of staffs who work harder to meet the management’s demand for more and better goods or services using the cheapest tools and methods, while receiving the minimum income and expecting the lowest level of
comfort and happiness. It is needless to say that this over-exploited, under-paid, under-equipped and unhappy team will be unable to maintain the level of productivity expected from this unit in the long run and will be led to negative adaptation mechanisms, such as absenteeism and quits (Borjas, 1979). Losing trained workers on a permanent basis (through quitting) or a temporary one (through absenteeism) will lead the management to spend more resources to recruit and train new staff, which, in turn, lowers productivity. This introduces a new factor to be considered when speaking about productivity, namely staff morale.

Staff morale (i.e. job satisfaction) has received a great deal of attention from economists and policy makers (Jones et al, 2008). Although studying staff morale and its impact on their attitude towards their job are of a subjective nature and, therefore, not popular in traditional economics, the fact that staff morale is able to predict absenteeism and quits has been echoed in various studies (e.g. Borjas, 1979; Freeman, 1978; Hamermesh, 1977).

The likeliness to quit as a result of low job satisfaction has received more attention from researchers in different countries in recent years, due to access to broader data and more accurate analysis methods. In Germany, for example, Clark et al (1998) used data from ten waves of the German Socio-Economic Panel (1984–93) and found that workers who reported dissatisfaction with their jobs were statistically more likely to quit than those with higher levels of satisfaction. This was, later, confirmed by more quantitative studies, such as those by Shields and Ward (2001), Frijters et al (2004) and Kristensen and Westergård-Nielsen (2004).

Absenteeism has been defined as “unscheduled employee absences from the workplace” (Jones et al, 2009). Employers put a significant amount of effort in reducing absenteeism in order to: maintain the output volumes; prevent unnecessary pressure on some employees; avoid temporary help costs; prevent loss; keep customers satisfied; etc. (Oi, 1962). Absenteeism has also been studied in more detail by the use of new technology in recent years.

Clegg (1983) confirmed that low levels of job satisfaction contributed to higher absenteeism rates, lack of punctuality and a higher propensity to quit. The study by
Drago and Wooden (1992) on 601 workers from four different countries indicated that
closeness and harmony of the employees and job satisfaction can reduce absenteeism.
This was also confirmed by a study by Wegge et al (2007) on 436 employees, where
satisfaction and involvement had great impact on both indicators of absence
behaviour (involuntary and voluntary absence). As noted above, further to the
voluntary reaction of the staff (i.e. withdrawal), involuntary impacts, such as
deterioration of mental and psychological health have also been linked to low job
satisfaction (Faragher et al, 2005).

3.3.3 A definition for productivity
Based on the above discussions, the term ‘productivity’ is re-defined as follows to suit
the extents of this study:

“Productivity is the extent to which resources available to a production unit are
exploited, so that staff can consistently provide the highest amount of high quality
goods/services for the clients”.

It could be argued that the definition given by Roll and Moran (1984) (presented in
Section3.3), in fact, covers the seemingly additional ideas introduced under this re-
definition (namely, high quality and staffs’ consistency), when it mentions “to achieve
[the system’s] goals”. Another argument for rejecting this new definition might be its
inadequacy in explaining productivity in fully-automated systems by giving too much
weight to staffs’ influence. In response to both these criticisms, it is re-affirmed that
this definition is presented with a view on later discussions in this study, which is
limited to human-run healthcare service facilities (please see below).

Founded on this new, more precise definition, productivity can be defined as a
function of these three factors and it is essential to maintain a careful balance
between these three indicators of productivity:

- service quality;
- resources; and
- staff morale

These indicators will be discussed in more detail in Sections 3.4 to 3.7 where they are
applied to nursing staff in hospitals.
3.4 Nursing staff productivity

Productivity, as defined above, can be achieved in hospitals through various approaches, including, but not restricted to: proper training of the staff; public awareness of how to use the facility; enhancing medical procedures and devices; improving management of the hospital in different levels; and finally, the factor that is the focus of this study, the design of the hospital and its circulation systems. Based on Vischer (2003), design factors in a hospital, such as lighting, acoustics, ventilation and thermal comfort, affect ‘individual productivity’ of nursing staff, whereas spatial and furniture layout influences ‘team productivity’ of nurses. Based on the definition presented in Section 3.3.3, the level of productivity in a ward, as a production unit, is a function of these three factors:

- its success in delivering its intended services (service quality);
- staffs’ dedication to delivering the service (staff morale); and
• the effectiveness of spent funds, workforce, energy, materials and time (resources).

In this section, a review of the effects of ward design on each of these three factors is presented.

3.5 Impact of ward design on service quality

World Health Organization (WHO) states in its Vision that “Health is a state of optimal physical, mental and social wellbeing and not only the absence of disease” (Dilani, 2007). The main service expected from a hospital ward is, therefore, to provide suitable care for the patients, in order to accelerate their process of healing. This covers a broad range of provisions from facilitating visits and treatments by medical staff to providing for daily needs of a patient and from welcoming patients’ friends and family to preventing the spread of infections. These are all affected by different aspects of design, such as space size, proportion, clear circulation, natural light, views, materials and connections.

Reviews, such as the one presented by Devlin and Arneill (2003), indicate that patients consider the design of their hospitals and wards to influence the speed of their recovery, effectiveness of their treatment, level of their stress and their sense of ‘wellness’. Other design-related issues considered important by patients are air quality, way-finding, natural light, temperature, materials and colours, landscaping and artworks (Devlin and Arneill, 2003).

3.5.1 Cross infections

There are no accurate statistics of the number of patients who acquire an infection in hospitals in the UK and of those dying from such infection. A report produced by The House of Commons in 2005 estimates the yearly number of hospital acquired infections to be more than 300,000 with around 9% of patient at any one time being affected by them (House of Commons, 2005). The same report suggests that hospital acquired infections are responsible for around 5000 deaths and £1 billion extra NHS cost per year. Patients with one or more infections remain an average of 11 extra days in hospital and incur costs that are on average 2.8 times greater than uninfected patients (House of Commons, 2005).
The above data show that controlling hospital acquired infections speeds up the process of healing of patients and reduces healthcare costs and eventually, improves the productivity of the healthcare unit.

Two of the most commonly discussed layout-related issues in regards to controlling cross-infection in hospital are bed spacing and number of beds in each room. There are different guidelines for the spacing of beds in a hospital ward. Health Facilities Note 30 (HFN 30): Infection control in built environment (NHS Estates, 2002) suggests that bed centres should be at least 3.6 m apart. This number may seem too generous considering that usually beds in hospital wards are spaced at a distance of 2.5 m to 2.7 m. But from an infection control point of view it is logical that good space to work and sufficient space for apparatus will reduce infection risk (House of Commons, 2005). For the number of beds in a room, HFN 30 recommends a maximum of 4 beds in a bay to reduce cross-infections and facilitate cohort nursing. Also, at least 50% of all beds in new hospitals should be in single bed occupancy (NHS Estates, 2002, Dowdeswell et al, 2004 and Maben et al, 2012).

3.5.2 Medical errors
“Each year, about 850,000 patients in England are harmed, or nearly harmed, by their hospital care” (Donaldson, 2005). Ulrich et al (2008) listed events such as physical error made during surgical procedure, incorrect diagnosis and medication error under the term ‘medical errors’. Many factors could contribute to medical errors. Some of the factors that are related to design include noise, lack of space, poor lighting and other design failures. Phiri (2006) suggests that in order to prevent medical errors, it is more important to focus on the design of work processes and work spaces rather than human errors by staff.

There are a large number of studies on the negative impact of noise, especially loud and unpredictable noise, on people’s attention and performance, in particular when tasks are more complicated (Leather et al, 2003). Many studies in non-healthcare settings have demonstrated that performance and errors can be affected by lighting level (Ulrich et al, 2008). Such poor performance in a healthcare setting may lead to medical errors. For example, a large-scale study in pharmacies (Buchanan et al, 1991)
proved that medication dispensing error rates can be reduced by 2.6% as a result of sufficient lighting on work surfaces.

Many medical errors happen during the transfer of patients between rooms or units (Cook et al, 2000; Ulrich and Zhu, 2007). Some of the reasons for these errors are delays, communication discontinuities among staff, loss of information and differences in computers or systems (Ulrich et al, 2008). A case study in Indiana, US demonstrated that using acuity-adaptable rooms could reduce transfers by 90% and medication error by 67% (Hendric et al, 2004). Even single patient rooms that are not acuity adaptable, provide better staff communication and less patient transfer and therefore fewer medical errors (Chaudhury et al, 2006).

### 3.5.3 Patient physical wellbeing

#### Patient falls
The National Patient Safety Agency has reported over 200,000 fall incidents in hospitals per year, of which over 500 have ended up in hip fractures and 26 in deaths (NPSA, 2007). Even less serious cases of fall can have consequences such as distress, loss of confidence, pain and loss of independence. These incidences can also cause feelings of anxiety and guilt for the patients’ relatives and hospital staff. It can also mean additional cost for the NHS for extra treatment, increased length of stay and legal procedures (NPSA, 2007).

Reports show that most patient falls occur in the bedroom, followed by the bathroom (Chang et al, 2004). This has been associated with design shortcomings such as slippery floors, inappropriate door openings, poor placement of rails and accessories and inappropriate heights of toilets and furniture (Brandis, 1999). One of the solutions suggested by case studies was providing space for the presence of families and making them available to help patients or call for aid when needed. This reduced number of fall incidences by about 70% (Hendrich et al, 2004).

#### Patient pain
According to distraction theory, pain requires considerable conscious attention and if patients become diverted by or engrossed in a pleasant distraction, they have less attention to direct to their pain and this will reduce the feeling of pain. The theory
predicts that the more engrossing an environmental distractions, the greater the pain reduction (McCaul and Malott, 1984). Based on this theory, many studies have shown that viewing nature may decrease pain by encouraging positive emotions, reducing stress and distracting patients from focusing on their pain. (e.g. Malenbaum et al, 2008; Ulrich et al, 2006; Ulrich, 2008; Tse et al, 2002; Lee et al, 2004).

Another approach for pain reduction is to increase level of serotonin, neurotransmitter known to inhibit pain pass ways, one way to increase serotonin level in body is presumed to be exposure to day light (Ulrich et al, 2008). This is supported by the results of case studies such as the one conducted by research team directed by Walch (2005).

**Patient sleep**

There is enough evidence to support that sufficient sleep is needed to maintain and also recover general health. Study shows that adequate rest period for uninterrupted sleep is needed for healing wounds and rebuilding damaged tissues (Adam and Oswald 1984). Sleep quality (i.e. the type and depth of sleep, the distribution over 24 hours, and other sleep architectural parameters) is as important as its quantity (i.e. total sleep time) (Parthasarathy and Tobin, 2004). Fragmentation and poor sleep architecture are two of the factors that can negatively affect sleep quality (Arup, 2009). Sleep disruption and the deprivation are very common problems in healthcare settings, especially for high acuity patients who are more sensitive to unpleasant environmental condition (BaHammam, 2006). Two major environmental factors that need to be controlled to allow a deeper and more restorative sleep are noise and light.

In some studies environmental noise has been reported to be the main sleep disturbing factor for 58% of patients (Ugras and Oztekin, 2007). Other studies emphasise on the role of lighting as an important environmental factor affecting sleep pattern (e.g. Higgins et al, 2007).

**3.5.4 Patient mental and social wellbeing**

**Patient stress**

Patient stress is a negative outcome in itself. It also has an adverse effect on many other outcomes. Many detrimental sociological, physiological, neuroendocrine and
behavioural changes have been associated with stress (Gatche et al, 1989; Ulrich, 1991). For example, Kiecolt-Glaser and others have shown that stress can increase levels of cortisol (a natural steroid), release stress hormones that tax the heart and other major organs and suppress immune system functioning (Kiecolt-Glaser et al, 1987). These will decrease resistance to infection and worsen recovery outcome such as wound healing (Cohen et al, 1991; Kiecolt-Glaser et al, 1987).

Noise is one of the known factors that elevates psychological and physical stress in patients as indicated by negative feeling such as anxiety and annoyance (Synder-Ahlpern, 1985). And detrimental physiological changes such as elevated heart rate and blood pressure (Morrison et al, 2003). The most important design measure to reduce noise in hospital ward appears to be single bedrooms (Gabor et al, 2003). A study across 1462 healthcare facilities showed that satisfaction with noise level was on average 11.2 % higher for patients in single bedroom than for those in multi bedrooms (Press Ganey Inc., 2003). Another approach for reducing noise levels is to eliminate noise sources and insulate noisy equipment (Blomkvist et al, 2005).

Many studies emphasise on stress-reducing benefits of viewing nature by increasing positive feeling such as pleasantness and calm and diminishing negative emotions such as anxiety and anger (Van den Berg et al, 2003; Ulrich, 1991; Ulrich, 1979; Hartig et al, 1995). There is also convincing evidence that looking at built environments that lack nature (e.g. car parks, roof tops and rooms) may worsen stress and reduce the rate of restoration in patients (Van den Berg et al, 2003; Ulrich, 1991).

**Patient depression**

Depression is a serious, widespread and costly problem in healthcare facilities (Ulrich et al, 2008). There is significant evidence to believe that exposure to daylight and also bright artificial light reduces depression. A major study in United State concluded that light treatment for depression is as effective as most antidepressant medicines. Additionally, light exposure can treat depression 2 to 4 weeks faster than antidepressant drugs (Golden et al, 2005). Other studies in Canada (Beauchemin and Hays, 1996) and Italy (Benedetti et al, 2001) suggest a reduction of 2 to 4 days in the stay time of those patients who were assigned to sunny rooms.
Patient privacy and confidentiality

In addition to legal aspects of patient privacy and confidentiality, research has shown that inadequate privacy may cause patients to withhold personal information or refused to be examined (Barlas et al, 2001). This will obviously lower patient satisfaction and worsen healthcare outcomes. Research has made different suggestions for what designers can do to protect patient’s speech privacy and visual privacy. Some of these suggestions are the provision of single bedrooms (Press Ganey, 2003), installing hard-wall partitions rather than curtains (Karro et al, 2005), installing high-performance sound-absorbing ceiling tiles (Hagerman et al, 2005) and providing private discussion rooms near waiting, admission and reception areas (Joseph and Ulrich, 2007).

Patient satisfaction

Telephone interviews with 380 discharged inpatients determined that environmental satisfaction had a big effect on the overall satisfaction of patients ranking only below quality of nursing and clinical care (Harris et al, 2002). Some of the environmental factors that patients found most effective in their satisfaction were as follows (Harris et al, 2002):

1. colour of the wall, artwork, comfortable bed, television working properly and easy access to anything in the patient room;
2. a window with a nice view and accessible bathroom in the room and a room located away from noisier areas of the unit;
3. adequate lighting, quiet surroundings and a comfortable temperature;
4. a private room, environmental means for privacy (e.g. a closed door) ; and
5. cleanliness of the room.

There are also eight environmental factors that have been addressed as significant in achieving family members’ satisfaction (Verhaeghe et al, 2005):

1. have a waiting room near the patient;
2. see the patient frequently;
3. bathroom near the waiting room;
4. have comfortable furniture in the waiting room;
5. have friends nearby for support;
6. have a telephone near the waiting room;
7. have a place to be alone while in the hospital; and
8. provide the ability to be alone at any time.

3.5.5 Way finding
Way finding problems in hospitals are costly and stressful and have a particular impact on outpatients and visitors who are often unfamiliar with the hospital and are otherwise stressed and disoriented. One study suggests that direction-giving by people other than information staff occupy more than 4,500 staff hours, the equivalent of more than two full-time positions (Zimring, 1990). One of the most important components of a well-integrated way finding system is the characteristic of the overall structure of the system of rooms and corridors that affect the path people take (Haq and Zimring, 2003). Different studies (e.g. Werner and Schindler, 2004; Ruddle and Peruch, 2004) show that corridor junctions with perpendicular intersections make way finding significantly easier in comparison with those with angled intersection.

While there are several studies that look at way finding in hospitals (e.g. Baskaya et al, 2004; Schneider and Taylor, 1999; Brown et al, 1997), it is quite difficult to isolate the independent role of a single design factor on way finding performance.

3.6 Impact of ward design on staff morale
One of the first quantitative studies in this field, which was prompted by concerns about recruitment and retention difficulties in the public health, was the study by Shields and Ward (2001). They established the link between job satisfaction and nurses’ intention to quit the National Health Service (NHS) and found that job dissatisfaction may increase the probability of quitting by 65%.

Moxam (2003) states that for staff, the top four elements identified as “very important” in their physical environment are: air quality, noise/quiet, temperature and a tie
between natural light and amount of space. Staff also rate personal controls over light and temperature, and window views, as highly important.

3.6.1 Staff stress
There is considerable evidence on the negative effects of stress on healthcare workers (e.g. Tummers et al, 2001; Barrett and Yates, 2002; Hader et al, 2006; Harris et al, 2006; Corr, 2000; Fischer et al, 2000a; Fischer et al, 2000b; Le Blanc et al, 2001; Sexton et al, 2000; Smith et al, 2001). However, relatively few studies have examined how the physical environment contributes to staff stress. A review paper by Corr (2000) identified the physical healthcare environment as one of the causes of occupational stress. Two of the factors that are believed to affect the stress level of staff in healthcare settings are noise and light. Many studies have examined the effect of noise on patients in hospitals. But few studies have focused on its impact on healthcare staff. It has been established that staff perceive higher sound levels as stressful and interfering with the work (e.g. Bayo et al, 1995). In another study in Sweden, nurses perceived significantly lower work demands and reported less pressure and strain when the sound-reflecting ceiling tiles in their work place were replaced by sound absorbing ones (Blomkvist et al, 2005). Single patient rooms are also perceived to be less stressful for staff because of the possibility of noise control (Harris et al, 2006).

Research has shown that light significantly alleviated the subjective distress associated with night shift work (Leppamaki et al, 2003). Another study found that staff with more than three hours of day light exposure during their shift had less stress than staff with less day light exposure (Alimoglu and Donmez, 2005). More research is needed to understand the impact of natural light on staff stress.

3.6.2 Staff satisfaction
Lack of support from the physical environment can make already stressful working condition worse. However, not many studies have examined the effects of environmental factors on job satisfaction. Most of the research in this field has focused on natural light and how it affects staff’s job satisfaction. Research shows that natural light in healthcare facilities has the most positive environmental impact on work life of hospital staff (Mrockzek et al, 2005). This was confirmed by the study conducted by Alimoglu and Donmez (2005).
3.7 Impact of ward design on resources

Apart from the obvious resources affected by the design of a ward, which are their different build and maintenance costs and materials, the utilisation of a number of other resources of a ward can also be affected by its design. One of these resources is time. The design of a ward can facilitate the activities of a ward in a way that some routine services are performed more efficiently and quickly, for example, by shortening the walking distance between areas in a ward that are used frequently by the staff. This will free some of the staff time to provide better care to a larger number of patients and prevent their exhaustion. In this way, this design strategy will also reduce the utilisation of another very important resource, which is labour.

3.7.1 Patient transfers

The transfer of patients between rooms or units can be a source of medical errors (Hendrich et al, 2004), patient injuries (Brandis, 1999) and Staff injuries (Engst et al, 2005; Garg and Owen, 1992; Ronald et al, 2002). The time spent by nursing staff on transferring patients can also be used for providing direct care and treatment. This means that staff effectiveness is also affected by the amount of patient transfer in a hospital (Hendrich et al, 2004). A possible solution, as mentioned before, is to create an acuity-adaptable care process and to provide patient rooms that substantially reduce transfers by up to 90 % (Hendrich et al, 2004). Single-patient rooms, also provide less patient transfer as compared to multi bed patient room (Chaudhury et al, 2006).

3.7.2 Length of patient stay

Studies that focus on the effect of physical environment of hospitals on patients’ length of stay are relatively limited. Among them, studies on lighting and nature views have consistently identified a positive impact from both. Research shows that patients in sunny rooms have shorter lengths of stay than patients in dull rooms, with a more significant difference for female patients (Beauchemin and Hays, 1998). Another nationwide study in the US show that medical centres located in warmer and drier climates had shorter lengths of stay and those in colder climates had the longest lengths of stay in winter and autumn (Federman et al, 2000). There is a strong body of research on the beneficial impact of exposure to nature views (real nature or
simulated nature, such as pictures, videos or virtual reality) in improving patient outcomes including length of stay (e.g. Diette et al, 2003; Tse et al, 2002; Ulrich, 1991). One study concluded that patients had a shorter stay if they had a bedside window view of nature rather than looking out on to a brick wall (Ulrich, 1984).

3.7.3 Staff injuries
A report in 1992 showed that back injuries among nurses cost NHS £120 million per year in staff sickness, absences and wasted training of those forced to leave their jobs as a result (Jones, 1992). Same report mentions that research by nursing organisations suggests that about 80,000 nurses a year require time off work after patient lifting accidents and a further 3,600 nurses leave the profession because of the permanent damage caused. Another survey in the United States estimated that up to 38% of all nurses in the country suffer from back injuries. Most of these injuries are caused or aggravated by patient handling. However, it is encouraging that many studies have documented reductions in staff back injuries following the installation of assistive devices and improved procedures or room design (e.g. Hignett and Evans, 2006; Miller et al, 2006; Chhokar et al, 2005; Engst et al, 2005). For example, using ceiling-mounted or mobile lifts may help to reduce back injuries (Hignett and Evans, 2006; Keir and MacDonell, 2003).

3.7.4 Staff work flow
Research on aligning workplace design with work patterns has shown that such alignment can improve work flow and reduce waiting time (Pierce et al, 1990). According to one study of nursing staff, walking accounted for 28.9% of work time and was ranked second among various activities, following patient care activity that accounted for 56.9% of work time. Another study in the UK determined that caregivers spend 49% of their time in corridors (Dillani, 2010). There are also studies that show that the type of unit layout (e.g. Radial, Single Corridor, Double Corridor) influences the amount of walking among nursing staff (e.g. Sturdavant, 1960; Trites et al, 1970; Shepley, 2002 and Shepley and Davies, 2003). Sturdavant (1960) concluded that in units with a radial configuration, staff had to make fewer trips to attend patients as a result of direct view to patient rooms. Shepley and Davies (2003) established that the amount of staff’s walking in a unit shows a correlation with the layout of the unit. In
their study, they determined that nursing staff in a radial unit may need to walk up to 40% less than those in a rectangular unit. In addition, the majority of the staff surveyed preferred to work in radial units.

Some studies showed that decentralised nurse stations reduced staff’s walking time and increased patient care time, especially when supplies were also decentralised and placed near the nurse stations (e.g. Hendrich, 2003).

By shifting over to an acuity adaptable model, one study show a reduction in the number of patient transfers by 90% and thereby reduced the amount of nursing time spent on this (non-value) activity (Hendrich et al, 2004).

3.8 Summary

Clearly there are many different factors affecting the productivity of a hospital. One of these factors is the productivity of the staff and particularly nursing staff team. It is conceivable to emphasis on all aspects of nursing team productivity in the scope of this research and therefore the main focus of this thesis is on the impact of nurse movement on the productivity of the nursing team and consequently the productivity of the hospital.

This chapter presented a review on the definition of productivity and its importance in general as well as in hospital wards. The factors affecting productivity were studied from different viewpoints and the literature on the existing research in the field of nursing staff productivity was reviewed. The review presented in this chapter demonstrated that many factors (e.g., patient wellbeing, staff morale, etc.) affect productivity and all these factors are, in turn, influenced by the architectural design of the hospital. The following chapter will discuss how productivity factors are reflected by approaches towards hospital design.
4 Literature review - Hospital productivity in the current UK context
4.1 Introduction

The goal of this chapter is to review some of nationally recognised design, operational audit and strategic guidance and planning tools related to people circulation in order to gain specific background knowledge on the hospital productivity in the present UK setting. For this reason, design guidance and design tools, including Activity DataBase (ADB), AEDET Evolution, British Standards and British Standards Codes of Practice, Health Technical Memoranda (HTMs), Health Building Notes (HBNs), Health Facility Notes (HFNs) were reviewed. Furthermore, some of the hospital productivity assessment tools, including NHS Environmental Assessment Tool (NEAT), Patient Environment Action Team (PEAT), Patent-Led Assessment of Care Environment (PLACE) and Premises Assurance Model (PAM) are briefly introduced. Lastly, some quality assurance tool/programmes (LEAN and The Productive Series Programme) were studied to gather some contextual understanding in this area.

4.2 Incorporating productivity in hospital design

This section reviews the expectations from the design of a state-of-the-art hospital in today’s UK best practice. These are the targets required from the design of a hospital in briefing stage. Official organisations dealing with setting design criteria for UK hospitals are the Centre for Healthcare design in the Department of Health (DH) and NHS Estates and Facilities. Together, these two organisations have set standards, guidelines and suggestions for best practice in hospital design. The following documents are sources of standards for design and construction that are introduced by DH and NHS Estates to be considered when drawing up the architectural output specification of a hospital (from DH and NHS Estates, 2004).

4.2.1 Activity DataBase (ADB)

ADB is the Department of Health’s briefing and design tool used to develop healthcare environments. It provides room data sheets and graphical room layouts, produced from Department of Health (DH) datasets - derived from Health Building Notes (HBNs) and Health Technical Memoranda (HTMs), and reflecting DH baseline standards. It has been estimated that ADB is used on over 90% of healthcare construction projects (Autodesk, 2010b). ADB interfaces with AutoCAD products and is used by architects to develop BIM models, or traditional floor layouts. ADB users can create their own
project-specific briefs and design using the library of rooms and departments provided in the data sets. These include clinical and non-clinical spaces. A text and graphics library that includes 2D and 3D drawings is held in the same database. Macros and add-ons provide additional functionality such as specialised reports, 3D rendered drawings for visualisation, and use of ADB with AutoCAD Revit and Autodesk Architecture.

ADB data is structured into departments that correspond to the Health Building Notes. Each department displays a list of rooms required for that service area. New projects are created either by copying whole departments or selected rooms and editing these to match their specific requirements. Users can search, preview and insert rooms to match their schedules. Departments and rooms can be copied into the user’s project and are then completely self-contained. Any changes made will not affect any other project. A datasheet for each room provides information detailing the following (Space for Health, 2013).

- the activities, recommended size, personnel and planning relationships;
- the engineering requirements, for example: room temperatures, safe hot water temperatures;
- architectural finishes required;
- a schedule of equipment; and
- a graphical room layout.

The ADB room layouts are available in AutoCAD, Autodesk Architecture and Revit formats. They are easily inserted into bespoke floor plans and may be manipulated to fit the bespoke areas. Component scheduling and updates made to drawings (e.g. exact floor areas) are reflected in the room data sheets when changes are saved.

ADB, as the only source of DH-approved best-practice briefing and design data, is continuously updated by the Department of Health to align it with the latest standards and guidance in Health Building Notes and Health Technical Memoranda (ADS, 2011). ADB applies some of the practice-based concepts of reducing walking distances inside hospital rooms. However, the application of the increasing amount of evidence-based
concepts of productivity improvement within rooms or in the corridors is not a point of emphasis in ADB.

4.2.2 Achieving Excellence in Design Evaluation Toolkit (AEDET) and AEDET Evolution
To support achieving and monitoring high design quality, NHS Estates have produced a design appraisal procedure (AEDET) that will provide the basis of an appraisal of the design of a hospital. “Healthcare building design frequently involves complex concepts, which are difficult to measure and evaluate” (DH Estates and Facilities, 2008). AEDET has been designed to enable the user to evaluate the quality of design in healthcare buildings. It provides a set of criteria for evaluating the points of strength and weakness in the design of a healthcare building.

The newest version of AEDET is known as AEDET Evolution. It is a toolkit that forms the key agenda for design reviews and is being used as a benchmarking tool. The toolkit uses ten criteria – grouped into three main categories – to evaluate individual designs. The three main categories of the criteria introduced by AEDET are Impact, Build quality and Functionality. Impact criteria cover aspects such as character and innovation, form and material, staff and patient environment and urban and social integration. Build quality, on the other hand, consists of criteria like (technical) performance, engineering and construction. Out of these two categories, only the impact category of “staff and patient environment” (Section C in AEDET Evolution tool) is more directly relevant to the issues concerning productivity.

The interest of this research also lies in the criteria category of Functionality. Functionality criteria are themselves divided into three Sections (Sections H, I and J in AEDET Evolution tool). These sections deal with all those issues to do with the primary purpose or function of the building. This category helps assessing how well the building serves these primary purposes and the extent to which it facilitates or inhibits the activities of the people who carry out the functions inside and around the building.

4.2.3 British Standards and British Standard Codes of Practice
British Standards and British Standard Code of Practice represent best practice in many different areas. Since these cover a very extensive range of documents, only some of which are directly applicable to a project, and which contain inconsistencies and
contradictions, they are not always mandatory and sometimes are simply treated as
guidance. Early guidance for the arrangement of spaces in a hospital go back to the
1960s (e.g. PD 6432-2, BS 4330), which are now either withdrawn or superseded. More
recent standard guidance, such as BIP 2073 and BS EN ISO 22870 have made
recommendations on improving patient care quality. No direct standard specific to the
productivity of nursing staff has been issued.

4.2.4 Health Technical Memoranda (HTMs)
HTMs give comprehensive advice and guidance on building and engineering
technology used in the delivery of healthcare. They include Firecode (DH, 2006), which
sets standards for the layout, design, construction and fire safety management of
hospitals and other healthcare premises. Other HTMs include guidelines for
decontamination (DH, 2009), protection and energy efficiency and sustainability (DH et
al, 2006). This series of DH publications has a rather technical nature and does not deal
with issues such as productivity management.

4.2.5 Health Building Notes (HBNs)
Health Building Notes are a series of advice on implementing Department of Health’s
policies in the briefing and design of healthcare buildings. They are supplemented by
Health Guidance Notes (HGNs), which highlight new legislation and respond to
changes in departmental policy or reflect changing NHS operational requirements.
These provide detailed ergonomic data and specify critical dimensions for the efficient
functioning of activities such as isolation (DH and NHS estates, 2005), pathology
services (DH and NHS Estates, 2005b) and mortuary services (NHS Estates and DH,
2005).

“Health Building Note 04-01: Adult in-patient facilities” (Department of Health, 2008)
offers some perspective on different methods of designing an in-patient ward. It
makes some recommendations for designing a better ward without focusing on the
evidence behind such recommendations. One of these recommendations is to
“minimise the distance between patient rooms and staff workstations and the
distances between all patient rooms”. However, this is mainly from an anecdotal point
of view rather than relating to the subject of productivity.
4.2.6 **Health Facility Notes (HFNs)**

Health Facility Notes contain no formal policy input from the Department of Health, but they do provide guidance on certain key issues. An example is the HFN ‘Design against crime: a strategic approach to hospital planning’, which deals with the impact of space on crime and security and how design can be used in the prevention of crime. The HFN series has been discontinued since 2004 and individual titles have been subsumed under their relevant sections in the NHS catalogue.

4.2.7 **Other NHS Estates guidance**

Health notices produced by NHS Estates relating to hazards and safety have been drafted as a result of experience in the field. The Patients’ Charter also establishes minimum standards to be achieved in specific areas, including the provision of single-sex wards, privacy and access for the physically impaired.

4.3 **Hospital productivity assessment**

In this section, a number of hospital operational audit tools developed by NHS and DH for quality control purposes are briefly presented. NHS Environment Assessment Tool, Patient Environment Action Team, Patient-Led Assessment of Care Environment and Premises Assurance Model are tools that are introduced in this section and their relevance to the concept of productivity is discussed.

4.3.1 **NHS Environmental Assessment Tool (NEAT)**

To support the Government’s policy of tackling pollution and improving the environment and help the NHS deliver its targets, NHS Estates have produced an NHS Environmental Assessment Tool ("NEAT") that provides a holistic approach to the environmental assessment for the NHS.

4.3.2 **Patient Environmental Action Team (PEAT)**

“The Patient Environment Action Team (PEAT) programme is a self-assessment of a range of non-clinical services which contribute to the environment in which healthcare is delivered in both the NHS and Independent healthcare sectors within England” (Square et al, 2012). PEAT assesses inpatient healthcare sites in England with more than ten beds (NHS, 2011) and its focus is on patient environment, food, cleanliness, infection control, privacy and dignity.
4.3.3 Patient-Led Assessments of Care Environment (PLACE)

PLACE is a new operational audit tool for evaluating the excellence of the hospital environment, which substituted PEAT reviews from April 2013. PLACE assessments appeal to all hospitals transporting NHS-funded care. PLACE’s goal is to replicate patient’s views on privacy, dignity, cleanliness, food and general building maintenance concerns through annual assessments (HSCIC, 2013).

4.3.4 Premises Assurance Model (PAM)

PAM is the NHS’s operational audit tool, which intends to offer assurance and a nationally consistent approach for assessing NHS premises performance (DH and NHS, 2013). “The NHS Premises Assurance Model provides individual NHS organisations with a way of measuring how well they run their estate” (DH and NHS, 2013) as well as permitting the NHS bodies to better comprehend the efficiency, effectiveness and safety that are essential to run the estate and how it relates to patient experience (DH and NHS, 2013).

4.4 Improving hospital productivity

Healthcare buildings and particularly hospitals are one of the most expensive buildings to build. Consequently, the level of efficiency and excellence of the system performance in such buildings has more value and importance. LEAN and The Productive Series are two of the quality assurance tools/programmes more frequently used for improving productivity in healthcare sector. These tools are discussed in the following sections.

4.4.1 Lean

The concept of Lean thinking began to appear once the times of traditional craftwork was over and industrial revolution occurred (Bollbach, 2012). The focus of LEAN is value. It seeks to eliminate all non-value adding components and processes at the same time as improving those that enhance value (Constructing Excellence, 2006). LEAN is a tool that although was born in manufacturing sector, could be effectively applied in several other fields such as construction, accounting, management and services (e.g. healthcare). Although health care differs in many ways from manufacturing, LEAN principles are being successfully applied for transforming health
care services and have a positive impact on productivity, cost, quality, and timely delivery of services (Miller, 2005).

4.4.2 Productive Ward - Releasing Time to Care
Productive Ward - Releasing Time to Care is a programme developed by NHS Institute for Innovation and Improvement as part of a greater programme called “The Productive Series”. This programme follows the ideas presented by the Friesen system of nursing units (1970s) in which the nursing and non-nursing functions previously centred at the nursing station are separated and direct nursing duties are transferred to the patients’ room while centralising non-nursing duties. In the Friesen nursing units studied, nursing time spent outside patient rooms is reduced by 38% compared to the traditional nursing units; registered nurses walked 32% less while nursing assistants 52% less (James and Tatton-Brown, 1986).

The other subdivisions of this programme’s agenda are: The Productive Mental Health Ward, The Productive Community Hospital, The Productive Leader, The Productive Operation Theatre, Productive Community Services and Productive General Practise. Productive Ward is essentially a quality improvement initiative (Scottish Government, 2010) that focuses on improving ward processes and environments to assist nurses devote more time on patient care, lessen staff absence, decrease the length of patient stay and reduce waste (NHS, 2013).

4.5 Summary
Phiri et al (2011) state that “from the earliest periods of architecture and building, actions by designers and builders have been heavily influenced by rules, regulations, standards, and governance practices. What’s new is the rising expectations of the role of the physical environment in improving the quality and safety of care” (Phiri et al, 2011). The literature review in Chapter 3 established a refined definition for hospital productivity suitable for the purpose of the research. In this chapter, the aim was to revise a number of national design, operational audit and strategic planning tools related to people circulation in order to gain specific background knowledge on the hospital productivity in the present UK setting. The review comprised three groups of guidance and audit tools for: incorporating productivity in hospital designs; hospital
productivity assessment; and improving hospital productivity. This review provided a conceptual knowledge on the available hospital design targets as well as NHS and DH developed strategies in relevance to productivity.
5 Literature review - Approaches towards hospital ward design
5.1 Introduction
The aim of this chapter is to identify different types of hospital layout design and review the exemplar practices. This will shape the basis of the selection of layout types in regards to access and circulation systems. Hospitals are normally large buildings and this means that deciding on the scale of the units of analysis is very important. If a hospital is studied in its entirety, the study will be limited to the general and overall layout of the building and its circulation systems. This will lead to overlooking the many issues that may exist in smaller scales within the units. On the other hand, a too focused study, which deals with individual rooms or spaces, can mean ignoring important aspects such as adjacencies and people flow.

Therefore, it is a reasonable choice to focus the study on a more intermediate scale to allow for conclusions that will cover the biggest part of the circulation issues. The ward seems to be a more appropriate scale here, because apart from being from that intermediate scale, it also accommodates majority of the active time of most of the medical staff.

For this reason, the main focus of this part of the literature review will be on determining different approaches in designing wards in the past as well as more recent trends in healthcare provision. A combination of the lessons learned from the design evolutions to date and the foreseeable needs of the populace in the near future builds a foundation for finding the right direction for future design of the wards.

5.2 Typology of hospital ward designs

5.2.1 Introduction
Different wards have different layout requirements, spaces, and adjacencies and so on and, therefore, according to these requirements, the circulation system will form the layout of the ward. The type of ward layout is formulated by the arrangement of patient space, nurse base and staff support space (Alalouch, 2009). James and Tatton-Brown (1986) classified the ward types into seven types: Open/Nightingale design, Corridor/Continental design, Duplex/Nuffield design, Racetrack/Double Corridor design, Courtyard design, Cruciform/Cluster and the Radial design. Health Building Note 04 (NHS Estates, 1997) also provides a list of different hospital wards in the UK as
follows: Nightingale ward; Sub-divided ward (early 20\textsuperscript{th} century and post war); Nuffield ward; Falkirk ward; and Nucleus ward (a pair of 24-bed ward, a six-bed room and a single-bed room ward). Another classification of ward types by Bobrow and Thomas (2000) presents Double-Loaded, Race Track, Compact Circle, Cross Shape, Compact Square and Compact Triangle as the main categories of ward layout design. In this study, a combination of these three classifications is used in order to cover a more comprehensive variety of different ward layout designs.

In the following sub-sections (from Section 5.2.2 to Section 5.2.11), 10 different hospital wards are introduced based on a chronological rearrangement of the classifications given by James and Tatton-Brown (1986) and NHS Health Building Note 04 (NHS Estates, 1997). At least, one example is presented in order to investigate the practical application of the ideas of each layout type.

5.2.2 Open/ Nightingale ward
The Nightingale ward (Figure 5-1) or Long-nave ward (as called by NHS Estates, 1997) is a type of hospital ward, which contains “one large room without subdivisions for patient occupancy” (Pattison et al, 1996). It was developed at the end of 1870s and was named after Florence Nightingale. It may have side rooms for utilities and perhaps one or two side rooms that can be used for patient occupancy when patient isolation or patient privacy is important (Pattison et al, 1996). According to Pattison, Nightingale wards contain Open bed base for approximately 30 beds usually arranged along the sides of the ward. Observation of the patients by the nursing staff tends to be easier in a Nightingale ward than in bays. According to HBN 04 (NHS Estates, 1997), men and women were cared for in separate wards.

Figure 5-1 Nightingale ward, St. Thomas Hospital, London (James and Tatton-Brown, 1986)
5.2.3 Corridor/ Continental

The initiation of this ward type coincided with Florence Nightingale’s return from the Crimean war, which influenced the design of new hospitals by ensuring that the ward environment had high ceilings and was big and airy in order to help patients feel better (Guy’s and St Thomas’, 2010). However, patients preferred being nursed in a bay rather than in a Nightingale ward (Pattison et al, 1996). To consider this concern, in the Corridor (Continental) design, patients are located in rooms with four to six beds per room (Figure 5-2). The Corridor design may be in a “T”, “C”, or “L” shape. (Catrambone et al, 2009).

Figure 5-2 St. Thomas Hospital, London (James and Tatton-Brown, 1986)

5.2.4 Radial ward

In the Radial design (Figure 5-3 and 5-4), the nurse station is positioned at the centre of a circular open space, around which all other spaces of the ward are situated. This permits a “fishbowl” view of each room from the nurses’ station (Catrambone et al, 2009). A study by a group of researchers lead by Catrambone (2009) found that, in general, the Radial ward design was the most desirable (compared to Single and Double Corridor designs), both in terms of saving unnecessary ward travel and increasing time with patients. Moreover, members of the nursing staff indicated a preference for assignment to the Radial ward. The fact that nursing staff in the Radial unit had more free time was interpreted as an indication that more patients could be housed on the ward.
5.2.5 Subdivided ward

In the early 20th Century, a modification of the Nightingale ward appeared as the “Subdivided ward”. The nursing station and a single room split the ward in two. There was no change to sanitary facilities and beds had less area. The overall management and clinical supervision in this model was to a large extent similar to those of Nightingale wards with the difference that Subdivided ward allowed men and women to be cared for in separate wings of the same ward (NHS Estates, 1997).
5.2.6 Nuffield/Duplex
This type of ward dates back to the 1950s. The Duplex configuration (Nuffield) is similar to the Corridor design, but is split into two sections with each including its own station and shared support space (Catrambone et al, 2009). Rearranging beds in two sections (Figure 5-6) and reassessing nursing patterns meant that more patients could be admitted to the ward. “The beds continued to be in small groups each with its own sanitary area, but the growing awareness of the problems of cross infection - coupled with the desire to avoid disturbance to other patients - introduced a special room on each ward for carrying out clinical procedures and treatments” (Smith, 1966).

“The single nursing team largely remained, but on a day-to-day basis, the team was split to cover separate areas of the ward. By this time, patients of several consultants might be accommodated in one ward. Sometimes, the wings were used to accommodate the patients of different consultants or patients of different sex” (NHS Estates, 1997).
5.2.7 Racetrack/Double Corridor ward
Post-war Racetrack appeared in 1950s-60s with provision of 16-60 beds in various mixes of patient dependency. “This ward layout provided a mixed-sex ward with multi-bed bays for use either by female or male patients” (NHS Estates, 1997). The 'Racetrack' ward had patients' rooms arranged around a central core of services (Figure 5-9). 'Sister's desk' was replaced by a nursing station, where staff could sit instead of being on their feet all day by their patients. Privacy was fine for those admitted for elective surgery, but when seriously ill, the constant observation and presence of the nurses were more important (Rivett, 2009). The Racetrack (Double Corridor) design has nursing work and support spaces between two corridors. This is believed to be one of the most common designs in the US (Page and Page, 2004). This ward type suffers from long corridors with no natural light and view. Barefoot (1992) called it a “failure”: “The Racetrack ward is a failure; one should avoid too long corridor without windows. The reassurance of relating to outside orientation is vital. It can be done with corridor breaks giving pleasant views of the outside.”
Figure 5-9 Racetrack ward, High Wycombe Hospital, Buckinghamshire, UK (James and Tatton-Brown, 1986)

5.2.8 Falkirk ward
The Falkirk ward (Figure 5-10) type appeared in 1960s. HBN 04 (NHS Estates, 1997) categorises this ward type as a variation of Racetrack design, with central core of facilities and dispersed work stations. 4 bedded bays, which enjoy more generous bed space standards with internal glazed partitions, are of other characteristics of this ward type.

Figure 5-10 1960s Falkirk ward (NHS Estates, 1997)

5.2.9 Courtyard ward
According to Catrambone et al (2009), the Courtyard ward is another variation of Racetrack design with a courtyard for ventilation in the middle of the building. In this type of plan, courtyards of varying sizes are inserted into the core areas to provide natural light and ventilation.
5.2.10 Cluster ward

In this type of ward design, the layout is driven by the geometry. “The combination of orthogonal and diagonal axes can generate close packing plan forms for single room layouts” (NHS Estates, 2005). “Geometric designs are used to gain more external wall area so that the use of natural light and ventilation can be increased. They also provide solution to deal with deep plans and internal corners, which commonly produce “dead” space which cannot be used for continuous nursing activity” (NHS Estates, 2005). The most common form of the Cluster ward is Cruciform, which is a modification of the Corridor plan to ensure that as many patients as possible are gathered around the nursing station while providing privacy enhancements such as walls and doors (Catrambone et al, 2009).
5.2.11 Nucleus/Deep Plan ward
The Nucleus or Deep Plan ward originally belongs to 1980-1990s when oil crisis of mid 1970s recognised of energy demands of deep planned buildings. Under this design, “Florence Nightingale’s original concept of hospitals with fresh air, light, and views was replaced by deep plan hospitals that prioritized efficiency over human comfort and healing” (Burpee, 2008).
The layout has a modular concept design based on energy conservation concepts of maximising external wall area available for windows and limit number of floors. Support facilities are located in the centre. In the case of a single room, the en-suite facility is provided. Nucleus ward can be a pair of 24-bed or a six-bed room and a single-bed room (NHS Estates, 1997).

Figure 5-14 Nucleus ward, a pair of 24-bed wards (NHS Estates, 1997)

Figure 5-15 Nucleus ward, a six-bed room and a single-bed room (NHS Estates, 1997)
5.3 Some recent trends in hospital ward design

5.3.1 Single-bed rooms
The NHS started promoting the use of single-bed patient rooms in the 1990s and 2000s. The main drivers for the promotion of single-bed rooms instead of shared rooms in inpatient wards were: to control healthcare associated infection (HCAI); to improve patient environment to meet patients’ expectation; and to comply with the (then) newly issued regulations on workplace safety of the ward staff and disability discrimination (NHS Estates, 2005). Based on the above, the NHS and the DH have issued a guidance suggesting the inclusion of 50% single room accommodation in any new hospital builds, while presenting evidence of the advantages of 100% single-bed rooms (NHS Estates, 1997). These advantages were expected to include reduced infection rates, fewer medical errors, faster patient recovery rates, increased privacy, dignity and comfort and less disruption from other patients, improved control over their environment, enhanced sleep, and enhanced contact with families (NHS Estates, 1997). Also, staff were expected to be able to provide more personalised patient contact, with fewer interruptions and less time spent walking. Some potential disadvantages had also been identified, such as: reduced social interaction and thus patient isolation, less surveillance by staff, increased failure to rescue and increased rates of slips, trips and falls (NHS 2005).

After a few years of the implementation of this policy, a recent study in 2012 by Maben and others has presented anecdotal evidence of how these expectations were met in some hospital wards that had adopted the 100% single room scheme. This study shows that single-bed rooms offer improved privacy and physical comfort (sleep and access to toilets/showers), but have a negative impact on access to staff and social interaction. The study also states that “the impact of single room accommodation on staff-to-patient observation, staffing levels, adjustments to staff skill mix, and staff travel distances is unclear. The costs and economic impact of more single room accommodation are also unclear” (Maben et al, 2012).

5.3.2 Acuity-adaptable rooms
Spear speaks of “A spatial configuration and fit-out that support the clinical functions, patterns of practice, and amenities common to all patients independent of the
patient’s diagnosis, therapy or acuity” and calls it an acuity-adaptable room (Phiri, 2003). These rooms are designed in a way to accommodate different levels of patient acuity from critical care through step-down monitored beds. The main driver for this proposition was to minimise movements of patients to and from different departments through different stages of their stay in the hospital to reduce the chances for accidents and falls, medical errors and cross infections (Hendrich et al, 2007).

The concept of acuity-adaptable rooms is usually, although not necessarily, intertwined with single-bed room design. Many acuity-adaptable rooms are single-bed rooms comprising of three main “zones” designed for patients, caregivers and family members with equipment and furniture to facilitate a longer stay in hospital (Phiri, 2003).

When applying the concept of acuity-adaptable room in its purest sense is not possible (e.g. for spatial or organisational reasons), rooms can be acuity-adaptable to some extent, even if only to limit the amount of patient movements within a single ward. Gregory and Astley (2009) suggested this solution for the UK, where the organisation of acute hospitals does not tend to support this concept.

5.3.3 Dementia care provisions
The growing average age of the users of the NHS services means that twenty five per cent of people accessing acute hospital services are likely to have dementia and the number of people with dementia is expected to double during the next 30 years (The King’s Fund, 2013). In other words, by 2043, half of the service users of the NHS will have the usual problems of the over aged people (e.g. with mobility, sight and hearing) and, above that, serious problems with memory, learning, perception and reasoning as well as high levels of stress and anxiety (Marshall, 2013). This trend is argued to be threatening the security of both patients and staff by raising the statistics for falls, violent and aggressive behaviour and staff quitting (Waller, 2013).

Provisions for a safe healing environment for people with dementia may include: noise reduction panels and furnishing; consistent floor coverings (in both colour and texture); accessible outdoor area and fresh air; and clear signing for toilet doors and toilet seats.
(Marshall, 2013). There has been a debate on the suitability of Racetrack design for wards accommodating dementia patients. Many have suggested a Racetrack design as an answer to the need of dementia patients for continuous and obstacle-free walk. Others have argued that excessive and relentless walking may cause frustration and dehydration and therefore a good design for people with dementia should avoid creating loops. Instead, some ‘destinations’ should be positioned at the end and along the corridors to give meaning to patients’ walks (BBH, 2013).

5.3.4 Bariatric care provisions
The NHS reports that the obesity rate has increased from 13% for men and 16% for women in 1993 to 24% for men and 26% for women in 2011 (NHS, 2013). Apart from this rise in the numbers, the fact that obesity is normally accompanied by a range of other health complications (e.g. high blood pressure in almost half of the obese people as reported by the NHS, 2013) means that this group are considerably over-represented in their use of health and social care services. Hospitals and wards need to be designed in a way to assure bariatric patients’ safety, comfort and dignity. In hospital, severely obese patients often require specialist furniture and equipment to receive basic care, e.g. beds, chairs, commodes, wheelchairs, hoists and toilet facilities.

Spatial factors can present risk for the care of bariatric patients on a hospital ward, during transportation of a patient between departments, and within specialist departments such as theatre, diagnostics, maternity, and the mortuary. Therefore, factors such as corridor width, maximum weight limit of lifts, and movement space in toilets must be calculated based on the ergonomic characteristics of obese people and sizes of their specialist transportation equipment (Hignett et al, 2007). Also to assure safety of both patients and staff, the ward design should consider use of mechanical hoists, wheelchairs, sliding sheets and commodes (Trimble, 2003).

5.3.5 Use of computerised layout optimisation methods
Computer programmes have been developed in an attempt to identify the best layout or configurations for buildings. Computerised layout packages take activity relationship charts or from-to charts developed by the user and generate any specified number of layouts. These can be scored and compared by the computer and/or the layout analyst.
The final decision must be made by the designer. The chief advantage in computerised packages is generating large number of alternatives.

Although data relating to the purpose of each journey was not necessary for this research (which deals with the physical conditions of the journey rather than the contribution of different activities to the overall traffic), they were still collected as they have the potential to help future studies. Therefore, the method provided data for further research, only part of which is presented and analysed in this thesis.

Recent developments in building simulation techniques (combining system dynamics, discrete event simulation and agent-based modelling) and associated computer software offer a useful and robust approach to determining the relationships between hospital nurse productivity and the contribution of layout and circulation. Some other packages used for this purpose are ALDEP (Seehof and Evans 1967), Vectorworks10 (Nemetscheck, 2014), Affinity (Khelmani, 2010) and Onuma (Onuma Inc., 2014).

5.4 Summary
The literature study presented in this chapter covered general issues around layout design of hospital wards. First, the evolution of hospital ward design from the time of Florence Nightingale until today was discussed through a review of 10 of the most common ward design approaches in the last 150 years. A brief narration of some of the points of strength and weakness of these designs as stated in the literature as well as examples of each design were also introduced.

This was followed by a more focused discussion on design implications of the attempts to address some of the new challenges in healthcare provision in the UK. These challenges are imposed by both financial restraints and changes in the demographics of the NHS service users.

Using the knowledge acquired from the literature review, ward design types introduced in this chapter will be modelled around the data obtained from a case study to provide a basis for a comparative study of these designs as planned in research methodology.
6 Case study and archetypal models
6.1 Introduction

As mentioned in Section 1.4 the aim of this research is “to improve the productivity of hospital nursing staff through better people circulation and layout”.

One of the steps taken to achieve this goal was identifying available hospital/ward layout designs and their characteristics (Chapter 5). Another step is to identify which design type is more productive in terms of nursing staff movement. In other words, how circulation design of a hospital ward influences the amount of time nursing staff are wasting by walking in corridors and thus what type of ward layout/s is/are more productive with reference to nursing staff circulation. To do this, at least one case study representing each selected ward layout was needed. These case studies needed to have identical characteristics (such as the number of the staff and patients, workload, facilities and equipment etc.) and their own circulation design systems. It is needless to say that finding such case studies that can be representatives of all required layout categories and at the same time identical in all other aspects is impossible. This left the study with two options.

The first option was to compromise on the similarity of the wards in terms of characteristics other than their circulation systems. In other words, a number of wards that represented different ward types and were “fairly identical” in other aspects would be selected and compared. The obvious flaw of this option would be the difficulty of defining “fairly identical”. There was a wide range of different changes from case to case that could confound the results of any comparison. Finding an “acceptable” range for these changes would contradict the objectivity of the study.

The second option was to take one real case study representing one ward type and build other case studies by changing no other characteristics but their circulation systems, i.e. to retain the design of all individual spaces and only change the corridors and the arrangement of the rooms in relation to each other. The ideal way of doing this would be to build real-life and real-size wards and study their performance in real-time. In lack of time and budget to do so, building these wards in a virtual world (i.e. archetypal modelling) was concluded to be the best alternative method. In this method generic forms are constructed that represent the actual characteristics of the
design in a simple and repeatable manner by eliminating the complexities found in real
buildings and allowing for a more systematic comparative analysis of geometry and
built form (Malekzadeh, 2009). In short, the method taken in this chapter consists of:

- studying one real hospital ward;
- creating a virtual model of that ward;
- creating virtual representative models (i.e. archetypal models) of other
  ward types by changing only the circulation system of the original type and
  preserving all other characteristics, including the size of individual spaces,
  number of beds, number of nursing staff and even the details of the
  movements of the nursing staff; and finally
- comparing the time wasted due to the overall design of the circulation
  systems of the wards.

But before applying this method, a discussion on the selection of the ward types is
necessary. The following section describes how different designs of wards have been
encapsulated in four general categories. The archetypes to be used for comparison will
be based on this categorisation.

6.2 Selection of the studied ward types

In Chapter 5 (Approaches towards hospital and ward design), ten of the most
commonly used ward design categories (i.e. Nightingale, Corridor, Radial, Subdivided,
Nuffield, Racetrack, Falkirk, Courtyard, Cluster and Nucleus) were presented based on
the literature review. These are re-grouped in this section into four mega-categories,
by eliminating or combining some of the original ones.

Some of these designs have been developed to more suitable designs in more recent
years (e.g. the evolution of Nightingale ward to Corridor and Nuffield wards). Nucleus
design was also a strategy adopted mainly to reduce energy consumption of the
hospitals at the expense of patients and staff’s comfort and healing requirements of a
healthcare facility (Burpee, 2008). These designs have now been abandoned and thus,
will not be included in the comparison stage of this study. This leads to removing three
of the 10 ward types mentioned earlier (i.e. Nightingale, Courtyard and Nucleus).
Cluster design also does not necessarily shape a different/special circulation system (at
least in a ward level) and for that reason, is not considered in the final shortlist. In addition, some of the other types in the list show enough similarity, in relation to their circulation patterns, to be considered in the same category. For example, Subdivided and Nuffield wards can be taken as variations of the same type (Figure 6-1).

This leads to a new list of ward layout types to be used in archetypal analysis stage of the research. This list consists of Corridor, Radial, Nuffield and Racetrack ward layouts (Figure 6-2).
6.3 The case study

6.3.1 Case study selection
As mentioned in Section 6.2, the method chosen for the comparison of the above four categories was to study a real-life representative of one of the four categories and then use its characteristics for modelling the other three categories. This plan made the otherwise arduous task of case study selection more practical. Now, the only major criterion for case study selection was the representativeness of the selected case study to one of the four categories and, as mentioned before, the vast majority of all hospital wards can be considered to belong to one of these four categories. In other words, almost any hospital ward that could grant access to its space and data had become a suitable choice.

Earlier collaboration of the researchers at Loughborough University with healthcare providers within the UK and abroad had created a range of opportunities for proceeding this research with the process of case study selection. Among these opportunities, Atieh Hospital in Tehran, Iran was concluded to be the most convenient in matters of access to the ward space, staff and information. Furthermore, a preliminary study of the design of this hospital proved there was a significant amount of convergence with many of the current UK trends in hospital design guidance and practice, e.g. the provision of 50% single-bed accommodation in the ward and at least one acuity-adaptable room in each ward as discussed in Section 5.3.2. Based on these considerations, Atieh Hospital was selected as the case study for undertaking this part of the research.

6.3.2 Selected case study's general information
Atieh Hospital (Figure 6-4), is located in the northwest of the capital city of Iran, Tehran. It has been a busy hospital since start of its work at 1999 with 15 operation theatres and the final capacity of 350 in-patients in a surface area of 4300 square meters spread into 12 floors. The location of hospital gives the users of the building an easy and convenient access from the main highways of Tehran (Figure 6-3). More than 200 specialized doctors work for this hospital with the availability of 24 hours service in Intensive care, Emergency care, Post-surgery, Pathology, Brachytherapy, Chemotherapy, General surgery, Thoracic surgery, Cardio-vascular surgery, Open heart

Atieh Hospital is a private establishment where the Ministry of Health and Medical Education has the constant supervision on its service and performance. At the moment, Atieh hospital is holding the Grade A Evaluation Licence, which is the highest accreditation a private hospital can achieve.

Atieh hospital accommodates all in-patients in twelve wards located in second, third and fifth floors. The largest ward of Atieh with the capacity of twenty two in-patient beds was under some construction/maintenance at the time of data collection. Therefore, the second largest ward of the hospital, Saba Ward, was selected for data collection purposes.

Figure 6-3 Atieh Hospital urban accessibility (Atieh Hospital, 2013)
6.3.3 General observation of the case study ward

Saba Ward (Figure 6-5) accommodates sixteen in-patients in four Double-bed Rooms and eight Single-bed Rooms in an approximate floor area of 440 m². The ward is specified to internal surgeries and hosts patients who require different types of surgeries such as: orthopaedic, urology, general surgeries with open, advanced or laparoscopic methods, brain and neurosurgeries, spinal cord, aesthetic surgeries, plastic surgery, ear, nose and throat (E.N.T.) surgeries, thorax surgery are admitted and cared for as well as patients who require different cardio-vascular surgeries.

Rooms are arranged around a corridor bent in the shape of letter ‘L’ with the nursing station positioned at the bend of the corridor to provide a complete view to the whole ward. Most of Single-bed Rooms have a floor area of 17.5 m² (including their en-suite sanitary facilities). This number is 25.5 m² for Double-bed Rooms. The area of other spaces in the ward was measured as follows.

- Nurse Station: 12 m²
- Treatment Room: 25 m²
- Staff Room (including toilet and shower): 24.5 m²
- Staff Changing Room: 7 m²
- Hoteling Storage: 3 m²
- Dirty Room: 1.5 m²
- Cleaning Utility: 0.8 m²

Patient care activities are performed by three types of staff members: head nurse; nurse; and nurse assistant. Housekeepers are also responsible for the physical maintenance and cleanliness of the ward. The nursing activities of different staff types are designed based on the following shift pattern (Table 6-1).

Table 6-1 Number of ward staff per shift

<table>
<thead>
<tr>
<th>Shifts</th>
<th>07:00-13:00</th>
<th>13:00-19:00</th>
<th>19:00-07:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required staff</td>
<td>1x Head nurse/In-charge nurse</td>
<td>1x Head nurse/In-charge nurse</td>
<td>1x Head/In-charge nurse</td>
</tr>
<tr>
<td></td>
<td>3x Nurses</td>
<td>3x Nurses</td>
<td>2x Nurses</td>
</tr>
<tr>
<td></td>
<td>2x Nurse Assistants</td>
<td>2x Nurse Assistants</td>
<td>1x Nurse Assistants</td>
</tr>
<tr>
<td></td>
<td>2x Ward Housekeeper</td>
<td>2x Ward Housekeeper</td>
<td>1x Ward Housekeeper</td>
</tr>
</tbody>
</table>
There were no meaningful changes in the workload distribution between different days of the week. This observation was confirmed by the staff in the interviews. The reason stated was the random nature of the health problems referred to this ward.

The nursing staff were observed to assume duties as follows.

- **Head Nurse:** Head Nurse or In-Charge Nurse in the ward is responsible for the performance of all staff and the monitoring of nurses, nurse assistants and housekeepers to make sure they are achieving all their targets. She/he also makes sure that all the patients’ needs are met and Hospital’s service level standards are observed by allocating resources (including nursing staff, medication, doctors and equipment) where they are needed. In absence of Head-Nurse, one of the most experienced nurses in the ward who has been trained to act as In-Charge nurse assumes the Head Nurse’s duties.

- **Nurse:** In the observed ward, the main part of the care, especially medical and emotional care, received by the patients and their families is provided by the Nurses. Furthermore, Nurses play a major part in monitoring and recording patients’ well-being and complementing activities of the doctors in their absence. They are also prepared to deal with different types of emergency that could occur in a ward. As part of their daily routine, Nurses also have frequent journeys to other parts of the hospital outside their own ward. These journeys are normally to escort patients to their destinations outside the ward or to escort them from other departments back to the ward.

- **Nurse Assistant:** A significant part of the physical care of patients is performed by Nurse Assistants. These include all non-medical matters that facilitate the healing process of the patients, such as supporting personal hygiene and daily living needs. Also, transportation of the patients to and from other departments is one of the responsibilities of the Nurse Assistants.

- **Ward Housekeeper:** Housekeepers were observed to be purely responsible for the upkeep of the facilities of the ward. The Housekeepers’ duties included cleaning and sanitisation of toilets and showers, patient room equipment, nurse station, medical equipment, corridors, escape routes, bins, cupboards and lifts. Cleaning and preparation of the patient room and bed before the
arrival of a new patient was also part of their job. Although some data collection from their activities was performed, it was later decided not to include the Housekeepers in the calculations related to the nursing staff because of their complete exclusion from nursing responsibilities.

Figures 6-5 to 6-23 offer a general view of the studied ward and staff’s daily tasks.
Figure 6-6 Nurse Station is the starting point and destination for all nurses’ journeys.

Figure 6-7 Location of Nurse Station relative to all areas of the ward is of crucial importance.

Figure 6-8 In locating Nurse Station, factors such as visual access to some rooms is also important.

Figure 6-9 Communal parts of the ward also need to be visible from the Nurse Station.

Figure 6-10 For a short while (during shift handover), the number of staff is doubled.

Figure 6-11 Most of the non-walking time of nurses is spent for documentation at Station.
Figure 6-12 Single-bed Room

Figure 6-13 Double-bed Room

Figure 6-14 Isolation-adaptable Room

Figure 6-15 Isolation-adaptable Room

Figure 6-16 Single-bed Room en suite bathroom

Figure 6-17 Isolation-adaptable Room bathroom
Figure 6-18 Corridors provide quick and safe access to different parts of the ward.

Figure 6-19 Staff Room accommodates nurses’ break times as well as admin activities.

Figure 6-20 Treatment Room is the destination for most nurses’ journeys.

Figure 6-21 Treatment Room provides space for medical equipment and in-house cleaning.

Figure 6-22 current patients’ daily records are kept and accessed in the Nurse Station.

Figure 6-23 Storage of restricted access drugs is one of the other functions of Treatment Room.
6.3.4 Data collection
Data collection was carried out between 26th May and 20th Jun 2013 (a brief diary is available in Table 6-2). Forty two members of staff, including head nurse, nurse, nurse assistant and ward housekeeper, participated during different working shifts.

Table 6-2 Data collection diary

<table>
<thead>
<tr>
<th>Day</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 01</td>
<td>Meet with the Chairman of the Board of Directors, Head of Board of Nursing and Head of Human Resources</td>
</tr>
<tr>
<td>Day 02</td>
<td>Meet with the Head of Estates and Facilities Department and visiting the hospital’s different wards and departments to get acquainted with the hospital and make a decision on the case study ward</td>
</tr>
<tr>
<td>Day 03</td>
<td>Meet the Head Nurse of Saba Ward, observing the nursing activity and make a list of their duties</td>
</tr>
<tr>
<td>Day 04</td>
<td>Interview different nursing staff (nurse, head nurse and nurse assistant) of Saba Ward to validate the provided list of their activity</td>
</tr>
<tr>
<td>Day 05</td>
<td>Design the data collection forms</td>
</tr>
<tr>
<td>Day 06</td>
<td>Do one shift trial data collection to identify the perfection and accuracy of the developed forms and find the gaps</td>
</tr>
<tr>
<td>Day 07</td>
<td>Nurse data collection 07:00-13:00 and 13:00-19:00 (12 hours)</td>
</tr>
<tr>
<td>Day 08</td>
<td>Nurse data collection 07:00-13:00 and 13:00-19:00 (12 hours)</td>
</tr>
<tr>
<td>Day 09</td>
<td>Nurse data collection 07:00-13:00 and 13:00-19:00 (12 hours)</td>
</tr>
<tr>
<td>Day 10</td>
<td>Nurse data collection 19:00-07:00 (12 hours)</td>
</tr>
<tr>
<td>Day 11</td>
<td>Nurse data collection 19:00-07:00 (12 hours)</td>
</tr>
<tr>
<td>Day 12</td>
<td>Nurse data collection 19:00-07:00 (12 hours)</td>
</tr>
<tr>
<td>Day 13</td>
<td>Interview the Head Nurse</td>
</tr>
<tr>
<td>Day 14</td>
<td>Head Nurse data collection 07:00-13:00 and 13:00-19:00 (12 hours)</td>
</tr>
<tr>
<td>Day 15</td>
<td>Interview the Head of Building and Construction Department</td>
</tr>
<tr>
<td>Day 16</td>
<td>Head Nurse data collection 19:00-07:00 (12 hours)</td>
</tr>
<tr>
<td>Day 17</td>
<td>Interview the head of Human Resources</td>
</tr>
<tr>
<td>Day 18</td>
<td>Nurse Assistant data collection 07:00-13:00 and 13:00-19:00 (12 hours)</td>
</tr>
<tr>
<td>Day 19</td>
<td>Interview the head of new Atieh Hospital design team</td>
</tr>
<tr>
<td>Day 20</td>
<td>Nurse Assistant data collection 19:00-07:00 (12 hours)</td>
</tr>
<tr>
<td>Day 21</td>
<td>Interview the Head of Board of Nursing</td>
</tr>
<tr>
<td>Day 22</td>
<td>Ward Housekeeper data collection 07:00-13:00 and 13:00-19:00 (12 hours)</td>
</tr>
<tr>
<td>Day 23</td>
<td>Interview 1x Nurse, 1x Nurse Assistant and 1x Ward Housekeeper informally</td>
</tr>
<tr>
<td>Day 24</td>
<td>Ward Housekeeper data collection 19:00-07:00 (12 hours)</td>
</tr>
<tr>
<td>Day 25</td>
<td>Review</td>
</tr>
</tbody>
</table>

Before the start of the data collection, the aim and expectations of the study were explained to the participating managers through a series of meetings. This helped
building up a strong relationship with different levels of management, which helped the extensive process of data collection smooth and amiable. These initial meetings included sessions with Chairman of the Board of Directors, Head of the Board of Nursing and Head of Human Resources. Also a walkthrough accompanied by the Head of Estates and Facilities Department helped a better understanding of the situation of different wards in order to select the ward to be studied. As a result, Saba Ward was selected and the overall process of data collection was finalised by the help of the Head Nurse of the ward.

The first step of data collection involved observing nursing staff’s activities in order to create realistic lists of duties and tasks performed by different types of nursing staff throughout each working shift. The lists were then validated by the help of relevant staff members to assure their comprehensiveness. A summary of these lists is presented in Table 6-3.

<table>
<thead>
<tr>
<th>Head Nurse</th>
<th>Nurse</th>
<th>Nurse Assistant</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Shift handover</td>
<td>• Shift handover/ Patient evaluation</td>
<td>• Shift handover</td>
</tr>
<tr>
<td>• Control and supervision of all patients</td>
<td>• Drug trolley Check</td>
<td>• Help to patients’ with personal hygiene</td>
</tr>
<tr>
<td>• Input of medical tests and pursuit</td>
<td>• Documentation</td>
<td>• Help to patients with daily living needs and activities</td>
</tr>
<tr>
<td>• Attendance to doctor for patient visits</td>
<td>• Medication Management</td>
<td>• Transportation of patients</td>
</tr>
<tr>
<td>• Check of doctor’s orders and pursuit</td>
<td>• Serum application</td>
<td>• Response to patients’ calls</td>
</tr>
<tr>
<td>• Notification of relevant doctor after admitting a new patient</td>
<td>• Wound management care</td>
<td>• Documentation</td>
</tr>
<tr>
<td>• Control and supervision of nurses’ activities</td>
<td>• Vital signs monitoring</td>
<td>• Preparation of patients for operation</td>
</tr>
<tr>
<td>• Staff rota/shift allocation</td>
<td>• Communication with doctors</td>
<td>• Urine/blood bag check</td>
</tr>
<tr>
<td>• Attendance to patient complaints/buzzes</td>
<td>• Follow up of doctors’ orders</td>
<td>• Bed preparation</td>
</tr>
<tr>
<td>• Report of any faulty equipment and maintenance</td>
<td>• Education to patients/families</td>
<td>• Bed linen inventory check</td>
</tr>
<tr>
<td></td>
<td>• Emotional support</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Preparation of patient for operation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• New patient admission</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Escort of patient to/from theatre</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Escort of patient to/from special sampling centre</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Escort of patient from theatre to ward/post-operation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Response to patients’ calls</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Attendance to visitors’ requirements</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Write up of reports and records</td>
<td></td>
</tr>
</tbody>
</table>

Based on the observations and arrangements made in the preparation phase, a strategy for data collection was decided. The aim of this strategy was to observe all types of staff members within a 24-hour cycle and record their movements between
different spaces in the ward. This judged to be sufficient for the observation of head nurse and nurse assistant’s activities that have little changes in their routine from day to day. For Nurses, however, whose duties are much more dependent on the types of patients they are attending, the routines and even the workload could meaningfully vary from day to day. For this reason, it was deemed best to observe each working shift of the nurses three times to eliminate the possibility of having unbalanced data on their activities. This meant direct observation of

- 72 hours of Nurse activity;
- 24 hours of Head Nurse activity; and
- 24 hours of Nurse Assistant activity.

These were distributed over two weeks of observations in a pattern to cover all shifts equally. All efforts were also made to insure that observations cover as many different participants as possible (rather than observing the same nurse in different shifts). This was to eliminate the confounding effect of individual’s personal working patterns.

As a result, Data Collection Forms in Figure 6-24, Figure 6-25 and Figure 6-26 were designed and tested through a pilot study over a shift to ensure the logical flow and practicality of the data collection procedure.

The planned method would enable the researcher to gather five different variables of data on each journey within the ward:

- the purpose of the journey;
- its origin;
- its destination;
- start time; and
- end time.

Although the data on the purpose of each journey may seem irrelevant to the present research (which deals with the physical conditions of the journey rather than the contribution of different activities to the overall traffic), it was decided that their collection may help future studies. Therefore, the method provided data for further research, only part of which is presented and analysed in this thesis.
<table>
<thead>
<tr>
<th>Name:</th>
<th>Period: From... to</th>
<th>Page Number:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title: Nurse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1- Patient evaluation/shift handover</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2- Checking drug trolley</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3- Documentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4- Managing medications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5- Serum application</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6- Changing wound bandage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7- Observing/monitoring vital signs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8- Communicating with doctors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9- Doctors' orders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10- Educating patients/families</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11- Emotional support</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12- Preparing patient for operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13- New patient admission</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14- Escort patient to theatre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15- Escort patient for special sampling centre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16- Escort patient theatre to ward/post-ope</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17- Responding to patients calls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18- Dealing with visitors' requirements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19- Writing up reports and records</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20- Break</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 6.24 Nurse data collection sample form
<table>
<thead>
<tr>
<th>Name:…………………….</th>
<th>Period: From……………. to …………...</th>
<th>Page Number:……...</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title: Head Nurse</strong></td>
<td></td>
<td>60 minutes Period</td>
</tr>
<tr>
<td>Date:………………………</td>
<td>1- Shift handover</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 36 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60</td>
</tr>
<tr>
<td>2- Control and supervision of all patients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3- Inputting medical tests and chase up</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4- Accompanying doctor for patient visits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5- Checking doctor’s orders and chase up</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6- Notifying relevant doctor after admitting a new patient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7- Control and supervision of nurses’ activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8- Rota shift staff allocation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9- Sorting out patient complaints/buzzes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10- Report any faulty equipment and maintenance</td>
<td>11- Break</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name:…………………….</th>
<th>Period: From……………. to …………...</th>
<th>Page Number:……...</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title: Nurse Assistant</strong></td>
<td></td>
<td>60 minutes Period</td>
</tr>
<tr>
<td>Date:………………………</td>
<td>1- Shift handover</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 36 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60</td>
</tr>
<tr>
<td>2- Helping patients with personal hygiene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3- Helping patients with daily living needs and activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4- Transporting patients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5- Responding to patients calls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6- Documentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7- Preparing patients for operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8- Checking urine/blood bag</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9- Bed preparation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10- Bed linen inventory check</td>
<td>11- Break</td>
<td></td>
</tr>
</tbody>
</table>
Each sheet of the form records activities of a participant within one hour with a resolution of one minute. The columns and the rows show the time and nature of the activities subsequently. The form is filled with lines representing the duration of one activity. The lines are coded with numbers that indicate the rooms visited (by the participant while performing the activity) as shown by circled numbers at the point of entrance to each room in Figure 6-27. In case of rooms with more than one entrance (such as Nurse Stations) the entrance offering a shorter journey is chosen.

![Figure 6-27 Origins and destinations of journeys in the ward](image)

At the start of each shift, one member of staff (as decided formerly by conferring the Head Nurse) would be invited to take part in the study. To observe compliance with ethical research guidelines, all participants were informed of the aim and procedure of the study and assured of the confidentiality of all data collected from them. This was done both verbally and in form of a written notification (Participants’ Information Sheet in Appendix B). All participants were also advised that they were free to accept or refuse to take part in the study or withdraw at any point. Every participant took part in the study by giving written consent (Participants’ Consent Form in Appendix B).

The researcher would then track the participant’s journeys from room to room throughout their working shift and record the relevant information for the whole shift length. This study was not interested in the movements of the participants inside
rooms (as the main concern of study is the overall layout of the ward and the design of the corridors rather than the rooms themselves). This also saved a significant amount of time in gaining ethical clearance needed for approaching patients and their families.

Figure 6-28 presents an example of the completed observation forms for the journeys of an anonymous participant (Nurse Z) within one hour.
6.4 Archetypal models

6.4.1 Corridor design

After the observation of the case study, it was essential to simplify the layout of the studied ward (Figure 6-5) in a form that can be taken as a representative of one of the ward designs (in this case, Corridor design) while retaining the main structure of its circulation design. This would help later comparison of the studied ward against other circulation systems by differentiating between factors that needed to be carried forward to other designs (e.g. number of rooms and their floor areas) and factors that are specific to each design (e.g. length of corridors).

Figure 6-29 is presenting the simplified layout of the selected case study, Saba Ward. Out of the four selected ward design categories (Figure 6-2), this ward represents Corridor design.

The archetypal models for other design types are based on the fixed spatial characteristics of this model. Therefore, the only main variance between the four models would be the staff circulation routes. The adjacencies of the spaces and rooms are dictated by the features of the wards derived from literature as well as the
intention to use the floor area in the most efficient way. The width of the corridors in all archetypal models is precisely the same as the case study (i.e. 2.4 m). The area of Corresponding rooms is kept identical wherever the design permitted.

In case of used linen storage bin (Code 5 in the models), the condition dictated by the case study was to keep the distance to ward exit to minimum without obstructing walking paths. The same condition was observed in locating Code 5 in other models.

6.4.2 Nuffield design
According to literature review stated in Section 5.2.6, Nuffield Ward type is formed in two divisions (with two nursing stations) that share one support zone. The following layout (Figure 6-29) was developed bearing in mind the above stated description of this design and feeding the other characteristics such as the number of the rooms, spaces, beds etc. from the case study. The overall floor area of the two Nurse Stations has also been kept equal to the floor area of the Nurse Station in the case study. The same applies to the floor area of the Treatment Rooms.

![Figure 6-30 Nuffield Archetypal Model](image)

6.4.3 Racetrack design
Based on Section 5.2.7, a Racetrack ward is a ward with the nurse station and all other supporting areas in the centre, separated from the patient rooms by an encircling corridor. The following model (Figure 6-31) was generated according to the above information and the assumptions stated in Section 6.4.1.
6.4.4 Radial design
As per the previous two sections (6.4.2 and 6.4.3), the Radial design model (Figure 6-32) was developed from the literature (5.2.4) using the assumptions made in Section 6.4.1. The centre of a classic Radial ward is normally used for locating nurse station to grant unbroken view line to all patient rooms. On the other hand, the case study design dictates a Treatment Room that is immediately adjacent to the Nurse Station (i.e. distance between Nurse Station and Treatment Room equals zero). Combining these two obligations from two different backgrounds resulted in designing a novel configuration of the Nurse Station at the centre of the model presented in Figure 6-32, which satisfies both direct view to patient rooms and immediate access to Treatment Room from the Nurse Station.
6.5 Summary

In this chapter, the systematic steps taken to generate a robust method of data gathering and application were presented and the advantages of implementation of a case study as part of this robust method were clarified. Further in this chapter, the selected case study was introduced and its suitability for the current study was discussed. A discussion on the method designed for data collection was presented and the advantages of archetypal modelling for the progress of the study were explained. The chapter concluded by presenting the archetypal models of different ward layout designs. This chapter will set the foundation for the analysis of the different models that will be reported in the following chapter.
7 Comparative analysis of the archetypal models
7.1 Introduction

In Chapter 6, an overview of the case study and the methods designed to collect data on the nursing team’s journeys were described. This chapter presents the results and analysis of the data collected from the case study in order to understand the patterns of the journeys and also provide a set of input data for the comparison of the archetypal models.

Using the collected data, all different designs have been modelled to provide an understanding of the circulation patterns of the nursing team in each layout design. This will, in turn, help the process of ranking the designs based on nursing staff productivity.

The method introduced by this study for the analysis of the journey data in a ward can be considered as a refined and improved version of the method used by Pelletier and Thompson in devising the ‘Yale Traffic Index’ (Pelletier and Thompson, 1960). Therefore, it seems appropriate to briefly discuss this method at this point and highlight its areas of improvement.

The Yale University research team identified sixteen different “areas” in a hospital ward (or nursing unit as they name it) and investigated the journeys (links in their terminology) of the staff between these areas. They combined data on the frequency of the journeys happening between different areas with a “representative” distance walked in journeys between the two areas to create what they coined as the Yale Traffic Index. They then used this index as a means of comparison to decide on the most efficient ward design in terms of walking distance of the staff. After considering a range of ward designs they concluded that the result of such comparison is not related to the size of a ward, but rather is highly dependent on its design (Pelletier and Thompson, 1960).

The pioneering approach of this method in quantifying functional efficiency as a design evaluation tool was then replicated by many of the computerised methods that were introduced in the following decades and for this reason this study holds a reference position in this field. However, there are certain major concerns, some of which have
been pointed out by previous reviews. Freeman highlighted one of the major flaws in the method as “a serious error” in measuring journey distances (Freeman, 1967).

As mentioned earlier, Pelletier and Thompson used a representative value for the distance between two areas. In the case of the distance between patient rooms (contributing almost 20% of the journeys observed in their study), this representative value was “the average distance travelled between pairs of rooms on a single round” (Pelletier and Thompson, 1960) whereby a nurse moves from one room to the adjacent room. This is equivalent to assuming that when a nurse leaves one patient room, she will always go to the room next door, which makes the value taken by the team the minimum distance route rather than a representative value.

To correct this error, it was decided in the present study to treat patient rooms individually rather than to group them in one “area”. In this way, both regular movements between rooms (such as those happening during a ward round) and random journeys are covered in the investigation and are not lost in an averaging process. The same approach was taken for studying all other rooms. For this reason, the focus of this research is on the “spaces” within a ward (as opposed to “areas” as defined by Yale University researchers).

Another limitation of the Yale study was that they had amalgamated the data collected from different staff types and that there was no differentiation between the journeys taken by each of these types. Considering that different levels of staff within a ward have different duties, reveals that a design type that reduces the walking distance of one staff type may prove to have a negative impact on the walking routine of another type. Therefore, in the present study, it was deemed necessary to keep the data of different staff types separate from each other during the analysis. This will also allow for potential studies in the future on the costs of the journeys within a ward (in relation to the salaries of different staff levels).

Furthermore, the approach of the Yale team in combining the journeys happening inside and outside the rooms was another weakness of their method. Journeys inside rooms are much more dependent on the position of other people in the room, the furniture arrangement and the type of activity a member of staff is undertaking and
such factors may impose a significant amount of inaccuracy on the decisions made about the layout design of the ward. Journeys in corridors, however, are normally simple movements from one room to another room along the shortest path. Combining these two different types of movement was decided to confound the findings in the present research and was therefore avoided.

Modifications and improvements made to Yale method and presented in this chapter provide a more robust alternative for this method as a comparative design evaluation tool.

7.2 Analysis of the journey frequency data from the case study
Field observations provided empirical data on the frequency of each journey taken by nursing staff within the ward. As elaborated in Section 6.3.4, the working shifts of different staff types were observed using forms in Figure 6-24, Figure 6-25 and Figure 6-26. In total, 120 forms were completed, each of them corresponding to one hour of the working time of one member of staff, belonging to Nurse (N), Head Nurse (HN) or Nurse Assistant (NA) staff type. Meaningful patterns were revealed in the data collected from the case study using a set of data analyses. The following is a report on these analyses.

7.2.1 Method
The collected data were transformed by manually extracting the journey routes taken by the participant as recorded in the hourly observation forms. In total, 420 journey routes were identified. Since the journey distance between two points is not altered by the direction of the journey, the journey frequency data for the two journeys with alternating origin and destination were combined into one row in Excel worksheet. For example, the frequency data for the journey labelled as “1 to 2” includes the number of movements from both 1 to 2 and reverse (i.e. 2 to 1). Therefore, a total number of 210 journey routes were identified. This was transferred to MS Excel worksheets for N, HN and NA staff types.

The full table of the frequency data for 210 journey routes for N, HN and NA is available in Appendix C. Figure 7-1 shows the first few rows of this table. As mentioned earlier (Section 6.3.4), the journey data collection for N was repeated three times to
eliminate confounding observations. The data recorded in the Excel sheets for N (Columns J to M in Figure 7-1) give the average value of the three sets of data collection.

The rightmost vertical section of the table (Columns AA to AD in Figure 7-1) collates all room to room journeys in the ward within a period of 24 hours. The values in this section were calculated using the average number of individuals in each staff type based on the data presented in Table 6-1, where number of Ns is recorded to vary between 2 and 3 and number of NAs between 1 and 2. Since the total length of the day shifts (morning and afternoon) is equal to the length of the night shift (= 12 hours), the overall number of staff in each type is calculated as the mathematical average of the two numbers. For example, since the ward is run by 2 NAs for 12 hours and by 1 NA for the other half of the day, the overall number of journeys that all NAs make per 24 hours is calculated to be 1.5 times bigger than the number of journeys by one NA.

Although, the first column in the table lists all physically possible journey routes in the ward, some of these routes are almost never used by the nursing staff, because they are specific to the tasks performed by non-nursing staff. For example, code number 4 in the layout (Figure 6-27) belongs to Dirty Room, which is almost uniquely used by the ward housekeeper and, therefore, most of the routes to or from this space, often,
have a frequency of 0 in nursing staff journeys. Similar is the case of spaces numbered as 5 (Dirty Sheets Bin), 11 (Cleaning Utility) and 21 (Storage). Room number 20 (Staff Changing Room) is also used by the staff either before the start of their shift or after its end and therefore there are almost no journeys to this room during working times. After eliminating zero-frequency routes, a total of 80 routes remained for further investigation. Table 7-1 lists these 80 routes.

7.2.2 Overall analysis and frequency levels
Approximately, a total of 1300 room to room journeys are made by the nursing team in this ward per 24 hours (Table 7-1). This is almost equal to one journey per 67 seconds. A number of conclusions were made studying the journey frequency in different routes. These observations also indicate how critical the design of each route is.

➢ Frequency Level 1

As evident from Figure 7-2, the most frequent journey of the nursing staff (the only journey taken more than 100 times during 24 hours, equal to 8% of all daily journeys) occurs between Nursing Station and Treatment Room (spaces numbered as 1 and 2). This is in agreement with the observations made directly by the researcher on the importance of Treatment Room in hosting many activities of the nursing staff, such as medicine preparation, in-house cleaning and sanitisation, medicine and equipment stock check, and temporary storage of monitoring equipment and clean bed sheets. A good strategy in the design of the ward, therefore, is to keep spaces 1 and 2 adjacent to each other. This strategy had been considered in the design of the case study by directly connecting the two spaces through a door and eliminating any room to room walking between them. The same strategy was followed in the design of the archetypal models and, as a result, no time is spent in any of the four models for getting from 1 to 2 and vice versa.
<table>
<thead>
<tr>
<th>Route</th>
<th>Frequency/Shift</th>
<th>7am-1pm</th>
<th>1pm-7pm</th>
<th>7pm-1am</th>
<th>Total/24 hrs</th>
<th>Head Nurse (HN)</th>
<th>Nurse Assistant (NA)</th>
<th>Team (2.5 N + HN + 1.5 NA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 2</td>
<td>10</td>
<td>7</td>
<td>8</td>
<td>25</td>
<td>55</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>1 to 3</td>
<td>7</td>
<td>6</td>
<td>10</td>
<td>23</td>
<td>53</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>1 to 4</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>24</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 5</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>10</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 6</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1 to 7</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1 to 8</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 9</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 10</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 11</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 12</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 13</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 14</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 15</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 16</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 17</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 18</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 19</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 20</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 21</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 22</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 23</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 24</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 25</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 26</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 27</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 28</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 29</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 30</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 31</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 32</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 33</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 34</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 35</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 36</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 37</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 38</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 39</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 40</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 41</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 42</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 43</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 44</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 45</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 46</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 47</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 48</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 49</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 50</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 51</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 52</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 53</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 54</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 55</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 56</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 57</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 58</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 59</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 to 60</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>10</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Figure 7-2 Journey frequency - Whole Nursing Team
The next 5 most frequently taken journeys (all journeys taken between 50 and 100 times a day) are also to or from Nursing Station. The other ends of these journeys are rooms number 3 (Staff Room), 7 (Isolation-adaptable Room) and 12, 15 and 16 (Double-bed Rooms).

In the case study ward, apart from hosting staff’s quiescence and sustenance, the Staff Room served an additional function as non-medical administration office and meeting room of the ward. Subsequently, Route 1 to 3 holds a substantial share of the daily journeys of the team because of the high frequency of its journeys. This suggests restricting the distance between the two spaces to the minimum as per the case study. The same strategy has been followed in other models. In the case of Nuffield design, the presence of two separate Nurse Stations in the design, means that the Staff Room cannot be as easily accessible (to the staff who spend most of their time in Nurse Station) as in other designs.

Visits from Nurse Station to Room 7 create one of the greatest journey frequencies in a day. The reason is that the room is occupied by a patient in need of special and frequent treatment. However, the design needs of Room 7, normally, result in this room being one of the furthest rooms away from Nurse Station. The two designs that allow for keeping the distance between Isolation-adaptable Room and Nurse Station to a minimum, i.e. Nuffield design (with one of the Nurse Stations closer to Room 7) and Radial design (which offers an access to Room 7 as direct as that to all other patient rooms) are successful cases of controlling the daily walking distance in this Route.

Visits to Double-bed Rooms are, evidently, more frequent than those to Single-bed Rooms. Many tasks, especially those related to patients, need to be repeated twice to serve both patients in these rooms. This has been represented by the high rank of the routes between Nurse Station and Double-bed Rooms in Figure 7-2. The only exception is the route to Room 14; where for most of the duration of the observations was occupied by only one patient. It is reasonable to assume this route to be in Frequency Level 2 in normal circumstances.
The six routes with a frequency level of 2 accommodate 29% of the daily journeys of the nursing staff in the ward.

- **Frequency Level 3**

Most other journeys happening more than once an hour in average correspond to the routine tasks in patients rooms. This pattern reflects two categories of journeys: those from Nurse Station to Single-bed Rooms; and those performed during ‘taking rounds’ for activities such as doctor visit, medication, shift handover, linen change and cleaning. The latter category does not seem to be greatly dependant on design type and the nursing team would take the physical order of the rooms for such tasks regardless of the overall arrangement of the spaces. Journeys from Nurse Station to other parts of the hospital, such as pharmacy, offices, patient arrival, restaurant, etc. (Route 1 to 6), are also in this range of frequency. In total, 19 routes are categorised under this frequency level. About 41% of the daily journeys in the ward happen in these 19 routes.

- **Frequency Level 4**

All other active routes fall in this category of the least critical routes. The 54 routes with this frequency level are used for about 22% of the daily journeys of the staff.

- **Frequency Level 5**

These are the 130 routes that were observed not to be used for daily journeys of the nursing staff and were eliminated from the list of active routes in Section 7.2.1. These routes should be considered as the first choice if compromises are to be made in the design of the ward in favour of more critical routes and activities.

<table>
<thead>
<tr>
<th>Frequency Level</th>
<th>Number of Routes</th>
<th>Share in daily journeys</th>
<th>Average share of each route</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>29%</td>
<td>5%</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>41%</td>
<td>2%</td>
</tr>
<tr>
<td>4</td>
<td>54</td>
<td>22%</td>
<td>&lt;0.5%</td>
</tr>
<tr>
<td>5</td>
<td>130</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>
7.2.3 Analysis by staff type
The results listed above described the patterns in journey frequencies of all nursing staff as a team. Although this has been and will remain the main concern of this thesis, the wellbeing of none of the individual staff types can be overlooked. For this reason, a brief analysis of the journey frequencies of each staff type was performed. The results of this analysis, as demonstrated in Figures 7-3, 7-4 and 7-5, established the following.

- The largest number of journeys belongs to NA (almost 350 journeys per 24 hours per NA), followed by N (250 journeys) and finally HN (150 journeys). This means that, in average, the need for moving to another room (or to outside the ward) occurs every 4 minutes for NA, every 6 minutes for N and every 9 minutes for HN.
- The same pattern is observed in the variety of the routes taken by different staff types. During the data collection periods, out of the 80 active routes in the ward, only 25 of them were ever taken by HN and 47 by N. NA, on the other hand, took 69 of the routes at least once in 24 hours.
- Route “1 to 2” (between Nurse Station and Treatment Room) remains the most frequently taken route by Ns and NAs. In a 24 hour average, each member of these two staff types makes at least one journey per hour between these two spaces.
- For HN, most journeys happen between Nurse Station and Staff Room, where most of the non-medical administration activities, such as rota allocation, holiday allocation and ward staff meetings are concentrated.
- The situation of the patient(s) in each room has a significant impact on the frequency of N’s visits. For example, one of the most frequently visited rooms by N is room number 7, the Isolation-adaptable Room.
- In the case of HN and NA, however, the number of visits to similar patient rooms has a more consistent pattern.
- Almost all journeys of Ns and HNs are within the ward. For NAs, however, Journeys to other parts of the hospital form a significant part of their daily tasks. This is shown by the frequency of journeys to code 6, Ward Entrance/Exit.
Figure 7-3 Average journey frequency - One Nurse
Figure 7-4 Journey frequency - Head Nurse
Figure 7-5 Journey frequency - One Nurse Assistant
7.3  Analysis of the journey distance data from archetypal models

In order to be able to calculate the overall length of the room to room journeys of the nursing staff, in addition to the journey frequency (measured from empirical data in Section 7.2), the journey distance of each route was also evaluated using analytical methods. A combination of these two sets of empirical and analytical data formed the basis of the comparative analysis of the archetypal models.

7.3.1  Method

The first step in calculating journey distances was to identify origin/destination points (O/D points) in each model. Each O/D point represents one of the spaces in the ward and indicates the distance calculation point corresponding to that space. In rooms, for example, the O/D point is the door of the room or, more precisely, the middle point of the door opening. Some spaces have more than one O/D point. For example, Nurse Stations have three O/D points; two connecting them to the corridor and one to the Treatment Room. This represents the reality of the Nurse Station design in the case study and has been retained in all other models to assure the consistency of the method.

The second step consisted of designing journey paths between each pair of O/D points. Understandably, journey path of a real person between two points, further to the location of those points, is affected by many factors, such as speed of movement, existing traffic, ease of movement and even personal preferences. This means that journey paths are, by nature, impossible to predict or formulise. Even if these paths are recorded and measured from persons’ real movements, the use of such measurements is not practical for an analytical study for two reasons. Firstly, such paths are not repeatable (for the reasons mentioned above) and secondly, calculation of their length is not easy or accurate (due to the organic shape of the real movement paths).

Therefore, the decision was made to stylise journey paths by simplifying all movements into combinations of movements on right lines and right angles. In other words, the journey path between two O/D points, both located in one corridor comprises two straight lines (connectors) starting from the two O/D points,
perpendicular to the centre line of the corridor (at connection points) and a line along the centre line of the corridor between the two connection points.

The final step is to measure the length of this path by summing up the lengths of its components. Figure 7-6 shows an example of applying this method to one of the models.

Figure 7-6 Calculation of the lengths of journey path components

7.3.2 Journey distances in archetypal models
Based on the above method, all 21 O/D points in different models were identified and coded (Figures 7-7 to 7-10) and journey distances for all 80 active routes (as listed in Table 7-1 Shortlisted journey routes) were calculated in all archetypal models. Results of these calculations are presented in Table 7-3. The total given by this table is a general representative of the walking distances of one model in comparison to others, but it must be noted that different routes are still not weighted according to the frequency of their usage and therefore, the total given here cannot be taken as the final result of the comparison.
Figure 7-7 O/D points in Corridor model

Figure 7-8 O/D points in Nuffield model
Figure 7-9 O/D points in Racetrack model

Figure 7-10 O/D points in Radial model
<table>
<thead>
<tr>
<th>Route</th>
<th>Corridor</th>
<th>Nuffield</th>
<th>Racetrack</th>
<th>Radial</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 2</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>1 to 3</td>
<td>9.40</td>
<td>15.26</td>
<td>5.40</td>
<td>6.38</td>
</tr>
<tr>
<td>1 to 4</td>
<td>10.50</td>
<td>10.53</td>
<td>15.33</td>
<td>6.14</td>
</tr>
<tr>
<td>1 to 6</td>
<td>21.80</td>
<td>13.57</td>
<td>28.06</td>
<td>7.11</td>
</tr>
<tr>
<td>1 to 7</td>
<td>19.00</td>
<td>5.21</td>
<td>22.72</td>
<td>2.79</td>
</tr>
<tr>
<td>1 to 8</td>
<td>19.00</td>
<td>9.33</td>
<td>21.40</td>
<td>4.67</td>
</tr>
<tr>
<td>1 to 9</td>
<td>14.40</td>
<td>5.21</td>
<td>12.58</td>
<td>2.79</td>
</tr>
<tr>
<td>1 to 10</td>
<td>8.60</td>
<td>5.21</td>
<td>9.73</td>
<td>3.07</td>
</tr>
<tr>
<td>1 to 11</td>
<td>7.30</td>
<td>6.53</td>
<td>11.92</td>
<td>2.79</td>
</tr>
<tr>
<td>1 to 12</td>
<td>2.40</td>
<td>5.21</td>
<td>7.61</td>
<td>3.07</td>
</tr>
<tr>
<td>1 to 13</td>
<td>6.10</td>
<td>5.21</td>
<td>8.93</td>
<td>3.07</td>
</tr>
<tr>
<td>1 to 14</td>
<td>5.40</td>
<td>5.21</td>
<td>8.44</td>
<td>3.07</td>
</tr>
<tr>
<td>1 to 15</td>
<td>1.10</td>
<td>6.53</td>
<td>16.38</td>
<td>4.67</td>
</tr>
<tr>
<td>1 to 16</td>
<td>5.80</td>
<td>5.21</td>
<td>20.72</td>
<td>4.67</td>
</tr>
<tr>
<td>1 to 17</td>
<td>7.10</td>
<td>5.21</td>
<td>22.04</td>
<td>2.79</td>
</tr>
<tr>
<td>1 to 18</td>
<td>19.00</td>
<td>9.33</td>
<td>21.40</td>
<td>4.67</td>
</tr>
<tr>
<td>1 to 19</td>
<td>17.70</td>
<td>9.33</td>
<td>19.62</td>
<td>4.67</td>
</tr>
<tr>
<td>1 to 20</td>
<td>14.40</td>
<td>5.21</td>
<td>12.58</td>
<td>2.79</td>
</tr>
<tr>
<td>2 to 3</td>
<td>12.83</td>
<td>17.59</td>
<td>7.98</td>
<td>11.03</td>
</tr>
<tr>
<td>2 to 4</td>
<td>13.93</td>
<td>12.86</td>
<td>17.91</td>
<td>10.40</td>
</tr>
<tr>
<td>2 to 6</td>
<td>24.93</td>
<td>15.90</td>
<td>30.64</td>
<td>11.76</td>
</tr>
<tr>
<td>2 to 7</td>
<td>22.73</td>
<td>11.66</td>
<td>23.98</td>
<td>9.32</td>
</tr>
<tr>
<td>2 to 8</td>
<td>21.33</td>
<td>11.66</td>
<td>19.62</td>
<td>9.32</td>
</tr>
<tr>
<td>2 to 10</td>
<td>18.03</td>
<td>7.54</td>
<td>15.16</td>
<td>7.44</td>
</tr>
<tr>
<td>2 to 11</td>
<td>15.13</td>
<td>12.01</td>
<td>18.17</td>
<td>9.64</td>
</tr>
<tr>
<td>2 to 12</td>
<td>12.23</td>
<td>7.54</td>
<td>12.31</td>
<td>7.44</td>
</tr>
<tr>
<td>2 to 13</td>
<td>10.93</td>
<td>8.86</td>
<td>14.50</td>
<td>7.44</td>
</tr>
<tr>
<td>2 to 14</td>
<td>6.03</td>
<td>8.86</td>
<td>10.19</td>
<td>7.44</td>
</tr>
<tr>
<td>2 to 15</td>
<td>9.73</td>
<td>7.54</td>
<td>11.51</td>
<td>7.72</td>
</tr>
<tr>
<td>2 to 16</td>
<td>9.83</td>
<td>7.54</td>
<td>11.02</td>
<td>7.44</td>
</tr>
<tr>
<td>2 to 17</td>
<td>6.33</td>
<td>8.86</td>
<td>18.96</td>
<td>9.32</td>
</tr>
<tr>
<td>2 to 18</td>
<td>10.03</td>
<td>7.54</td>
<td>23.30</td>
<td>9.32</td>
</tr>
<tr>
<td>3 to 12</td>
<td>3.20</td>
<td>12.49</td>
<td>6.73</td>
<td>14.16</td>
</tr>
<tr>
<td>3 to 14</td>
<td>9.50</td>
<td>18.22</td>
<td>10.61</td>
<td>7.22</td>
</tr>
<tr>
<td>3 to 16</td>
<td>14.80</td>
<td>12.65</td>
<td>5.44</td>
<td>12.65</td>
</tr>
<tr>
<td>4 to 7</td>
<td>11.00</td>
<td>7.76</td>
<td>16.61</td>
<td>8.49</td>
</tr>
<tr>
<td>4 to 12</td>
<td>4.27</td>
<td>7.80</td>
<td>21.37</td>
<td>7.83</td>
</tr>
<tr>
<td>4 to 14</td>
<td>10.60</td>
<td>14.53</td>
<td>12.05</td>
<td>14.77</td>
</tr>
<tr>
<td>4 to 15</td>
<td>14.20</td>
<td>11.72</td>
<td>10.73</td>
<td>12.02</td>
</tr>
<tr>
<td>4 to 18</td>
<td>21.80</td>
<td>17.34</td>
<td>5.86</td>
<td>8.02</td>
</tr>
<tr>
<td>6 to 7</td>
<td>4.50</td>
<td>10.76</td>
<td>7.74</td>
<td>7.50</td>
</tr>
<tr>
<td>6 to 14</td>
<td>21.40</td>
<td>17.53</td>
<td>22.18</td>
<td>13.30</td>
</tr>
<tr>
<td>6 to 18</td>
<td>33.60</td>
<td>15.90</td>
<td>9.07</td>
<td>9.41</td>
</tr>
<tr>
<td>6 to 19</td>
<td>34.90</td>
<td>10.76</td>
<td>7.75</td>
<td>7.53</td>
</tr>
<tr>
<td>7 to 8</td>
<td>2.30</td>
<td>15.76</td>
<td>3.72</td>
<td>4.28</td>
</tr>
<tr>
<td>7 to 9</td>
<td>3.70</td>
<td>9.33</td>
<td>8.08</td>
<td>5.34</td>
</tr>
<tr>
<td>7 to 16</td>
<td>23.20</td>
<td>22.70</td>
<td>16.68</td>
<td>11.57</td>
</tr>
<tr>
<td>8 to 9</td>
<td>2.50</td>
<td>22.69</td>
<td>6.76</td>
<td>3.46</td>
</tr>
<tr>
<td>8 to 12</td>
<td>12.80</td>
<td>15.80</td>
<td>14.07</td>
<td>5.34</td>
</tr>
<tr>
<td>8 to 10</td>
<td>5.30</td>
<td>3.72</td>
<td>6.86</td>
<td>4.28</td>
</tr>
<tr>
<td>8 to 11</td>
<td>5.30</td>
<td>6.91</td>
<td>22.92</td>
<td>8.59</td>
</tr>
<tr>
<td>10 to 11</td>
<td>5.30</td>
<td>6.91</td>
<td>22.92</td>
<td>8.59</td>
</tr>
<tr>
<td>10 to 12</td>
<td>8.20</td>
<td>7.93</td>
<td>5.25</td>
<td>8.28</td>
</tr>
<tr>
<td>10 to 13</td>
<td>9.60</td>
<td>9.33</td>
<td>21.92</td>
<td>12.83</td>
</tr>
<tr>
<td>10 to 14</td>
<td>11.62</td>
<td>22.74</td>
<td>3.69</td>
<td>10.51</td>
</tr>
<tr>
<td>10 to 15</td>
<td>11.62</td>
<td>22.74</td>
<td>3.69</td>
<td>10.51</td>
</tr>
<tr>
<td>10 to 16</td>
<td>11.62</td>
<td>22.74</td>
<td>3.69</td>
<td>10.51</td>
</tr>
<tr>
<td>11 to 15</td>
<td>11.00</td>
<td>10.34</td>
<td>5.39</td>
<td>3.46</td>
</tr>
<tr>
<td>11 to 16</td>
<td>6.00</td>
<td>22.65</td>
<td>3.72</td>
<td>10.53</td>
</tr>
<tr>
<td>11 to 17</td>
<td>8.60</td>
<td>25.22</td>
<td>11.17</td>
<td>13.45</td>
</tr>
<tr>
<td>11 to 18</td>
<td>12.20</td>
<td>28.27</td>
<td>15.51</td>
<td>14.51</td>
</tr>
<tr>
<td>11 to 19</td>
<td>13.50</td>
<td>22.65</td>
<td>16.83</td>
<td>16.39</td>
</tr>
<tr>
<td>11 to 20</td>
<td>13.50</td>
<td>22.65</td>
<td>16.83</td>
<td>16.39</td>
</tr>
<tr>
<td>12 to 13</td>
<td>2.40</td>
<td>16.41</td>
<td>9.41</td>
<td>11.17</td>
</tr>
<tr>
<td>12 to 14</td>
<td>2.90</td>
<td>7.98</td>
<td>15.15</td>
<td>9.34</td>
</tr>
<tr>
<td>12 to 15</td>
<td>2.90</td>
<td>7.98</td>
<td>15.15</td>
<td>9.34</td>
</tr>
<tr>
<td>12 to 16</td>
<td>2.90</td>
<td>7.98</td>
<td>15.15</td>
<td>9.34</td>
</tr>
<tr>
<td>12 to 17</td>
<td>5.40</td>
<td>3.72</td>
<td>22.60</td>
<td>6.40</td>
</tr>
<tr>
<td>12 to 18</td>
<td>6.00</td>
<td>24.44</td>
<td>26.94</td>
<td>5.34</td>
</tr>
<tr>
<td>12 to 19</td>
<td>10.40</td>
<td>8.02</td>
<td>24.85</td>
<td>3.46</td>
</tr>
<tr>
<td>13 to 15</td>
<td>5.70</td>
<td>3.52</td>
<td>7.24</td>
<td>3.46</td>
</tr>
<tr>
<td>13 to 16</td>
<td>7.00</td>
<td>9.34</td>
<td>9.06</td>
<td>5.34</td>
</tr>
<tr>
<td>14 to 19</td>
<td>7.50</td>
<td>8.02</td>
<td>3.72</td>
<td>4.28</td>
</tr>
<tr>
<td>Total</td>
<td>899</td>
<td>909</td>
<td>1128</td>
<td>649</td>
</tr>
</tbody>
</table>
7.4 Comparative analysis of the archetypal models

True comparison of different design types in regards to the walking distance of the staff is not feasible without considering both frequency of the journeys and their distances. For this reason, the empirical data on journey frequencies (as described in Section 7.2) and the analytical data on their distances (Section 7.3) were combined to give the daily walking distances associated with each individual route as well as the whole model. Table 7-4 and Figure 7-12 present the distances walked by the whole nursing team in each route per day.

7.4.1 Results

As a result of the above analysis, the overall daily walking distance of the whole nursing team in each of the archetypal models is determined. As shown in Figure 7-11, Figure 7-12 and Table 7-4, in Corridor design, represented by the case study (Saba Ward, Atieh Hospital, Tehran), the nursing team walk more than 10 Km a day in corridors only (walking distances inside rooms are not subject of this analysis). Re-arranging the same rooms according to Nuffield model does not result in any meaningful change in the walking distance of the team. This, however, is not the case with the other two designs.

![Figure 7-11 Daily walking distance of nursing team in each model](image-url)
<table>
<thead>
<tr>
<th>Route</th>
<th>Corridor</th>
<th>Nuffield</th>
<th>Racetrack</th>
<th>Radial</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 2</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>1 to 3</td>
<td>190.38</td>
<td>183.11</td>
<td>454.06</td>
<td>596.48</td>
</tr>
<tr>
<td>1 to 4</td>
<td>68.25</td>
<td>68.45</td>
<td>99.65</td>
<td>39.91</td>
</tr>
<tr>
<td>1 to 6</td>
<td>610.40</td>
<td>379.96</td>
<td>785.68</td>
<td>199.08</td>
</tr>
<tr>
<td>1 to 7</td>
<td>1344.50</td>
<td>393.36</td>
<td>1755.36</td>
<td>210.65</td>
</tr>
<tr>
<td>1 to 8</td>
<td>555.75</td>
<td>272.90</td>
<td>625.95</td>
<td>136.60</td>
</tr>
<tr>
<td>1 to 9</td>
<td>346.63</td>
<td>182.71</td>
<td>333.70</td>
<td>91.45</td>
</tr>
<tr>
<td>1 to 10</td>
<td>129.60</td>
<td>46.89</td>
<td>113.72</td>
<td>25.11</td>
</tr>
<tr>
<td>1 to 12</td>
<td>658.62</td>
<td>399.00</td>
<td>745.16</td>
<td>235.11</td>
</tr>
<tr>
<td>1 to 13</td>
<td>137.48</td>
<td>122.98</td>
<td>224.49</td>
<td>52.55</td>
</tr>
<tr>
<td>1 to 14</td>
<td>55.00</td>
<td>119.40</td>
<td>174.40</td>
<td>70.35</td>
</tr>
<tr>
<td>1 to 15</td>
<td>320.25</td>
<td>273.53</td>
<td>468.83</td>
<td>161.18</td>
</tr>
<tr>
<td>1 to 16</td>
<td>322.65</td>
<td>311.30</td>
<td>504.29</td>
<td>183.43</td>
</tr>
<tr>
<td>1 to 17</td>
<td>58.80</td>
<td>182.84</td>
<td>458.64</td>
<td>130.76</td>
</tr>
<tr>
<td>1 to 18</td>
<td>355.75</td>
<td>272.90</td>
<td>625.95</td>
<td>136.60</td>
</tr>
<tr>
<td>1 to 19</td>
<td>346.63</td>
<td>182.71</td>
<td>333.70</td>
<td>91.45</td>
</tr>
<tr>
<td>2 to 3</td>
<td>127.23</td>
<td>174.43</td>
<td>79.14</td>
<td>109.38</td>
</tr>
<tr>
<td>2 to 4</td>
<td>62.69</td>
<td>57.87</td>
<td>80.60</td>
<td>46.80</td>
</tr>
<tr>
<td>2 to 6</td>
<td>58.17</td>
<td>37.10</td>
<td>71.49</td>
<td>27.44</td>
</tr>
<tr>
<td>2 to 7</td>
<td>333.79</td>
<td>111.22</td>
<td>373.18</td>
<td>109.74</td>
</tr>
<tr>
<td>2 to 8</td>
<td>53.04</td>
<td>27.21</td>
<td>55.95</td>
<td>21.75</td>
</tr>
<tr>
<td>3 to 12</td>
<td>4.80</td>
<td>18.74</td>
<td>10.10</td>
<td>21.24</td>
</tr>
<tr>
<td>3 to 14</td>
<td>28.50</td>
<td>54.66</td>
<td>31.83</td>
<td>21.66</td>
</tr>
<tr>
<td>4 to 7</td>
<td>16.50</td>
<td>11.64</td>
<td>24.92</td>
<td>13.34</td>
</tr>
<tr>
<td>4 to 12</td>
<td>12.81</td>
<td>23.40</td>
<td>64.11</td>
<td>23.49</td>
</tr>
<tr>
<td>4 to 14</td>
<td>15.90</td>
<td>21.80</td>
<td>18.08</td>
<td>22.16</td>
</tr>
<tr>
<td>6 to 7</td>
<td>6.75</td>
<td>16.14</td>
<td>11.61</td>
<td>11.25</td>
</tr>
<tr>
<td>6 to 14</td>
<td>32.10</td>
<td>26.30</td>
<td>32.27</td>
<td>19.95</td>
</tr>
<tr>
<td>6 to 18</td>
<td>100.80</td>
<td>45.18</td>
<td>27.21</td>
<td>28.23</td>
</tr>
<tr>
<td>7 to 8</td>
<td>92.96</td>
<td>636.97</td>
<td>150.35</td>
<td>172.98</td>
</tr>
<tr>
<td>7 to 9</td>
<td>6.17</td>
<td>15.55</td>
<td>13.47</td>
<td>8.90</td>
</tr>
<tr>
<td>7 to 16</td>
<td>34.80</td>
<td>34.05</td>
<td>25.02</td>
<td>17.36</td>
</tr>
<tr>
<td>8 to 9</td>
<td>99.38</td>
<td>901.93</td>
<td>268.71</td>
<td>137.54</td>
</tr>
<tr>
<td>8 to 12</td>
<td>16.00</td>
<td>19.75</td>
<td>17.59</td>
<td>6.68</td>
</tr>
<tr>
<td>9 to 10</td>
<td>228.34</td>
<td>160.27</td>
<td>295.55</td>
<td>184.40</td>
</tr>
<tr>
<td>9 to 12</td>
<td>32.00</td>
<td>32.97</td>
<td>32.97</td>
<td>21.33</td>
</tr>
<tr>
<td>9 to 14</td>
<td>29.00</td>
<td>5.27</td>
<td>38.78</td>
<td>8.90</td>
</tr>
<tr>
<td>9 to 17</td>
<td>35.40</td>
<td>46.43</td>
<td>32.87</td>
<td>24.59</td>
</tr>
<tr>
<td>10 to 11</td>
<td>15.90</td>
<td>37.44</td>
<td>80.94</td>
<td>43.41</td>
</tr>
<tr>
<td>10 to 12</td>
<td>37.07</td>
<td>326.63</td>
<td>203.00</td>
<td>320.16</td>
</tr>
<tr>
<td>10 to 13</td>
<td>20.00</td>
<td>19.44</td>
<td>45.67</td>
<td>26.31</td>
</tr>
<tr>
<td>11 to 12</td>
<td>7.95</td>
<td>10.37</td>
<td>34.38</td>
<td>12.89</td>
</tr>
<tr>
<td>11 to 18</td>
<td>64.20</td>
<td>54.69</td>
<td>22.05</td>
<td>21.78</td>
</tr>
<tr>
<td>12 to 13</td>
<td>95.77</td>
<td>138.49</td>
<td>702.41</td>
<td>603.70</td>
</tr>
<tr>
<td>12 to 14</td>
<td>48.40</td>
<td>43.62</td>
<td>81.18</td>
<td>51.37</td>
</tr>
<tr>
<td>12 to 15</td>
<td>15.83</td>
<td>28.74</td>
<td>24.12</td>
<td>47.30</td>
</tr>
<tr>
<td>12 to 16</td>
<td>52.29</td>
<td>102.13</td>
<td>15.87</td>
<td>47.30</td>
</tr>
<tr>
<td>12 to 19</td>
<td>29.85</td>
<td>25.68</td>
<td>35.34</td>
<td>17.36</td>
</tr>
<tr>
<td>14 to 11</td>
<td>339.27</td>
<td>300.18</td>
<td>216.96</td>
<td>374.10</td>
</tr>
<tr>
<td>14 to 15</td>
<td>31.17</td>
<td>29.30</td>
<td>15.27</td>
<td>9.80</td>
</tr>
<tr>
<td>14 to 16</td>
<td>165.00</td>
<td>622.88</td>
<td>102.30</td>
<td>289.58</td>
</tr>
<tr>
<td>14 to 17</td>
<td>32.90</td>
<td>44.39</td>
<td>18.76</td>
<td>20.18</td>
</tr>
<tr>
<td>14 to 18</td>
<td>18.30</td>
<td>42.41</td>
<td>23.27</td>
<td>21.77</td>
</tr>
<tr>
<td>14 to 19</td>
<td>40.50</td>
<td>67.95</td>
<td>50.49</td>
<td>49.17</td>
</tr>
<tr>
<td>15 to 16</td>
<td>108.00</td>
<td>73.85</td>
<td>42.59</td>
<td>50.27</td>
</tr>
<tr>
<td>15 to 17</td>
<td>101.98</td>
<td>280.63</td>
<td>532.78</td>
<td>328.46</td>
</tr>
<tr>
<td>15 to 18</td>
<td>29.40</td>
<td>24.06</td>
<td>42.57</td>
<td>19.20</td>
</tr>
<tr>
<td>15 to 19</td>
<td>21.60</td>
<td>44.28</td>
<td>36.41</td>
<td>70.29</td>
</tr>
<tr>
<td>16 to 17</td>
<td>186.30</td>
<td>128.14</td>
<td>779.70</td>
<td>122.80</td>
</tr>
<tr>
<td>16 to 18</td>
<td>33.75</td>
<td>9.15</td>
<td>101.03</td>
<td>20.03</td>
</tr>
<tr>
<td>16 to 19</td>
<td>28.63</td>
<td>22.06</td>
<td>68.84</td>
<td>9.52</td>
</tr>
<tr>
<td>17 to 18</td>
<td>212.83</td>
<td>157.32</td>
<td>288.34</td>
<td>113.78</td>
</tr>
<tr>
<td>17 to 19</td>
<td>61.00</td>
<td>84.06</td>
<td>81.54</td>
<td>48.06</td>
</tr>
<tr>
<td>18 to 19</td>
<td>86.46</td>
<td>213.20</td>
<td>98.89</td>
<td>113.46</td>
</tr>
</tbody>
</table>

Total 10524.29 10602.22 15138.37 7113.66
Figure 7-12 Nursing team’s room to room walking distance per day
A Racetrack design for the same ward would result in a substantial increase of 44% in the daily walking of the team by exceeding 15 Km of walking in a day. On the other hand, a Radial design would reduce this amount to the proximity of 7 Km, which means more than 32% less walking every day.

This suggests Radial design to have a clear advantage over other studied designs in terms of corridor walking distance of the nursing team provided that the daily activities of the team are similar to those applied here.

### 7.4.2 Sensitivity analysis

Results given above are both specific and general. They are specific to this size of ward (in number of patients, beds and rooms), this type of patients (general surgery patients), this number of staff (a relatively small team of nursing staff), this set of activities (as observed in data collection period) and this geographical and cultural background (a private health provider in the mega city of Tehran). It would be irrational to claim that the results of the study can be generalised to other settings, where the above factors are not identical to those of the studied ward. However, the variety of possibilities for different scenarios is so vast that it renders taking all these possibilities in consideration almost impossible.

On the other hand, these results are general in the sense that they examine the activities of the whole nursing team in a whole day. It is a valid argument that the same general results may not apply to more detailed studies on specific team members or specific working shifts. Sensitivity analysis can help track the impact of changes in the scale of study on the results.

The results of the analysis of nursing team’s walking distances in each shift (presented in Figure 7-13) reveal that Racetrack and Radial types retain their position in offering the greatest and smallest walking distances consecutively during the daily analysis. The other two types (i.e. Corridor and Nuffield) have also a similar situation to their daily analysis, but only during the morning shift. They show a greater difference during afternoon and night shifts, but these differences are in two different directions (meaning that in the afternoons it is Nuffield type that offers the shorter distance and
at night the shorter distance belongs to Corridor design). These differences cancel each other out in the overall analysis.

![Graph showing walking distance per shift in different design types](image)

**Figure 7-13** Nursing team's walking distance per shift in different design types

**Figure 7-14** summarises the analysis of the average daily walking distance for one member of each of the staff types N (Nurse), HN (Head Nurse) and NA (Nurse Assistant). When analysed by staff type, again the positions of Racetrack and Radial designs do not change. Comparison of Corridor and Nuffield types, however, shows that except for N, other staff types experience less walking in Corridor design. For N, Nuffield has a small advantage over Corridor by offering smaller walking distance.

In conclusion, data analysis results are slightly more sensitive to changes in staff types in comparison to changes in shifts. However, these changes are not so significant to affect the decision on final ranking of the design types.
Furthermore, although all effort has been made to keep the general adjacency order of the rooms consistent in all different archetypal models, it is impossible due to the design implications of the models to have a perfect match in all cases. Again, it could be argued that changes in room arrangements may invalidate the results achieved through the study. Therefore, another analysis is needed to investigate the sensitivity of the results to changes in the sequence of the rooms.

In the case study data collection, the frequency of the journeys between each pair of rooms and the length of these journeys were observed and recorded. These observations correspond to the activities of the nurses during the observation time. The argument is that the results derived from these data could be confounded by the distribution of the nurses’ activities within the data collection period. For example, if a room located in the far end of the ward (from the Nurse Station) was occupied by a patient in need of more frequent attention during data collection, this will have a notable impact on the overall walking distance of the team. However, in another occasion, the same patient could have been located in a room nearer to the Nurse
Station, which means a lower total walking distance compared to the previous scenario.

To examine the above argument, the workload of the nursing team was equally distributed between similar rooms. In other words, the frequencies of journeys from similar rooms to a common destination were considered identical and equal to the average of the journey frequencies from all of those rooms to the destination. Similarity in this sense was only applicable to patient rooms, because there was only one of each of the other room/spaces and the only rooms that had similar function to each other were the patient rooms.

There were three types of patient rooms in all the models studied here: 7 Single-bed Rooms; 4 Double-bed Rooms; and one Isolation-adaptable Room. The Isolation-adaptable Room, being unique in number, was not subject of this sensitivity analysis (considering that its positioning had been kept as consistent as possible in all models). Each of the other two types of patient rooms formed a category of spaces, for which the journey frequencies were normalised and made equal.

Routes with very low or no journey frequencies (routes with a journey Frequency Level of 4 or 5 as described in Section 7.2.2) were eliminated from the study due to their insignificant share in the daily journeys of the nursing staff. Routes to or from patient rooms with a Frequency Level of 1, 2 or 3 were categorised in three groups:

- 7 Routes between the Nurse Station and Single-bed Rooms (Routes 1 to 8, 1 to 9, 1 to 10, 1 to 13, 1 to 17, 1 to 18 and 1 to 19);
- 4 Routes between the Nurse Station and Double-bed Rooms (Routes 1 to 12, 1 to 14, 1 to 15 and 1 to 16); and
- 11 Routes between adjacent patient rooms (Routes 7 to 8, 8 to 9, 9 to 10, 10 to 12, 12 to 13, 13 to 14, 14 to 15, 15 to 16, 16 to 17, 17 to 18 and 18 to 19).

The normalised journey frequencies for these categories were calculated to be 24, 53 and 36 consecutively. This normalised value substituted the original values for each routes journey frequency to provide an even distribution of nursing team’s workload between similar rooms. Analysis of the nursing team’s walking distance was repeated
using this new set of frequency data. Figure 7-15 presents the results of this analysis together with the results of the original study (discussed in Section 7.4.1) and shows that variation in the order of similar rooms has negligible impact on the analysis of archetypal models for nursing team’s walking distance.

![Figure 7-15 Walking distance of the team, normalised for top 3 frequency levels](image)

### 7.5 Summary

The empirical data collected from the case study were analysed for extracting journey frequency data. This analysis revealed five distinct levels of frequency among the journey routes in the ward. These levels also correspond to the priority of each of these routes during the layout design of the ward. Another set of data, i.e. journey distance data was obtained from the archetypal models designed in Chapter 6 using a method for calculating the distance between two ends of each pair of origin/destination points in the ward.

Combining these two sets of data helped comparing different design types in regards to the total walking distance of the nursing team per day in each of the designs. This analysis showed that with the given activity data, Radial design offers the shortest walking distance for the whole team by eliminating almost one third of the amount of
walking done by the team in a day in Corridor design. The Racetrack design proved to
impose the greatest amount of walking to the team (more than twice as much as
Radial design). Walking distances in Corridor and Nuffield designs were almost equal.

Sensitivity analysis showed that the analysis results do not show significant divergence
by changes in working shifts or staff types. In all different variations, Radial and
Racetrack designs remained the designs with consecutively shortest and longest
walking distances. Changes in the order of similar rooms also showed minimal impact
on the results.
Guidelines for improving hospital staff productivity and circulation
8.1 Introduction

In this chapter, results of the study are distilled into the format of guidelines that provide a better understanding of nursing staff productivity as influenced by the layout design of the ward. This includes: a review of the theoretical implications of integrating productivity in the design philosophy of hospital wards; a discussion on the method of ranking ward designs based on nursing staff’s productivity; and an introduction of some generic recommendations for the design of high-productivity wards.

8.2 Definition of a high-productivity ward

As comprehensively discussed in the literature review of this thesis (Chapters 3 and 4), there are many factors that define the productivity of a hospital. Only a fraction of these factors are related to the environment of the hospital, which affect productivity through affecting one or more of the three indicators of hospital productivity (namely, service quality, staff morale and resources).

Wasted time due to layout and circulation design of the hospital is only one of the many factors influencing hospital productivity, but it was discussed to have a negative impact on all three productivity indicators. It reduces service quality by diverting part of the potential caregiving time to unnecessary travelling between different spaces in a hospital. It has a negative impact on the morale of the nursing staff for imposing fatigue and the sense of time wastage. It also wastes one of the most valuable resources of any production unit, which is time, especially skilled staff time.

Therefore, while acknowledging the importance of all other factors, the time spent by the nursing staff for their room to room journeys was introduced as one of the important factors involved in determining productivity of a hospital ward. From this perspective, a high-productivity ward needs to impose minimum amount of room to room walking on the nursing staff.

To insure this, a method is introduced to choose the best option from among possible design options for a ward. Although this method was established and exemplified for design types based on established categories of approaches towards ward layout, it is not strictly limited to those few designs. On the contrary, it can be used for all design
options available for a ward in order to rank them according to the amount of walking imposed by each of them on nursing staff.

8.3 Method
To offer a better understanding of the terminology of these guidelines, it is essential to offer a definition for some of the terms frequently used in the current context.

**Route**: In these guidelines, the route between two spaces is defined as a succession of straight lines which join a number of given points and paths between two spaces taken in the following order.

![Diagram](image)

**Figure 8-1 Succession of the components of a journey route**

1. **Origin Point**: the middle point of the door opening of the space where a journey starts.

2. **Origin Connector**: the shortest line between Origin Point and Origin Connection Point.

137
3. **Origin Connection Point**: the nearest point on the central line of the corridor to the Origin Point.

4. **Corridor Central Line**: a straight, curved or broken path on the geometric axis of the corridor that connects Origin and Destination Connection Points.

5. **Destination Connection Point**: the nearest point on the central line to the Destination Point.

6. **Destination Connector**: the shortest line between Destination Connection Point and Destination Point.

7. **Destination Point**: the middle point of the door opening of the space where a journey ends.

The schematic diagram in Figure 8-2 shows a simple example of the above components for a hypothetical route from Room A to Room B.

![Schematic presentation of the components of a journey route](image)

**Figure 8-2 Schematic presentation of the components of a journey route**

**Journey**: each incidence of a member of staff’s movement from a room to another room along the journey route.

**Journey Distance**: the length of the route for each journey.
**Journey frequency**: number of incidences of a journey in a given unit of time (e.g. day, shift, etc.).

The method introduced by this study relies on an understanding of two factors: movement patterns of the nursing staff; and impact of the ward layout on the length of these movements. The former factor provides data on the frequency of the journeys associated with each route within the ward and the latter defines the distances covered by each route. These two sets of data are different in nature and their implications. Some of these differences are summarised in Table 8-1. The following presents a discussion on how these two sets of data are obtained and combined to help predicting the impact of different design options on staff’s productivity.

<table>
<thead>
<tr>
<th>Data type:</th>
<th>Journey frequency data</th>
<th>Journey distance data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Source:</strong></td>
<td>Staff movement patterns</td>
<td>Layouts design options</td>
</tr>
<tr>
<td><strong>Collection method:</strong></td>
<td>Direct observation</td>
<td>Calculation</td>
</tr>
<tr>
<td><strong>Nature:</strong></td>
<td>Empirical</td>
<td>Analytical</td>
</tr>
<tr>
<td><strong>Accuracy:</strong></td>
<td>Precise</td>
<td>Approximate</td>
</tr>
<tr>
<td><strong>Representativeness:</strong></td>
<td>Case-specific</td>
<td>Generic</td>
</tr>
<tr>
<td><strong>Repeatability:</strong></td>
<td>Normally distributed</td>
<td>Absolute</td>
</tr>
<tr>
<td><strong>Enhancement method:</strong></td>
<td>Sample size</td>
<td>Precision</td>
</tr>
</tbody>
</table>

### 8.3.1 Journey frequency data

As mentioned above, journey frequency data are obtained from direct observation of staff movement patterns. Such data, although precise for the observation subject, are not generic to other similar subjects without statistical analysis. Therefore, to enhance the richness of the data, it is important to have access to a large pool of balanced data. Ideally, observations should cover all different types of the staff working in a ward. They should also respond to different workloads in accordance to time variations (e.g. different times of the day, different days of the week, different seasons, etc.).
Collection of such data needs to be planned in a way to cause minimum interruption in the working duties of the staff and no invasion of patients’ privacy. One suggestion for collecting journey frequency data is the use of electronic tracking devices coupled with a data logging software. This involves all participants to be tagged with radio frequency identification (RFID) devices. Sensors installed at O/D points register every incidence of the participant crossing the point. The data collected in this way are then superimposed on a graphic representation of the ward to catalogue the frequency of the journeys in each route during the observation period. Advantages of this method include the possibility of simultaneous observation of multiple participants, possibility of recording interactions of different participants and the prospect of prolonged and non-stop observations with minimum labour. On the other hand, a lack of an ethnographic observation seems to be the main disadvantage of this method. In other words, although this technology keeps an exact record of the movements within the ward and is precise with the number of movements and their durations, etc., it does not reflect on why movements happen and how different they are from each other. All movements are judged of equal value while they may not necessarily be so. This method is a better choice when a large sample size seems to compensate for shortcomings in data quality and relevance.

An alternative method is to take a stance more inclined towards ethnography of the events and actions. This needs the presence of researchers on the site for the duration of observations. It is the researchers and their observations that decide, for example, if a registered occurrence of journey from Point A to Point B was a necessary and irreplaceable journey to perform a duty or was simply an optional ‘stroll’ at a time of light workload. If the data from RFID were to be trusted without further probation, a simultaneous movement of all staff and patients in one direction to respond to a fire alarm might add a significant wrongful bias to the observations, while learned interpretation of a researcher would put such data in its specific category to prevent accumulation of biased and confounded data. Therefore, this method is the chosen practice when the need is felt for the addition of a degree of interpretivism to the method in order to differentiate between different levels of data quality and relevance.
Therefore, whether through a more technological approach or a more ethnographic one or even a combination of the two, the data collected in this stage should provide the following information on each single journey of each participant:

- purpose (the reason of the journey and if it is or it is not part of a routine and repeatable task);
- route (the origin and the destination of the journey);
- frequency (the number of times a journey is taken); and
- duration (the start time and the end time).

One of the earlier methods used by researchers for recording staff journeys was the use of strands of cotton on a plan drawing of the ward. In this method (demonstrated for example by Nuffield Trust, 1955) the intensity of nurse traffic in different spaces of the ward can be visually compared (e.g. Figure 8-3).

Figure 8-3 A method for recording nurses traffic intensity in different spaces (Nuffield, 1955)
The focus of this method is more on how many journeys pass through each space of the ward rather than how and why a journey happens. A potential improvement to this method may entail collection of data on the origin and destination of each journey in relation to the task a nurse is performing. Data collection procedures and sample forms presented in this thesis (Section 6.3.4) may help design of such data collection method.

Figure 8-4 Observations for journey frequency data

8.3.2 Journey distance data
Journey distance data, as stated earlier, are obtained from the study of layout design by measuring and calculating the length of each route from Origin Point to Destination Point. This measurement may be performed using a simplification convention, such as moving on right lines and right angles (as explained in Section 8.3). This convention concedes the fact that the measurement given through this approach may not be a precise representative of a person’s walking distance. However, it offers a consistent method that, at least for the sake of comparison, is equally applicable to different routes and different designs. When applied to all the routes in all different design options, this method provides a complete list of distances between every single pair of O/D Points, which forms one of the two sets of the data needed for a comparative analysis of different design options.

Design options may be specifically designed for the given briefing, in which case the criteria presented for maximum similarity in number of spaces and their sizes and
adjacencies are normally assured. In the absence of specifically designed options, hypothetical designs representing established ward design types may substitute real designs. Archetypal modelling system presented in Section 6.4 of this thesis was an example of such practice applied to the spatial specifications of the case study.

Whether through specifically designed options or hypothetical ones, the approach introduced for measuring and calculating journey distance data devises the second set of data needed for the comparative analysis of different options.

### 8.3.3 Comparative analysis of the models based on the walking distance of the nursing team

Combining the two sets of the aforementioned data results in determining the amount of walking each route imposes on the staff team per day. By calculating the total of walking distances of the routes in each option, a ranking of the options in order of the team’s walking distance per day is constructed.

In addition to the total walking distances, this method can also address smaller scales of comparison (e.g. comparison of different shifts or different team members as presented in Section 7.4.2). It can also be used in finding the optimum arrangement of rooms in relation to the walking distance between the team. Figure 8-4 presents a schematic summary of the above method.

![Figure 8-5 The design comparison method outline](image)
8.4 Design recommendations for high-productivity wards

8.4.1 Nurse Station
As the evidence provided in this study established, Nurse Station is, by far, the most frequently visited space in a hospital ward. More than 50% of the daily journeys of the nursing team either start from or lead to this one space. It is, therefore, imperative to consider the positioning of this space as the first priority in the layout of a ward from the viewpoint of minimising unnecessary walking by nursing staff.

Regardless of the overall layout of the ward, Nurse Station needs to be located in a central point of the ward providing easy access to patient rooms, Acuity-adaptable Room, Treatment Room, Staff Room and Ward Entrance. However, compact designs, such as Radial design, offer an advantage over linear ones, such as Corridor and Racetrack design, in keeping the walking distances to the end-of-the-row rooms to minimum. Inclusion of a few smaller stations, instead of one central nurse station (as per Nuffield design) is another strategy to allow easy access of the nurses to different rooms.

8.4.2 Treatment Room
More than 15% of all journeys to or from Nurse Station (and 8% of all journeys in the ward) occur between Nurse Station and Treatment Room. This is the most critical route in the ward from a walking distance perspective. Many tasks of the nurses (which start from the Nurse Station) need a stop in the Treatment Room. Nurses need to pick up medicines, wound dressing sets and monitoring equipment from Treatment Room before attending patients. Most of the medical tools also need to be returned to this room for in-house cleaning. A significant part of documentation tasks are also performed here.

Therefore, it is essential to keep the distance between this room and the Nurse Station to minimum, or completely eliminate it (by providing direct access between two spaces without the need of going through a corridor) to insure prevention of any extra walking for the nursing staff. This strategy is also applicable to all design types by easily placing these spaces next to each other in the design and providing a door between
them. In the specific case of Radial design, care must be taken that direct access and view from the Nurse Station to patient rooms is not blocked by Treatment Room.

### 8.4.3 Staff Room

In the studied case and, consequently, in the models created based on that, Staff Rooms had functions covering a broader range than those of a normal Staff Room. Normally, ward staff visit the Staff Room only to take their breaks, have some quiet time, eat a sandwich, have a friendly chat or drink a cup of coffee. In the arrangements used in this thesis, however, Staff Room also played the role of the ward ‘office’ hosting non-medical administrative tasks of the staff, and especially the Head Nurse.

This, although not unprecedented (according to the expert interviews during the case study), is not a necessary part of Staff Room’s functions. Therefore, the bias of the data in over-estimating the importance of the journeys to and from this space (with nearly 8% of all journeys in the ward) should be considered when this data are used to inform design guidelines. In general, if Staff Room assumes extra functions as an administration office, it needs to be located in close proximity of the Nurse Station and Treatment Room.

### 8.4.4 Ward Entrance

Apart from movements between different rooms inside a ward, all other daily corridor walks of the ward staff crosses the point of entrance to the ward. The share of journeys to or from this point in daily nursing staff’s journeys was slightly greater than 3%. When considered that these journeys are to places outside the ward, where the distances are much greater than those of internal journeys, the importance of these journeys in the daily share of staff’s walks is signified. The greatest part of these journeys, however, occurs outside the ward and is, therefore, out of the scope of this study.

As far as this study is concerned, the most important space in relation to Ward Entrance is Nurse Station. This means that Nurse Station should be kept close to Ward Entrance. Further to minimising the walking distance between the two spaces, this strategy also insures that staff in the Nursing Station have a constant visual control over the Entrance. This is a quality that was recommended by the nurses and
architects alike during expert interviews. However, the centrality of the Nurse Station (as stated in Section 8.4.1) is of a greater importance and should overrule its proximity to the Entrance when both qualities cannot be satisfied in a design.

8.4.5 Patient rooms
In addition to maximum accessibility and visibility from the Nurse Station, patient rooms also need to facilitate ‘taking rounds’ (performing tasks that need to be repeated in all patient rooms one after another). For this reason, it is recommended that patient rooms are kept next to each other in a way that all of them can be accessed in one round trip from the centre of the ward (i.e. Nurse Station). Placing patient rooms in separate wings in a ward or designing other spaces in between of a row of patient rooms, which adds un-necessary distance between the doors to two consecutive patient rooms, are design strategies that should be avoided if possible.

8.4.6 Proximity matrix
To summarise the above guidelines, the suggested proximities of different spaces in a ward are presented in form of a matrix (Table 8-2). In this matrix, the strongest proximity need is coded as 1 and the least important ones as 5. The spectrum between these two ends expresses how important it is for the designer to keep a pair of ward spaces close to each other.

Table 8-2 Ward spaces proximity matrix

<table>
<thead>
<tr>
<th></th>
<th>Service &amp; Utility</th>
<th>Ward Entrance</th>
<th>Single-bed Room</th>
<th>Isolation-adaptable Room</th>
<th>Double-bed Room</th>
<th>Staff Room</th>
<th>Treatment Room</th>
<th>Nurse Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nurse Station</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Treatment Room</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Staff Room</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double-bed Room</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isolation-adaptable Room</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-bed Room</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ward Entrance</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Service &amp; Utility</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

146
It is essential to note that this matrix is only advised for minimising the nursing team’s walking distances. Other factors that may affect the positioning of a ward’s different rooms and spaces are not to be compromised by this one factor. Also, the walking distances of other people in a ward, including non-nursing staff, patients, and visitors, should be considered in the final design of the ward. It should also be noted that the space names in this matrix reflect a set of specific functions as defined by the case study. These functions may have different definitions in other cases.

### 8.5 Summary

This chapter summarised some of the lessons learnt from the study presented in this thesis. These lessons were categorised in three different levels of theory, method, and recommendations. At the first level, a theoretical basis was presented that offered explanations for some of the definitions and terminologies used in the guidelines. The next level introduced a method for selection of a design type by comparison and ranking of different layout options according to their impact on the daily walking distance of the ward staff. The third and final level involved specific design recommendations on spatial arrangement of a hospital ward as informed by the present study.

These guidelines provide a decision-making aid for healthcare planners and designers in the process of circulation system selection in hospital ward design by explaining the implications of the chosen systems on the walking distance and, consequently, the productivity of the nursing staff. Such competence positions these guidelines as an essential aid in the decision-making process of both new-build designs and refurbishment projects. It also has the potential for being used in the operational management of hospital wards by helping re-arrangement of space utilisation for maximising staff productivity. From this point of view, parts of these guidelines can be re-defined for application in other sectors, where operation productivity is influenced by the distances between different components of the system.
9 Conclusions, recommendations and further work
9.1 Introduction
In this chapter, findings of the study and its contribution to knowledge and practice are presented. Also, some of the measures that would enhance the validity of the results in a broader context and should be considered in future studies are discussed.

The study was set out to explore the concept of high-productivity hospital wards and has identified the nature of nursing staff productivity and how it is influenced by ward design and current UK standards and guidelines, as well as different classical and modern approaches towards ward design. The study has also sought to investigate the impact of these different approaches on the daily routine of nursing staff. The general theoretical literature on this subject is inconclusive.

9.2 Conclusions of the objectives
The study sought to achieve the following objectives.

1. Articulate current knowledge on the relationship between productivity and people circulation.
2. Explore and demonstrate the importance of good access and circulation in hospitals.
3. Review and compare application of current UK design standards and guidelines and hospital productivity audit and planning tools, in order to identify the hospital productivity in the current UK context.
4. Analyse productivity and circulation aspects of the most common types of hospital designs.
5. Develop guidelines for improving hospital nursing staff productivity and circulation.

Following, a discussion on how these objectives have been addressed in the study is presented.

9.2.1 Objective One
‘Explore and demonstrate the importance of good access and circulation in hospitals’

The first objective of this research was to establish an understanding of the importance of layout design in the performance of the hospitals. This objective has been addressed in the earliest passages of this thesis in Chapter 1.
A review of the previous research demonstrated that an unnecessarily significant amount of nursing staff’s time is spent in corridors for moving between different spaces of a hospital instead of caregiving services. Any reduction in this wastage could enhance the performance of the hospital. The importance of hospital staffs’ caregiving time is better understood when issues such as continuous rise in the number of the NHS users, constant staff shortage of the NHS and the financial implication of building new hospitals are taken into consideration. This emphasises the importance of the design of healthcare buildings that allow service provision to the maximum number of patients by the minimum number of staff without overlooking the physical and psychological needs of the staff.

9.2.2 Objective Two
‘Articulate current knowledge on hospital staff productivity and its relationship with layout design’

Within its second objective, the research set to provide knowledge on how hospital staff productivity is defined and how it is influenced by the design of the hospital. The delivery of this objective was the main focus of Chapter 3.

Productivity is considered to be highly intertwined with concepts such as performance, efficiency and effectiveness and was defined by this study to be determined by the following three factors: service quality; staff morale and resources. All of these three factors can be influenced by layout design. A good hospital design can improve service quality by reducing cross infections and medical errors and promoting patients’ physical, mental and social wellbeing as well as facilitating users’ way-finding. It can also improve staff morale by reducing their physical and mental stress and dissatisfaction. Moreover, a good layout design can reduce patients’ length of stay and staff injuries. By this and also, by providing easier patient transfers and staff workflow, it can affect the resource demands of a hospital as well. This ascertains the strong impact of the design layout on hospital staff productivity.
9.2.3 Objective Three
‘Review and compare application of current UK design standards and guidelines and hospital productivity audit and planning tools, in order to identify the hospital productivity in the current UK context’

This objective was covered in Chapter 4 by reviewing some of nationally recognised design, operational audit and strategic planning tools related to people circulation from hospital productivity point of view.

There is a long list of guidelines that hospital designers need to consider and sometimes comply with. There are also a variety of tools that have been implemented for assuring continuous compliance of the hospitals with the aforementioned guidelines. However, a very small number of these guidelines and tools directly deal with the impact of a hospital’s design on its staff’s productivity. Some quality improvement initiatives, such as Lean and Productive Ward, have considered optimising the procedures within a hospital ward towards increasing productivity, but have not addressed the design layout in this context. The study established the need for guidelines that distinctively refer to layout design for high-productivity hospital wards.

9.2.4 Objective Four
‘Identify most common types of hospital ward designs and their characteristics’

Chapter 5 addressed the above objective by identifying different types of hospital layout design and reviewing the exemplar practices in order to shape the basis of the selection of layout types in regards to access and circulation systems.

Typology of ward layout designs based on their room arrangement has been tried by different researchers before and has resulted in different layout type lists. From the point of view of nursing staff’s circulation, a typology of different layout designs of a ward needs to be based on the design of its circulation space (corridors) and the arrangement of ward rooms around this space. By studying previous typologies and eliminating designs that are now outdated or have evolved into other design types and by combining those layouts that can be included under the same category, most ward
layouts can be categorised in four main groups, namely Corridor, Nuffield, Racetrack and Radial designs (this has been discussed in Section 6.2).

The claim that these categories cover most design types is only valid when implications of the context within which each ward is designed is understood and considered. For example, in the design of most UK hospital wards today, trends such as emphasis on the number of single-bed rooms and acuity-adaptable rooms and also the increasing number of users suffering from dementia and bariatric conditions need to be addressed.

9.2.5 Objective Five
‘Analyse nursing staff’s circulation in the most common types of hospital design’

This objective was addressed by devising a data collection and analysis method (as discussed in Chapter 6) and systematic application of this method in the analysis of a case study and its alternative design options (Chapter 7).

The nursing team’s movements between different rooms of a ward need to be studied by identifying routes that they use more frequently in their daily tasks. For this reason, journey routes and the frequency of their usage need to be identified. When combined with the data (such as the length of each route) derived from different design options, this data can help identify the most productive option from the perspective of nursing team’s daily walking between rooms. An exemplar usage of the method to probe different design options for a selected case study resulted in a ranking of the options according to the overall walking distance of the nursing team.

9.2.6 Objective Six
‘Develop guidelines for improving hospital nursing staff productivity and circulation’

In response to this objective, a set of guidelines was presented in Chapter 8. These guidelines include a set of definitions, methods and design recommendations. Recommendations offered by the guidelines address the positioning of different rooms (i.e. Nurse Station, Treatment Room, Staff Room, Ward Entrance, Patient Rooms, etc.) within a ward and presents a proximity matrix of the ward spaces with the aim of minimising nursing team’s walking distances.
These guidelines are presented as a decision-making aid to help identify design options that impose minimum amount of extra walking on the ward’s nursing team. Furthermore, they can be used in planning spatial rearrangements in existing wards to improve productivity of the ward by reducing nursing team’s wasted time in room to room walking.

9.3 Findings
This section highlights some of the main findings of this research as identified through the preliminary investigations, the case study, the modelling and the comparative analysis of layout designs. These findings include: further empirical and analytical support for the impact of the ward design on nursing staff’s performance; a ranking of the suitability of different design layouts for minimising staff’s unnecessary walking in wards similar to the case study; the importance of considering different staff members’ needs in such analyses; and a ranking of the criticality of different routes within a ward.

9.3.1 Importance of good access and circulation in hospital wards
The analysis in Section 7.4.1 revealed that even in a relatively small ward like the one presented in the case study, the nursing team (collectively) may have to walk more than 15 Km per 24 hours only in the corridors (in the case of the Racetrack design). It also exhibited that the careful selection of ward design type (in this case, selection of Radial design over Racetrack design) can eliminate up to 53% of room to room walking of the nursing staff. This supports further analytical evidence for the perceived importance of design type selection in hospital wards as stated in the literature review.

9.3.2 Staff circulation in different hospital ward designs
The comparative analysis showed that for the studied case, and arguably for other wards with similar functions, placing a few smaller Nurse Stations in different parts of the ward (as in Nuffield design) although offering better access from the Nurse Station to patient rooms, does not have a significant impact on the overall walking distance of the nursing staff in comparison to a conventional Corridor design. Radial design offered the best option for the studied ward with the smallest amount of walking distance among different design types. Racetrack design, on the other hand, proved to impose the greatest amount of walking on the nursing staff and was, therefore, the least desirable design among the studied types, at least for the ward in the case study.
9.3.3 Variance by staff type
Above findings were derived from the study of the entire nursing team. When different staff types were studied, the results were not always the same and some partial variations were observed in the results. The most notable variation was the difference between the Corridor design and the Nuffield design. These two designs resulted in almost equal amount of room to room walking when analysed for the entire nursing team. However, when different staff types were considered, the results showed two different patterns. Although Nuffield design offered reduction in the amount of room to room walking of the ward Nurses (represented by N in Figure 7-14) when compared to Corridor design, it had a negative impact on the walking imposed on other staff types, i.e. Head Nurses (HN) and Nurse Assistants (NA).

9.3.4 Critical routes
An analysis on the frequency of room to room journeys within a ward (in Section 7.2) revealed five categories of journey frequency levels, which corresponded to how critical each of the 210 routes was in the overall design of the ward. Based on this analysis, the highest level of criticality belonged to the route between the Nurse Station and the Treatment Room, which on its own hosted 8% of the daily journeys in the ward. This means that in the design of a ward similar to that studied in this thesis, the distance between Nursing Station and Treatment Room should be eliminated or kept to the minimum and no other route should be given priority over the route between these two spaces.

The next level of criticality belonged to the routes from the Nurse station to Staff Room, Isolation-adaptable Room and Double-bed Rooms. In average, 5% of the daily journeys happened in each of these six routes. The category comprising the routes in the third criticality level comprised 19 routes, each of them holding about 2% of the daily journeys in the ward in average. These were routes from the Nurse Station to other Single-bed Patient Rooms and to the Ward Entrance. Another group of routes in this category were those between adjoining patient rooms.

The fifth category included 54 routes, each of them hosting (in average) less than 0.5% of the daily journeys of the ward. These routes and the ones that were never used during one working day of the ward (the 130 routes with a journey frequency of 0 and
a criticality level of 5) were discussed to be the best choices for a compromise when trying to shorten the distance of one of the routes in higher levels.

9.4 Contribution to knowledge and practice
Contributions made by this study to knowledge and practice can be categorised under five main titles as follows.

- Literature review
- Data collection method
- Case study dataset
- Archetypal modelling method
- Comparative study method
- Guidelines

9.4.1 Literature review
The literature collected and presented under this research has provided a comprehensive view of the issues around hospital ward productivity from three different points of view: productivity theory and methods for the assessment and improvement of productivity; existing guidelines, tools and methods for incorporating productivity measures in ward design; and a timeline of theories, trends and practices affecting ward design from the time of Florence Nightingale until today. This collection has provided a base for future studies in the field.

9.4.2 Data collection method
The study also makes a methodological contribution, having also introduced a robust, yet practicable method for collecting data on the movements of the nursing staff in the ward, based on the observations and judgements of a single researcher within limited time and budget. All different stages of the method, from case study selection to engaging with participants, planning, ethical considerations, data collection, data cleansing and preliminary analysis have been presented in relevant passages of the thesis. The method is specifically designed for studying nursing staff’s movements, but is also adaptable to similar settings where people’s circulation and movements are studied.
9.4.3 Case study dataset
Lack of access to detailed datasets on nurses’ daily activities and movements within a ward caused a great amount of delay for the present study. Significant amounts of time and budget were spent to create such a dataset. Now, a reliable set of data generated through a robust methodology within this research is available for similar studies in the field. As mentioned earlier, not all of the data collected from the case study were analysed and presented in this thesis (for not being directly related to the topic of the study). These data and their analysis will be gradually presented to the academia through future publications.

9.4.4 Archetypal modelling
A method for allowing comparison in the absence of comparable designs has been used and further developed in this research. This method is applicable to situations where different design types of ward layout need to be studied, but all factors influencing the performance of each type (except for those related to their spatial arrangement) are to be eliminated to prevent the emergence of confounding results. The method substitutes the almost impossible task of finding real case studies that are different in spatial arrangement and identical in all other aspects by a combination of one case study and a few hypothetical models that represent remaining arrangements while retaining other characteristics of the case study. Such models can then be used in various analyses and simulations in different studies. Archetypal models designed for this research represent different ward design types based on the spatial needs of the case study and can be used for similar studies or developed to accommodate the needs of studies with different scales and scopes.

9.4.5 Comparative study method
The study has presented a method for extracting meaningful patterns from the data gathered during case study and archetypal modelling phases to inform the amount of nursing staff’s walking in different design types. The first stage of this method involves identifying all possible routes between different ward spaces. At the second stage, an analysis of the frequency data on all journeys from the case study highlights routes with a higher criticality level. These are routes visited more often than others during the daily routine of the nursing staff and, for that reason, need to be kept in minimum
length. This part of the method can be used in studies in search of spaces and rooms that need to be kept in close proximity.

The next stage of the method handles data on journey distances in the archetypal models. The improvised method for calculating these distances addresses the problem of non-repeatability of journeys (the fact that the route between two points can be taken in an endless number of different ways) by a simple geometrical solution that assures the consistency of the calculation method. This consistency was discussed to compensate for the estimation errors occurred as a result of the geometrical solution based on right lines and right angles when a comparison between different distances is more important than the accurate value of each distance.

The final stage of the method combines data on journey frequencies and journey distances in order to allow for a comparison between different design types according to the overall walking distance of the team. Further to the entire team, the same method is applied to individual staff types to observe the implications of design selection on each of them. This method can be modified to inform other similar comparisons based on the walking distance of the team.

9.4.6 Guidelines
The Guidelines presented in this thesis have been designed as an aid for understanding and implementing nursing staff productivity in the design of new-build wards and in the refurbishment plans of the existing ones. The guidelines comprise three main sections. The first section provides a theoretical basis for understanding the nature of staff productivity in the context of hospital ward functions. The second section offers details on the use of the data collection, cleansing and analysis method of the study. The third section summarises some of the lessons learnt from the exemplar study that have the potential to be generalised in form of recommendations to be used in similar designs.

The guidelines include recommendations for the positioning of different ward spaces (Nurse Station, Treatment Room, Staff Room, Ward Entrance and Patient Rooms) within the ward and in relation to each other with the goal of minimising the room to room walking of the nursing team. These guidelines, together with their enclosed
Proximity Matrix of ward spaces have the potential to be used in the design of all wards with similar functions to those of the ward in the case study of this thesis.

9.5 Limitations of the research

It is essential for the results and recommendations of this research to be understood, judged and applied within the intended and unintended limitations of the study.

9.5.1 Limitations in the scope of the study

It was clear from the inception of the study that investigating all aspects of productivity for all staff members in all types of hospital wards was impossible. Therefore, the context of the research was limited to investigating:

- only saved room to room walking time among all different aspects of productivity;
- only nursing staff among all hospital staff; and
- only hospital wards with a size and function similar to those of the case study among all different wards.

Therefore, the main scope of the study must be seen as an exemplar method of investigation in this field rather than a comprehensive investigation in itself.

9.5.2 Operational limitations of the study

As with most other research projects, this study was defined by time and budget restrictions. In the absence of such restrictions, the study would, for example, have access to a greater number of case studies for a longer period of time. This would mean a more reliable set of data capable of addressing specific situations of different case studies as well as offering a more comprehensive aggregation of the data for extracting more widely-generalised results. Access to a few cases of each ward type in different sizes and from different locations and for a period of time that could represent the entirety of the service period of a ward would have been an ideal scenario. Without this luxury, the study has attempted to make the best use of the data gathered from one case study within three consecutive weeks.

Another ideal scenario (that would greatly enhance the reliability of the study results) was the opportunity to add some empirical validation to the analytic soundness
presented by this study’s data analysis. For example, application of the guidelines in the design process of a new ward (or refurbishment of an existing one) and monitoring their impact on the future performance of the ward and its staff could have a significant impact on verifiability and validity of both findings and the guidelines.

9.6 Recommendations for future work/research

The first group of recommendations for the furtherance of the present study correspond to the limitations mentioned in the preceding section and they are:

- performing similar studies for other staff types and other ward types and highlighting similarities and dissimilarities of the results with those of the present study;
- studying variations of the ward’s workload by time (e.g. different days of the week, different seasons, etc.) and their impact on the results of the analysis; and
- incorporating the guidelines in ward design or refurbishment projects and providing feedback on its success level.

Other recommendations for enhancing the impact of this study may include:

- developing a framework based on the guidelines and recommendations of this study;
- developing a computerised tool for facilitating the utilisation of the framework in design process;
- consulting experts from medical and architectural backgrounds for providing further validation for the findings of the study and for its associated guidelines;
- synthesising study findings to strengthen practical significance, for example, treatments at the bedside in single inpatient rooms has reduced the need for treatment rooms and in turn reduced nurses travel distances;
- investigating how the study findings improve operations on the ward, enhancing staff productivity, nursing staff logistics and increase staff satisfaction to inform the Fable Hospital 2.0 and the Business Case for building better hospitals; and
• investigating corridor journeys that extend outside a ward to provide understanding for a better insight to staff’s walking distances in a wider scope.

9.7 Summary
This chapter provided evidence for the delivery of the research objectives through this thesis. It can be, therefore, concluded that the aim of the study, namely “to improve the productivity of hospital nursing staff through better people circulation and layout” has also been achieved. Furthermore, in this chapter, findings of the study were also paraphrased and its contributions were explained under four main headings. The chapter concluded with the final two sections on limitations of the present study and recommendations for future ones.
References


Alalouch C. R. (2009), Hospital ward design: Implications for space and privacy, PhD thesis, Herriot-Watt University, UK.


Arup (2009), Literature research on influences of the hospital environment on patient outcomes, Arup, UK.


BaHammam A. (2006), Sleep in acute care units, Sleep and Breathing, 10(1), pp. 6-15.


Bell P. A., Thomas C. G., Greene T., Fisher J. and Baum A. S. (2001), Environmental psychology, USA.


British Standards (1968), BS 4330:1968 Recommendations for the coordination of dimensions in building, controlling dimension, British Standards, UK.


Bryman A. and Bell E. (2003), Business research methods, Oxford University Press, UK.


Buffa E. S., Armour G. C. and Vollmann T. E. (1964), Allocating facilities with CRAFT, Harvard University, USA.


Crotty M. (1998), The foundations of social research: meaning and perspective in the research process, Sage Publications, UK.

Department of Health (2006), Health Technical Memorandum 05-01: Managing healthcare fire safety, Crown, UK.


Department of Health (2008), Health Building Note 04-01: Adult in-patient facilities, Crown, UK.

Department of Health (2009), Health Technical Memorandum 01-05: decontamination in primary care, dental practices, Crown, UK.

Department of Health and NHS Estates (2004), Public Private Partnerships in the NHS: the design development, protocol for PFI schemes: Revision 1, Crown, UK.


DH and NHS (2013), The NHS Premises Assurance Model (NHS PAM), Crown, UK.


Eilon S., Gold B. and Soesan J. (1976), Applied productivity analysis for industry, Pergamon Press, UK.


Freeman J. R. (1967), Quantitative criteria for hospital inpatient nursing unit design, PhD thesis, Georgia Institute of Technology, USA.


Gesler W., Bell M., Curtis S., Hubbard P. and Francis S. (2004), Therapy by design: evaluating the UK hospital building program, Health and Place, 10(2), pp. 117-128.


Goode P., Anderson S. and Wilson C. S. J. (2009), The Oxford companion to architecture, Oxford University Press, USA.


Hendrich A. (2003), Optimizing physical space for improved outcomes: satisfaction and the bottom line, Proceedings of Minicourse, Atlanta, GA:
Institute for Healthcare Improvement & The Center for Healthcare Design, USA.


House of Commons (2005), Improving patient care by reducing the risk of hospital acquired infection: a progress report, TSO, UK.


Hussey J. and Hussey R. (1997), Business research: a practical guide for undergraduate and postgraduate students, Macmillan, USA.


Khemlani L. (2010), Trelligence Affinity: extending BIM to space programming and planning, AECbytes, Building the Future.


Lawson B. and Phiri M. (2003), The architectural healthcare environment and its effect on patient health outcomes, report on an NHS Estates funded research project, TSO, UK.


Maben J., Penfold C., Robert G. and Griffiths P. (2012), Evaluating a major innovation in hospital design: workforce implications and impact on patient and staff experiences of all single room hospital accommodation, Report of phase 1 findings for HaCIRIC, NNRU, UK.

Malekzadeh M., (2009), Positioning of outdoor space in house design, PhD thesis, Loughborough University, UK.


Miller D. (2005), Going LEAN in healthcare, Institute for Healthcare Improvement, USA.


NHS Estates (2002), Health Facility Note 30: infection control in built environment: design and planning, NHS, TSO.

NHS Estates (2005), Ward layouts with single rooms and space for flexibility, TSO, UK.

NHS Estates and DH (2005), HBN 20: Facilities for mortuary and post mortem room services, Crown, UK.


Nuffield (1955), Studies in the functions and design of hospitals, Nuffield Provincial Hospital Trust, UK.


Patton M. Q. (1990), Qualitative evaluation and research methods, Sage Publications, USA.

Pelletier R. J. and Thompson J. D. (1960), Yale Index measures design efficiency, The Modern Hospital, 95(5), pp. 73-77.


Phiri, M, Mills G. R. et al (2011), Flexibility in healthcare infrastructure at a time of austerity: do standards and tools reflect the reality of designing for dementia, the elderly, children and refurbishment or reconfiguration? HaCIRIC11, 26-29 Sep 2011, UK.

Phiri, M. (2006), Does the physical environment affect staff and patient health outcomes? a review of studies and articles 1965-2006, TSO, UK.


Scottish Government (2010), Leading better care and releasing time to care: implementation and progress to date: a briefing paper, Scottish Government, UK.


Sink D.S. and Tuttle T.C. (1989), Planning and measurement in your organisation of the future, Industrial Engineering and Management Press, USA.


Vischer J. C. (2003), *Designing the work environment for worker health and productivity*, Design and Health, WCDH, Canada.


Zimring C. (1990), The costs of confusion: non-monetary and monetary costs of the Emory University Hospital wayfinding system, Georgia Institute of Technology, USA.
Interviews with HaCIRIC researchers

A set of preliminary interviews was carried out with eight research associates and research assistants within HaCIRIC (Health and Care Infrastructure Research and Innovation Centre). All the interviews took place in Civil and Building Engineering department, Loughborough University between 29th May and 16th April 2010.

The aim of these interviews was to get a broader view of the topic of the research and to guide and check the direction of the literature review.

Interview questions:

1. What does productivity mean to you and how do you define it?
2. What measures/tools could be used to assess hospital productivity?
3. How could/will your research impact on hospital productivity?
4. What MSV (modelling, simulation and visualisation) tools could be used to assess and improve productivity?
5. What are the key factors that need to be considered when design for people circulation within a hospital?
6. How does people circulation impact on hospital performance and productivity?
7. What design theory and tools could be used to improve layout with respect to people circulation?
8. Who are the key experts (academic/industry) in this area?
<table>
<thead>
<tr>
<th>Interview questions</th>
<th>Summarised answers</th>
</tr>
</thead>
</table>
| 1-What does productivity mean to you and how do you define it?                     | - Designing more flexible spaces for clinical purposes  
- Decentralised ward that reduces nurses walking distances  
- How staff work efficiently  
- Right equipment and right people  
- A combination of people, space and equipment’s productivity  
- Meeting patients’ needs throughout the system  
- Staff satisfaction  
- Number of operations and procedures per annum  
- Making the best use of particular assets                                                                                                                                 |
| 2-What measures/tools could be used to assess hospital productivity?                | - End-users of the hospital (patients’) perception  
- Surveys, observation and interview the end-users about waiting time, frequency of services and travel distances  
- Performance Management Department’s set of targets to collect data on system’s productivity (e.g. the number of operations a year, monitoring the time that took an ambulance to get to the patient) |
| 3-How could/will your research impact on hospital productivity?                    | - Hazard perception: If a hospital’s emergency evacuation and hazard perception have been well thought of, psychologically, the staffs have more confidence and productivity in both normal and emergency situations.  
- Space optimisation: nurses do not like their conversations to be heard by patients.  
- Healing environment: the more therapeutic a design is, the more productivity it will offer.  
- Thermal comfort: thermal comfort of people inside the hospital will improve productivity of them.  
- Value standards:                                                                                                                                                                      |
| 4-What MSV (modelling, simulation and visualisation) tools could be used to assess and improve productivity? | - MedModle, ECOTEC, Space Syntax, Autodesk Revit, BIM, ADB, Sidelines, Simul8, Virtual Reality (creating digital mock up), FlexSim, Active Plan, CodeBook                                                                                                                                 |
| 5-What are the key factors that need to be considered when design for people circulation within a hospital? | - The concept of centralisation and decentralisation of nursing station  
- Ward scenario  
- Whether you are designing for in-patient or out-patient as they have different access routes  
- Patients’ age group  
- Aesthetics, social behaviour, staff behaviour and ergonomics  
- The standards and guidelines  
- Location of the structural columns (in terms of the horizontal free
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
</table>
| **circulation design** | - Location of services and high risk area, texture of the floor, natural ventilation, natural lighting, travel distances, location of the furniture and fittings  
- More modular design giving more flexibility and multi-functional potential  
- Staff safety and protection by design  
- Zoning of the building (staff zone, public zone, etc.)  
- Designing standard, flexible, reusable areas (since needs, technology and models of care change all the time)  
- Volume of people are passing each path (in order to choose the sufficient width) |
| **6-How does people circulation impact on hospital performance and productivity?** | - Walking distances of nurses and visitors.  
- The most productive hospital is the one with no flow at all. So Tele-care is productive in terms of people flow.  
- There is a need to study whether flow of patients to the equipment is more productive or flow of equipment to the patients. |
| **7-What design theory and tools could be used to improve layout with respect to people circulation?** | - “Form, Space and Order”  
- The theory of designing separate and individual areas for different group’s circulation (Zoning).  
- Space Syntax  
- Adjacencies  
- “Form and Function”  
- Modular design |
| **8-Who are the key experts (academic/industry) in this area?** | - Industry  
  - MJ Medical  
  - BDP Architects  
  - Norman Foster and partners  
  - ANA (Anne Nobel Architects)  
  - Laing O’rourke company  
  - BRE (Building Research Establishment)  
- Academic  
  - MARU  
  - Purdue University, USA  
- Government  
  - DH  
  - NHS  
  - PEAT (Patient Environment Action Team) |
Interview with a Lead Facilitator for Productive Ward

22 April 2010, Lincoln

Interviewer: Masoumeh Nazarian, PhD research student, Loughborough University

Interviewee: The interviewee is a Clinical Improvement Facilitator in an NHS Trust Hospital with 22 years of nursing experience. As a Junior Sister, she took on the role of Productive Ward Lead on one of the Pilot Wards of the NHS. Since July 2009, she has been working within the Clinical Improvement Unit as the Lead Facilitator for Productive Ward.

Aims of the interview:

- To guide and check the direction of the literature review
- To identify innovative layout design solutions

Interview Plan:

<table>
<thead>
<tr>
<th>Area</th>
<th>Questions</th>
<th>Sub/Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Background information</td>
<td>A1. How long have you worked on healthcare sector?</td>
<td>A2. Healthcare planner, architect, project manager, nurse, nurse supervisor, doctor, etc.</td>
</tr>
<tr>
<td></td>
<td>A2. Please briefly describe your main roles/involvement in healthcare development?</td>
<td></td>
</tr>
<tr>
<td>B. Hospital productivity</td>
<td>B1. What does “hospital productivity” mean to you and how do you define it?</td>
<td>B2. IT tools, MSV tools, etc.</td>
</tr>
<tr>
<td></td>
<td>B2. What measure/tools could be used to assess “hospital productivity”?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B3. What are the key adjacencies in a “productive ward”?</td>
<td></td>
</tr>
<tr>
<td>C. People circulation</td>
<td>C1. What makes a design of a hospital ward a good design in terms of access and circulation?</td>
<td>C1. Criteria for good A&amp;C design</td>
</tr>
<tr>
<td></td>
<td>C2. How does people circulation impact on hospital productivity?</td>
<td>C2. How you could link these two e.g. in Lincoln hospital/other hospitals you have worked in before?</td>
</tr>
<tr>
<td></td>
<td>C3. In terms of people circulation, which of these two aspects are more important: “circulation inside a ward” or “circulation outside the ward”?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C4. What are the issues around “infection control” within hospital regarding “circulation”?</td>
<td></td>
</tr>
</tbody>
</table>
D. Productive Ward

D1. Based on your experience in “productive ward” how a more “productive ward” could be achieved?
D2. What were the challenges during the project?
D3. What barriers have you faced?
D4. What would you say that is innovative about what you have done?
D5. What considerations were given to “bed spacing”?
D6. Were mock up used before construction and what type of consultation took place?
D7. What type of treatment is being provided

E. Future

E1. Are you still looking to improve your work?
E1. What are the plans for the future?

F. Key experts

F1. Are you aware of any similar work that has been done?
F1. Name, contact details

Highlighted comments:

- Anything that can “release time” and take this time back to “patient care” is productivity.
- Measures to be used to assess hospital productivity: length of patients’ stay, patients’ satisfaction, staff feedback and cleanliness of the hospital.
- Criteria for good access and people circulation: natural light, easy access for beds, easy to clean, air flow and ventilation.
- Out-patient flow is more important than in-patient flow.
- Issues to consider in terms of infection control: reduce traffic within hospital by having a fixed and limited time for visitors.
- Regarding the “Productive Ward” project: having more financial resources could ease achieving a more productive ward.
- Challenges and barriers during project: financial resources and lack of time, the need for releasing some staff to work on this project, getting engagement from other departments and organisations.
- The rules of the “Productive Ward” could be used in any ward types.
- Future projects: Productive Doctor, Productive Discharge, Productive Theatre and Productive Clinic
Interview with an Associate in Space Syntax

29 April 2010, London

**Interviewer:** Masoumeh Nazarian, PhD research student, Loughborough University

**Interviewee:** The interviewee qualified as an architect and continued her academic training at University College London (UCL). She completed an MSc in Advanced Architectural Studies with a thesis on High Security Mental Hospitals. She joined Space Syntax as Consultant in 2004 and became an Associate in 2006.

**Aims of the interview:**

- To guide and check the direction of literature review
- To identify innovative layout design solutions

**Interview Plan:**

<table>
<thead>
<tr>
<th>Area</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Background information</td>
<td>A1. How long have you worked on healthcare design?</td>
</tr>
<tr>
<td></td>
<td>A2. Please briefly describe your main roles/involvement in healthcare development?</td>
</tr>
<tr>
<td></td>
<td>A3. What were the types of projects?</td>
</tr>
<tr>
<td>B. Hospital productivity</td>
<td>B1. What does “hospital productivity” mean to you and how do you define it?</td>
</tr>
<tr>
<td></td>
<td>B2. What measure/tools could be used to assess “hospital productivity”?</td>
</tr>
<tr>
<td></td>
<td>B3. What are the key adjacencies in a “productive ward”?</td>
</tr>
<tr>
<td>C. People circulation</td>
<td>C1. What makes a design of a “hospital ward” a good design in terms of “access and circulation”?</td>
</tr>
<tr>
<td></td>
<td>C2. How does people circulation impact on hospital productivity?</td>
</tr>
<tr>
<td></td>
<td>C3. In terms of people circulation, which of these two aspects are more important: “circulation inside a ward” or “circulation outside the ward”?</td>
</tr>
<tr>
<td></td>
<td>C4. What are the issues you consider</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sub/Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2. Healthcare planner, architect, project manager, nurse, nurse supervisor, doctor, etc</td>
</tr>
<tr>
<td>A3. hospital, community hospital, medical centre</td>
</tr>
<tr>
<td>B2. IT tools, MSV tools, etc</td>
</tr>
<tr>
<td>C1. Criteria for good A&amp;C design</td>
</tr>
</tbody>
</table>
| **D. Space Syntax** | **D1. What is the theory of Space Syntax?**  
**D2. What are the methods of Space Syntax?**  
**D3. Based on some of your previous projects what do you mean by “Pedestrian activity forecasting” and how do you do it?**  
**D4. What tools and methods do you use to model and analyse people flow?**  
**D5. “Den Helder Gemini hospital” in Netherland was one of your projects on 2008. What aims and objectives did you consider doing this project?**  
**D6. What were the challenges during the project?**  
**D7. What barriers have you experienced?**  
**D8. What would you say that is innovative about what you have done?**  
**D9. Were mock up used before construction and what type of consultation took place?** |
|---------------------|-------------------------------------------------------------------------------------|
| **E. Further advice** | **E1. Please describe the two most successful innovative people flow analysis from your recent projects. Why they were successful?**  
**E2. Please describe two examples of good practice in terms of people flow and circulation you have adopted for the design of hospital ward?**  
**E3. Are you still looking to improve your work?**  
**E4. What are the plans for the future?** |
| **F. Key experts** | **F1. Are you aware of any similar work that has been done?**  
**F1. Name, contact details** |
| **G. Document** | **G1. Is there any document/ drawing or extra information I could have a copy of please?** |

**Highlighted comments:**

- **Main projects:** urban projects, some healthcare projects as well, more related to visitors circulation and “way finding”.
- **Some of the healthcare projects:**
• The Netherlands project: analysing four different hospital wards

• Hillingdon Hospital: 100% single room accommodation, comparative analysis of four different hospital wards looking at spatial layout and observation issues.

• London Clinic Private Hospital: providing design advise during redevelopment in terms of way finding and connectivity of different spaces

• Current healthcare project is for Department of Health (DH) and is looking at a hospital with 100% single room accommodation.

• **Definition of Hospital productivity:** reducing staff walking distances and increasing staff communication and knowledge transfer

• **Tools for measuring hospital productivity:** Tools from Space Syntax help to understand the connectivity of different spaces, quiet areas and where people might get lost. There is also software within Space Syntax that calculates walking distances and visibility.

• **Key “adjacencies” in a “productive ward”:** the connectivity of theatre to other relevant spaces is very important and also challenging in terms of layout design.

• **Criteria for good access and people circulation:**
  
  ▪ **Criteria for good access and circulation between the hospital wards:** visibility of vertical circulation (stairs and lifts), direct connection, existing public spaces such as café and shops.

  ▪ **Criteria for good access and circulation within the hospital ward:** the location of staff base/nurse station, visibility of the bed heads from corridors, shorter walking distances, and visibility from rooms (patient’s bed) to nurse station.

• **Importance of circulation inside a ward/circulation outside the ward:** They are both important. Going to a hospital is always stressful. The idea of “Hospital Street” (case studies in Norway and the Netherlands) can help a lot.

• **Hospital Street:** You could not say it is a hospital, looks like a shopping centre, high ceiling, visibility of different levels from the ground floor, open public area (café and shops etc. on the first floor), easy understanding of where you are and you want to go. The focus of this design is normalising hospitals.
• **Infection control**: having more single room accommodation will reduce the infection.

• **Single room accommodation**: may increase walking distances (it depends on the layout design of the ward). It may look more expensive. However, balancing the cost of maintenance and also reducing length of stay and recovery time, etc. make it a cost effective solution for infection control.

• **Space Syntax theory**: the relationship between “space” and “people” and how people use the space. Why when a building is built beautifully in terms of architecture, it may not work in terms of layout?

• **Space Syntax method**: is quite unique; has been developed over the last 25 years in UCL University. No two projects are the same, because no two places are the same. Each project has got its own research questions and methodology. Data collection is normally running every hour. For example, you count people present in the selected space. You may pick a nurse and follow her for few minutes. After gathering the data, needed it is time for analysing them.

• **Importance of the visibility of nurse station from patient’s bed**: patients are calmer. They do not feel nervous and lonely. They call the nurse less frequently.

• **Challenges and barriers**: getting the Ethical Approval is the main one

• **Novelty of Space Syntax**: the approach is quite unique. You can test it beforehand. You do not have to build something and then realise that is not working.

• **Main clients**: local authorities, councils, private developers, architects

• **Two successful projects in terms of people flow**:
  - Den Helder Gemini Hospital in the Netherlands: evidence-based evaluation of circulation pattern and patient environment in the existing hospital and development of design principles for the new Gemini Hospital with YNNO.
  - Middlesex Hillingdon Hospital Pilot: evaluation of ward layout for the delivery of care, focusing on the impact of 100% single room accommodation in hospital wards, for the Department of Health and National Patient Safety Agency.
• **Improving in the future**: very close relationship with UCL Space Syntax lab, there are lots of case studies available to test different things

• **Similar work**: Intelligent Space, which works with Atkins is doing similar as Space Syntax. The difference is Space Syntax can analyse any kind of projects whilst Intelligent Space is focused on buildings only.
Interview with a Healthcare Architect at MARU

19 May 2010, Loughborough

Interviewer: Masoumeh Nazarian, PhD research student, Loughborough University

Interviewee: The interviewee is a Senior Lecturer and Architect at MARU (Medical Architecture Research Unit) in London.

Aims of the interview:

- To guide and check the direction of literature review
- To identify innovative layout design solutions

Interview Plan:

<table>
<thead>
<tr>
<th>Area</th>
<th>Questions</th>
<th>Sub/Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Background information</td>
<td>A1. How long have you worked on healthcare design?</td>
<td>A2. Healthcare planner, architect, project manager, nurse, nurse supervisor, doctor, etc</td>
</tr>
<tr>
<td></td>
<td>A2. Please briefly describe your main roles/involvement in healthcare development?</td>
<td>A3. hospital, community hospital, medical centre, etc.</td>
</tr>
<tr>
<td></td>
<td>A3. What were the types of projects?</td>
<td></td>
</tr>
<tr>
<td>B. Hospital productivity</td>
<td>B1. What does “hospital productivity” mean to you and how do you define it?</td>
<td>B2. IT tools, MSV tools, etc</td>
</tr>
<tr>
<td></td>
<td>B2. What measure/tools could be used to assess “hospital productivity”?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B3. What are the key adjacencies in a “productive ward”?</td>
<td></td>
</tr>
<tr>
<td>C. People circulation</td>
<td>C1. What makes a design of a “hospital ward” a good design in terms of “access and circulation”?</td>
<td>C1. Criteria for good A&amp;C design</td>
</tr>
<tr>
<td></td>
<td>C2. How does people circulation impact on hospital productivity?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C3. In terms of people circulation, which of these two aspects are more important: “circulation inside a ward” or “circulation outside the ward”?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C4. What are the issues you consider regarding to “infection control” within hospital regarding “circulation”?</td>
<td></td>
</tr>
<tr>
<td>D. MARU</td>
<td>D1. What were the challenges during your healthcare projects?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D2. What barriers have you experienced?</td>
<td></td>
</tr>
</tbody>
</table>
|   | D3. What would you say that is innovative about what you have done?  
D4. Were mock up used before construction and what type of consultation took place? |
|---|---|
| E. Further advice | E1. Please describe two examples of good practice in terms of people flow and circulation you have adopted for the design of hospital ward?  
E2. Are you still looking to improve your work? |
| F. Key experts | F1. Are you aware of any similar work that has been done?  
F1. Name, contact details |
| G. Document | G1. Are there any document/drawing or extra information in MARU library I could have a copy of please? |

**Highlighted comments:**

- **Background:** Architect by background (practicing for 20 years) but has been involved in healthcare planning for the last 8 years.
- **Hospital productivity:** different perspectives can define productivity in hospital differently, meeting patient targets, new efficient thinking of people flow in hospital
- **Productivity assessment:** Comparison between efficient flows. Potentially, ties in with building spaces and how they are working. This is a valuation that brings the environment into productivity assessment.
- **Measuring tools for productivity:** tracking patient through the process, comparison study of different layout design based on Activity DataBase (ADB)
- **Key adjacencies in a productive ward:** environmental impact must be considered during decision-making process. There has not been enough work regarding the impact of space. The current works done in this area are more concerned with how to improve what already exists.
- **Criteria for good access and circulation design in a hospital ward:** good analysis about adjacencies, to understand what is important for whom depending on the hospital model, how facilities management coming together in a hospital plan.
• **Impact of people circulation on hospital productivity:** there are some great examples in Europe in terms of people flow where there is good understanding of the separation between the public and staff (public spaces, semi-public spaces and staff spaces). For example St Pau Hospital in Barcelona.

• **Importance of the circulation inside the ward vs. circulation outside the ward:** there are three types of hospital users: patients, visitors and staff. The obvious factor to consider is patient’s privacy and dignity (e.g. moving from the ward to the theatre. Do the patients cross the public areas?). There should be a balance of importance between these two circulations.

• **Infection control:** When people start crossing over different zones (public, semi-public and staff zones) is potentially pretty problematic. The new extension of St Pau hospital in Spain is quite impressive in this case.

• **Challenges:** Pulling together the best structured information and thinking about what tools of planning is useful to get some clarity over the subject. In terms of planning circulation it is needed to set out the principle of organisations. During planning, getting out of “messy bits of information” or “half-baked ideas” or different drivers.
Interview with a Healthcare Architect at Anshen+Allen

16 July 2010, London

Interviewer: Masoumeh Nazarian, PhD research student, Loughborough University

Interviewee: The interviewee is an Associate Director at Anshen+Allen. She is one of the UK’s leading healthcare architects and medical planners. She joined Anshen+Allen about 15 years ago.

Aims of the interview:

- To guide and check the direction of the literature review
- To identify innovative layout design solutions

Interview Plan:

<table>
<thead>
<tr>
<th>Area</th>
<th>Questions</th>
<th>Sub/Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Background information</td>
<td>A1. How long have you worked on healthcare design?</td>
<td>A2. Healthcare planner, architect, project manager, nurse, nurse supervisor, doctor, etc.</td>
</tr>
<tr>
<td></td>
<td>A2. Please briefly describe your main roles/involvement in healthcare development?</td>
<td>A3. hospital, community hospital, medical centre</td>
</tr>
<tr>
<td></td>
<td>A3. What were the types of projects?</td>
<td></td>
</tr>
<tr>
<td>B. Hospital productivity</td>
<td>B1. What does “hospital productivity” mean to you and how do you define it?</td>
<td>B2. IT tools, MSV tools, etc.</td>
</tr>
<tr>
<td></td>
<td>B2. What measure/tools could be used to assess “hospital productivity”?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B3. What are the key adjacencies in a “productive ward”?</td>
<td></td>
</tr>
<tr>
<td>C. People circulation</td>
<td>C1. What makes a design of a “hospital ward” a good design in terms of “access and circulation”?</td>
<td>C1. Criteria for good A&amp;C design</td>
</tr>
<tr>
<td></td>
<td>C2. How does people circulation impact on hospital productivity?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C3. In terms of people circulation, which of these two aspects are more important: “circulation inside a ward” or “circulation outside the ward”?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C4. What are the issues you consider</td>
<td></td>
</tr>
</tbody>
</table>
D. Further advice

D1. Please describe the two most successful innovative people flow analysis from your recent projects. Why they were successful?
D2. Please describe two examples of good practice in terms of people flow and circulation you have adopted for the design of hospital ward?
D3. Are you still looking to improve your work?

E. Key experts

E1. Are you aware of any similar work that has been done?
E1. Name, contact details

F. Document

F1. Is there any document/drawing or extra information I could have a copy of please?

Highlighted comments:

- **Background**: architect by background and worked for the company for the last 15 years. The main focus of the company is medical planning, especially larger projects in PFI (Private Finance Investment) market. Also modernising old Victorian hospitals. Norfolk Norwich was the first healthcare project has been done by this company.

- **100% Single bed hospital**: Because of the economic crisis, 100% single bed hospital might not become a norm for many years. Pembury Hospital is one Anshen+Allen’s project that will be finished in November and is a 100% single room hospital. During the process of designing this type of hospital, if the architect is not careful, he/she will end up with a (similar with hotels) linear plan with long and dark corridors. These are the challenges during designing a 100% single bed hospital.

- **Hospital productivity in terms of staff productivity**:
  - An efficient layout is very important on the functional relationship.
  - All the support rooms should be positioned in a correct relationship with what the medical staff trying to do.
  - The layout should avoid long travel distances.
- The rooms must be planned in logical and rational shapes so you get the best out of the area.
- They will be more productive if they are working in a pleasant environment. If the staff do not enjoy the place they work in, they take more time off sick.
- Using technology in order to decrease the paper work will improve staff productivity.

- **Measuring productivity:** We have done a study about nurses walking distance on three different layout designs (T shape, Racetrack, Linear and Triangular ward). We also worked with Intelligent Space to look at angles of visions. Space Syntax and Intelligent Space are almost the same. The only difference is Intelligent Space has done more healthcare projects.

- **Key adjacencies in a productive ward:**
  - The key is the nurse base which the position of everything else in a ward depends on it.
  - The relationship between staff base and the visitor entering to the ward is very important as well as the relation between the staff base and the patient room in a way that gives a good coverage to all.

- **Productive ward in terms of circulation design:**
  - For visitors: Needs a clear entry and clear understanding where they need to go and also considering security issues.
  - For staff: Addresses the above needs in the circulation routes.
  - For the patient: Brings light and pleasant aesthetical environment and helps with way finding. We can use light and view to nature to emphasise the key circulation points.

- **Zoning system in hospital design:** you can do it up to a point, but because of the great pressure on the floor area you cannot completely separate them. Also, you are often trying to balance access to light. The only department you can separate these zones completely is the theatres (dirty corridor, patient flow and staff routes). To do all these, you end up with a deep plan and, as a result, lack of natural light in the back corridors. Pembury Hospital is a good design
that has tried to have zones as much as possible. The main challenge is the more you separate the zones, the more you drag spaces away from the daylight. You can use courtyards etc. but all they do is to spur things out and the corridors tend to be even longer.

- **Importance of circulation inside a ward vs. circulation outside the ward:**
  - For visitors (as they are stressed), it is really important that they find their way to the ward in a most simple way. Once they are in the ward, they probably will not get lost.
  - Like visitors, patients will be ok as soon as they get to the ward.
  - For staff, the design should be in a way that they do not travel long and complicated routes as this will affect their productivity.

- **Infection control:** infection control is a very big issue in hospital design these days. You should have a clear strategy and policy for separating the suppliers, dirty and clean routes. It is crucial how we detail the rooms (e.g. the place of wash basin needs to be as close as possible to the patient as well as being in the visual path of staff encouraging them to wash hands as soon as they get to the room). Also detail finishes and choice of material is very important.

- **Nurse productivity in different types of ward design:** they all have their own benefits. In Anshen+Allen we try not to have a formula. The layout system more than anything depends on the site, views and the brief you have. There is a geometrical challenge in different ward types. It also depends on how the hospital wants to run the supplier system.

- **Innovation at Anshen+Allen:** At master planning, we have a very clear vision of the building and the flow of people within the building. There is no formula and each new project has got its own innovative solutions. For some buildings, it might be an atrium that solves the problem (RVI Children Hospital in Newcastle) and in some other a linear garden. It really depends on the client as well. If they are interested in innovation, you can work better.

- **Two successful projects in terms of people flow:**
  - Pembury Hospital in terms of ward circulation design
  - Norfolk Norwich hospital with an interesting design
Appendix B – Ethical considerations
Participant Information Sheet

Nursing staff productivity: the role of ward layout and people circulation

Main Investigator: Masoumeh Nazarian, m.nazarian@lboro.ac.uk, School of Civil and Building Engineering, Loughborough University, Leicestershire, UK, LE11 3TU, +44 (0)1509 263171

Supervisors:
Prof Andrew Price A.D.F.Price@lboro.ac.uk, School of Civil and Building Engineering, Loughborough University, Leicestershire, UK, LE11 3TU, +44 (0) 1509 222627
Dr Peter Demian P.Demian@lboro.ac.uk, School of Civil and Building Engineering, Loughborough University, Leicestershire, UK, LE11 3TU, +44 (0) 1509 228541

What is the purpose of the study?
This study aims to explore the relationship between hospital ward layout design and nursing staff productivity. In order to achieve this, different types of ward design will be compared in terms of nurses’ daily activities. The data gathered from nurses’ movement would be used as input data for qualitative and quantitative analyses.

Who is doing this research and why?
The research will be done by Masoumeh Nazarian who is a PhD student at Loughborough University and supervised by Prof. Andrew Price and Dr. Peter Demian. This study is part of a Student research project supported by Loughborough University.

Once I take part, can I change my mind?
Yes. After you have read this information and asked any questions you may have, we will ask you to complete an Informed Consent Form. However if at any time, before, during or after the sessions you wish to withdraw from the study, please just contact the main investigator. You can withdraw at any time for any reason and you will not be asked to explain your reasons for withdrawing.

Will I be required to attend any sessions and where will these be?
No, you just need to turn up to work normally. I might follow you and ask a few questions.

Is there anything I need to do before the sessions?
No.

Is there anything I need to bring with me?
No.

What type of clothing should I wear?
No special clothing is required, just your regular work clothes.

Who should I send the questionnaire back to?
The researcher will collect it from you.

What will I be asked to do?
You will not be asked anything special. Just do your normal duty and I will follow you.
What personal information will be required from me?
Name, Job profile and experience

Are there any risks in participating?
No.

Will my taking part in this study be kept confidential?
The information provided by you will be treated in strict confidentiality and the findings will be used only for research purposes.

What will happen to the results of the study?
The results of the study will be analysed in order to test the productivity of nurses in different ward layouts and will be presented in the researcher’s PhD thesis. They may also be used for future publications.

I have some more questions. Who should I contact?
Prof. Andrew Price and Dr. Peter Demian

What if I am not happy with how the research was conducted?
If you are not happy with how the research was conducted, please contact the research team directly or Mrs Zoe Stockdale, the Secretary for University’s Ethics Approvals (Human Participants) Sub-Committee:

Mrs Z Stockdale, Research Office, Rutland Building, Loughborough University, Epinal Way, Loughborough, LE11 3TU. Tel: 01509 222423. Email: Z.C.Stockdale@lboro.ac.uk

The University also has a policy relating to Research Misconduct and Whistle Blowing which is available online at:
http://www.lboro.ac.uk/admin/committees/ethical/Whistleblowing(2).htm.
به نام خدا

اطلاعاتی در باره ی تحقیق برای شرکت کنندگان

عنوان تحقیق: راهنمای کاری پرستاران - نقش طراحی بخشن و میرفکوراسیون

محتوی اصلی: مجموعه نظریات، دانشکده مهندسی ساختمان دانشگاه لانبورو، انگلستان

تلفن: 00441509232452
ایمیل: m.nazarian@lboro.ac.uk

استادان راهنما: پرفسور آندرو حمایی، دانشکده مهندسی ساختمان

تلفن: 00441509222627
A.D.F.Price@lboro.ac.uk

دکتر پیتر دیمیان، دانشکده مهندسی ساختمان، دانشگاه لانبورو، انگلستان

تلفن: 00441509228541
P.Demian@lboro.ac.uk

هدف تحقیق: هدف این تحقیق بررسی رابطه طراحی بخش‌های بیمارستانی و راهنمای کاری پرستاران در باشد. برای این منظور کمک‌های مختلفی که پرستاران ممکن است با آنها در کار خواهند کرد. اطلاعات مربوط به حرفه، رفت و آمد پرستاران مورد تحلیل قرار گرفته و کمک‌هایی در بهینه‌سازی این موارد ارائه شده است.

جهت این تحقیق را انجام می‌دهد و چرا؟ این تحقیق توسط مجموعه نظریات دانشجوی دکتری جامعی از دانشکده اقتصاد انجام می‌گیرد. این تحقیق تحت نظر حرفه و انسانی استادان راهنما پرفسور پراپوس گرفته و دکتر دیمیان می‌باشد.

آیا در حین شرکت در این تحقیق دارم یا نه؟ به دلیل وجود موارد مخصوص و موضوعی از آنها، پیشنهاد می‌شود. این تحقیق بهترین و امکان کنید. دکتر چه مرکزیته که مایل باشید می‌توانید با تماس با کمک اصلی (مجموعه

Loughborough University

199
نظریه‌ای از روند تحقیق خارج شوید. درصورت انتشار، شما مجبور
به توضیح دلایل خود نیم‌باشید.

آیا مجبورم که در جلساتی حضور داشته باشم؟ خیر، شما کار و
وهای معمول کورا را انجام می‌دهید. محقق شما را دنبال می‌کند.
در هنگام این کار ممکن است سوالاتی از شما پرسند.

آیا قبل از شروع کار باهکاری انجام دسته‌ای خیر؟

آیا ایزارد و وسیله‌هایی باهکاری محرومه داشته باشم؟ خیر

آیا نباید با همیشه بی‌دوستی باشد؟ خیر، تابعیت شما لازم نیست فقط نیاز
معمول کار

جمه اطلاعات شخصی از من خواسته می‌شود؟ خیر، عوامل کاری

تاریخ

آیا هرکسی مرا تهدید می‌کند؟ خیر

آیا شرکت‌کننده در این بررسی و اطلاعات مربوط به مردمان می‌ماند؟
بله، اطلاعات بسته آمده کاملاً مربوط به مردمان می‌باشد و تاریخ تجزیه و
تحلیل این اطلاعات در تالیف رسانه دکتری مورد استفاده واقع می‌شود.

در صورت مراجعه ایشان به چه کسی می‌توانم تماس بگیرم؟

پزشک براید و دکتر دیگر.

نتایج تحقیق به چه منظوری مورد استفاده قرار گرفته؟

نتایج تحقیق در تز دکتری و مقاله‌های اختراعی آنها به دو کار می‌رود.

۱. اکثر از نتایج تجزیه و تحلیل اطلاعات را تطبیق کنیم که کدام‌یک
شما می‌توانید توانایی امکان‌پذیری و در زمینه انتخابی تحلیلات
تحقیق در وب سایت زیر مطالعه قرماپیدید:

www.lboro.ac.uk/admin/committees/ethical/whistleblowing2.htm
Participant Consent Form

Hospital Nurse productivity- the role of layout and people circulation

INFORMED CONSENT FORM

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethical Approvals (Human Participants) Sub-Committee.

I have read and understood the information sheet and this consent form.

I have had an opportunity to ask questions about my participation.

I understand that I am under no obligation to take part in the study.

I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.

I understand that all the information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others.

I agree to participate in this study.

Your name:

Your job profile:

Your experience in years:

Your reference number:

Your signature:

Signature of investigator:

Date:
به نام خدا
عنوان تحقيق: راندمان کاری برستاران - نفض طراحی بخش و سیرکولاسیون
فرم موافقت همکاری در تحقيق

هدف و جزئیات این تحقيق براي اینجانب تشریح شده است. من
می دانم که این مطالعه میدانی به منشور پیشرفت علم و دانش طراحی
شده و مهم در حال انجام مجموع میکروبی دانشکده دانشگاه آفریق (کشور
انگلستان) مورد شاید قرار گرفته است.

• من مطالعه این فرم و برکه "اطلاعات شرکت کننده" را مطالعه
کرده و فهمیده ام.
• من فرم و برسیدن هرکسی پرسشی در مورد همکاری ام را در این
تحقیق داشته ام.
• من هیچ گونه داشته ام، تحت بیشکه فشاری
• در مورد چنین مشارکت در این تحقیق واکنش نکرده ام.
• من هیچ گونه در مورد ملیتی و یا بر دلیلی، تحت اشتراک
همکاری را داشته و مجبور شناورهای بوده که نابیان
انجام نمی‌گذارم.
• من هیچ گونه در مورد اطلاعات مربوط به مشارکت من در این تحقیق
به شورت محترم و مربوط خواهم. ما نهاد از کنونو
اطلاعات در شرکت اینجای براي اینجانب، مطلع و یا فرد دیگر داشته

نام و نام خانوادگی: 
امضاء: 
تاريخ: 

202
Appendix C - Journey frequency data for staff types
<table>
<thead>
<tr>
<th>Route</th>
<th>Bus/Tram Frequency/Shifts</th>
<th>Rail/Road Frequency/Shifts</th>
<th>Minibus/Coach Frequency/Shifts</th>
<th>Local/NEAS Frequency/Shifts</th>
<th>Towns (2.5h – 3h) Frequency/Shifts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7am</td>
<td>8am</td>
<td>9am</td>
<td>10am</td>
<td>11am</td>
</tr>
<tr>
<td>1</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>2</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>3</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>4</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>5</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>6</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>7</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>8</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>9</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>10</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>11</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>12</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>13</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>14</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>15</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>16</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>17</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>18</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>19</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>20</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
</tbody>
</table>

204
<table>
<thead>
<tr>
<th>Buses</th>
<th>Buses (EU)</th>
<th>Korea (DM)</th>
<th>Korea (A)</th>
<th>YSRD (2.5 N + HW1.5 N)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency/Shifts</td>
<td>Frequency/Shifts</td>
<td>Frequency/Shifts</td>
<td>Frequency/Shifts</td>
</tr>
<tr>
<td>4 to 8</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>4 to 12</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>4 to 16</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>4 to 20</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>5 to 12</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>5 to 16</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>5 to 20</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>5 to 24</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>5 to 28</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>6 to 12</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>6 to 16</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>6 to 20</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>6 to 24</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>6 to 28</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>7 to 12</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>7 to 16</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>7 to 20</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>7 to 24</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>7 to 28</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>8 to 12</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>8 to 16</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>8 to 20</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>8 to 24</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
<tr>
<td>8 to 28</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
<td>Ym</td>
</tr>
</tbody>
</table>

205