UNIVERSITY OF CENTRAL LANCASHIRE

RAISING THE PROFILE OF FACILITIES MANAGEMENT (FM) IN HEALTHCARE - MANAGING PERFORMANCE OF INFECTION CONTROL

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September 2014

RAISING THE PROFILE OF FACILITIES MANAGEMENT (FM) IN HEALTHCARE - MANAGING PERFORMANCE OF INFECTION CONTROL

A thesis submitted in partial fulfilment of the requirements of the University of Central Lancashire for the degree of Doctor of Philosophy

The Grenfell-Baines School of Architecture, Construction, and Environment
University of Central Lancashire

September 2014

STUDENT DECLARATION

I declare that while registered as a candidate for the research degree, I have not been a registered candidate or enrolled student for another award of the University or other academic or professional institution.

I declare that no material contained in the thesis has been used in any other submission for an academic award and is solely my own work.

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The Grenfell-Baines School of Architecture, Construction, and Environment

ABSTRACT

Hospital-acquired infections (HAIs) are a major problem in the National Health Service (NHS) in the United Kingdom (UK). One reason for this is the failure of healthcare officials to tackle the root causes of HAIs. There is sufficient epidemiological evidence showing that HAIs can occur because of, *inter alia*, poor performance of Healthcare Maintenance (HM) services. Despite this link, HM has not received the level of attention it deserves from healthcare authorities. As a result, some HM managers do not measure the performance of HM services in infection control (IC). The aim of this research study therefore, is to improve the overall level of performance of HM services in the control of HAIs in the NHS. Hence, the adoption of six research objectives to identify the critical success factors (CSFs) and key performance measures in the control of maintenance-associated HAIs.

In addition to an in-depth literature review, a content analysis approach was adopted to establish the link between HM services and HAIs. Conversely, CSFs and performance measures in HM in IC were identified through the application of ground theory analysis. An exploratory case study was then conducted with two NHS trusts. The results of the exploratory case study revealed that some HM managers did not have the required knowledge to fulfil the research need of the study, i.e. development of the performance measurement system (PMS). Therefore, the Delphi approach was considered suitable to achieve the aforementioned need. In total, eight CSFs and fifty-three key performance measures are identified for reducing the burden of maintenance-associated HAIs in hospitals. For example, establishing clear lines of communication between the IC team and HM unit is crucial in the prevention of maintenance-associated HAIs in hospitals. Dust prevention is also identified by the healthcare experts as an important measure to prevent the transmission of maintenance-associated HAIs in high-risk patient areas.

Through the application of the Balanced Scorecard (BSC) approach, the CSFs and key performance measures were categorised into a performance matrix. The result was then used to develop a performance measurement system (PMS) to control maintenance-associated HAIs. Both performance tools i.e. the BSC matrix and PMS could be applied by HM managers to reduce rates of maintenance-associated HAIs in hospitals.

ACKNOWLEDGEMENTS

I would like to thank the Almighty God for the knowledge, wisdom, grace and endurance to complete this research project successfully. I am indebted to my Director of Study Dr Champika Lasanthi Liyanage for the time, guidance, encouragement, advice and criticisms provided throughout this research project. I am also grateful to my other supervisor Professor Akintola Akintoye, Dean of the Grenfell-Baines School of Architecture, Construction and Environment, for the valuable encouragement and contribution towards the realisation of this research project. My sincere gratitude also goes to Dr Kevin Butt, Dr Chris Lowe and Patricia Beard for making my stay at Uclan a pleasant one. I am appreciative to all those Healthcare Maintenance Managers and Infection Control Members who participated in this research study. This research project was funded by Uclan.

Thanks to my brother-in-law Mr Thomas Azap for providing moral and financial support. It is through your generosity that I am an achiever. Thanks to my mum Regina Ethiendem Njuangang and mother in-law Felicia Nkembeng Nkola for the immense support. My siblings Henry, Mariana, Dominic, Judith, Loveline, Elizabeth, Adel, Regina and Roland also provided emotional support. This research project would not have been possible without the moral and financial support provided by my loving little sister Adel Alemsu Njuangang. Special thanks to Mr Aka Leke Oben and wife Suzi Kemblings, Jarvis Matute, Emmanuel Asonganyi, and Columbus Awung. It was wonderful having the following kids around: Ezra-Rose, Ava-Lisa, Mark Awung, Jacque Aaron, Brian, Latoya, Evita, Alfred, Junior, Reece and Ethan. Thanks to Mrs Imafu Nvenakeng and husband, Debora Atabong, Juliet Asong, Wilfred Etiendem and Nkanjia Fualefac Fonge for the wonderful words of encouragement and prayers. My friends and their families Kinsley Tambe, Adeline Longla, Mike Likambi, Dr. Sylvia Forchap, Vera Koroye, Chris Ejieh, Gideon Nsom, Joshua Takwa, and Cameron Emmanuel Forty for the wonderful support. I would like to express my appreciation to my exceptional and beloved wife Fualefeh Irene Nkola Njuangang who never complaint about my absence. Thanks for the wonderful discussions and insights you provided throughout this research project. And to my children Leo-Raphael Njuangang, Dominic Akwalabeng Njuangang and Jane-Pearl Nkembengleke Njuangang for being patient and understanding. Thank you my little angles.

DEDICATION

To the woman of my life Fualefeh Irene Nkola;

Loving children Leo-Raphael, Dominic Akwalabeng, Jane-Pearl; and

Judith Awanju Njuangang (late sister)

Agnes Anyikeng (late grandmother)

Mbe Peter Nkemnyi Akwalabeng (late grandfather)

Dominic Njuangang (late father)

Aaron Nkola Fonge (late father in-law)

Felix Achale (late friend)

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ABBREVIATIONS

Abbreviation	Meaning
ACCA	Association of Chartered Certified Accountants
BSC	Balanced Scorecard
BSI	British Standards Institution
CCAR	Canadian Committee on Antibiotic Resistance
CCP	Critical Control Point
CDC	Centre for Disease Control and Prevention
CFU	Colony Forming Unit
DH	Department of Health
DTI	Department of Trade and Industry
ECDC	European Centre for Disease Prevention and Control
FM	Facilities Management
FMEA	Failure Modes and Effects Analysis
GP	General Practitioner
HACCP	Hazard Analysis and Critical Control Point Principles
HAI	Hospital-acquired Infections
HCAI	Healthcare Associated Infections
HEPA	High-Efficiency Particulate Air
HFM	Healthcare Facilities Management
HIV	Human Immunodeficiency Virus
HM	Healthcare Maintenance
HMM	Healthcare Maintenance Manager
HMPs	Healthcare Maintenance Policies
HMSs	Healthcare Maintenance Services
HMU	Healthcare Maintenance Unit
HPA	Health Protection Agency
HVAC	Heating Ventilation and Air Conditioning
IC	Infection Control
ICM	Infection Control Member
ICRA	Infection Control Risk Assessment
ICT	Infection Control Team
ICU	Infection Control Unit
IQD	Inter-quartile Deviation
MRSA	*Methicillin-resistant Staphylococcus aureus*
NAO	National Audit Office
NASA	National Aeronautic and Space Administration
NHS	National Health Service
NICE	National Institute for Clinical Excellence
PMF	Performance Measurement Framework
PMS	Performance Measurement System
POST	Parliamentary Office of Science and Technology
PP	Performance Prism
PPE	Personal Protective Equipment
PPS	Performance Pyramid System
QCA	Qualitative Content Analysis
RCM	Reliability Centred Maintenance
RCN	Royal College of Nursing
SLA	Service Level Agreement
TPM	Total Productive Maintenance
UK	United Kingdom
VAV	Variable Air Volume
WHO	World Health Organisation

CHAPTER 1 : INTRODUCTION

1.1 RESEARCH BACKGROUND

Hospital-acquired infections (HAIs) are a major cause of deaths and increased morbidity, especially in immune-compromised patients in the United Kingdom (European Academies Science Advisory Council, 2009). They lead to patient discomfort, prolonged length of hospital stay and permanent disability, as well as adversely affecting the treatment of a patient's original condition (Pratt, 2005). According to the Health Protection Agency, HAI means infections that were neither present nor incubating when a patient**,** visitor or hospital staff entered the hospital (HPA, 2012).

The term HAI is often used interchangeably with terms such as nosocomial, hospital infections, and healthcare associated infection (HCAI). The term HCAI was introduced by the Department of Health (DH, 2002) to refer to infections that occur in hospitals, as well as in primary care settings. Also used in the literature are terms to describe specific-related incidences of HAI. For example, 'intervention-related infection' refers to an infection that occurs because of an invasive healthcare intervention (Jamieson, 2008). HAIs that occur amongst healthcare staff are also referred to as 'occupational HAIs'. For the purpose of this study, the term hospital acquired infection (HAI) is used to avoid any confusion. This is because this research focuses on hospitals.

There appear to be variations in the literature on the time interval in which an infection could be classified as hospital acquired. It is often stated in the literature that HAIs are infections that occur within 48 hours after a patient has been admitted to, or discharged from hospital (World Health Organisation (WHO), 2002**;** Turner, 2008; Jamieson, 2008). However, the new definition of *Clostridium difficile* introduced in 2008 does not consider *C. difficile* as being hospital-acquired if a patient has spent less than three days in hospital (National Audit Office (NAO), 2009). In addition, Inweregbu *et al*. (2005) also noted that infections occurring 72 hours after a patient has been discharged or 30 days after an operation should be regarded as HAI. The lack of a clear definition of HAI could of course lead to varying data on the extent of the problem of HAI in the UK.

HAI is not restricted to hospitals alone, as it could also occur in general practices, day surgery centres, residential aged care, long-term care facilities, childcare centres, nursing homes, and community services (WHO, 2002). HAIs are caused by germs such as *Enterobacteriacae*, methicillin-resistant *Staphylococcus aureus* (MRSA), *Escherichia Coli* (*E. coli*), *Staphylococcus aureus* (*S. Aureus*), etc. According to the HPA (2012), the most common types of HAI in the UK are pneumonia and other respiratory infections (22.8%), urinary tract infections (17.2%), surgical site infections (15.7%), clinical sepsis (10.5%), gastrointestinal infections (8.8%), and bloodstream infections (7.3%). A patient's susceptibility to HAI is influenced by a number of factors such as immunity, age, physical and psychological wellbeing, as well as medical intervention (May, 2000). The hospital unit wherein medical intervention is received also plays a vital role in the incidence of HAI.

HAIs are a major problem in healthcare delivery throughout the world. According to estimates by the WHO, out of every one hundred patient admitted to hospital at any one time, seven in the developed and ten in the developing countries acquire at least one type of HAI (WHO, 2011). The European Centre for Disease Control and Prevention estimate that about 3.2 million patients in European acute care hospitals acquire HAIs every year (ECDC, 2013). The same study estimates that, in the UK, about 1,602 patients in acute care acquire HAI every year. Since the introduction of mandatory surveillance in 2001, there has been a steady fall in the rate of MRSA and *C. Difficile* in England (HPA, 2012). According to HPA (2009), MRSA bloodstream infections in England fell from 6,383 in 2006/07 to 2,933 in 2008/09 (a 54% reduction). Equally, the rate of *C. Difficile* fell from 55,499 in 2007/08 to 36,097 in 2008/09 (a 35% reduction).

By reducing the rate of MRSA and *C. Difficile*, the NHS has been able cut costs on such issues as drug therapy, hospital re-admission, ward closures etc. According the National Institute for Health and Clinical Excellence, every 5% reduction in the rate of

MRSA and *C. Difficile* could result in a cost saving of about £4.9 million annually to the NHS (NICE, 2011). This extra money and resources could be put into alternative projects elsewhere in the NHS.

Apart from those infections i.e. MRSA, *C. Difficile*, which are under mandatory surveillance, there is no evidence suggesting that rates of HAIs are falling. It appears that many healthcare authorities and researchers continue to focus their attention on the clinical causes of HAI. A review of the literature indicates that HAI also occurs because of non-clinical errors, i.e. poor healthcare facilities management (HFM) practices in the healthcare setting. The operation of non-clinical services in hospitals may result in the contamination of inanimate objects such as bed rails, tables, etc with pathogenic microorganisms that cause HAI (Royal College of Nursing, 2005). HFM services that have a direct link to HAIs are divided into hard and soft services (Table 1-1). Hard HFM services specifically deal with the technical issues of the hospital. Examples of hard HFM services with a link to HAI include the planning, designing and construction of new hospitals, healthcare maintenance (HM), inter-connectivity between clinical spaces, air change logistics, spatial relationships and water supply (Centre for Disease Control and Prevention (CDC), 2003). Soft HFM services relate to support services dealing with the performance of people (Olomolaiye *et al*., 2004). Examples of soft HFM services that relate to HAI include cleaning, waste management, catering, and laundry (NHS Executive, 1995; Department of Health (DH), 2004).

Table 1-1: Hard and Soft HFM Services Linked to HAIs

Hard FM		**Soft FM**
➢ The planning and designing of hospital buildings ➢ Construction of new hospital buildings	➢ Construction work in and around hospitals**:** – Alteration – Conversion – Fitting out – Renovation – Repairs – Maintenance – Demolition ➢ Inter-connectivity between clinical spaces ➢ Water supply ➢ Pest control	➢ Cleaning ➢ Laundry ➢ Catering ➢ Waste management

Of the HFM services outlined above, this research project will focus mainly on HM. There is strong epidemiological evidence of the close link between healthcare maintenance and HAIs. For example, maintenance work carried in and around hospitals may dampen structures, areas, or items made of porous materials or characterised by cracks and crevices (sink cabinets in need of repairs, carpets, ceilings, floor, walls, upholstery, and drapes). If unattended, these surfaces might support the growth of moulds and serve as potential sources for pathogenic microorganisms (CDC, 2003). Despite evidence showing the strong link between HM and HAIs, this fails to attract enough attention from healthcare authorities. As a result, some HM units do not have a strategy for controlling HAIs. Some HM units do not even have pre-set goals and objectives in infection control (IC).In maintenance, there is a known history of staff relying too much on technical experiences and behaviours and for not connecting with core business objectives (Lee and Scott, 2008).

Maintenance prevents disruption of core business activities that may have undesirable outcomes (e.g. customer dissatisfaction, non-compliance with legal requirements, health and safety problems, increase in energy consumption and environmental loss, etc.) (Lam, 2007). In spite of this, it appears that HM often takes low priority in the overall operating strategy of organisations. As a result, organisations are often reluctant to allocate sufficient budget for the HM unit to carry out alternative maintenance strategies. In the words of Thun (2004, as cited in Bivona and Montemaggiore, 2005: p. 4) this creates a vicious cycle whereby *"repairs eat up prevention, resulting in a situation with many unexpected machine breakdowns and an overloaded maintenance department"*. All these eventually result in poor performance in HM services, which then exacerbates the problem of HAIs. Currently, there is insufficient research into these performance issues of HM services in relation to HAI. Moreover, little is known whether service level agreements (SLA) in HM put sufficient emphasis on the control of HAIs in the NHS.

1.1.1 Aim and Objectives

From the foregoing discussion, it is clear that improving the performance of HFMs in infection control can reduce the rate of HAIs in the NHS. In addressing the research gaps identified above, this research project aims to examine the ways and means of improving the overall level of performance of HM services in the control of HAIs in the NHS. The overall aims of this research project are met through the following research objectives:

1. Investigate historical evidence in establishing the connection between facilities management services and hospital-acquired infections.
2. Examine the causes of and measures to reduce HAIs in relation to healthcare facilities management services.
3. Use a document analysis approach to establish critical success factors (CSFs) and performance measures in healthcare maintenance services in the control of HAIs.
4. Analyse and prioritise the aforementioned (objective 3) critical success factors and key performance measures for healthcare maintenance services in the control of HAIs.
5. Distribute the previously established critical success factors and performance measures on a healthcare maintenance Balanced Scorecard matrix (HM-BSC Matrix).
6. Develop a performance measurement system (PMS) in HM to control HAIs.

1.2 THE RESEARCH PROCESS

As shown in Figure 1-1, this research project is divided into preliminary, exploratory, further and advanced research phases. The preliminary phase is concerned with identifying the research gap and the research problem, and formulating the research aims and objectives of this study. This is achieved mainly through the extensive review of literature from multiple sources. A preliminary literature review led to the organisation of research materials into the following key themes: FM, HFM, HAIs, IC, and performance management. Whilst research material relating to FM, HFM and performance management were drawn from social sciences databases, those relating to HAIs and IC were drawn primarily from clinical research databases. Additionally, data was also gathered from professional databases and government websites.

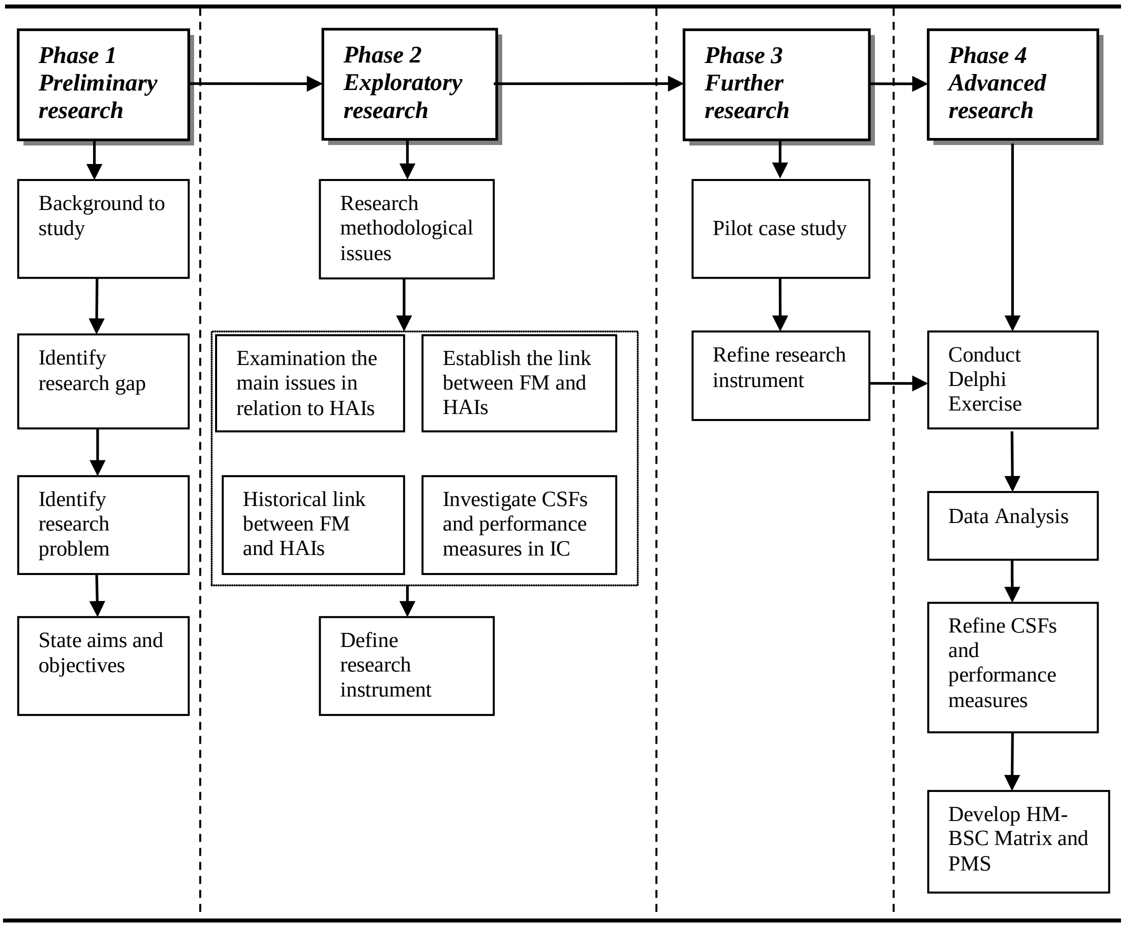

Figure 1-1: The Research Process

Analysis of the themes and patterns that emerged from the initial literature review prompted the need for an in-depth literature review in the exploratory phase. As indicated in Figure 1-1, the in-depth literature review is broadened to include methodological issues, historical links between HFM and infection control, HAIs, critical success factors (CSFs) and performance measures in HM in IC. The deeper understanding this provided led to further development and refinement of the research gap, and the problems, aims, and objectives of the study. The research instrument is also developed at the exploratory phase of the research study.

In the third phase (further research), a pilot study is conducted through the application of a case study. This was to test the appropriateness and robustness of the research instrument in meeting the research needs of this study. The main method for soliciting data was through the application of semi-structured interviews. The result of the pilot study provided a better understanding of the HM unit, and refinement of the research and interview questions. It also exposed the weaknesses of the case study and the application of the Delphi approach in this research study. In the advance phase of this research, data collected about the CSFs and performance measures are analysed and synthesized.

1.3 SCOPE OF THE RESEARCH STUDY

The scope of this study is identified in relation to geographical area and the type of NHS hospitals under which the HM unit operates. Because of devolution, it is possible that variations exist between HM services across the different regions of the UK. According to the Martin (2008), devolution has created "… *different National Health Services across the UK*…" Therefore, to reduce ambiguity, this research study shall focus on HM services in England alone.

Since several arrangements are used in the provision of healthcare services in the NHS, this study also focus on Acute NHS Trusts. According to NHS Choices (2011), Acute NHS Trusts provide high-quality healthcare services, and employ a large part of the NHS workforce (both clinical and non-clinical). Given the scale of their operation, it is logical to assume that Acute NHS Trusts have the right mix of experts to generate the sort of rich data needed in this research study. In this research therefore, two groups of Delphi participants were specifically selected to identify the CSFs and performance measures in HM in IC. These are HM managers and infection control (IC) members. In the NHS, the business of infection control and prevention is directly under the auspices of the IC department.

1.4 CONTRIBUTION TO KNOWLEDGE AND ORIGINALITY

There are not many research studies focusing on the subject of performance measurement in HM in IC. According to May and Pitt (2012), few studies of this nature are published in the facilities management (FM) or clinical domains. This research is one of the few examining these issues from an FM perspective. In the second and third chapters of this research study, historical and epidemiological evidence is provided of the link between HFM services and HAIs. Such evidence draws the attention of healthcare officials to the contribution of HFM services in the control of HAIs in the NHS. The findings of this research may make it possible for local policies and guidelines to be implemented to drive performance HM in IC. Demonstrating the contribution of HFM in IC will raise awareness amongst HFM staff, and increase their level of participation and involvement in the business of IC in the NHS

The third part of this research study examines issues relating to the performance of HM services in the control of HAIs. So far, there are not many studies in this area. The CSFs and key performance measures that are identified in this research study are crucial for measuring performance in HM services in IC. To make it even easier, the CSFs and performance measures have been presented in a HM-BSC Matrix, detailing their levels of importance in IC. A performance measurement system (PMS) is also developed for measuring the performance of HM in the control of HAIs. Although the CSFs and key performance measures relate specifically to HM services, they could also be adapted for application in other HFM services.

1.5 STRUCTURE OF THE THESIS

This thesis is made up of eight chapters:

- **Chapter 1** provides a general overview of the various areas covered by the thesis. These include the research problem, as well as the aims and objectives of the study. Also in chapter one, a summary is provided of the different methodological approaches adopted throughout the research study.
- **Chapter 2** focuses on the examination of the main issues related to IC in the NHS. In addition to defining the term HAIs, an in-depth literature review is also conducted on the socio-economic and health implications of HAIs. The processes (sources, routes) involved in the transmission of HAIs are also examined. Also in this section, a review of the literature is conducted on the clinical and non-clinical risk factors in the transmission of HAIs in hospitals. In the last section, historical evidence is summarised on the role of non-clinical services in IC.
- **Chapter 3** examines the non-clinical factors associated with the transmission of HAIs in hospitals. Only those HFM services with strong epidemiological association with HAIs are examined in this chapter. These factors include the planning and design of hospitals, cleaning, HM, waste management, laundry and catering services. Under each of these aforementioned HFM services, measures to reduce the incidence of HAIs are also examined.

- **Chapter 4** is about the methodology adopted throughout this research study. Methodological issues include for example research design, research paradigms, grounded theory analysis (open coding, axial coding, and selective coding), the use of an exploratory case study, and the Delphi approach.
- **Chapter 5** examines issues related to the performance of the HM unit in IC. The chapter starts with the definition of the words performance, performance measurement (PM), and performance management. It then moves on to review different Performance Management Systems (PMSs), as well as examining the current challenges of measuring performance in HM in IC. In the last section, the results of qualitative data analysis using QRS NVivo are presented. The results detail the CSFs and performance measures in HM in IC.
- **Chapter 6** presents the results of the Delphi round one and two exercises to analyse the CSFs and performance measures in HM in IC. The results of the Delphi round one exercise are presented qualitatively, while those of the Delphi round two are presented quantitatively.
- **In Chapter 7,** the results of the third round Delphi exercise are presented. These are performance measures with low-level consensus in the second round of the Delphi exercise. Also in chapter seven, the results of the second and third rounds of the Delphi exercises are analysed. The results are then used to develop an HM-BSC matrix and PMS to control HAIs.
- **Chapter 8** is the final chapter of this research study. The conclusions presented here are guided by the aims and objectives set forth in this research study. Recommendations are presented to HM managers, academicians, and health officials on ways to improve performance in HM in IC.

CHAPTER 2 : HOSPITAL-ACQUIRED INFECTIONS -AN OVERVIEW

2.1 INTRODUCTION

The chapter starts by defining the term hospital-acquired infections (HAIs). In addition to defining the term HAI, the socio-economic and health implications of HAIs in the NHS are also examined, including the different sources and routes in the transmission of HAIs. A distinction is also made between the clinical and non-clinical risk factors associated with the transmission of HAIs in hospitals. Historical evidence of different historical epochs (i.e. the Pre-Medieval, Medieval, and Victorian eras) is presented, establishing the link between non-clinical services and hospital-acquired infections. In the final section, the work of the likes of Pringle, Lind, Semmelweiss, and Nightingale are analysed demonstrating the significance of non-clinical services in infection control.

2.2 DEFINING THE TERM HAI

The term hospital-acquired infection (HAI) is often used interchangeably with terms such as nosocomial infection, hospital infection and healthcare-associated infection (HCAI). The term HCAI refers to infections that occur in hospitals, as well as in other healthcare settings, i.e. primary care (DH, 2002). Also used in the literature are terms to describe specific-related incidences of HAI. For example, an '*intervention-related infection*' refers to an infection that occurs because of an invasive healthcare intervention (Jamieson, 2008). For the purpose of this study, the term HAI will be used throughout. This is because HAI is a generic term associated with HAIs occurring in hospitals.

To define HAI, it is important to first define the word infection, and state its characteristics (Ellenberg, 2004). According to Ellenberg, any definition of the word infection has to take into account the pathological reaction of an organism and the disease caused by a microorganism. An infection is therefore "…*an invasion of the body by a pathogenic microorganisms or the pathological state resulting from such invasion due to the action of toxins produced by the microorganisms*" (Reader's Digest, 1987: p.

3000). Therefore, conditions such as colonisation and inflammation are not HAIs (Horan, *et al*., 2008). Other conditions not classified as HAI include:

- Infections associated with complications or the extension of infections already present
- Infections acquired by infants transplacentally, e.g. *herbes simplex*
- The reactivation of a latent infection in a patient admitted to hospital, e.g. *herbes zoster*.

According to Ellenberg (2004: p. 721), the two elements of HAIs are "*the hospital structure, its human and material environment; and the hospital function—to care*". Therefore, to classify an infection as HAI or HCAI, the source of the infection has to be associated with the provision of medical care in a healthcare establishment or institution (hospital, GP surgery, care home, dental practice, etc). This research however, focuses on the occurrence of HAIs in hospital settings.

Because HAIs have to originate in the hospital, the patient at the time of entering hospital should have no sign of a present or incubating infection (NAO, 2000; Parliamentary Office of Science and Technology (POST), 2005; Office of the Auditor General of Ontario, 2008). Physicians gather clinical evidence (i.e. observation of wounds, review of patient charts and clinical records) and/or diagnosis (i.e. direct observation during surgery, endoscopic examination, diagnostic studies, and clinical judgment) about the patient for signs of HAIs (CDC, 2003, as cited in Horan *et al*., 2008), if they suspect any incidences of HAI.

Variations exist in the literature concerning the time interval for classifying an infection as HAI. Most authors agree that HAIs are infections that occur within 48 hours of the admission or discharge of a patient from hospital (WHO, 2002**;** Turner, 2008; Jamieson, 2008). However, the definition of *Clostridium difficile* introduced in 2008 does not consider *Clostridium difficile* to be an HAI if the patient has spent less than three days (sixty hours) in hospital (NAO, 2009). According to Inweregbu *et al*. (2005), infections occurring 72 hours after a patient is admitted or discharged from hospital, or 30 days after undergoing an operation can be classified as HAI as well.

In this research study, the definition of HAI will be synonymous with the one used by NAO, DH, WHO. Therefore, HAI will be those infections that occur within 48 hours of a patient being admitted or discharged from hospital.

2.3 QUANTIFYING THE COSTS OF HAI

The inability of most healthcare facilities to collect reliable diagnostic data has made it difficult to estimate the global burden of HAIs. Different countries and regions employ diverse criteria to measure the prevalence of HAIs. According to the NAO (2000), variations exist in the definition of HAIs, data collection methods, the range of hospitals or patient conditions considered, the types of HAIs monitored and causative agents. The focus of the UK government's strategy on healthcare is on quality and efficiency rather than profit and competition (Wilcox and Dave, 2000) . "*However, the constantly changing external environment, advancing technology, legislation, clinical excellence and the drive to maximize healthcare resources have made costing of infection control a management priority*" (Wilcox and Dave, 2000: p. 1).

Measuring the cost of HAI is difficult, and many researchers employ different methodologies, definitions and stringency in this regard (ibid). Moreover, the financial impact associated with HAIs varies between different sites of infections and involves many different agents (Graves, 2004). As shown in Table 2-1, the full range of the costs of HAIs is divided into three broad categories: direct cost (i.e. medical cost), indirect cost (i.e. productivity and non-medical cost), and intangible cost (i.e. diminished quality of life) (Scott, 2009).

Out of the many costs associated with HAIs, direct costs are the easiest to quantify (Graves, 2004; Scott, 2009; Plowman *et al*., 2001). The direct costs of HAI refer to costs incurred by hospitals because of HAIs. There are two types of direct cost of HAIs: fixed and variable costs. The fixed costs of HAI refer to the unavoidable costs hospitals incur in the short term (Graves, 2004). The prevalence of HAIs in hospitals exerts pressure on fixed items such as buildings, utilities and equipment. Unlike the variable costs of HAIs, hospitals cannot easily exchange fixed costs for cash. Variable costs are associated with those expenditures that hospitals could easily terminate, and such savings can be expressed in real cash (Graves, 2004). Examples of variables costs include items such as medication, food and consultation.

Table 2-1: HAIs Cost Categorisation

Categories of cost	
Direct hospital cost	***Fixed costs*** Buildings Utilities Equipment/Technology Labour (laundry, environmental control, Administration ***Variable costs*** Medication Food Consultations Treatments Procedures Equipment Testing (laboratory and radiography) Supplies
Indirect cost	Lost wages Diminished productivity on the job Short- and long-term morbidity Mortality Income lost by family members Foregone leisure time Time spent by family/friends for hospital visits, travel costs, home care
Intangible cost	Psychological cost (e.g. anxiety, grief, disability, job loss) Pain and suffering Change in social functioning/daily activities

(Adapted from: Scott, 2009)

The direct costs of HAI represent a huge drain on scarce hospital resources. As a result, healthcare organisations tend to focus their attention on drug acquisition and increased length of hospital stay (Wilcox and Dave, 2000) (see Table 2-2). The cost of drug acquisition and increased length of hospital stay are quantified using several methods. These include crude weighting, concurrent and comparative methods etc. The comparative method is the most favoured method employed by researchers (Wilcox and Dave, 2000). In the comparative method, data is collected on the level of resources employed in the treatment of patients with and without HAI. Thereafter, the level of resources used on each group is compared (Graves, 2004). As the comparative method requires a large study of control between the two groups (sex, age, diagnosis, treatment procedures and co-morbidities), it may result in the bias of omitting patients for whom no matches are found (Haley, 1991, as cited in Graves, 2004). Although focusing on the cost of drug acquisition and length of hospital stay does not accurately show the full cost of HAI, it creates political urgency and raises awareness of the problem of HAIs in hospitals (Graves, 2004).

Table 2-2: Estimating the True Cost of HAI

Well described costs	Poorly described costs
– **Drug (antimicrobial acquisition)** – **Increased hospital stay**	– Control measures (e.g. isolation facilities, cleaning, committees, policies) – Impaired hospital activity (e.g. ward closure, surgical waiting lists initiatives) – Confidence, performance of staff – Litigation – Effects on community – Morbidity (e.g. social, economic loss) – Mortality (particularly crude vs. attributable mortality)

(Source: Wilcox and Dave, 2000: p. 2)

Presently, the rate of HAIs in the UK is about 6.0% (ECDC, 2013). Before the introduction of mandatory surveillance of MRSA and *C. difficile* in 2001, the rate of HAIs in the UK was about 9% (NAO, 2000). The number of MRSA fell from 1,898 in the period 2008/09 to 1,481 in the period 2010/11. According to NICE (2011), these reductions resulted in huge financial savings for the NHS, based on the estimate that a mere 5% reduction in the rate of MRSA and *C. difficile* could save up to £4.9 million annually. Although progress is being made to reduce rates of HAIs further, UK is still lagging behind other Western European countries. Figures released by the ECDC (2013) show the rate of *C. difficile* in England higher than in the Netherlands, France, Spain, and Italy. In that same study, Wales is only next to Hungary, which has the worst rate of *C. difficile* in Europe. HAIs are therefore a huge burden to healthcare organisations and the community, and thus need urgent attention.

2.4 PROCESSES OF THE TRANSMISSION OF HAI

The transmission of HAIs can occur in many ways. An infection normally occurs when a microorganism such as bacteria, protozoa, virus, or fungus invades a susceptible host. According to the Parliamentary Office of Science and Technology, bacteria cause most cases of HAIs (POST, 2005). The majority of bacteria and viruses that inhabit our community and hospitals are not pathogenic and in some instances are beneficial to the body (WHO, 2002). However, the natural environment may also provide a suitable environment through which people become infected with microorganisms. According to the Royal College of Nurses (RCN) (2000), the common points of entry of pathogens into the human body are generally the natural orifices (mouth, nose, vagina, urethra, ear, rectum), mucous membranes and skin breaks. HAI commonly affects the urinary tract, respiratory tract, gastrointestinal tract, skin, and the bloodstream (NAO, 2009). A reservoir from which an infection arises is usually called the source (WHO, 2002).

For a source of infection to be active, it needs to be in an optimum condition. The source of infection must contain sufficient numbers of virulent microbes that retain an aggressive quality to survive and multiply. These requirements are only met if the microbes are supplied with sufficient water (damp surfaces) or if embedded in protein-containing body fluids (May, 2000; WHO, 2002). As shown Table 2-3, the survival of microbes depends on microbial and environmental factors (Neely, 2008). Even when pathogens survive in the built environment of the healthcare facility, they can only get to a susceptible host in the presence of a source and a means of transmission of the infective microorganisms (May, 2000). The control and prevention of HAI depends on how one or more of these links are broken or interrupted (see Figure 2-1).

Table 2-3: Factors that Affect Microbial Survival

Microbial factors	Environmental factors
– Specific microorganism: genus, species, and strain – Concentration of the microorganism on the surface	– Light, UV radiation – Temperature – Humidity – Medium in which the microbe is suspended – Surface on which the microbe is deposited

(Source: Neely, 2008: p. 5)

2.4.1 Sources in the Transmission of HAI

The transmission of HAI in the built environment of the healthcare facility can originate from one of the following three sources: endogenous (self-infection, autoinfection), exogenous (cross-contamination) and the environment.

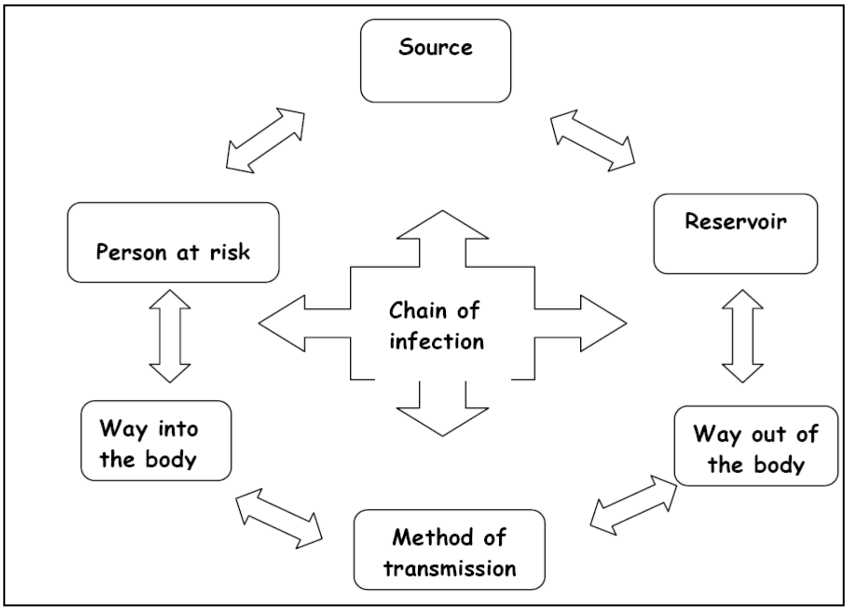

Figure 2-1: The Chain of Infection

(Source: Health Protection Agency, 2009; p. 29)

2.4.1.1 Endogenous Sources of HAIs

Endogenous (self-infection or autoinfection) infection occurs when a patient's own endogenous flora originating from the mouth, vagina, skin, or gastrointestinal tract cause an infection. In endogenous infection, there is usually direct body surface-to-body surface contact and physical transfer of microorganisms between an infected or colonised person. A patient might also be infected by the body fluid from another patient or through vertical transmission of microorganisms from mother to baby in the uterus (May, 2000). The transmission of an infection through this route is called direct contact transmission.

During operative or invasive procedures performed in theatres, wards and x-ray departments, microorganisms might enter the bloodstream of a patient and cause an infection (NAO, 2000). Medical devices make it easy for microorganisms originating from the patient's body flora to enter deeper tissues or blood when inserted into the vein (DH, 2003). Jamieson (2008) refers to such infections as 'intervention-related infections'.

2.4.1.2 Exogenous Sources of HAIs

Exogenous (cross-contamination) infections generally originate from other healthcare facility users like patients, health personnel, and visitors. The common mode of transmission of exogenous infections is through the hand, sneezes, and coughs (May, 2000). The presence of patients who are infected or are carriers of pathogenic microorganisms presents potential sources of infection to patients, staff, and visitors. This, coupled with the crowded condition of hospitals, frequent transfer of patients from one unit to the other, and the concentration of patients highly susceptible to infection in one area, may contribute to exogenous sources of HAI. According to the Nursing Times (2013), general and acute hospitals in England have bed occupancy rates of over 89%. Studies have shown that higher bed occupancy rates lead to higher rates of infection (ibid).

Healthcare providers, visitors, care providers, or family members of inpatients may themselves be carriers of pathogenic microorganisms. About 30-60% of symptomless healthcare workers carry *Staphylococcus aureus* in their nasal passages (WHO, 2002), which may pose the risk of HAI to other healthcare users. The WHO (2002) identifies five sources in the introduction of community-associated infections in hospital environments (WHO, 2002):

1. The respiratory tract (e.g. tuberculosis and respiratory viruses)
2. Infected blood (viral hepatitis and human immunodeficiency virus (HIV)
3. Faeces (Salmonella, *shigella*, *vibrio*)
4. The air or skin scales (chickenpox, herpes, *Staphylococci*, *Streptococci*)
5. Infected discharges (pus)

2.4.1.3 Environmental Sources of HAIs

Environmental infections normally originate from sources linked to non-clinical services, i.e. food, water, and contaminated inanimate environmental objects including equipments and medications (Canadian Committee on Antibiotics Resistance (CCAR), 2007). Non-clinical operations such as construction, renovation, demolition, and cleaning can lead to the contamination of inanimate objects such as beds, tables, ceilings, floors and equipment. When these contaminated objects get in contact with a susceptible host, they may lead to the incidence of HAIs.

The transmission of pathogenic microorganisms from sources linked to non-clinical operations occasionally result in an explosive outbreak of HAIs (CCAR, 2007). For example, the poor handling of food in hospitals can cause an outbreak of *Salmonella*, *shigella spp*., *Escherichia coli* 0157:H7 or other infections (May, 2000). In other cases, the contamination of the water cooling system in air conditioning equipment can cause outbreaks of *legionella pneumophilia* in hospitals (CDC, 2003) (these issues are examined in-depth in Chapter 3).

2.4.2 Routes in the Transmission of HAI

Several routes exist in the transmission of microorganisms from a source to a new host. The CCAR (2007) identifies five routes in the transmission of microorganisms: contact, droplet, airborne, common vehicle, and vector-borne. These are examined in the next section.

2.4.2.1 Contact Transmission

Contact transmission is probably the most important and frequent mode of transmission of HAIs (CCAR, 2007). Two forms of contact transmission exist: direct and indirect contact transmissions. In the direct contact transmission, pathogens might get to a susceptible host through direct contact with the body fluids of an infected individual (May, 2000). Such contact might occur when a healthcare worker turns a patient, gives a patient a bath, or performs other care-related activities that involve direct personal contact (CCAR, 2007). Direct contact may also occur between two individuals in the hospital, with one serving as source of the pathogen and the other as the susceptible host. An example is sexually transmitted diseases. Indirect contact, on the other hand, involves the transmission of pathogenic microorganisms from contaminated objects such as items of equipments, beds and tables to a susceptible host. Some blame non-clinical services for the indirect transmission of pathogenic microorganisms in hospitals.

2.4.2.2 Droplet Transmission

During coughing and sneezing, droplets containing microorganisms maybe generated from an infected person and propelled a short distance to a susceptible host. Certain hospital procedures such as suctioning and nebulised medications may also generate droplets. Pathogens present in sneezes and coughs normally evaporate in less than a second into small droplet nuclei of 2µm diameter, and may remain suspended for four hours before settling (Xie *et al*., 2007, as cited in Curtis, 2008). When deposited on the conjunctivae, nasal mucosa or mouth of a susceptible host, these pathogens might cause an infection. However, because droplets do not stay long in the air, most patient areas do not necessarily need special handling and ventilation equipment (CCAR, 2007; CDC, 2003). This does not however eliminate the risk of droplets contaminating the surrounding environment and posing significant risk to susceptible patients. Examples of pathogens that may spread in this manner are influenza virus and rhinoviruses (CCAR, 2007; May, 2000).

2.4.2.3 Airborne Transmission

Airborne transmission is associated with FM activities like renovation, maintenance, refurbishment, and the use of rotary powered foot care tools. Performing these activities around hospitals may disturb environmental reservoirs such as soil, water, dust, or decaying organic matter. The ensuing suspended dust particles or evaporated droplets (5mm or smaller in size) may contain skin cells carrying bacteria such as *Staphylococcus aureus* or spores such as *Clostridium difficile* and *Aspergillums* (May, 2000).

Dust particles have the potential to remain suspended in the air for long periods. Once in the healthcare environment, these pathogenic microorganisms may settle in different ecological niches and pose the risk of HAI to susceptible patients. Many epidemiological investigations have associated microbial contamination of surfaces and fabrics in the healthcare environment with the outbreak of infectious diseases.

2.4.2.4 Common Vehicle Transmission

'*Common vehicle transmission*' usually refers to the transmission of pathogenic microorganisms through water and food. Healthcare workers use water for several purposes i.e. bathing, drinking, cooking, and pharmaceuticals. It is therefore necessary for the physical, chemical, and bacteriological characteristics of water to conform to local regulations and standards (WHO, 2002). Through the preparation of food, the washing or general care of patients, steam or aerosol inhalation, etc it is possible for water to become contaminated with microorganisms that cause HAIs (WHO, 2002). Moist environments and aqueous solutions present in hospitals serve as potential reservoirs for waterborne microorganisms (CDC, 2003). Given ambient conditions, these microorganisms can proliferate and pose substantial risks to healthcare users. The

CDC (2003) identified five routes in the transmission of waterborne infections in hospitals:

1. Direct contact (e.g. through hydrotherapy),
2. Ingestion of water (e.g. through consuming contaminated ice),
3. Indirect contact transmission (e.g. from an improperly reprocessed medical device),
4. Inhalation of aerosols dispersed from water sources,
5. Aspiration of contaminated water.

The convalescence of patients is highly dependent on the quality and quantity of food they receive in hospitals. Therefore, ensuring that their food is safe should be a/the-top management priority in hospitals. Through eating contaminated food, a patient might suffer from bacterial food poisoning (acute gastroenteritis). Vehicles of transmission of food poisoning and food borne infections include water, milk, and solid foods.

2.4.2.5 Vector-borne Transmission

The presence of arthropods such as bugs, flies, fleas, lice, midges, mites, mosquitoes and ticks in hospitals may result in the transmission of HAIs. Transmission is normally through one of the following ways: sucking, biting, burrowing, or droppings. According to the WHO (2002), most vector-borne diseases occur in the tropics. In temperate regions, they occur as imported diseases. Examples of vector-borne diseases include scabies, pediculosis, malaria, and viral haemorrhagic fevers (May, 2000). Others include the African *trypanosomiasis* (sleeping sickness), *Trypanosoma brucei* (caused by the tsetse fly), and American *trypanosomiasis* (chagas disease).

2.5 EVALUATING THE RISK FACTORS IN THE TRANSMISSION OF HAI

The foregoing discussion suggests that HAIs can occur because of clinical and non-clinical causes. However, because clinical causes account for much of HAIs, healthcare authorities tend to focus their attention on them. This does not mean that non-clinical causes of HAIs are not important. As shown in Figure 2-2, the transmission of HAIs can occur because of clinical, as well as, non-clinical causes. Therefore, to address the problem of HAIs, NHS officials must also focus on the non-clinical causes of HAIs. In the next section, the clinical and non-clinical risks factors in the transmission of HAIs are examined.

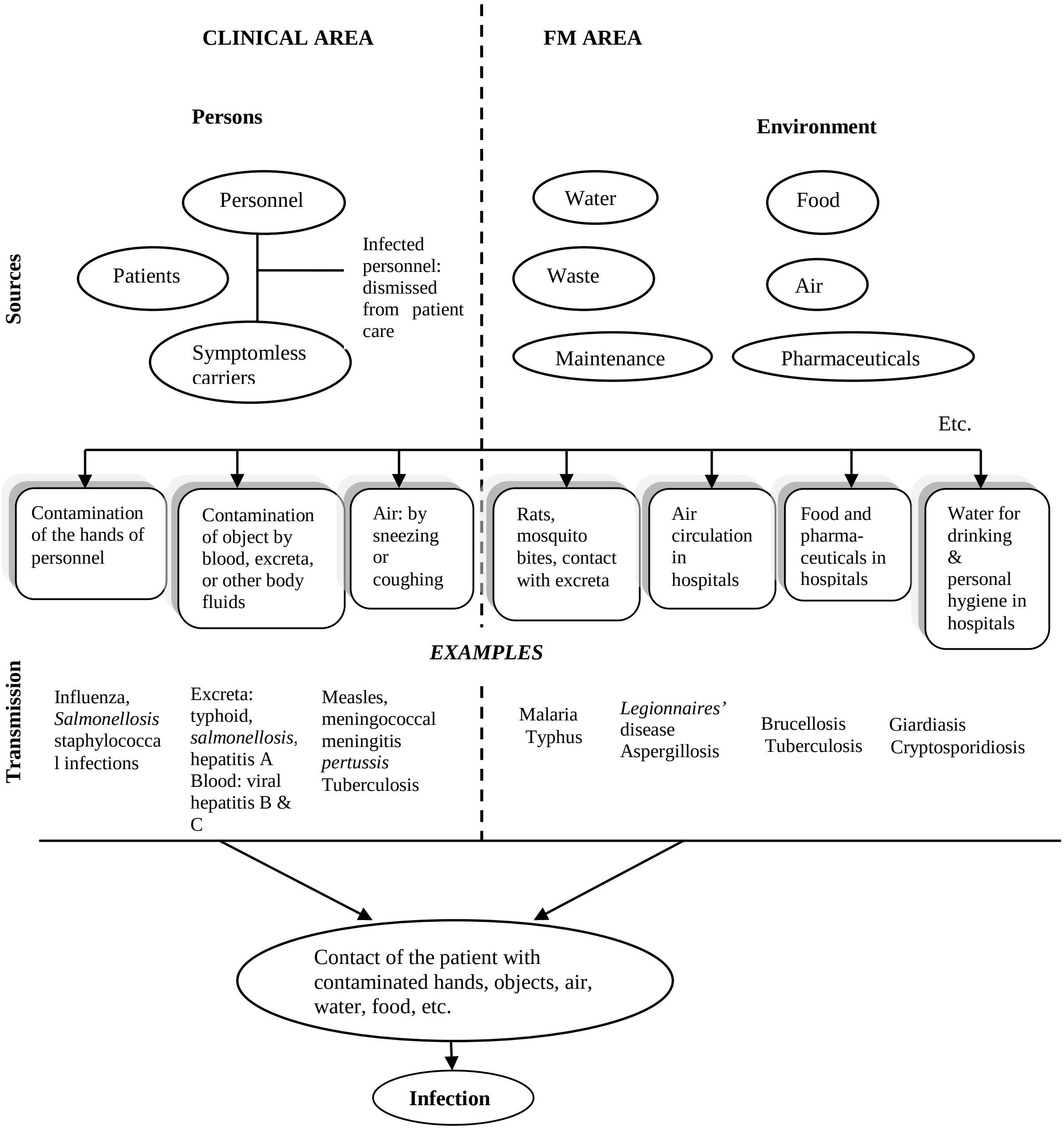

Figure 2-2: The Spread of HAI through Clinical and FM Routes

Source: Adapted from Billy, 2000: p. 152

2.5.1 The Clinical Risk Factors of HAIs

As shown in Table 2-4, the clinical risk factors of HAIs can be divided into therapeutic, behavioural, structural, organisational, and management risk factors. Whilst some people become immune to infections or able to resist colonisation, others may become asymptomatic carriers or develop a clinical disease (CCAR, 2007). The risk of a patient acquiring an HAI depends on certain characteristics such as age, immune status, underlying illness, diagnostic and therapeutic interventions (May, 2000; WHO, 2000; NAO, 2009). Because of their decreased resistance to infections, the old and very young are at a greater risk of acquiring HAIs. In addition, patients suffering from chronic diseases such as malignant tumours, leukaemia, diabetes mellitus, and immunodeficiency syndrome (AIDS) are also susceptible to infections with opportunistic pathogens (WHO, 2003). These patients have compromised immune systems.

The increasing use of new technologies and invasive procedures also increases the risk of HAI among immune-compromised patients. An example of such an infection, which is caused by widespread catheterization, is called catheter-associated bacteriuria (Hooton, 2010). Currently the hands of healthcare workers are one of the main routes in the transmission of HAIs in healthcare settings (Billy, 2000). The two types of microorganisms commonly found on the hands of healthcare workers are described as resident flora (normal flora or commensal organisms) and transient flora. As part of the body's defence mechanism, resident flora protects the body from the invasion of more harmful microorganisms. Although rarely implicated in the transmission of HAIs, resident flora may nonetheless pose the risk of an infection if during surgery or an invasive procedure they enter deep tissue (Kane and Faulds, 2007). Transient flora, on the other hand, are microorganisms that get onto the hands of healthcare workers through touching environmental surfaces, patients' laundry, or equipment, etc. Transient flora are located superficially on the skin and are responsible for the vast majority of HAIs in hospitals (Kane and Faulds, 2007).

In the UK, it is the responsibility of the government and local health authorities to minimise the risks of HAIs to healthcare users (DH, 2008). The clinical risk factors of HAIs can be reduced through the application of standard precautions. Standard precautions are a set of good practices applied in healthcare environments to minimise risk and exposure to HAIs (WHO, 2007). Standard precautions are designed to protect both healthcare workers and patients from infections. They reduce the risk of transmission from staff to patient, patient to staff, as well as from patient to patient. To reduce the risk of HAIs, staff at all times have to assume that blood and certain body fluids (urine, faeces, wound drainage, sputum) contain pathogenic microorganisms

(CCAR, 2007). Additional or transmission-based precautions are used in the event that a patient is known to have or suspected of having an infection that is transmitted by the air, droplet or contact route. Additional precautions should not replace standard precautions, but rather, complement them.

Hand hygiene (either by hand washing or hand disinfection) is probably one of the most effective ways of preventing the transmission of HAIs in healthcare settings (CCAR, 2007; RCN, 2005; Pratt, 2005). However, many studies have found that healthcare workers perform hand hygiene less than half the time they should do (CCAR, 2007). The reason is the lack of motivation on the part of healthcare workers to adhere to hand hygiene practices. According to Ayliffe *et al*. (1982), failure to employ the right hand-washing technique may lead to healthcare workers missing particular areas of their hands, thus posing a risk to patients. It is therefore necessary that hospitals, and especially individual wards, be provided with sufficient hand washing basins.

Table 2-4: Clinical Factors Affecting the Risk of HAIs

Therapeutic factors	**Organisational factors**
– Extremes of age (old and young) – Low birth weight – Underlying illnesses that compromise the immune system – Prolonged hospitalization – Invasive medical procedures that introduce bacteria into tissues – Type of treatment – Profligate and inappropriate use of antibiotic	– High bed occupancy – Increasing movement of patients – Poor staff/patient ratios – The type of hospital – Intensive care admissions
Behavioural factors	**Management factors**
– Poor hand washing compliance – Unhygienic staff practices – Poor implementation of standard and additional precautions in infection control	– Lack of insight into available best evidence for infection control prevention – Ineffective leadership – Inadequate resource allocation
Structural factors	
– Number of single room – Hand basins	

(Source: Adapted from Pratt, 2005: p. 2; Health Canada; 2001; p.1)

2.5.2 Non-clinical Risk Factors of HAIs

The non-clinical risk factors in the transmission of HAIs can be divided into two groups: environmental and behavioural risk factors (see Table 2-5). Environmental risk factors are associated with non-clinical operations in hospitals. Non-clinical services such as maintenance (CDC, 2003; Ohsaki *et al*, 2007), cleaning (May, 2000; DH, 2004, Liyanage and Egbu, 2005; Davies, 2009), catering (Griffith *et al*, 1998), laundry (NHS Executive, 1995) could potentially expose healthcare users to the risk of HAIs. Behavioural risk factors are associated with the attitudes of non-clinical staff in controlling HAIs in hospitals. These include for example poor hand hygiene practices. Some of these issues are covered in detail in Chapter 3.

Table 2-5: FM Factors Affecting the Risk of HAIs

Environmental factors	Behavioural factors
– Exposure to construction activities (Risk factors associated with filamentous fungi infections) – Exposure to soil excavations during construction and malfunction of plumbing systems (Risk factors for legionnaires' disease) – Dirty and contaminated medical instruments, surfaces – Age of hospital/healthcare facility – Laxity in the implementation of maintenance, construction etc policies and regulations – Inadequate food and water control practices – Poor waste management, cleaning and laundry practices	– Poor hand-washing compliance – Unhygienic staff practices – Poor implementation of standard and additional precautions in infection control

(Sources: Adapted from Pratt, 2005: p. 2; Health Canada, 2001: p.1)

Despite the apparent risk of HAIs, non-clinical services only get attention when there is another outbreak of HAI in the NHS. In 2013, seven patients at the Basildon and Thurrock University Hospitals NHS Foundation Trust were infected with *Legionella*, the bacteria that cause Legionnaires' disease (The Evening Standard, 2013). The source of the infections was attributed to the hospital's water system. The hospital failed to clean key parts of the system, i.e. hoses, and showerheads. Such incidences cost the NHS huge sums of money in terms of ward closures, litigation, prescription, investigation, cleaning etc. Following the outbreak of legionnaires at the Basildon and

Thurrock University NHS Foundation Trust, the judge ordered that they pay a fine of £100,000. In addition, they were also ordered to pay the prosecution's legal costs of £175,000.

On June 2014, there was also an outbreak of *Bacillus cereus* at Guys and St Thomas's Hospital in London. *Bacillus cereus* is a type of bacterium that may cause nausea, vomiting, fever and diarrhoea in susceptible hosts (Triggle, 2014). As shown in Table 3-2, *Bacillus cereus* may be caused by dust, soil, and vegetation generated through maintenance work in hospitals. Although the source of the outbreak of *Bacillus cereus* at Guys and St Thomas's hospital is still under investigation, the route of transmission was through liquid baby food administered by drip. According to Boseley (2014), writing for the Guardian, the outbreak caused the death of a baby, and life-threatening septicaemia in fourteen others (BBC, 2014).

The discussion above demonstrates the need to tackle the non-clinical causes of HAIs in the NHS. One of the first requirements is to increase the level of adherence of non-clinical staff to infection control practices. For example, non-clinical staff need to be given adequate training on hand-washing techniques. Presently, it appears, much focus is on the education and training of clinical staff. Non-clinical staff do not undergo the sort of mandatory training on IC that clinical staff do (NAO, 2000). The situation is even worse for non-clinical staff working for contracted firms. Although these staff often work closely with susceptible patients, they rarely receive any form of training in infection control. UNISON, the trade union representing non-clinical staff, blames the outsourcing of non-clinical services for contributing to the high rates of HAIs in the NHS (Davies, 2005). Because of lack of interest, it has been difficult to ascertain the extent of the non-clinical causes of HAIs in the NHS. In the next section, historical evidence is used to explore the evolution of the role of non-clinical services in the control of HAIs in hospitals.

2.6 THE HISTORICAL LINK BETWEEN NON-CLINICAL SERVICES AND HAIS

The aim of this section is to demonstrate the historical link between non-clinical services (i.e. planning and designing, cleaning, maintenance, laundry, catering and waste management) and HAIs in hospitals. The history of some of these non-clinical services in the prevention and control of HAIs probably dates to the oldest known hospital. During that time, there was little understanding about the transmission of HAIs in hospital. In addition to the UK, examples are drawn from other countries. The next section is divided into the Pre-Medieval, Medieval, and Victorian epochs.

2.6.1 Infection Control in the Pre-medieval Era

The role of non-clinical services in HAIs spans many centuries in hospitals around the world. Hospital buildings to accommodate and care for the sick existed 500 B.C. in places such as Palestine, India, and Greece (Selwyn, 1991). However, most of these facilities were mainly for ritual purification. During the pre-medieval era, there was little understanding of the link between non-clinical services and the transmission of HAIs. For example, the provision of fresh air at one of the world's oldest wards at Epidauros-Greece was to bring *"...much credit to the god and his shrine* . . . (Selwyn, 1991, p. 2). Disease was regarded as a supernatural punishment for sins committed (Meers *et al*., 1992). Passages and texts of religious books were interpreted and used to provide cures to diseases.

The Charaka-Samhita (a Sanskrit textbook of medicine) published about the fourth century B.C. contains one of the earliest pieces of advice on hospital construction and hygiene. It contained environmental control principles that could still be relevant to today's hospitals. For example, a mansion was expected to be spacious, roomy and open to the currents of the wind. A mansion was not to "*be exposed to smoke, or dust, or injurious sound or touch or taste or form or scent. . .'* (Selwyn, 1991: p. 9). Advice was also provided on the purity and cleanliness of the mansions. An example of a hospital built on such advice was a commodious oriental hospital (A.D.500) in a remote location in Mihintale in modern-day Sri Lanka (Selwyn, 1991).

The earliest documented evidence of non-clinical services in Europe can probably be traced to the Roman era. The Romans had a *medicus clinicus* (a physician who attended to a patient sick in bed) or a *chirurgus* (a surgeon) who attended to the needs of the public (Cilliers and Retief, 2006). Whilst poor patients were brought to the *taberna* (consulting-room for Roman physicians) for immediate treatment, the wealthier ones were visited at home. There is no literary or archaeological evidence suggesting that the *taberna* had beds for the nursing of patients (Cilliers and Retief, 2006). The Romans did not have services with the special purpose of providing community care for the sick, poor, and needy. What the Romans had were army hospitals (*valetudinaria*) to take care of soldiers. With the creation of a Roman professional army, it became necessary for them to establish hospitals close to frontiers rather than send people home for treatment. The legionary hospital at Vetera in Germany is an example of a *valetudinaria* that had rooms, beds and kitchens to take care of wounded soldiers (Selwyn, 1991).

2.6.2 Facilities to House the Sick in Medieval Christian Hospitals

The fall of the Roman Empire saw the deterioration of hygiene in Europe, starting from around the fifth century A.D. (Selwyn, 1991). However, Christians, unlike the Romans, embraced charity as one of their basic doctrines. Monasteries sprang up throughout Europe and became the focus of learning and education, scholarship, charity and medicine (Ellerton Church Preservation Trust, 2010). Besides providing accommodation for travellers, monasteries took care of the sick, poor and elderly. Leper hospitals started appearing in the UK about the 12th century (Historic Scotland, 2010).

The income of monasteries depended mainly on revenue generated from farms, husbandry, and small industries. They also sometimes benefited from legacies, lands, property, and money left by the wealthy, who wanted the church to preserve their memory or those of their love ones. For example, the duke of Suffolk set up a hospital at Ewelme (Oxfordshire) in 1437 in memory of Alice, his duchess (Platt, 1978). It was also usual for the king to grant permission for monasteries to take wood from the Royal forest, or hay or straw from crown land. In 1226, Henry 111 gave ten cartloads of dry wood to St John's Hospital (Markham, 1997). Some of the contributions donated to monasteries were also used to repair churches, as was the case with the hospital chapel at Burford in 1305 (Markham, 1997).

By the late Middle Ages, chantries had become so popular that the vast majority of hospitals and almshouses owed their existence to them (Platt, 1978). By the 1547, the number of almshouses in the UK had grown to about 750 (English Heritage, 2007). During this time, the church (especially monasteries) was the major player in the care of the sick, old and infirm in the UK. Thus, Christian beliefs were embedded in the planning, designing and construction of healthcare facilities at the time. Unlike the Romans, Christians regarded sickness as a punishment inflicted by God for sins committed by individuals or the community (Ayliffe and English, 2003). The church even opposed the washing and caring of the body and focused its attention on saving the soul instead. Traditionally, the sick were laid in the body of the church with the chancel serving as the chapel (Platt, 1978). These places were often richly decorated with wooden crosses, paintings, and chandeliers. Nevertheless, by the 12th century, separate halls to accommodate the sick were constructed. Recent excavation at the St Bartholomew, Gloucester, and St Mary hospitals, show the chapel set centrally at right angle to the infirmary hall. The halls were long in nature and divided by wooden screens.

After the 13th century, common dormitories started giving way to separate rooms to house the sick (Markham, 1997). The St Helen’s hospital at Abingdon was rebuilt in 1446 having thirteen separate chambers. It also became common practice for separate accommodation to be provided to hospital wardens. Most hospitals also had large kitchens and burial grounds (Markham, 1997). Despite minor improvement in healthcare facilities, medieval Christian hospitals did not understand the link between the healthcare built environment and the spread of diseases. That probably explains why the Black Death or bubonic plague ravaged Europe during the period 1348-1359 (Ayliffe and English, 2003). It was unknown at the time that the Black Death was transmitted through the black rat and its flea, Pulex irritans, to susceptible hosts. If anything was gained from the plague, is was the fact that people started seeking alternative ways to explain the cause of disease. During that time, the cause of disease was mainly attributed to the corruption of the air.

The Black Death reinforced the idea of segregating infectious patients from the rest of the community. It also prompted the introduction of new forms of prophylaxis that were unknown at the time (Ayliffe and English, 2003). For the first time, it was suspected that the clothes and bedding, etc of the infected contributed to the spread of disease. As a measure to curb the possibility of cross contamination, authorities carried out the disinfection or burning of fomites, and introduced quarantine (Ayliffe and English, 2003). Plagues also led to the introduction of temporary pest houses to isolate infected patients from the rest of society (Historic Scotland, 2010). Compared to today’s standards, medieval forms of disinfection or fumigation were nothing more than the usual burning of aromatic herbs and incense.

Corruption of the air was often attributed to such factors as extreme weather, and the decaying of organic matter, corpses, cesspools and marshes, etc. It was thought that the air contained invisible minute poisonous particles (miasmas) that when inhaled into the body were capable of causing disease (Alexander, 1985). Knowledge about different infectious diseases was very limited, and it was thought that miasmas could cause any disease (Ayliffe and English, 2003). It was therefore common practice for new healthcare establishments to consider ventilation. The design of hospitals in continental Europe was starting to influence native models in the UK. An example is the Savoy hospital that was built on a continental design (Platt, 1978). Evidence also shows the use of the more modern quadrangular plans in the UK after the 14th century. The new Fitzalan *Maison Dieu* at Arundale is an example (Platt, 1978).

2.6.3 The Early Victorians – the State of Non-clinical Services

The period right up to the Victorian era relied on monasteries for healthcare. Mortality rates were generally high, and patients had to endure very unhygienic conditions that would not be accepted by today's standards (Platt, 1978). Not only were hospitals severely overcrowded, they lacked basic infection control practices to prevent the spread of infection. According to Alexander (1985), wards had giant beds, each of which was occupied by sick patients, crammed together to keep warm. The normal capacities of hospital beds were often exceeded. The salient fact was that, irrespective of the infectious nature of a patient's illness, they were all mixed together in single wards and beds. It was common at Hotel Dieu of Paris to find two or three smallpox patients, several surgical cases or four parturient women lying in one bed (de Chaumont, 2005-10). Similar conditions were also documented in American and British hospitals.

Early hospitals in the UK lacked proper arrangements for the removal of excreta. Sinks, waste pipes, and bath-pipes were all directly linked to sewers, leading to the introduction of sewer poisons into hospitals. The lack of evidence-based guidelines on the planning, designing and construction of hospitals meant that architects erected huge monumental public building that failed to consider infection control and prevention (The British Medical Journal (BMJ), 1897). Whilst the frontages of hospitals were erected in the form of Grecian temples with elaborate porticos, the wards were often crowded together. The only consideration given to the prevention of 'miasma' was ventilation through the window.

When these hospitals were faced with overcrowding, the shortfall in construction became evident in the number of hospital infections that were witnessed. The introduction of anaesthesia in 1846, and the many accidents during the construction of the railways in the UK, resulted in an unusually high load of surgical operations in hospitals (BMJ, 1897). The lack of adequate infrastructure and trained personnel to carter for these high-risk patients meant that hospitals could not cope with the huge influx of patients. At the St. Bartholomew's hospital in 1835, there were only 104 sisters and nurses to cater for about 5,644 patients (BMJ, 1897). The very high ratio of patients to nurses meant that hospital hygiene was poor.

Unlike today, Victorian nurses "*perform[ed] all the usual duties of servants* [domestics]*, in waiting on and cleaning the patients, beds, furniture, wards, and stairs*" (BMJ, 1897: p. 1661). They were provided with only two gowns and a cap every year. Their duties and those of the kitchen staff were supervised by matrons who themselves were not nurses (Helmstadter, 2002). Besides making sure that the wards were cleaned and in good order, matrons ensured that staff exhibited good moral conduct and attended work according to schedule. They were also in charge of the accommodation provided to nursing staff and their assistants. It can be said that Victorian matrons were the healthcare facilities mangers of yesteryear.

Despite the appalling condition of Victorian hospitals, nothing was done to alleviate the plight of patients. It was, however, the appalling medical condition of British military hospitals which prompted the British authorities to do something about civilian hospitals. At Scutari, it was common practice to find as many as 10,000 sick soldiers housed in filthy, poorly maintained and vermin-infested barrack accommodation (Hampshire Record Office, 2007). There was an acute shortage of wards, and corridors were often used to cater for patients suffering from contagious diseases. It was these appalling conditions, and the high rate of mortality suffered by soldiers, that attracted the attention of the likes of Sir John Pringles and Florence Nightingale.

2.6.3.1 Non-Clinical Services Start to Gain Prominence in Infection Control

In 1858, the government appointed a Commission to inquire into the regulations affecting the sanitary conditions of the army, the organisation of Military Hospitals and the treatment of the sick and wounded. The findings of the Commission revealed the dire state of non-clinical services in hospitals. The Commission officially criticised the ‘corridor plan’ used in the construction of the new military hospital at Netley, and the deplorable conditions in which soldiers received medical treatment. The Commission officially sanctioned the ‘pavilion principle’ in the construction of military hospitals (Cook, 2001). This of course gave impetus for calls to reform civilian hospitals. This was also accentuated by the advancing medical knowledge at the time, i.e. insights into ventilation and sanitation.

One of the notable figures in championing the cause of improvements to non-clinical services was Florence Nightingale. Relying on her experience in the Crimea, Nightingale was able to push for healthcare reforms in UK hospitals. Nightingale argued that high mortality was linked to the poor state of non-clinical services (i.e. agglomeration of patients under the same roof, inadequate space, etc) in hospitals. Although her most remarkable achievement was in the area of nursing, she was also a keen promoter of the *new building style* ‘pavilion plan’ that originated in France in the 18^{th} century (Cook, 2001). The pavilion plan was introduced in the UK in the 19^{th} century, before the ‘germ theory’ was articulated (Cook, 2001).

Many at the time argued that the pavilion plan led to the dispersion of foul air, which customarily was blamed for diseases. Besides much emphasis on separation, segregation and ventilation, the pavilion plan was a substantial improvement in the way hospitals were designed and constructed. Amongst the numerous recommendations put forward by the advocates of the pavilion plan was the use of Parian cement or impervious materials to build the walls and ceilings of hospitals. Up to that point it had been common practice for sewerage to run under hospital buildings (King, 1966). Cesspools were removed from the immediate vicinity of hospitals, while closets and sinks were isolated from the main building by a ventilated lobby. The pavilion plan was seen by many as sanitary for the patient and convenient for the healthcare worker (Richardson, 1998; as cited in Cook, 2001). The construction of the first two-pavilion plan hospitals began in 1858: the Blackburn Infirmary and the Royal Marine Barracks at Woolwich.

Hospitals that adopted the pavilion plan had wards that were only one-storey (rarely two storeys) in height. The wards had no corridors that directly connected them together (BMJ, 1897). Instead, the pavilions were set at right angles to a linking corridor connecting the wards to centrally positioned service and administration buildings (English Heritage, 2007). The connecting corridors were either straight or encompassed a large central square, while the pavilions themselves were widely separated by lawns or gardens (King, 1966).

To minimise ‘miasma’ originating from the sanitary facilities, they were contained in towers or annexes at the end of the pavilions. Cross ventilation in the pavilions themselves was achieved through the location of two opposite rows of tall, narrow windows that ran from floor to ceiling. As originally recommended by Tenon and Poyet (originators of the pavilion principle), beds were placed in pairs between the windows. However, in subsequent years attempts were made to improve cross ventilation by placing only one bed at the window pier (Cook, 2001). Fires were also used judiciously to produce air drafts to remove ‘noxious vapour’ or miasma from the wards.

As medical knowledge advanced towards the end of the 19th century, there was a corresponding increase in the complexity and number of non-clinical services that were needed to safely run hospitals. The introduction of anaesthesia in the middle of the century led to the overcrowding of hospitals. This meant that hospitals could not rely on natural ventilation alone. Hospitals started adopting the use of combined heating and ventilation systems, notably the plenum system. The plenum system brought *“in air at eaves level, filtered, warmed and humidified it and expelled it at a rate of ten changes a day”* (English Heritage, 2007: p.5). It also became common practice for hospitals to have boiler houses to provide heating and hot water. Other facilities included kitchens, laundries, operating theatres, X-ray rooms, outpatient departments, offices, committee rooms, a chapel, a mortuary, and nurses’ homes.

The implementation of the pavilion plan in the UK marked the recognition of the significance of non-clinical services in the control and prevention of HAIs. It provided the foundation for the development and re-organisation of non-clinical services under what was to become known as the NHS Estates and Facilities. Table 2-6 shows the state of development of non-clinical services and levels of knowledge relating to infection control at various historical epochs.

Table 2-6: State of Non-Clinical Services at Different Historical Epochs

Historical period	Knowledge relating to infection control	State of non-clinical services
Pre-medieval hospitals	– Superstitious and primitive religious beliefs about the causes and cure of diseases – e.g. that disease was a punishment from God – Infection control practices - e.g. hygiene, cleaning and isolation practices - based on the interpretation of religious books i.e. Charaka-Samhita – Lack of understanding of the link between non-clinical services and infections – Healing mainly through ritual purity	– Lack of healthcare facilities to provide medical care to the public, no facilities management services – Patients receive treatment at home – Makeshift military hospitals (valetudinaria) – Provision of rooms, beds and kitchens to accommodate sick soldiers
Medieval hospitals	– Cause of disease associated with the Christian belief that disease was a punishment from God – Opposition to the washing and cleaning of the body – Ritual purity and penance regarded as healing practices ***At the end of medieval period*** – Cause of disease became associated with miasma 'bad air'	– Monasteries served as places for care of the sick, poor and elderly – Establishment of leper hospitals – Planning, designing and construction of hospitals based on Christian beliefs and teachings – Patient rooms had richly decorated alters, wooden crosses, paintings and chandeliers to beg for healing – Provision of large kitchens and burial grounds – Lack of coordinated non-clinical services in infection control – Management of clinical as well as, non-clinical services under the control of the church – Financial support to maintain the monasteries and care for the sick and venerable came from private donations, farms, husbandry and small businesses operated by the monasteries – Pest houses, quarantine of patients – Fumigation using aromatic herbs and incense to dispel 'bad stench'
Victorian hospitals	– Non-clinical services (e.g. cleaning, laundry, waste management) implicated in the incidence of hospital infection (puerperal fever) – Increased attention given to hospital hygiene, notably cleaning – Hand hygiene became significant in infection prevention – Purification and disinfection of hospital garments – Separation of nursing profession from domestic services	– Establishment of Victorian hospitals (voluntary hospitals, almshouses, cottage hospitals, etc) – Initial lack of evidence-based planning, design and construction of hospitals for infection prevention and control ***Towards the end of Victorian era*** – Introduction of pavilion plan, emphasis on natural ventilation of hospitals – Consideration of infection prevention in the planning, design and construction of hospitals – Emergence of FM services in UK hospitals – FM services under the control of hospital matrons – Accommodation to house nurses and other ancillary staff

2.6.4 Pioneers in Non-clinical Practices in Infection Control

The initiatives advanced by the early pioneers of infection prevention focused attention on the environmental causes of HAIs. Through their work, it became routine practice for healthcare workers to wash their hands in chlorinated solutions, wards to be scrubbed with lime, linens to be exposed to the effects of chlorine gases, and so on. Besides being innovations in medical practice, such practices also started to establish non-clinical services as an important player in infection control. Table 2-7 summarizes the work of the early pioneers in the environmental control of HAIs in hospitals.

Table 2-7: Milestones in the Prevention and Control of HAIs in Hospitals

Pioneer contributors	Infection control measures
Sir John Pringle (1707-1782)	– Demonstrated that poor ventilation, overcrowding and insanitary practices lead to infection – Revealed that the preservation of pure air and dispersion of the sick prevented infection – Campaigned against the indiscriminate fouling of the ground which could lead to faecal contamination and thus the spread of infection (cholera) – Instigated basic infection control measures like the covering of latrines with earth
James Lind (1716-1794)	– Provided instructions on the disinfection of cloths and fomites – Demonstrated the benefit of water filtration in hospitals to prevent water-borne infections – Recommendations on the prevention of vermin in hospitals
Alexander Gordon (1752-1799)	– Identified the hands of healthcare workers as sources of cross infection – Established the benefit of cleaning to reduce risk of infection – Recommended the burning or cleaning of cloths and garments of those suffering from contagious diseases – Showed the relevance of personal hygiene in infection control by instructing healthcare staff to wash themselves thoroughly before attending to patients – Identified dirty and soiled linen used by healthcare professionals as a potential route in the transmission of infections in hospitals – Recommended the fumigation of clothing used by healthcare workers after every use
Ignaz Semmelweiss (1818-1865)	– Provided epidemiological evidence linking the hands of healthcare workers to the spread of infections – Drew up instructions for the disinfection and cleaning of medical devices
Florence Nightingale (1820-1910)	– Demonstrated the usefulness of cleanliness in the prevention of hospital infections – Demonstrated the benefits of bathing patients and the washing of hospital linen (blankets, towels, sheets) to prevent hospital infections, – Introduced chutes for soiled linen – Showed that hospital catering was important in the convalescence of patients – Demonstrated that hospital maintenance and repairs were an important function in infection prevention – Established the benefit of clean supply of water in hospitals – Established and raised the status of nurses and domestic service workers in infection prevention and control – Provided statistics to show the link between non-clinical services and the incidence of hospital infections – Wrote notes on hospital management and construction

The scientific study of HAIs probably began around the first half of the 18th century (Selwyn, 1991; Forder, 2007). Despite their unscientific thoughts about the causes of diseases, early healthcare practitioners must be credited for their contribution in establishing a link between non-clinical services and the incidence of HAIs. In an attempt to provide an explanation of the contagiousness of diseases, 18th century physicians divided 'bad air' into two categories: 'inanimate human contagions' and 'inanimate non-human miasmata'. According to the theories of William Cullen, contagions emanated from patients suffering from such diseases as smallpox, and spread to those around them. Miasmata on the other hand were thought to originate from non-human sources such as swampy ground, and to cause febrile diseases such as typhoid, malaria and yellow fever (Alexander, 1985).

Having identified 'contagions' and 'miasmata' as the causes of diseases, little was done by healthcare authorities in the cities and towns to make hospitals safe. Attempts to reduce cross infection and improve the condition of civilian hospitals only gained prominence towards the end of the 18th century. This period was marked by the fading away of the old idea that hospitals were places of refuge or asylum for the poor, sick and destitute. Increasingly, hospitals became accepted as places with the object of curing and restoring the health of patients (BMJ, 1897). Improvement in the conditions of healthcare facilities to reduce the incidence of infections, however, occurred much earlier in army and navy hospitals.

Sir John Pringle, who served in the army from 1742 to 1748, was probably one of the earliest physicians to identify the built environment of healthcare facilities as a potential source of infections in hospitals. According to Selwyn (1966), Pringle's publication 'Observations on the Diseases of the Army' contained the first account of epidemiology, pathogenesis, the prevention of hospital cross–infection, and an appendix on antiseptics (Selwyn, 1966). Pringle blamed military hospitals and the bad air and other inconveniences associated with them for being one of the chief causes of diseases. Pringle denounced poor ventilation, overcrowding and unsanitary practices in hospital wards. By dispersing the sick and preserving pure air in the wards, Pringle was able to moderate or prevent the spread of contagions in military hospitals and camps (Pringle, 1752, as cited in Selwyn, 1966).

Pringle's views about the causes of infections were advanced than those of his contemporaries. The general belief at the time was that dysentery was caused by foul air, and that treatment involved bleeding, the use of emetics, and purging. Pringle on the other hand adopted a preventative and unorthodox approach. He recommended measures to prevent the indiscriminate fouling of the ground by soldiers, the daily covering of latrines with earth, and the moving of camps from foul ground in the event of a dysentery outbreak (Cook, 2001). Similar efforts were also being made at the time by James Lind to improve the condition of naval hospitals. In his book, published in 1757, Lind gave recommendations on the isolation of patients to reduce cross infection, and instructions on the disinfection of cloths and other fomites, the destruction of vermin and the filtration of water.

The experience Pringle gained whilst in the army proved valuable when he retired and joined civilian life. Barely two years after his retirement, there was an outbreak of jail fever in London (1750) which killed many, including the Lord Mayor and several judges (Selwyn, 1966). Relying on his experience in the army (including at the battle of Culloden, 1746), Pringle gave his recommendation on the issue by publishing a fifty-two page paper entitled 'The Hospital and Jayl-fevers' (Selwyn, 1966). In it, Pringle identified the clothes used by prisoners as a potential route through which jail fever spread in the prisons and courts. He recommended that the clothes of malefactors be burnt after execution and that prisoners be cleaned and dressed in clean clothes before attending court sessions.

In the fourth edition of his book 'Observation on the diseases of the army' (1764), Pringle established a clear link between the hospital and the prevalence of scabies that prevailed in the army. Unlike in the previous editions, Pringles stated that "*infection was propagated by a few ... (and) of all places the hospitals are most liable to the contagion, as receiving all sorts of patients*" (Selwyn, 1991: p. 20). This improved understanding of the contagiousness of diseases, especially in the transmission of puerperal fever, highlighted the need for infection prevention in civilian hospitals.

Another figure in environmental infection control was Alexander Gordon; considered by many as one of the pioneers of British Medicine and infection prevention in hospitals. According to Gould (2010), Gordon conclusively showed the contagious nature of puerperal fever and methods to prevent its spread. Unlike his contemporaries, Gordon used detailed observations to show the contagiousness of puerperal fever and to establish that doctors and midwives provided the route through which women became infected. Gordon showed that transmission was mainly through the hands of the physicians and midwives, and he recommended cleaning as a way of preventing the prevalence of puerperal fever. The bedclothes of patients were to be burned or thoroughly purified. Although similar recommendations and instructions had been advocated by Charles White and Alanson in 1773 and 1782 respectively, Gordon was amongst the first to establish the benefit of cleaning (Gould, 2010). Gordon called on those working with patients to wash themselves thoroughly. In addition, their garments were also to be fumigated thoroughly after every use (Gould, 2010).

It was not until many years after Gordon, in 1847, that Ignaz Semmelweiss demonstrated that the root cause of puerperal fever (the main cause of death after birth) was hospital staff. At the Vienna Allgemeines Krankenhaus, Semmelweiss observed that the rate of post-delivery mortality (puerperal fever) was 13-18% higher in one of the divisions where women were attended by physicians and medical students (Best and Neuhauser, 2004). In the second division, attended by midwife trainees or midwives, the rate of infection stood at only 2%. Semmelweiss reasoned that the cause of the higher rate of puerperal fever in the student division could be because students and physicians transmitted 'cadaverous' particles on their hands as they left the autopsy suite to work in the obstetric ward (White, 1981).

To mitigate the transmission of 'cadaverous' particles in the student division, Semmelweiss made it mandatory for students and staff to wash their hands with soap and to routinely use chloride of lime solution to clean their hands between patients. When this was done, the maternal mortality rate went down by 2% in the student division (Best and Neuhauser, 2004). There was even a further fall of 1% when Semmelweiss started washing the medical instruments in the student division. Despite the ingeniousness of Semmelweiss in demonstrating the usefulness of hand hygiene in infection prevention (asepsis), he failed to communicate his findings in a manner that would convince the wider public. Thus, like Gordon, his work met stiff resistance and it took a decade for it to be accepted by the medical community.

Unlike Gordon and Semmelweiss, Florence Nightingale convincingly showed that cleaning reduced the incidence of infections in hospitals. Her story began during the Crimean war, where she served as a nurse to sick and wounded soldiers. When she arrived in the Crimea in 1854, she was appalled by what she saw. "*...the beds on which the patients lay were dirty. It was common practice to put a new patient into the same sheets used by the last occupant of the bed, and mattresses were generally flock sodden and seldom if ever cleaned*" (Nightingale, 1854, as cited in Wormsbecker, 2002: p. 88). Nightingale mobilized a team of staff to scrub the hospital clean, and wash the sheets, blankets and towels. In addition to cleaning the hospital's kitchen and preparing better and more wholesome food for the patients, Nightingale got an army of engineers to repair the hospital's drains, and improve the supply of water (Hampshire Record Office, 2007). By doing so, Nightingale and her team were able to bring down the rate of mortality at Scutari.

Using statistics gathered whilst in the Crimea, Nightingale was able to push for sanitary reforms in UK hospitals. Her statistics revealed that far more soldiers died from infections, or 'zymotic diseases' that were presumably acquired in hospitals than in the actual war itself. Using the 'coxcomb' variant of pie charts, Nightingale established a direct link between hospital cleanliness and the rate of infection (mortality). As hospital cleanliness got better, the sizes of the wedges (monthly mortality rates) on the coxcomb got smaller.

2.7 SUMMARY

This research study shows that non-clinical services (i.e. planning and design, cleaning, maintenance, waste management, catering and laundry) play a pivotal role in the control of HAIs. The provision of non-clinical services in hospitals goes back many years. It was the pioneering work of Sir John Pringles, James Lind and Florence Nightingale which established the link between non-clinical services and HAIs. Their discoveries remain invaluable to all those involved in the control and prevention of HAIs.

Although the dawn of the 'bacteriological era' revolutionized the understanding of the spread of infections, in-depth literature review suggest that it nonetheless reduced the level of attention previously given to the non-clinical causes of HAIs. Today, non-clinical services such as cleaning, maintenance, waste management, catering, and laundry are treated as though they play no role in IC. Some of these non-clinical services have been outsourced to providers with very little knowledge of IC issues (Davies, 2005). This research study demonstrates the need for healthcare officials to pay attention to the clinical as well as the non-clinical causes of HAIs in the NHS.

CHAPTER 3 : THE CAUSES OF HAIs AND MEASURES TO REDUCE THEM – THE FM VIEW

3.1 INTRODUCTION

The aim of this chapter is to identify and establish the link between healthcare facilities management services (HFM services) and HAIs in the NHS. Although all HFM services support the effective delivery of clinical services, not all of them have a direct link with HAI. HFM services with a direct link with HAIs include planning and designing (both old and new) hospital buildings, cleaning, maintenance, waste management, catering and laundry services. Although the link between all of the aforementioned HFM services and HAIs is examined here, the focus of the study is on healthcare maintenance (HM). Also in this chapter, infection control practices to reduce the incidence of HAIs in HFM services are discussed.

3.2 HEALTHCARE FACILITIES MANAGEMENT (HFM) - ISSUES WITH HAIs

The start of the organisation and management of non-clinical services can probably be dated to 1948, following the creation of the NHS. During this period, non-clinical services were managed as separate entities, with lay officers reporting directly to the NHS governing body. This arrangement made it difficult for lay officers to effectively coordinate and manage non-clinical services. Consequently, many NHS workers started calling for the integration of all support services under one corporate unit. They argued that integration would lead to the development of quality systems for the effective planning and delivery of non-clinical services (Alexander, 1993). In 1954, the Bradbeer Report introduced a tripartite management system between medical, nursing, and lay officers (Clark and Rees, 2000). The report recommended that lay officers be given the responsibility for non-clinical services. This of course was the beginning of what became known as healthcare facilities management (HFM) in the NHS.

Many authors offer varied definitions of the term FM (also called facilities). For example, Atkin and Brooks (2009) define FM as "*the practice of coordinating the physical workplace with people and work of an organisation*". Although this definition is simple and well focused, Noor and Pitt (2009) criticize it for not mentioning how a well-managed FM function can contribute to the effectiveness of an organisation. A definition that addresses this criticism is the one proposed by Shohet and Lavy (2004: p. 211): "*the application of integrated techniques to improve the performance and cost effectiveness of facilities to support organisational development*".

FM in the healthcare sector (i.e. NHS hospitals) has earned itself the name healthcare facilities management (HFM). The NHS Estates (1998: p. 4) defines HFM as "*The process by which an NHS trust creates and sustains a caring environment and delivers quality hotel services to meet clinical needs at best cost*". HFM is useful in managing and providing strategic direction to the myriad non-clinical services in the NHS. HFM manages the service interface between clinical and support services, while at the same time paying special attention to the relevant parties concerned with the healthcare business. The relevant stakeholders in healthcare include end-users, service consumers, politicians, trade unions, environmentalists, etc. Their stake in healthcare primarily influences service quality and operational excellence in the NHS.

As shown in Figure 3-1, HFM comprises many services that may vary from one NHS hospital to another. According to Hinks (2003, as cited in Olomolaiye *et al.*, 2004) these services can be divided into two main categories – hard and soft HFM. Hard HFM relates to issues concerning processes, i.e. the maintenance of property, the inter-connectivity between clinical spaces, air change logistics, spatial relationships, structure and fabrics, water supply, electricity and telecommunication. On the other hand, soft HFM relates to the management of support services, i.e. cleaning, waste management, security and laundry. Some authors like Olomolaiye *et al*. (2004) divide HFM into 'people' and 'technological' categories. 'People' HFM includes support services dealing with the performance of people, i.e. cleaning, waste management, etc. On the other hand, 'technological' FM deals with the technical issues of the hospital, i.e. maintenance, water supply, etc.

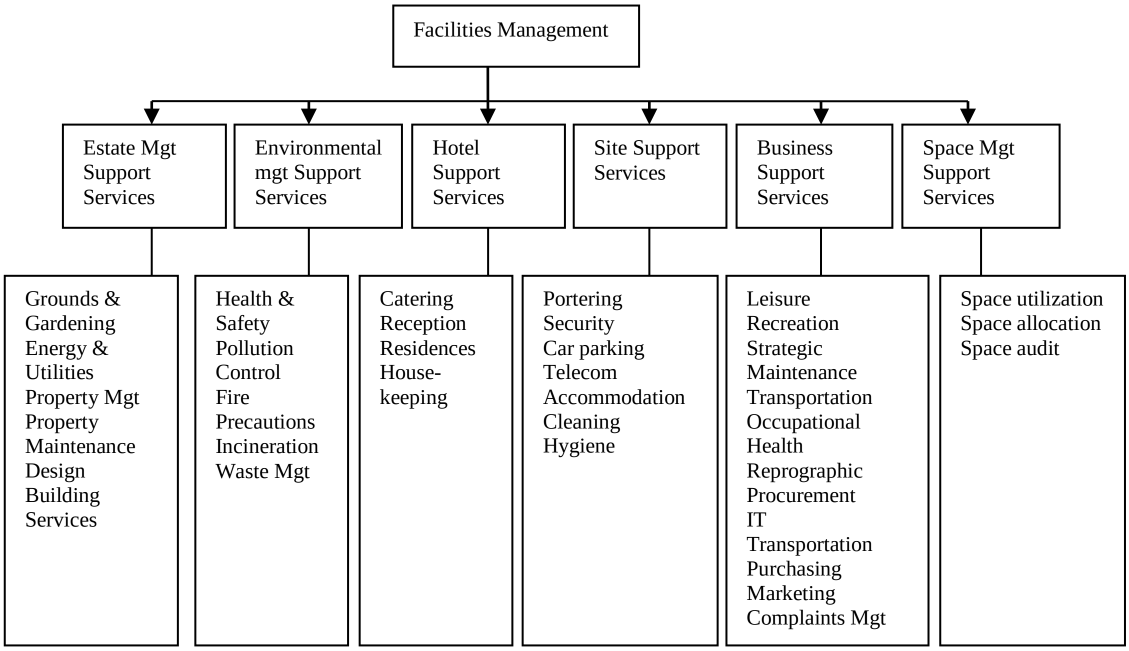

Figure 3-1: Overview of FM Services in the NHS
Source: Okoroh et al., 2001: p. 160

Although HFM consists of a great many services (see Figure 3-1 above), not all of them have a link with HAI. Those that have a link with HAI include planning and design, maintenance, cleaning, waste management, laundry and catering services. HFM services like cleaning (to avoid contamination of equipment and the built environment), catering (to avoid food contamination), building maintenance (to avoid cross- infection), and practices of healthcare FM workers (to avoid contact transmission) play an important role in the control of HAI (WHO, 2002).

Few healthcare authorities pay particular attention to tackling the non-clinical causes of HAIs in hospitals (CDC, 2003). According to Sheldon (2009), healthcare authorities generally underestimate the risk associated with environmental surfaces in the transmission of HAI in hospitals. Few UK guidelines and recommendations emphasize the role of HFM in infection control. Dancer (1999), for example, criticised the Department of Health's publication 'The Path of Least Resistance' (examining the unremitting increase in antimicrobial resistance) for devoting only a paragraph to hygiene and cross-infection. Although the Department of Health's publication 'Winning Ways 2003'mentioend non-clinical aspects to tackle HAI, it failed to mention HFM as a player in infection control. In two recent publications by the European Academies Science Advisory Council (2009), and Loveday *et al.* (2014) on environmental IC, HFM services like maintenance, waste management, catering, and laundry are not mentioned.

Because of the way healthcare officials see HFM, only a small number of hospitals have an HFM manager sitting in board meetings (Rees, 1998). The presence of an HFM manager in board meetings helps to state the case for and channel the course of the HFM unit in infection control. Although 25% of the NHS spending is on estate and facilities, only a meagre £372,000 was allocated for the financial year 2005-06 to estate and FM research (May and Pinder, 2008). For that same period, clinical research was awarded a staggering £650 million. This large difference is an indication of the fact that the NHS still does not see the contribution of HFM to its core business operation, i.e. patient wellbeing. When the NHS Estate was disbanded, some functions that were previously under the control of HFM were transferred to more clinically focused organisations and the National Patient Safety Agency (May and Pinder, 2008). This of course left HFM at a cross-roads (May and Pinder 2008), and drifted it further away from the core business operation of the NHS.

Establishing a clear link between non-clinical and clinical services is vital in the control and prevention of HAI in the NHS. Up to now, clinical and non-clinical staff have regarded their functions as two separate entities (Liyanage and Egbu, 2005). This could create ambiguous lines of responsibilities and communication between HFM and the major players in infection control (infection control teams and committees). Communication is central to good practice in IC. For infection control to be safely planned and implemented, communication between HFM and clinical staff needs to be multidirectional, i.e. up, down, and across the organisational and management structures of the NHS (Pratt *et al.*, 2002). In this way, relevant information such as surveillance and audit data, new evidence, guidelines and protocols will be coordinated and disseminated effectively to all staff.

Although government guidelines stipulate that IC should involve everyone working in the NHS, it appears the issue is not taken seriously in HFM. Whilst all new staff undergo an induction, mandatory training and education on HAI is often restricted to clinical staff. Even where such training and education includes non-clinical staff, temporary HFM workers employed by agencies and working in close proximity to susceptible patients are often left out (Davies, 2005). Sheldon (2009: p. 62) blames poor cleaning and hygiene practices for contributing to the "…*outbreaks of Influenza A - specifically the HlNl and ongoing deaths related to MRSA and C-Diff*". Whilst maintenance operatives are provided with guidelines regarding the ventilation requirements of wards, it is often up to them to achieve the required standards. So far, HM involves a number of practical issues such as patient and staff movements, legionella, and dust control, etc. The problems facing HFM in the control of HAIs in the NHS are outlined as follows (Sheldon, 2009; Liyanage and Egbu, 2005; Davies, 2005; Dancer, 1999; Rees, 1998):

1. Inadequate government guidelines and recommendations to show the importance of HFM in infection control.
2. The organisational structure in the management and control of HAI in the NHS does not specify any clear line of responsibility for HFM.
3. The fragmentation of the NHS Estate undermines the status and contribution of FM in infection control.
4. There is a lack of clear communication and link between non-clinical and clinical staff in the control of HAI.
5. HFM operatives receive insufficient training and education about the control of HAI.
6. There is limited research funding allocated to HFM to improve its performance in IC.

3.3 HEALTHCARE FACILITIES MANAGEMENT SERVICES LINKED TO HAIs

As mentioned earlier, not all HFM services are linked to HAIs. Those that are linked to HAIs and are being examined in this research study include planning and design, cleaning, waste management, laundry, catering and maintenance. Although all of the aforementioned HFM services are examined here, the focus of this research study will be on healthcare maintenance services (HM services).

3.3.1 Planning and Design Risks in Relation to HAIs

The healthcare built environment serves as an ecological niche in which healthcare users might become infected with HAIs. According to Cameron *et al.* (2005), the way hospitals are designed strongly affects rates of HAIs. In a meeting held in 2003, a group of microbiologists and infection control nurses agreed on the importance of making IC an integral part of the design, planning, building and operation of healthcare facilities (Stockley *et al*., 2006). This should apply to all projects irrespective of their funding source or political setting.

As a strategic issue, the planning and design of hospitals should involve all the relevant stakeholders in IC. It is important that clear lines of communication are established between members of the infection control team (ICT) and architects, engineers, HFM managers, hospital management, etc. The CDC (2003) included HFM in the list of multi-disciplinary coordination teams responsible for construction-related projects in hospitals (e.g. project inception, project implementation, final walk-through and completion, renovation, maintenance and demolition of hospital buildings). As demonstrated in Figure 3-2, the expertise of HFM is invaluable in a number of issues concerning the control of HAIs. Issues commonly addressed by the multi-disciplinary team in the planning and design of hospitals may include budget, space, equipment, cleaning areas, air handling units, project management plans, risk assessment, education for construction staff, compliance, etc.

The adoption of a holistic approach in the planning and design of hospitals is crucial in averting future infection-related problems that may arise at the building occupancy stages. According to the Health Protection Agency (HPA) (2008), the poor planning and design of hospitals may result for example in failure to include domestic rooms or sluice or clean utility rooms in the facility, or the fitting of carpets in clinical areas instead of washable floor coverings. The failure to include HFM in the planning and design of hospitals may affect the maintainability of hospitals, and heighten the incidence of HAIs. In order to design IC into hospital buildings, issues such as the ratio of bays to single rooms, the number of beds, and the provision of clinical as well as FM services are important. Although some researchers have found an association between the use of single rooms and the reduction of HAIs such as Methicilline-resistant *Staphylococcus Aureus*, *Pseudomonas Spp*. and *Candida Spp*., others have not (Bartley *et al.*, 2010). Where there is the lack of such clarity, Humphreys (1993) recommends that decisions should be based on experience, common sense, and general principles underlying infection control.

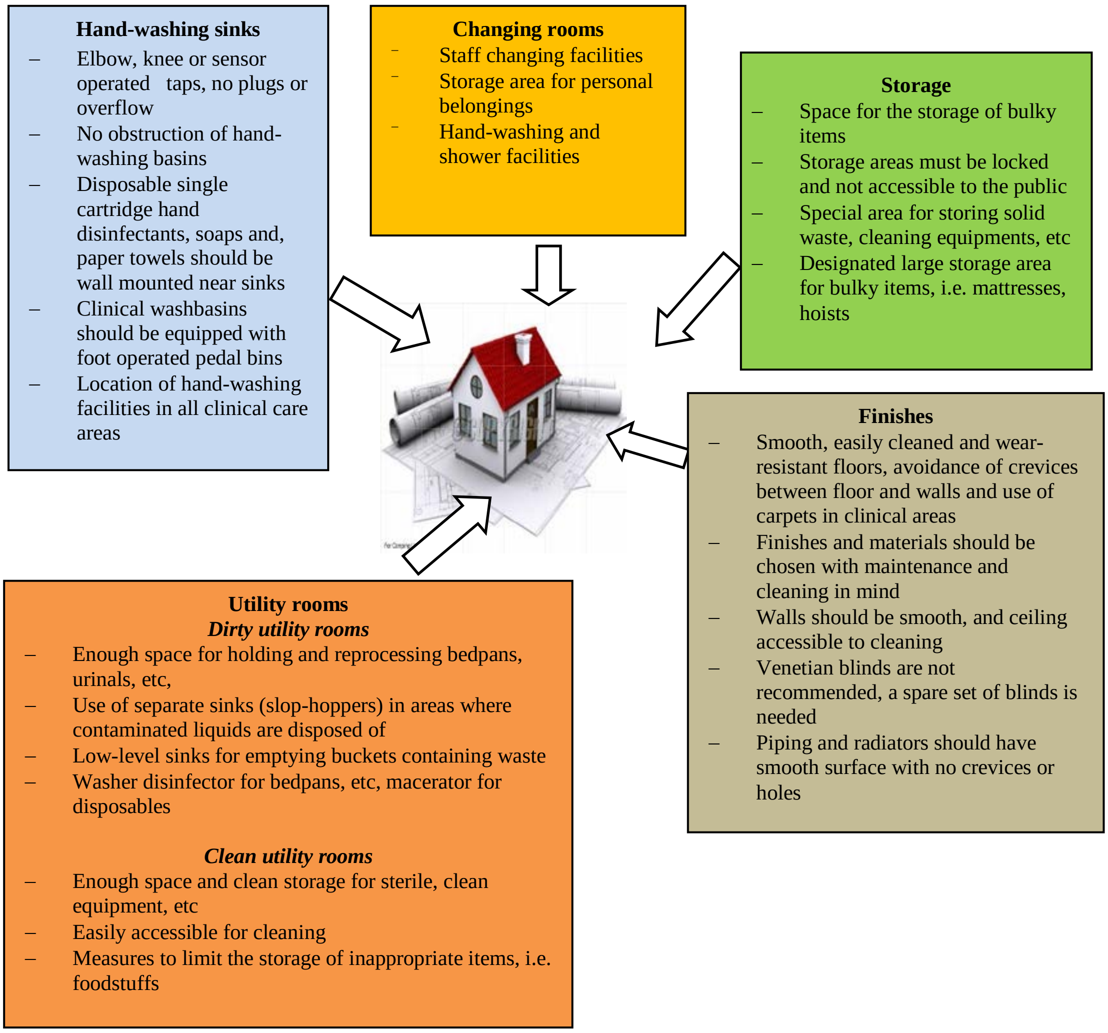

Figure 3-2: Basic FM Areas in the Planning and Design of Hospitals

According to Stockley *et al*. (2006: p. 286), “*proposed numbers of beds may make assumptions on occupancy rates, expected length of stay, the provision of community health care and social services*”. Although the provision of new beds will have to meet the requirements set by individual hospital units, these beds must also be cleanable to reduce any risk of environmental contamination. In addition to allocating at least 3.6m bed space between bed centres (HPA, 2008), hospitals are also required to provide sufficient hand washing facilities. Many healthcare professionals consider the provision of hand washing facilities in hospitals as the most important initiative to enhance patient safety (Pittet *et al.*, 2000). Although healthcare workers do not necessarily comply with hand washing guidelines and procedures (RCN, 2005, HPA, 2008), it is still an effective and practical means of reducing HAIs (HPA, 2008). Hand hygiene compliance can also be increased by designing the hospital environment in a way that reduces environmental contamination. For example, ancillary areas (clean and dirty utility rooms), storage rooms, finishes and changing facilities need to be of an acceptable hygiene standard. Figure 3-2 shows areas in which HFMs can contribute to IC during the planning and designing of hospitals.

3.3.2 The Role of Cleaning in the Control of HAIs

The healthcare built environment serves as an ecological niche in which inanimate objects may become contaminated with pathogenic microorganisms. The diverse populations of pathogenic microorganisms in the healthcare built environment come from several sources. Endogenously, contamination may come from a patient's normal intact skin or infected wound (Collins, 2008). Exogenously, contamination may originate from the occasional spilling of urine, pus, sputum or other fluids on building surfaces in hospitals. The environmental source maybe linked to HFM operations (i.e. cleaning, maintenance, laundry, catering and waste management services) in/close to areas housing patients. As shown in Table 3-1, there is strong epidemiological evidence linking environmental contamination of the healthcare built environment to the risk of Meticilline-resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile* (*C. difficile*) infecting patients. MRSA and *C. difficile* are on the list of commonly cited HAIs in the NHS. Sites that are commonly contaminated with these pathogenic microorganisms include rails on beds (Sexton *et al.*, 2006), cleaning wipes (Cheng *et al.*, 2011), computer terminals (Devine *et al.*, 2001), doctors' and nurses' pens (French *et al.*, 1998) and stainless steel door handles (Oie *et al.*, 2002), etc.

If contaminated surfaces in hospitals remain unclean, they may serve as reservoirs. The hands or gloves used by healthcare workers, patients and other healthcare users may become contaminated with these pathogenic microorganisms. Unknowingly, those with contaminated hands may become vectors in the spread of infections in hospitals (Gould *et al.*, 1996). Without thorough and effective cleaning, the healthcare built environment might become unsuitable for patient care. According to the World Health Organisation, most 'visible dirt' in hospitals contains microorganisms that can cause HAIs (WHO, 2003).

Table 3-1: Research into the Environmental Contamination of Hospital Surfaces

Author [year]	Type of infection/ sample area	Types of Contamination	Bedrails	Bathrooms	Floors	Linen	Door handles	Sinks/windows	Pens/pc parts	Sample size	Research Result	Conclusion/ Recommendation
Cheng *et al*. (2011)	MRSA Orthopaedic unit	Environmental contamination of re-useable cleaning wipes	√							8	In a total of 56 tests, MRSA was isolated in 48 pre-disinfection and 19 post-disinfection bedrails and in 29 pre-use and 38 post-use wipes	Wipes can transmit MRSA if not properly rinsed and disinfected between patient environments
Mutters *et al*. (2009)	*C. difficile*	Occurrence of *C-difficile* in the environment of *C-difficile*-positive and -negative patients			√					531	Compared to the *C. difficile*-negative patient environment, the *C. difficile*-positive patient environment had significantly higher counts of bacteria on the floor and elsewhere	The inanimate environment as well as patients and healthcare workers play an important role in the transmission of *C. difficile*. The use of real-time PCR to detect toxinogenic and non-toxinogenic *C. difficile* strains in the environment
Sexton *et al*. (2006)	MRSA Isolation wards	Environmental contamination of isolation rooms	√			√				25	Half of the surfaces tested were positive with strains similar to those isolated from patients	Environmental reservoirs can be a significant contributor to endemic MRSA. Cleaning is recommended
Oie *et al*. (2002)	MSSA/MRSA Psychiatry, obstetrics & gynaecology	Contamination of tubular stainless steel door handles					√			196	53 (27%) doors were contaminated with MSSA/MRSA (20.9% MSSA, 8.7% MRSA, 2.6% both)	Emphasize hand washing, improving and maintaining the patient environment
Verity *et al*. (2001)	*C. difficile* Side rooms used for the isolation of patients	The frequency , persistence and molecular epidemiology of *C. difficile* environmental contamination	√		√			√		660	153 (23%) environmental swabs tested positive for *C. difficile*. All of the patient isolates and 93% of environmental isolates were toxigenic	There appears to be a lack of consensus about the use of detergent or disinfectants to clean patient areas. The use of detergent might increase the persistence of some C. difficile strains. Phosphate buffered hypochlorite found to be effective.
Devine *et al*. (2001)	MRSA Acute medical &surgical wards	Environmental contamination of computer terminals							√	25	MRSA contamination in 6 (24%) of the 25 wards examined in two hospitals	Effective cleaning of the ward environment may have an impact on the contamination of pc terminals.
French *et al*. (1998)	MRSA	Contamination of doctors' and nurses' pens							√	36	Nine pens (25%) contaminated with MRSA	Reinforces the importance of hand hygiene, and the need to keep the environment clean
Skoutellis *et al.* (1994)	*C. difficile* (Pseudo membranous entero-colitis) Medical & oncology	Relationship between contamination of patient room carpeting and *C. difficile*	√	√	√					37	High numbers of PME patients contaminated the environment with *C. difficile*. Carpeted floors were more contaminated than uncarpeted floors ($p < 0.05$)	The environmental isolates from carpets can be pathogenic strains. Carpets should be considered as potential reservoirs of *C. difficile*.
Stacey *et al*. (1998)	MRSA	Contamination of TV sets in patient wards							√	25	Three TV sets were contaminated with EMRSA 15, 1 with EMRSA 16	Evidence that inanimate objects act as reservoirs for EMRSA. The movement of TV sets between patient rooms can act as a vector in the transmission of EMRSA.

Cleaning (also called domestics) plays an important role in reducing environmental contamination, and thus the incidence of HAIs. According to the John Hopkins University (2010: p. 2), cleaning is "*a process that helps removes organic and inorganic materials from objects and surfaces through the use of detergents*". In addition to removing those substances that support the growth of microorganisms in hospitals (Parker, 1999, as cited in May, 2000), cleaning helps restores appearance, maintains function and prevents the deterioration of hospital buildings (May, 2000). A clean hospital environment also has positive implications for staff morale, patient recovery times and the overall delivery of healthcare (DH, 2007).

As shown in Figure 3-3, cleaning is conducted on environmental surfaces (i.e. equipment or devices) that do not come into direct contact with patients during care. Environmental surfaces could be divided into two groups: medical equipment and housekeeping surfaces. Medical equipment surfaces include knobs or handles on haemodialysis machines, X-ray machines and dentals units, etc. Housekeeping surfaces are sub-divided into highly touched (i.e. doorknobs, bedrails light switches, etc) and minimally touched surfaces (i.e. floors and ceilings). Housekeeping surfaces fall under the auspices of HFM (i.e. domestics). The distinction between housekeeping surfaces that should be considered highly touched and minimally touched should be based on a risk-assessment approach. Once healthcare officials have established this distinction, a healthcare facility policy should be formulated specifying the methods, thoroughness, frequency and choice of product that should be used to clean these housekeeping surfaces. The CDC (2003) recommends that 'high-touched' housekeeping surface (i.e. wall areas around toilets in patient rooms) be more frequently cleaned and/or disinfected than surfaces with minimal hand contact. Items with minimal hand contact such as walls, blinds and window curtains only require cleaning when visibly soiled. Additionally, floors in healthcare settings do not require unwarranted cleaning. According to the CDC (2003), the disinfection of floors in hospitals does not offer any substantial advantage over regular cleaning using water and detergent. Many studies have shown that floors become rapidly re-contaminated from airborne microorganisms, because of the rotary movement of equipment wheels, shoes of healthcare users and body substances.

Poor cleaning practices have also been associated with the spread of microorganisms on hospital floors. For example, the incorrect dilution, preparation and storage of cleaning solutions may reduce the effectiveness of cleaning against pathogenic microorganisms. A lack of staff training and/or finance may also lead to the continued use of contaminated cleaning solutions, mop heads or cleaning cloths. To minimise the risk of floor contamination, the CDC (2003) recommends the frequent changing of cleaning solutions. Mop heads and other cleaning items should also be laundered and allowed to dry before re-use. Where cost permits, it is advisable to use disposable mops to clean hospital floors. Alternatively, mop heads should be replaced with clean ones each time a bucket of detergent/disinfectant is replaced.

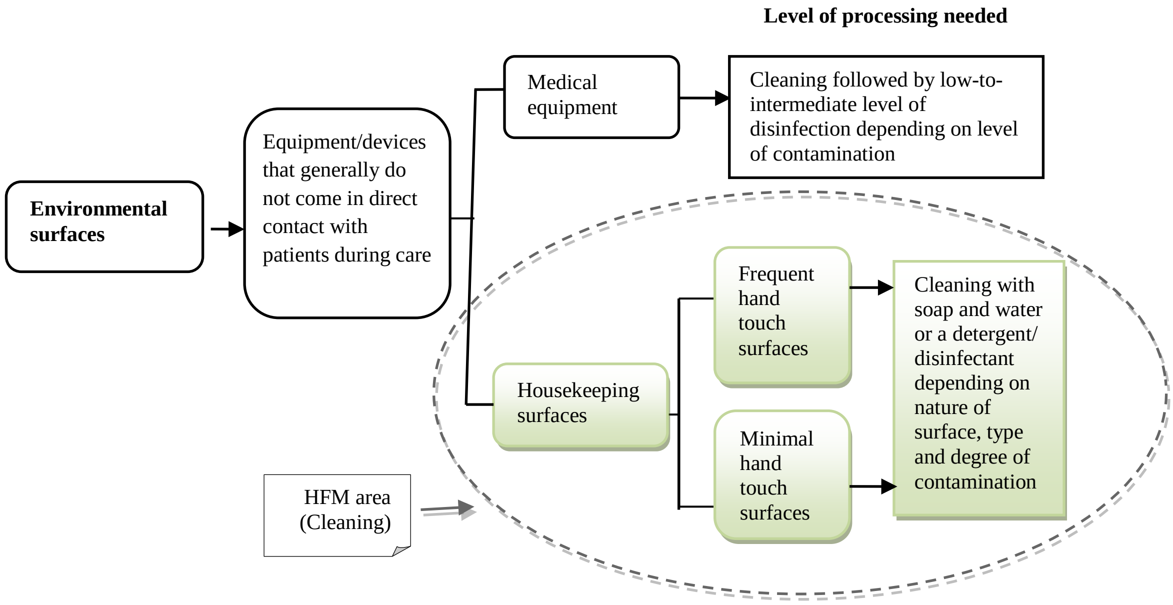

Figure 3-3: Classification of Cleaning in Infection Control and Prevention

3.3.3 The Link between Catering and HAIs

NHS Trusts are responsible for providing food to their patients on a daily basis, throughout the year. Judging by the number of patients, it can be said that the NHS has one of the largest catering services in the UK. This is a huge financial cost for the NHS. Back in 1992, the NHS spent about £223 million on 23,000 catering staff and £89 million on meals for patients (Anon, 1992). By 2005, the amount spent on providing food alone had gone up to £500 million (Lund and O’Brien, 2009). This is attributed to recent improvements in medical science and technology, which is leading to more invasive procedures and increasing the number of in-patients in the NHS.

Unlike food served at home and in restaurants, special care needs to be taken in the preparation of hospital food. This is because those eating hospital food may be patients (i.e. immune-suppressed, the elderly and children) who are vulnerable to infections. According to Barrie (1996), hospital food has to be palatable, attractive, nutritious and above all free from contamination. Unfortunately, this is not always the case with hospital food, which has sometimes been embroiled in food poisoning cases (Anon, 1992). According to the Parliamentary Office of Science and Technology, food poisoning is "*any disease of an infectious or toxic nature caused by the consumption of* [contaminated] *food or water*" (POST, 2003: p. 1). According to Lund and O'Brien (2009), the following factors are responsible for food poisoning:

- Improper holding time/temperature
- Contaminated equipment/protection from contamination
- Poor personal hygiene
- Chemical contamination
- Food from unsafe sources

The commonest symptoms of food poisoning are diarrhoea, vomiting and abdominal pains. The five major organisms that cause food poisoning in the UK are *Salmonella, Campylobacter, Clostridium perfringens, E. coli 0157* and *Listeria* (POST, 2003). *Campylobacter* accounts for most cases of food poisoning, while *E. coli* and *Listeria* cause severe disease in patients, albeit in small numbers. *Salmonella* remains the major cause of food-related death in England, killing about 119 people in 2000 alone (POST, 2003). In 1984, a major outbreak of food-borne salmonellosis occurred at the Stanley Royd Hospital, a large psychogeriatic hospital in Wakefield, Yorkshire. Although cooked beef was identified as the main vehicle in the transmission of *Salmonella typhimurium* phage type 49, officials also found the hospital kitchen heavily contaminated and unhygienic (Wilkinson, 1988). In this particular outbreak, 379 individuals (299 patients and 80 staff) showed bacteriological evidence of an infection (Wilkinson, 1988). The outbreak resulted in the death of 19 people.

In 2003, *Listeria monocytogenes* (*L. monocytogenes*) was isolated from the blood cultures of two patients in the oncology unit of a hospital in the UK (Shetty, 2009). Both patients, nursed in separate wards, had advanced malignancy, and were receiving palliative chemotherapy. Epidemiological investigations revealed that both patients had attended the outpatient department and eaten sandwiches provided by the hospital. Further investigation revealed that the factory supplying the hospital with the sandwiches had a *L. monocytogenes* contamination 'problem', following the re-laying of the factory floor in 2002. Even so, investigations revealed that the contaminated sandwiches were also not stored at the recommended temperature of 8 - 11^{0}C (Shetty, 2009).

This suggests that poor catering practices in the NHS can lead to HAIs. "*The solution to the problem of avoiding the contamination of food lies in proper hygiene, proper cooking, proper handling and proper storage of food* ..." (Stanley Royd Committee, as cited in Barrie, 1996: p. 14). This requires staff to receive proper training, retraining, and supervision in the prevention of food contamination. Although previous outbreaks of food poisoning led the UK government to introduction a number of policies and guidelines, the problem is far from being over. Many cases of food poisoning are still reported every year in the NHS. Recently, salmonella has been blamed for a number of deaths and infections in the UK.

3.3.4 The Link between Laundry and HAIs

The provision of clean linen in hospitals is a fundamental requirement in safe patient care. NHS hospitals have the duty under the Health and Safety at Work Act to reduce the risk of HAIs emanating from linen. A number of guidelines have therefore been provided on the handling, disinfection of used/infected linen. These guidelines apply to in-house and/or contracted-out laundry services. Hospital linen includes such items as bed linen, pillows, curtains (fabric and disposable), soft furnishings, hoist slings, mob heads, scrub suits, gowns and drapes for operating theatres, mattresses and their covers, etc.

According to Barrie (1994), varying numbers of microorganisms including Gram-negative bacilli, coagulase-negative staphylococci, and Bacillus species are present on hospital linen before laundering. The contaminants present on these items are mainly human skin scales, blood and body fluids (including urine and faeces) (NHS Community Health Oxfordshire, 2010). Although greater numbers of microorganisms are found on linen fouled with excreta, the risk to laundry staff is minimal provided this linen comes from low risk wards, and that staff wear protective aprons and gloves

(Barrie, 1994). However, hospital linen, which comes from patients suffering from gastrointestinal-related infections or other notifiable diseases, may pose the risk of HAIs to healthcare users (Maki *et al*., 1983). High-risk hospital linen usually comes from patients housed in isolation or other high-risk wards.

In order to differentiate between high and low risk linen, the DH provides guidance requiring the separation of hospital linen into three categories: used (soiled and foul), infected, and heat-liable (NHS Executive, 1995). Used linen is items soiled by use or fouled by excretion or secretion. Infected linen originates from patients known or suspected of an enteric infection, be colonised or clinically infected with MRSA, or known or suspected to have Tuberculosis or other notifiable diseases. Heavily fouled linen should also be treated as infected linen. Heat-liable linen is fabrics damaged by disinfection temperatures.

Although the risk of acquiring an infection through contaminated linen is low, it may nonetheless occur due to poor staff practices. Transmission of microorganisms is usually through the inappropriate handling, storage or processing of clean and soiled linen in hospitals (CDC, 2003). In a letter to the Editor of the Lancet, Brunton (1995: p. 1574) noted "*…laundry of clothing and bedding used in hospitals is largely taken for granted, but not uncommonly seems to be the source of outbreaks of infection*".

Weernink *et al.* (1995) investigated an outbreak of 47 cases of *Acinetobacter* isolates in an intensive care unit at the Regional Hospital Midden Twente in the Netherlands. They collected nineteen samples from the connectors of ventilation equipment, and 32 from the lids and necks of bottles for enteral nutrition. Analysis of the results indicated that 19 samples from the anaesthetic equipment, 1 from the respiratory equipment and 6 from enteral nutrition bottles yielded *Acinetobacters*. However, measures put in place to eradicate these organisms from these environmental sites did not succeed in reducing the prevalence of *Acinetobacter* in the intensive care unit. When further measures such as the introduction of chlorohexidine 4% liquid soap for daily hand washing failed to reduce the rate of *Acinetobacter,* officials decided to examine the hospital bedding. An inspection of the mattresses and beds did not raise any concern amongst officials. Thus attention shifted to hospital pillows, which were covered with cotton and filled with either chicken or duck feathers. Because these pillows could not withstand the recommended washing temperature (85^0C), they were being washed at a lower temperature (60^0C, followed by drying at 152^0C for 40 minutes). This of course was the cause of the outbreak of *Acinetobacter* in the intensive care unit. The result of the investigation resulted in the removal of the 700 feather pillows that were being used at Midden Twente. The remaining synthetic pillows were subsequently washed at 85^0C. Following the introduction of these measures, the number of infections and colonisation with *Acinetobacter* dropped remarkably. This research clearly highlights the need to protect patients from 'laundry-associated HAI', and laundry staff from the exposure to potentially infectious materials during the collection, handling and sorting of contaminated textiles in hospitals (CDC, 2003).

3.3.5 The Link between Healthcare Waste and HAIs

Generally, hospital waste is no more infective than residential waste (CDC, 2003). Some studies have shown that, although hospital waste contains greater numbers of different bacterial species, residential waste is more heavily contaminated (CDC, 2003). This does not however mean that there is no link between hospital waste and HAI. According to the Environment Agency (2002), there is a link between hospital waste and HAIs. This mostly concerns blood-borne virus infections associated with sharps injuries. Other infections associated with hospital waste include soft tissue and enteric infections (Environment Agency, 2002).

In a study by Blenkharn (2006), twenty-three clinical carts at nine Acute NHS hospitals were sampled for evidence of microbial contamination. Seventeen of the clinical carts that were in use at the time of sampling were filled with clinical waste bags or sharps bins. Three of the bags were overfilled with clinical waste, and this protruded from the gaping lids hat could not be closed fully. The remaining six waste carts were empty at the time of sampling. These waste carts were found in the hospital corridors, lobbies or stairwells close to wards or clinical departments. All the 23 clinical carts were visibly soiled externally, and the internal walls of two of the carts were heavily stained with what appeared to be dried blood spots. In addition, there were free fluids (dark brown fluid) at the base of some of these clinical carts. Two of the clinical carts containing waste from the nearby microbiology laboratory had at their base a thick film of foul-smelling and viscous gel that might have leaked from previous waste containers. Examination of the clinical carts indicated heavy microbial contamination. Large numbers of aerobic spore-bearing *bacilli* were isolated from the lids (15/23) and wheels (18/21) of the clinical carts examined. Coagulase-negative *staphylococci*, *micrococci* and *diphtheroid bacilli* were recovered from five of the 21 wheels examined. In addition, *Escherichia coli*, *Enterobacter spp*. and *Pseudomonas aeruginosa* were also recovered from a single cart standing outside a pathology laboratory complex. *Aspergillus spp*. were also recovered from the lid surface and wheels of two clinical waste carts standing at the open rear of a general ward block.

The findings of the aforementioned studies show that poor hospital waste practices may put patients at risk of acquiring HAIs. Waste generated in healthcare settings must be handled with care and separated into the required groups/categories.

3.3.6 The Link between Healthcare Maintenance (HM) and HAIs

The word maintenance is often used interchangeably with words like renovation, alteration, repair and de-commissioning. Many definitions of the word maintenance focus on the theme of retaining or restoring an item into its original state. Where such an operation is performed in a healthcare establishment, i.e. in NHS hospitals, it is termed healthcare maintenance (HM). The Woodbine Report (1970) defines the term HM as "*work undertaken to keep or restore hospital premises to acceptable standards of safety and efficiency having due regard to the needs of patients and staff within the immediate environment, the requirements of the NHS and the resources available*". Putting too much emphasis on resources may result in the provision of sub-standard maintenance services that expose healthcare users to the risk of HAIs. It is important for NHS Trusts to embed infection control as a key objective of the HM unit. The objectives of the HMU should fall under the following four main headings: "*ensuring system function (availability, efficiency and product quality); ensuring system life (asset management); ensuring safety; ensuring human well-being*" (Dekker 1996: p. 230). As pointed out earlier, this research study focuses on HM.

Modern hospitals and healthcare buildings consist of complex indoor facilities that have different end uses of indoor spaces and functions (Balaras *et al.*, 2007). The nature of the business of hospitals requires that they pay special attention to the indoor healing environment (Streifel, 2005). The continuous occupancy of hospitals and the challenge of upgrading utilities and installing new medical technology may result in potential disruptions, which expose patients to the risk of HAIs (Streifel, 2005). All of these issues pose challenges for healthcare authorities, who have the responsibility of rendering the indoor healing environment safe for patients, staff, and visitors.

Aspergillosis is one of the main infections caused by construction-related works like HM (Streifel and Hendrickson, 2002; Fournel *et al*., 2010; Bartley, 2000; Streifel, 2004). The American Thoracic Society [ATS] (2012: p. 1) describes, "*Aspergillosis as [an] infection that is caused by a fungus called Aspergillus*". Although many species of *aspergillus* exist, only four are responsible for many of the cases of aspergillosis. This includes *A. fumigatus* (66%), *A. flavus* (14%), *A. niger* (7%), and *A. terreus* (4%) (Paterson *et al*., 2000, as cited in Thompson and Patterson, 2008). Three different forms of aspergillosis are caused by *aspergillus* species: hypersensitivity pneumonitis (a reaction to *aspergillus* in the lungs), allergic bronchopulmonary aspergillosis (an asthma-like illness), and invasive aspergillosis (a life-threatening form of illness) (ATS, 2012).

The *Aspergillus* fungus lives in soils, decaying plants, rotting material and dust, etc. The size of conidia (2-3μm) means they can remain suspended in the air for a very long period of time (Royal Liverpool Children's NHS Trust, 2004). *Aspergillus* enters the body of a susceptible host through the lungs by inhalation of fungal spores (conidia). It may also enter the lungs of a susceptible patient through inhalation of water aerosols contaminated with *aspergillus* conidia (Thompson and Patterson, 2008). Although aspergilla are a natural part of the biological ecosystem (Burrill, 2008), they pose a significant risk to patients whose immunity has been compromised because of age, underlying illness, medical or surgical treatment (Joseph, 2006). In hospitals, maintenance work has been implicated in the spread of conidia through the airborne route (Hoffman *et al.*, 1999). According to Tabbara and Jabarti (1998), old hospitals (termed 'sick' buildings) are more likely to harbour spores of fungi including *Aspergillus*. Invasive aspergillosis affects ≤14 per cent of lung transplant recipients and ≤ 28 per cent of patients who have undergone allogeneic hematopoietic stem cell transplantation (Wald *et al.*, 1997). In Canada alone, about 50% of negative patient outcomes (including several deaths) have been caused by *Aspergillus fumigatus* (Health Canada, 2001, as cited in Burrill, 2008). Such figures have led the CDC (2005, as cited in Burrill, 2008: p. 56) to state that, "*HAIs may be associated with dust exposure during building renovation* [maintenance] *or construction*".

During maintenance (e.g. plumbing), water may dampen structures, areas, or items made of porous materials or characterized by cracks and crevices (sink cabinets in need of repairs, carpets, ceilings, floors, walls, upholstery, and drapes). Wet gypsum board and ceiling tiles have been found to support the growth of *Aspergillus* if unattended for more than 72 hours (MS Hospital Consulting, 2001, as cited in Riley *et al*., 2004). Subsequent disruption of the ceiling area, running cables through the ceiling, structural repairs (WHO, 2007), replacement of ductwork (Burrill, 2008), false fibrous thermal and/or acoustic insulation materials and roller-blind castings (French, 2005) may cause the disturbance of settled spores or the disruption of a locus of growth and lead to fungal aerosol pollution in hospitals. If unattended, these surfaces might support the growth of mould and serve as potential sources for pathogenic microorganisms (CDC, 2003).

As shown in Table 3-2, an incident at the University of Minnesota Hospital and Clinic resulted in a hole in the roof membrane. Out of about 4,000 litres of water that penetrated the concrete slab, 2,000 entered the patient area. According to Streifel (2004), this resulted in the abundant growth of *A. fumigatus* and high surface contamination (<300cfu/plate). Infection occurs when these airborne pathogens either settle onto a wound or other susceptible site, or are deposited on an environmental site (and later transported to a susceptible patient) or inhaled into the respiratory tract (Hoffman, 1999).

In a similar study by Sautour *et al*. (2007), maintenance work is also associated with the fungal contamination of the healthcare built environment. Their study was divided into two phases, conducted between October 2005 and March 2007. The primary objective of the study was to sample the air and surfaces in patient rooms. During the study period, fifteen rooms of the adult haematology unit were protected with HEPA (High-Efficiency Particulate Air) filtration, and eleven treated with Plasmer™. According to the European Space Agency (2014), a Plasmer™ "*is a multistage system with strong electric fields and cold-plasma chambers to eliminate microorganisms in the air*. Two of the rooms, which were used as control rooms, had no air treatment. Throughout the project, researchers collected 377 paired air and surface samples from the haematology unit. Analysis of the results showed a rise in fungal load before and after construction work. Before construction, fungal load ranged between 3.0 and 5.3 cfu/m^3 in the air and 1-1.5 cfu/m^3 for surfaces. However, during the first period of construction (phase A), fungal load ranged between 9.5 and 9.8 cfu/m^3 in areas near the construction site. The most prevalent fungi detected were *Penicillium*, *Aspergillus*, *Bjerkandera* and *Alternaria spp*. The source of fungal contamination was attributed to activities such as woodcutting operations, earth removal and digging, which generated large amounts of dust.

In a teaching hospital in Japan, Ohsaki *et al*. (2007) found that renovation and maintenance activities contaminated the air conditioning system, including the inlets and ducts of the air ventilation system, and introduced pathogenic microorganisms into the nearby wards. Out of 18 patients tested, four were diagnosed with bacteraemia, and three others considered contaminated. As shown in Table 3-2, many studies link HM with the incidence of HAIs in hospitals.

The foregoing discussions indicate the importance of ambient air quality in reducing the spread of HAI through the airborne route. Amongst the numerous indoor zones demanding special ventilation requirements in hospitals are infectious isolation rooms (Riley *et al.*, 2004), operating theatres (suites) comprising operating rooms or surgical theatres, their interconnecting hallways and ancillary work areas (Balaras *et al.*, 2007). Although, heating, ventilation and air-conditioning (HVAC) filtration systems are not capable of stopping all spores as they travel in the air stream (Burrill 2008), they nonetheless are important in the control and prevention of HAI through the airborne route (Balaras *et al*., 2007). Bone marrow transplant, leukaemia and renal patients with virtually no immunity are classified among the most susceptible hospital occupants (Burrill, 2008).

To ensure a safe and healthy hospital environment, the proper installation (Streifel, 2005), cleaning and maintenance of HVAC systems should be considered in infectious disease management (Chartered Institute of Building Services Engineers (CIBSE) (2000). There is evidence linking the type of air filter, direction of airflow, air pressure, air changes per hour in the room, humidity, and ventilation-system cleaning and maintenance to air quality and infection rates in hospitals (Joseph, 2006). The malfunctioning and contamination of HVAC systems with dust and moisture has been found to increase the risk of the spread of environmental fungi and bacteria in hospitals (Joseph, 2006). The water gradually accumulated in the ducts, humidifiers, and drain pans of ventilation systems may serve as potential breeding grounds through which biological contaminants infect susceptible patients (Riley *et al.*, 2004). Legionellosis is transmitted through this route. *Legionella* bacteria may get into the body of a susceptible patient through inhalation of tiny aerosols or droplet nuclei (Health and Safety Executive, 2002). Contaminated medical equipment may also introduce *L. pneumophila* into the lungs and throat of patients. Those at risk of acquiring Legionellosis include patients with chronic lung disease and throat cancers (WHO, 2007).

Despite the significance of HM in the control and prevention of HAI, it has not recieved the attention of healthcare authorities. According to Streifel and Hendrickson (2002), managers generally overlook the risk associated with construction-induced air pollution in hospitals. They do not spontaneously respond to mechanical ventilation deficiencies especially during construction works (Streifel, 2005). In addition, most contractors working on construction-related projects in hospitals are not yet accustomed to taking special precaution when tearing down, maintaining or renovating hospital buildings (Kidd *et al*., 2007). As a result, many patients in hospitals are exposed to the risk of acquiring HAIs. Even where special precautions have been taken, there is doubt whether in reality facilities actually manage special ventilation areas to the designed parameters specified in various guidelines (Streifel, 2005).

The problems associated with the poor performance of maintenance services in IC are likely to be accentuated by the fact that many healthcare facilities are always looking for ways to save money (Quayle, 1997, as cited in Riley *et al*., 2004). What impact the UK government's austerity measures will have on the performance of maintenance services in IC is something that needs investigation.

Table 3-2: Evidence of the Link between HM Services and HAIs

Author /year	Maintenance activity	Issue/unit investigated	Transmission route	Results	Conclusion/recommendation
Palaez *et al*. (2012)	Extensive building work in a hospital	Heart Surgery Intensive Care Unit	Deficiency in air conditioning system	*A. fumigatus* involved in seven cases of Aspergillosis	The epidemiological link between aspergillosis and environmental contamination is relatively strong
Ohsaki *et al.* (2006)	General renovation of a teaching hospital in Japan (1999-2004)	The outbreak of *Bacillus Cereus* in a Japanese teaching hospital. Patients with hematologic malignancies	HAVAC/AC units, patients' clothes	Out of the 18 patients tested, 4 were diagnosed with bacteraemia; 3 were considered contaminated.	Construction-related work increases risk of *Bacillus Cereus* in hospitals. It is important to identify and remove source of contamination.
Gibb *et al.* (2006)	Building work carried out in a room off the lobby of an eye theatre.	Whether building work was responsible for high incidence of eye infections.	Contaminated dust	Three cases of eye infections were identified within a short period.	Infection control practices fell short of the American guidance on dust containment during construction. Recommends close collaboration between the ICT & building work officials.
Kelkar *et al.* (2005)	Maintenance (cleaning) of window and wall mounted AC units.	The incidence of *Pseudomonas aeruginosa* in 25 hospitals in India.	HVAC/AC unit	Filters tested positive for fungi in 26% of the cases. Window mounted AC was more contaminated than wall mounted AC.	Recommends operating theatres adhere to cleaning & maintenance standards to reduce the contamination of the AC units.
Streifel (2004)	A hole in the roof membrane of the hospital, resulting in about 4,000 litres of water penetrating the slap space, of which 2,000 litres of water entered the patient area.	Whether water leakage into building structures and patient areas increases the risk of environmental contamination and Aspergillosis.	Wet structures	There was abundant visible mould in wet areas. *Aspergillus fumigatus* was predominant filamentous fungus in 8 of the 12 samples taken. There was also high surface contamination (<300cfu/plate).	Disturbance of water-damage areas [i.e. maintenance work] can create large outburst of transient spore clouds, which are hazardous to patients. Susceptible patients were moved from risk area, HEPA filter was used and decontamination of infected areas and cleaning were carried out.
Lutz *et al.* (2003)	Lack of proper maintenance of the air handling system	The outbreak of aspergillus in a tertiary hospital	Contaminated dust	There were 4 cases of *A. fumigatus*, 2 cases of *A. flavus*. Air sample in the theatre showed high concentrations of conidia-sized particles. Flecks of foil and bits of fibreglass used for noise insulation were found in several ducts. Rusted diffusers and grates in VAV units favoured condensation and growth of mould.	Hospitals using VAV units in air-handlers for clinical areas with susceptible patients may wish to check that interior insulating materials are not present or are in good condition.
Mahieu *et al.* (2000)	Replacement of ceiling, electrical rewiring, floor works, joinery, plumbing, painting and plastering	The relationship between spores of *Aspergillus spp.* in the air Neonatal intensive care unit	Contaminated dust	Mean air concentration before renovation was 11 cfu/m^2 (range: 0-30 cfu/m^2). During renovation, average air contamination at different locations varied from 126-397 cfu/m^2	The use of additional mobile HEPA air filtration is effective in reducing the concentration of *Aspergillus spp.* Efficient sealing and positive room pressure also effective in preventing aerobic contamination.
Hopkins *et al*. (1989)	Intensive renovation of the radiology unit located at the centre of the hospital	Whether renovation work in a radiology unit transmitted aspergillus to patients in distant hospital buildings.	Contaminated dust	Six patients identified with invasive aspergillus infection. All had used the radiology unit.	During construction-related activities, there is a need to provide well-maintained high-efficiency sources of air to protect patients.
Kennedy *et al.* (1995)	Structural alteration in a small unit housing infectious patients (procedures such as plumbing, rerouting of electrical cables, etc necessitated the removal of ceiling tiles, flooring and plaster)	The link between building work and contamination of the hospital ward	Contaminated dust	Despite infection control measures put in place, on day one high counts of *Aspergillus fumigatus* were recorded (94 cfu/m^2 in the ward areas, and 47cfu/m^2 in the corridor). Normal *Aspergillus fumigatus* counts in the corridor were 2 cfu/m^2	Possible cause of the contamination was attributed to an error that caused the removal of the seal tape around the partition door. The importance of physical measures such as closing and sealing of doors, and screening of areas in the hospital is emphasized here.
Fox *et al.* (1990)	Inadequate cleaning of the fibreglass in the HVAC system	The source of heavy contamination by *Penicillium* species in the hospital operating room	HVAC/AC units	Forty-seven patients had one or more cultures positive for *Penicillium* species. Thirty-four isolates (72%) were from the respiratory tract, and ten were from wound cultures taken from patients who had undergone operations in the contaminated operation room.	Ensure environmental sampling after temporary interruptions of positive pressure systems, formal certification of newly constructed air handling systems (regular recertification), and periodic microbial surveillance.
Streifel *et al.* (1987)	A leaking sink located in a wooden cabinet in a medication room. Rotten cabinet wood	The source of high levels of airborne penicillin species spores in a hospital corridor	Wet structures	A rise of about 1,480 thermotolerant fungal CFU/M^3 (All being *penicillin spp.*)	Rotten wood can support the growth of *A. fumigatus* & *A. flavus*. Inorganic material inside hospitals must be kept dry. Prompt drying, removal or application of fungicides on infected surfaces.

3.4 SUMMARY

In this chapter, epidemiological evidence is provided showing the link between HFM services and HAIs. The link between HFM and HAI starts with the planning and design of new hospitals and structures. Many issues concerning environmental infection prevention and control are best understood and communicated by HFM managers. Even the CDC recommends the inclusion of HFM managers in committees overseeing the planning and design of new or existing hospital buildings. Hospitals that are planned and designed by a multi-disciplinary team of experts are more likely to address most of the issues in infection control. Failure to address some of these issues may put healthcare users during the building occupancy stage at greater risk of acquiring HAIs.

At the building occupancy stage of hospitals, there is also epidemiological evidence linking HFM services like cleaning, maintenance, catering, waste, and laundry with HAIs. The sophistication of present day NHS hospitals makes the presence of these HFM services a necessity. In order to carry out their business functions, HFM staff work in close proximity with clinicians and patients. For example, domestic staff get into wards to clean tables and bed frames, etc, maintenance staff to fix or repair building components, catering staff to feed patients and laundry staff to deliver/collect linen. Some of these activities, if poorly executed, could expose patients to the risk of acquiring HAIs. Because of the link that exists between HFM and HAIs, it is important for NHS Trusts to measure the performance of HFM services in IC. Although the aim of this study is to draw attention to this need, the focus will be on HM.

CHAPTER 4 : RESEARCH METHODOLOGY

4.1 INTRODUCTION

Chapter 4 describes the methodology used in achieving the research objectives set forth in this research. The first part of this chapter examines issues relating to the research design, paradigms, methodology, and approaches applied in this study. The second part, focuses on the research framework, the pilot study, and the Delphi approach for primary data collection. The research framework covers a number of issues related to the literature review, content analysis, and grounded theory analysis. Finally, the key methodological issues concerning the pilot study and Delphi approach for identifying the critical success factors and performance measures in HM for infection control are examined in detailed.

4.2 RESEARCH DESIGN

Research gathers new facts about a particular phenomenon, in order to arrive at conclusions that may add to or change our understanding of that phenomenon. The outcome of good research depends on the research design. According to Yin (1989), research design "*deals with a logical problem and not a logistical problem*". The research design deals with almost everything for enhancing the internal and external validity of the research (Polit and Hungler, 1991, as cited in Draper, 2004).

In the literature, the umbrella terms research methodology and research method are used to describe the research design (Draper, 2004). The research methodology describes the overall approach used to answer the research questions, whilst the research methods describe, in practical terms, the way data will be collected and analysed. In any given research, the applications of the research methodology and research methods have to be concise, straightforward, and unambiguous.

According to Richards (2006), the business of designing research lies with the researcher. The researcher needs to oversee every phase of the research such as "…

planning the sequencing of the projects components and [moving] *between data gathering and data analysis*" (Richards, 2006: p. 74). Therefore, the research paradigm is an important factor in designing a piece of research (Draper, 2004). This is because the research paradigm influences the researcher's choice of research methodology. Certain research methodologies can be aligned only with certain research paradigms. It is also important for the researcher to take into account his/her own experience, as well as the support, cost, resources, accessibility and ethical considerations needed to conduct the research. All of these factors help the researcher select the most appropriate research design to answer the research questions. The next sections describe the research paradigm, methodology and methods applied in this study.

4.3 RESEARCH PARADIGMS AND PERSPECTIVES

Over the years, researchers have been able to navigate the strenuous journey of acquiring knowledge through the adoption of different research paradigms (Kim, 2003). The choice of the path a researcher decides to follow is determined by the way he conceptualizes the world; this is what is referred to as a research paradigm. Guba and Lincoln (1994: p.109) define a research paradigm as "*a systematic set of beliefs, and their accompanying methods, that provide a view of the nature of reality*". Research paradigms "*... describe the nature of the world, a person's place in it, and their relationship to the world*" (ibid, p. 109).

Because different inquirers view the world differently, it is clear that there will be divergent research paradigms, i.e. the adversarial paradigm that guides the legal system, the religious paradigm that guides religious studies, etc. Historically, inquirers focused predominantly on positivism to establish knowledge. However, over the years many contending paradigms have emerged. These research paradigms are categorised according to the way they provide answers to three fundamental questions relating to ontology, epistemology, and methodology (Krauss, 2005; Guba, 1990). The axiology and rhetorical structure of the research are equally important (Ponterotto, 2005).

In a research paradigm, the ontological perspective is about the philosophy of reality. From the ontological perspective, the objective of the researcher is to establish the form and nature of reality, and to investigate any unknowns in relation to the reality (Guba and Lincoln, 1994). According to these authors, scientific investigation should only relate to matters of 'real' existence and 'real' action. According to the ontological perspective, the next step is addressing how the researcher has come to know the reality under investigation. This is what is known as the epistemological perspective (Krauss, 2005). It involves establishing the nature of the relationship between the researcher and the 'reality' under investigation (Guba and Lincoln, 1994). For example, an epistemological position investigating 'real' reality requires the researcher to adopt an objective and value-free stance. The methodology clearly state the particular practices used to attain knowledge about the reality. According to Krauss (2005), the ontology, epistemology, and methodology interconnect in such a way that the response to one question constrains the response to the other. Axiology concerns the role and place of values in the research process, while rhetorical structure relates to the language and presentation of the research.

As stated earlier, several research paradigms exist for the acquisition of knowledge. However, as Goldkuhl (2012: p. 3) stated "… *the major part of the meta-scientific debate has concerned the two rivals interpretivism and positivism*" (see Table 4-1). With a history of over four hundred years, positivism has its roots in natural science (Guba and Lincoln, 1994). It was not until the 19^{th} century that researchers started applying the methods of the natural sciences to investigate social phenomena (Smith, 1983). According to Holt-Jensen (1987: p. 77), Auguste Comte started the "*classification of social interactions as physical science-like phenomena, to investigate and find their universal governing rules*". Positivists hold the ontological view that the true business of science is to discover the 'true' nature of reality and how reality 'truly' works (Guba, 1990). Positivism focuses on the application of empirical questions, i.e. questions that seek to uncover how things are in reality (Holt-Jensen, 1987). Positivists assume that researchers can reduce all phenomena to empirical indicators that represent truth (Sale *et al*., 2002). Epistemologically, positivists believe in the separation of the inquirer from the object of study. Because there is a real world operating in a natural way, researchers should put their questions directly to nature and allow nature to answer them back (Guba, 1990). Thus, nature plays a big role in deciding the methodology a researcher adopts in a study. In positivism, hypotheses relating to new patterns or any inconsistency in existing theories are deduced well in advance, tested and verified under well-controlled conditions (Kim, 2003). Criticisms of positivism led to another school of thought called post-positivism. However, the basic belief system of post-positivism differs very little from that of positivism (Guba, 1990). The emphasis of post-positivism is also on prediction and control (Guba, 1990).

Many researchers criticise the application of the positivist paradigm as a basis for knowledge inquiry in the social sciences. They argue that it is almost impossible to conduct value-free research. Metaphysical assumptions associated with issues like choosing a topic for scientific investigation are subjective in nature (Holt-Jensen, 1987). According to Kim (2003: 12), "*blind faith in the positivistic approach can potentially jeopardize the soundness of research in the social sciences*". Treating human beings as objects can reduce the researcher's understanding and predictive power with regard to human events. Another limitation of positivism lies in the fact that 'truth' as per the positivist paradigm is often stated probabilistically (Kim, 2003). As a result, positivists rely on "*... probabilistic inferences of truth in which theory never becomes regarded as fact*" (op cit: p. 12).

Table 4-1: The Positivist and Interpretivist Paradigms

Issue	Positivism	Interpretivism
Inquiry aim	Explanation: prediction and control	Understanding; reconstruction.
Nature of knowledge	Verified hypothesis established as facts or law.	Individual reconstructions coalescing around consensus.
Knowledge accumulation	Accretion - "building clocks" adding to "edifice of knowledge"; generalizations and cause-effect linkages.	More informed and sophisticated reconstructions; vicarious experience
Goodness or quality criteria	Conventional benchmarks of "rigour": internal and external validity, reliability and objectivity.	Trustworthiness and authenticity and misapprehensions.
Values	Excluded - influence denied.	Included - formative.
Ethics	Extrinsic; tilt toward deception.	Intrinsic; process tilt toward revelation; special problems.
Voice	"Disinterested scientist" as informer of decision makers, policy makers, and change agents.	"Passionate participant" as facilitator of multivoice reconstruction.
Training	Technical and quantitative; substantive theories.	Re-socialisation; qualitative and quantitative; history; values of altruism and empowerment.
Accommodation	Commensurable.	Incommensurable.
Hegemony	In control of publication, funding, promotion, and tenure.	Seeking recognition and input.

(Source: Adapted from Guba and Lincoln, 1994)

According to Guba and Lincoln (1994), the positivists' method of quantifying hypotheses and using mathematical formulae to predict and control natural phenomena is questionable in the field of social science. According to Dilthey, the goal of natural science (Naturwissenschaft) is scientific explanation, whereas the goal of human science (Geisteswissenschaft) is the understanding (verstehen) of social phenomena (Ponterotto, 2005). Thus, the nature of this research suggests that it falls within the realm of interpretivism. The basic premise of interpretivism is that the researcher and the research participant should not be treated as individual entities existing in a vacuum, but rather as human beings. They are also to be treated as part of the research process. This is because the ‘reality’ constructed in the mind of people can clearly be understood through an interactive researcher-participant dialogue (Ponterotto, 2005).

This research holds the ontological view of the existence of multiple realities and truths. In research of this nature, through the process of iteration, there is often the possibility for research participants to interpret reality differently. In addition, the socio-cultural environment in the construction of reality is not static. For example, the introduction of new legislation, regulation, or measures might alter realities in the NHS. On the epistemological front, this research believes that reality is created through an interactive process between the researcher and the research participant. To solicit rich data from the research participants, they must be treated as human beings, whose ideas and opinions do not come from space. By treating the research participants as part of the research process, the researcher is able to gain a deeper understanding of the social phenomena under investigation. This is because the research participants are the ones experiencing, processing, and labelling the ‘reality’ that is being investigated (Sciarra, 1999, as cited in Ponterotto, 2005).

The application of interpretivism in this research does not mean that it has no possible criticisms. Intertwining the values of the researcher with those of the research participant can make it difficult for the researcher to attain complete objectivity and neutrality. In addition, the way participants understand social phenomena is often based on their individual experiences, memories and expectations (Flowers, 2009). Thus, there is the possibility for participants to vary their interpretation of the social phenomena with the passage of time. Despite the sometimes tense debate surrounding the issue of research paradigms, the bottom-line is that “*all research in the social sciences represents an attempt to provide warranted assertions about human beings (or specific groups of human beings) and the environments in which they live and evolve*” (Biesta and Burbules, 2003, as cited in Johnson and Onwuegbuzie, 2004: p. 15).

4.4 RESEARCH METHODOLOGY

After deciding on the research paradigm, the next step for the researcher is the selection of the appropriate research methodology. In simple terms, a research methodology is a set of principles, procedures, and practices governing the research study. According to Sarantakos (2005, as cited in Tuli, 2010: p. 102) research methodology *"…translates ontological and epistemological principles into a set of guidelines showing how the research will be conducted"*. Different schools of thoughts such as positivism and interpretivism are associated with different research methodologies. Thus the research methodologies applied in this research study are consistent with the interpretative school of thought. Although grounded theory analysis and case study are the two research methodologies applied in this research study, others like phenomenology, ethnography, and narrative are discussed here briefly. According to Petty *et al*. (2012), these research methodologies are often associated with interpretivism.

Phenomenology is concerned with exploring people's everyday life experiences. It provides meaning to the 'lived experience' of several individuals in relation to a particular concept or in other words a phenomenon. It describes generally how things (including ourselves) come to exist as phenomena, identifies the structures of phenomena, modes of appearance, as well as the nature of experience that let them exist as they do (Guignon, 2012). Since phenomenology focuses on structures of experience and consciousness, it is deemed unsuitable for application in this research study. This is coupled with the fact that many have criticised it for being too descriptive (Guignon, 2012).

Ethnography on the other hand, is "… *the study of social interactions, behaviours, and perceptions that occur within groups, teams, organisations, and communities*" (Reeves *et al*., 2008: p. 512). Ethnography takes place in a natural setting involving people in a speech community (Wilson, 1977, as cited in Nurani, 2008). Ethnographers employ tools like sketches, photographs, videos, soundtracks, diaries, etc to describe world events. This research is not about the investigation of a phenomenon involving people in a speech community. Besides, ethnography has a bad reputation for transporting artefacts and secret objects from distant lands for analysis. Some of these objects and artefacts were even transported without the consent of the local people (Till, 2009). The nature and criticism levied against ethnography makes it unsuitable for application in this research study. This research study is not about the past or the study of the social interaction or behaviours of a group of people in a speech community. Another problem faced by ethnography is that of reliability. Because ethnography occurs in natural settings and focuses on process, it might be difficult to reproduce the event (Nurani, 2008).

Narrative - otherwise called 'story telling' - is the study of stories occurring in historical accounts, fictional novels, fairy tales, autobiographies, artefacts, etc. Each story has a setting in time and place, and reflects the views of the person narrating the story. According to Kramp (2004: p. 104), "*narrative is a vital human activity, which structures experience and gives it meaning*". As a form of literature with a recognisable structure and formal characteristics, narrative fills the gap between "what happened" and "what it means" (Joan Didion, 1961, as cited in Kramp, 2004). Narrative employs the interpretative approach in social science, and a storytelling methodology (Mitchell and Egudo, 2003).

In order to analyse data in narrative research, the story needs to be reorganised in a chronological order. This makes it easy for the researcher to interpret or employ thematic analysis in identifying key themes and/or aspects emerging from the data. The narrative methodology is not suitable for application in research of this nature. Besides the fact that this research study does not focus on historical facts, the narrative methodology has been criticised for lacking validity. According to Polkinghorne (2007: 10), "*the language description given by participants of their experienced meaning is not a mirrored reflection of this meaning*". In the process of telling their stories, it is possible that 'storytellers' consciously (for cultural, political, or economic reasons) or unconsciously leave out vital aspects of the story they are telling the narrator. Even where researchers infer from a text, they may unconsciously leave some key aspects of the story.

This discussion suggests that neither of the aforementioned research methodologies is suitable for application in this research study. Thus, the HM-BSCM, as well as the CSFs and performance measures in HM in IC were developed through grounded theory. However, the case study methodology was applied in the pilot study. Both grounded theory and case study methodologies are examined in detail in sections 4.6.3 and 4.7.

4.5 THE RESEARCH APPROACH

The next step for the researcher after selecting the research paradigm and methodology is deciding on the accompanying research approaches. So far, the decision is between two broad research approaches: the quantitative research approach (associated with positivism) and the qualitative research approach (associated with interpretivism) (Sale *et al.*, 2002). The quantitative research approach involves the study of natural phenomena, expressed in quantitative terms. Quantitative research involves subjecting quantitative data to rigorous quantitative analysis, in a formal or rigid fashion (Goddard and Melville, 2004).

Quantitative research can be sub-divided into the inferential, experimental and simulation approaches to research (Goddard and Melville, 2004). The inferential research approach concerns itself with the creation of a database, from which the researcher can infer the characteristic or relationships of population. An example of an inferential research is survey research. In survey research, the researcher conducts an in-depth study of a sample of the population (through questioning or observation), with the intention of inferring the characteristics of the rest of the population. In the experimental approach, the researcher has much greater control over the research environment. In some cases, the researcher may even decide to manipulate the variables, in order to observe the sought after effects this may have on the other variables. Unlike the inferential and experimental approaches, the simulation approach is neither variable-centred nor case-based (Gilbert, 1995). In simulation research, the researcher working in an artificial environment gathers relevant information and data about a research phenomenon (Goddard and Melville, 2004). The simulation approach is appropriate for researchers interested in building models for the understanding of future conditions.

Qualitative research methods, on the other hand, enable social scientists to study social and cultural phenomena in their natural setting. Because qualitative research is normative in nature, the qualitative researcher collects non-quantitative data, which is often not subjected to rigorous quantitative analysis (Goddard and Melville, 2004). Qualitative research employs techniques such as focus group interviews, projective techniques and in-depth interviews. These techniques bring meaning and understanding to the research question (Malina *et al.*, 2011). Unlike in quantitative research, the sample population in qualitative research does not represent a large population. Instead, the qualitative researcher employs "… *small, purposeful samples of articulate respondents"* (Sale *et al*., 2002). Normally, the respondents of qualitative research are more knowledgeable than the rest of the population about the research phenomena under investigation.

For many years, researchers have had to face the dichotomy of the quantitative/qualitative divide (Johnson and Onwuegbuzie, 2004). This of course has led to the emergence of the mixed research method. Creswell and Clark (2007: 5) defines the mixed research method as "... *a research design with philosophical assumptions as well as quantitative and qualitative methods*". Despite claims that a mixed research approach offers researchers a common working ground, its paradigmatic position is still debated (Buber *et al*., 2004). Some researchers consider the mixed research approach as a methodology, while others consider it as a method or technique (Creswell and Clark, 2007). Since the 70s, the debate about the benefits of the mixed research approach has shifted from 'purity' to 'pragmatism' (Buber *et al*., 2004). In this research study, the mixed research approach is considered as a research technique. Conducting mixed research requires the researcher to have knowledge of multiple methods and underlying assumptions, procedures and analysis. The researcher must also be able to understand and interpret the results of the different methods adopted in the study.

It appears that researchers have realised the need to focus on 'getting the research done' rather than wasting valuable time arguing about the research paradigm of the mixed research approach (Miles and Huberman, 1994, as cited in Buber *et al*., 2004). Although this research study is aligned with interpretivism, it nonetheless mixes qualitative and quantitative research techniques to answer the research questions (see Figure 4-1).

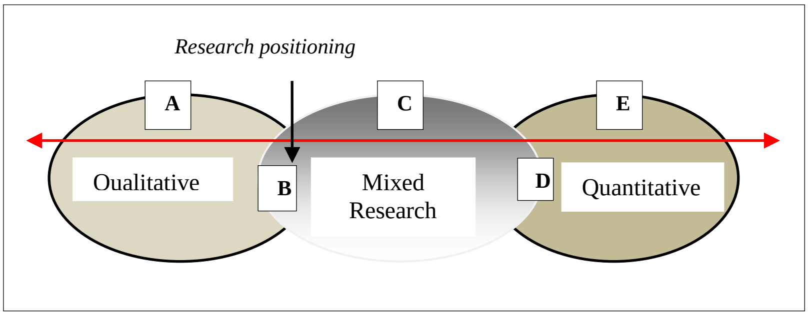

Figure 4-1: The Qualitative – Mixed - Quantitative Inquiry Continuum
(Source: Teddlie and Tashakkori (2008, as cited in Sonubi, 2011: p. 101.)

Areas A, E and C in Figure 4-1 represent the qualitative, quantitative and mixed research approaches respectively. A research study that is located at the end of the continuum (areas A and E) is viewed as either purely qualitative or quantitative in nature. This research study is located in area B. This indicates the fact that qualitative components dominate in this research study. For one of the research objectives, data that was generated through qualitative research approaches was used to develop the Delphi instrument. The Delphi instrument was then used to solicit quantitative data. The data was then analyzed using quantitative research techniques such as standard deviations, means and percentages, etc. The mixing of qualitative and quantitative research techniques in this study was to enhance the understanding of the research phenomena under study.

4.6 THE RESEARCH FRAMEWORK

As shown in Figure 4-2, the research methods applied in this research study are divided into three sections (1, 2 and 3). These are discussed in details in the next sections 4.6.1 – 4.10.1. In the first section, a literature review and qualitative content analysis (QCA) were used to establish the link between HM services and HAIs. The research and interview questions, as well the CSFs and performance measures were also developed through the in-depth literature review and grounded theory analysis (open coding, axial coding, and selective coding). Although there are similarities between QCA and grounded theory analysis, Hsieh and Shannon (2005) treat the two as separate research methods. This is the position held in this research study.

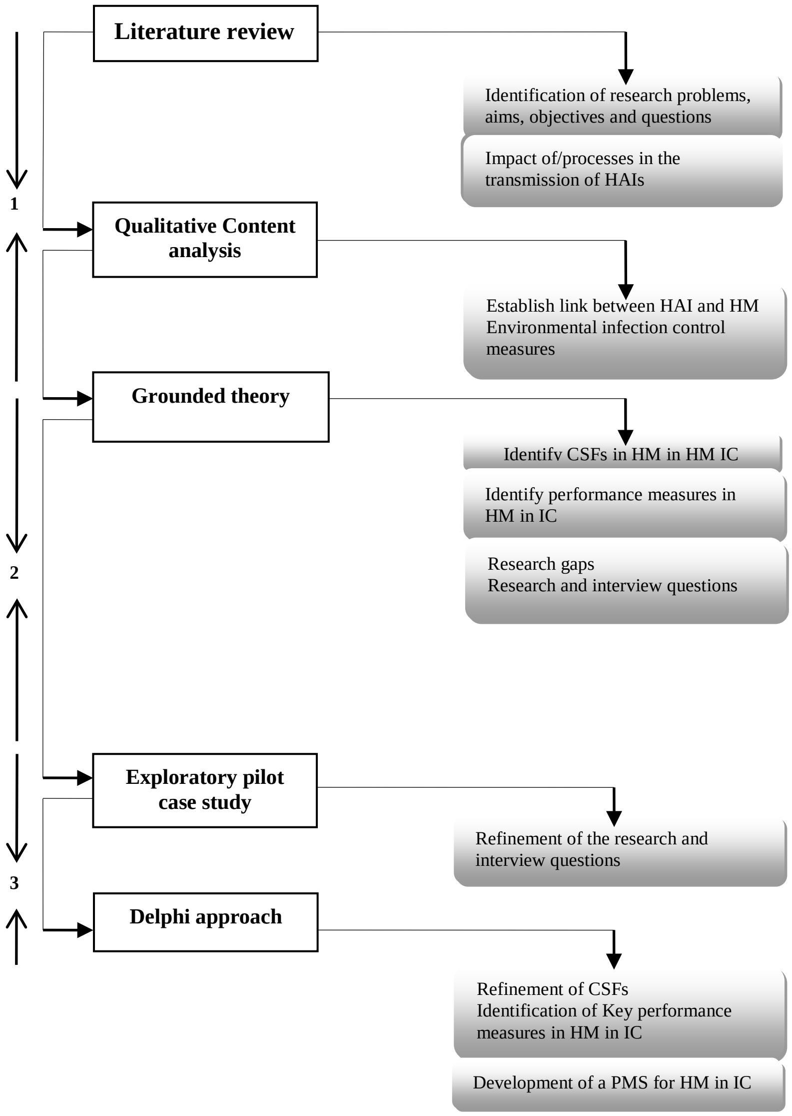

Figure 4-2: The Research Framework

4.6.1 Literature Review

Marrelli (2005: 40) defines the literature review as "*the identification, reading, summarisation, and evaluation of previously published articles books, reports, or internet entries on a particular topic*". Before conducting any literature review, it is necessary to define the criteria that will be used in selecting the research material. In this research study, the research materials were selected using criteria similar to those laid down by Mogalakwe (2006) and Marrelli (2005). According to these authors, all research materials in a study of this nature should be scrutinised for the following:

- Authenticity (any evidence has to be genuine, reliable and from dependable sources)

- Credibility (evidence has to be free from errors and distortions)
- Meaningfulness (evidence must be clear and comprehensible).

The preliminary phase of the literature review involved the reading of research materials drawn from a wide range of sources. Research materials used throughout this research study were categorised into nine different research topics and several sub-categories. The categorisaton of research materials made it easy for the researcher to identify relevant research materials about the subject under investigation. It also led to the identification of the research problems, aims and objectives, as well as the research questions of the research study. As new evidence emerged, the researcher moved back and forth adjusting and refining key elements of the research. The list below shows some of the main research areas covered in this research study.

1. History of FM services in infection
2. FM approaches:
   - Outsourcing,
   - PFI
   - In-house
   - Mixed
3. Impact of HAI:
   - Socio-economic and health cost of HAIs
4. Infection control-related issues:
   - IC practices
   - Hand hygiene
5. Risk management
6. Design and construction
7. Link between FM and HAIs:
   - Cleaning services
   - Waste management
   - Catering
   - Laundry
   - Maintenance
8. Performance-related issues:
   - Performance measurement and management
   - Programs to manage maintenance operations
   - Maintenance strategies

4.6.2 Qualitative Content Analysis: Linking HM with HAIs

In this study, the establishment of the link between HM and HAIs is through the application of qualitative content analysis (QCA) – an inductive approach to content analysis. Hsieh and Shannon (2005: P. 1278) define QCA "*as a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns*". QCA allows researchers to examine speech/texts in their specific context, in order to gain "*better understanding of social reality in a subjective but scientific manner*" (Zhang and Wildemuth, 2008: 1).

To investigate the link between HM and HAIs, certain requirements were put in place for the selection of research materials. This included the use primary research materials focusing on epidemiological issues involving HM services. According to Zhang and Wildemuth (2008), researchers choose samples for QCA purposively. Thus, materials to establish the link between HM and HAIs had to come from clinical databases. However, a search of clinical databases using the terms *maintenance* and *HAIs* did not produce significant results. Therefore, the search was extended to include words like *construction, renovation, building, refurbishment* and *demolition,* etc. These words are used interchangeably by clinicians to refer to construction-related work. One common feature of all of these construction-related activities is that they generate dust, which may contaminate the healthcare built environment. A comprehensive search of the databases using the aforementioned key words led to the identification of a few more research materials. In total, eleven key research documents were specifically selected for providing epidemiological evidence of the link between HM and HAIs. This small number of research documents indicates that this area of research has not been thoroughly examined.

Because of the small number of research materials, coding was done manually. This dealt with only the manifest content of the research materials. Manifest content refers to words that are literally present in the documents, i.e. large pieces of data (word, phrases, sentences, paragraphs, etc) (Kondracki *et al*., 2002). As shown in Table 3-2, the research materials were coded into the following categories: author, maintenance activity, area/unit, transmission route, results, and conclusions. Each of these categories holds valuable information that demonstrates the significance of HM services in the control of HAIs. For example, the category labelled 'maintenance activities' contains information relating to the type of maintenance activities (e.g. work on hospital roofs and air handling systems, leaking sinks, electrical wiring, plumbing, or structural alterations, etc) associated with the transmission of HAIs in hospitals. These maintenance activities pose a risk of HAIs to patients located in areas such as eye theatres, neonatal intensive care units and operating rooms. On the other hand, the category labelled 'transmission route' provides information on how these infections occur, e.g. from dust contamination, wet structures, etc. The 'result' category indicates where (eye theatre, neonatal intensive care unit, etc) and how many patients were infected with maintenance-associated HAIs. The 'conclusion' category contains information on the prevention and control of maintenance-associated HAIs in critical patient areas/units.

4.6.3 Grounded Theory: Selection of Documents

Grounded theory has its roots in sociology. It was developed by Glaser and Strauss from the University of California in the 1950s (Petty *et al*., 2012). According to Cope (2009: p. 647), grounded theory involves at its heart "*a set of strategies, tools, and central principles that aid researchers in doing inductive, reflexive, and rigorous analysis of data*". Although grounded theory is considered by many as an analytical technique, it nonetheless can be used in almost all the areas of research. Bitsch (2005) describes grounded theory as the metaphor of qualitative research. One of the major strengths of grounded theory is in the fact that it ensures critical thinking and discovery without prior knowledge (Jones *et al.*, 2005). Grounded theory is useful in research of this nature with few research materials focusing on the subject of performance measurement and management in HM in IC. In this research study, data was gathered from many sources, without any preconceived notion of what the research and interview questions were. However, the researcher's professional knowledge and priori-knowledge about the NHS were crucial during the initial phase of the research project. In grounded theory, this is referred to as 'theoretical sensitivity', i.e. the ability of the researcher to think about data in theoretical terms (Bitsch, 2005).

In this research study, extensive research material was collected and interpreted with an open mind. As key aspects of the research developed, they were tested and refined several times. In grounded theory, this is referred to as the 'constant comparison' method. Coding is an important research tool which is used in grounded theory to identify key themes emerging from the analysis of data. Besides the benefit of organizing and categorising data, coding also allows researchers to draw insights from the patterns and core themes that emerge from this process (Cope, 2009). As new evidence emerges, the researcher continuously re-evaluates and codes data. Once it is clear that no further patterns or themes are emerging from the coding of data, the researcher then develops a theory that is 'grounded' in the phenomenon.

In recent years, it has become common practice for researchers to state whether they are applying the Glaserian or Straussian analytical method in grounded theory. After Barney Glaser and Anselm Straus developed the two fundamental variants of grounded theory - theoretical sampling and constant comparison - both moved their separate ways. In later years, differences in their experiences and perspectives led to two different methods of analyzing data in grounded theory (Cooney, 2010). The point of contention between Glaser and Strauss relates to whether verification should be an outcome of grounded theory analysis or not (Cooney, 2010). Glaser remained faithful to grounded theory, maintaining that induction is the only way of conducting grounded theory. Working in collaboration with Corbin, Straus insisted that induction, deduction, and verification were equally important in grounded theory. Whereas Glaser describes two approaches in coding data - substantive and theoretical coding -, Strauss and Corbin describe three – open, axial and selective coding. Since Straussian grounded theory provides explicit guides for data analysis (Cooney, 2010), it will be the preferred method applied in this research.

Grounded theory analysis is used in this research to identify the CSFs and performance measures in HM in IC. This of course requires the identification and selection of appropriate research material for coding. Prior knowledge is acquired from the QCA process to establish the link between HM and HAIs. The research materials used in conducting the QCA were added to those in grounded theory analysis. As shown in Table 4-2, 27 research materials were used in the grounded theory analysis. Clinical research materials were categorised under 'clinical peer reviewed journals'. Peer-reviewed journals refer to research materials that have undergone scrutiny by experts before publication. These peer-reviewed journal papers contain rich information on the control and prevention of HAIs in HM. In total, ten clinical peer-reviewed journal papers were considered for grounded theory analysis.

Table 4-2: Assigning Codes to the Research Materials

Literature Type	No	Title	Publishing Body	Year	Assigned Codes
Government Documents	1	Reducing Healthcare Associated Infection in Hospitals in England	House of Commons	2009	***GD-1***
	2	The Health and Social Care Act 2008: code of practice for the prevention and control of healthcare associated infections and related guidance	Department of Health	2009	***GD-2***
	3	Improving Patient Care by Reducing the Risk of HAI: A progress report	National Audit Office	2004	***GD-3***
	4	Towards Cleaner Hospitals and Lower Rates of Infections	Department of Health	2004	***GD-4***
	5	Winning Ways: working together to reduce HCAI in England	Department of Health	2003	***GD-5***
	6	Getting Ahead of the Curve: a strategy for combating infectious diseases	Department of Health	2002	***GD-6***
	7	The Management and Control of HAI in the NHS Trusts in England	National Audit Office	2000	***GD-7***
Health Care Maintenance Policies	8	Maintenance Policy for Estates: (including Planned & Preventative)	NHS Plymouth	2011	***HM-8***
	9	Estates Services Management Policy	Berkshire NHS Trusts	2011	***HM-9***
	10	Infection Control in the Built Environment Policy: (A Guide for Estates, Infection Control & Property Services, Capital Planning Teams, Managers & Clinical Teams)	NHS Fort Valley	2010	***HM-10***
	11	Estate Maintenance Policy	Northamptonshire NHS Trust	2010	***HM-11***
	12	Policy for the Maintenance of PCT Premises	NHS Kirklees	2009	***HM-12***
	13	Estates Maintenance Policy: (Including Planned Preventative Maintenance)	Yeovil NHS Foundation Trust	2009	***HM-13***
	14	Policy for Planned Preventative Maintenance – Estates: (Required by Health Act 2006)	5 Boroughs Partnership NHS Trust	2009	***HM-14***
	15	Estates Maintenance Policy	NHS Shetland	2008	***HM-15***
	16	Estates & Facilities Management General Policy	South Tees NHS Trusts	2008	***HM-16***
	17	Infection Control Guidelines for Maintenance Staff: (Estates, Facilities, Hotel Services)	Barnet, Enfield & Haringey NHS Trust	2004	***HM-17***
Clinical Peer-Reviewed Journals	18	Airborne Aspergillus contamination during hospital construction works: Efficacy of protective measures	Association for Professionals in Infection Control and Epidemiology	2010	***CR-18***
	19	Prospective survey of indoor fungal contamination in hospital during a period of building construction	Journal of Infection Control	2007	***CR-19***
	20	Undetected Bacillus pseudo-outbreak after renovation work in a teaching hospital	British Infection Control Society	2006	***CR-20***
	21	A cluster of deep bacterial infections following eye surgery associated with construction dust	The Hospital Infection Society	2006	***CR-21***
	22	Fungal contamination of air conditioning units in operating theatres in India	Journal of Hospital Infection	2005	***CR-22***
	23	Outbreak of Invasive *Aspergillus* Infection in Surgical Patients, Associated with a Contaminated Air-Handling System	Clinical Infectious Diseases	2003	***CR-23***
	24	Demolition of a hospital building by controlled explosion: the impact on filamentous fungal load in internal and external air	Journal of Hospital Infection	2002	***CR-24***
	25	A Cluster of Invasive Aspergillosis in a Bone Marrow Transplant Unit Related to Construction and the Utility of Air Sampling	Division of Infectious Diseases, University of Massachusetts	2001	***CR-25***
	26	A prospective study on factors influencing aspergillus spore load in the air during renovation works in a neonatal intensive care unit	Journal of Hospital Infection	2000	***CR-26***
	27	Air sampling for Aspergillus spp. during building activity in a paediatric hospital ward	Department of Microbiology Yorkhill NHS Trust	1995	***CR-27***

Further literature review led to the categorisation of research materials into two additional groups: government documents (guidelines, regulations), and healthcare maintenance policies (from NHS Trusts). Government documents refer to informational materials published by government bodies and agencies on IC. Examples of such government bodies and agencies include the Department of Health, National Audit Office, British Medical Association, Parliamentary Office of Science and Technology and the House of Commons, etc. Generally, government publications can take the form of books, pamphlets, periodicals, internal sites and DVDs, etc. A search of these databases did not produce many documents focusing on maintenance-associated HAIs. As a result, only seven government documents were selected for grounded theory analysis.

Healthcare maintenance policies (HMPs) of individual NHS Trusts were also selected for grounded theory analysis. The Universal Dictionary (1987: 1194) defines policy "*as an overall plan or course of action adopted, as by ...business organisation* [a hospital], *designed to influence and determine immediate and long term decisions or actions*". HMPs cover a wide range of maintenance-related issues like maintenance strategies, statutory compliance in IC and water safety plans, etc. Strategically, the HMP is supposed to be linked to the mission and objectives of the NHS Trusts. HMP is about what management expects maintenance employees to do (Coetzee, 1999). It is therefore logical to assume that HMPs contain valuable information in the identification of the CSFs and performance measures in HM in IC. A search of NHS Trusts websites found fifteen HMPs. However, because five of these HMPs did not contain sufficient information on IC, they were excluded from the grounded theory analysis.

4.6.3.1 Open Coding – Identifying the Critical Success Factors (CSFs) in HM in IC

After the document selection process, the next step in grounded theory is called open coding. Strauss and Corbin (1990: p. 61) define open coding as "… *the process of breaking down, examining, comparing, conceptualizing, and categorising data*". Through the technique of open coding, researchers are able to identify and develop categories and subcategories in terms of their properties and dimensions.

In this research, the process of open coding was carried out through the application of qualitative content analysis software called QRS NVivo7. The software makes it easy to work with multiple documents, whilst at the same time organising, managing, and coding qualitative data in an efficient way. Through QRS NVivo 7, researchers are also able to edit text, take notes and make memos, create nodes and categories, as well as retrieving text. The software also has a visual representation function, which enhances the impression of the interrelationships between nodes. For example, in this research study, to get a better understanding of the data analysis, colours were employed to differentiate the various nodes.

In total 27 documents were loaded onto QRS NVivo7. Whilst going through the documents, several questions pertaining to the purpose of the coding exercise and relevance of research material were frequently asked (i.e. in terms of IC). This keeps the attention of the researcher focused at all times on the subject under investigation. In-depth analysis of the research materials provided sufficient information for unravelling some of the intricacies of the CSFs and performance measures in HM in IC. Figure 4-3 shows how the documents were classified. A parent node is like a container in which different themes (words, sentences, ideas or paragraphs) with similar connotations are coded. On many occasions, as new information emerged from the documents, a 'parent node' was combined with another; or its name refined or deleted altogether. The process only stopped when it became clear that all the 'parent nodes' had been identified. As shown in Figure 4-3, eight NVivo 'parent nodes' were identified through open coding. This was further refined as follows:

1. Maintenance strategies
2. Risk assessment
3. Infection control practices
4. Liaison and communication with the infection control team (ICT)
5. Service level agreements (SLA)
6. Customer satisfaction
7. Staff Education
8. Maintenance resources

Nodes

Name	Sources	References
Maintenance Strategies	7	22
Risk Assessment	6	11
Infection Control Practices	20	71
— Cleaning Practices	6	7
— Hand Hygiene	4	7
— Maintenance Staffs Practices	6	17
— Management Requirements	9	23
— Transportation Practices	1	3
— Ward Practices	10	14
Liaising & communication	9	20
SLA	7	12
— Contracted Staff Requirement	2	2
— Contractor Capability Requirement	3	4
— NHS Trusts Requirement	3	5
Patient Satisfaction	1	1
Education and Development	11	21
— Development	1	1
— Education	10	20
Resources	5	10

Figure 4-3: Axial Coding - 'Parent and Child' Nodes

4.6.3.2 Axial Coding – Identifying the Performance Measures in HM in IC

Axial coding involves the examination of the relationships, interactions and cause-and-effect-relationships between categories and sub-categories (Mehmetoglu and Altinay, 2006). In axial coding, it is still possible for researchers to develop child nodes from the parent nodes, which are developed through open coding. As shown in Figure 4-3, during axial coding, 'child nodes' were developed for some of the 'parent nodes'. For example, for the 'parent node' infection control practices, six 'child nodes' were identified i.e. cleaning practices, hand hygiene and maintenance staff practices, etc. After the development of the 'child nodes', specific-related themes identified in the source documents were coded therein. Figure 4-4 exemplifies the coding of themes into one of the 'parent nodes' (Resources). In this research, the 'parent nodes' and 'child nodes' were refined and modified several times.

Name: Resources

<Internals\\GD-2> - § 1 reference coded [0.04% Coverage]

Reference 1 - 0.09% Coverage

sufficient resources dedicated to keeping the environment clean and fit for purpose; and d

<Internals\\HM-13> - § 1 reference coded [0.62% Coverage]

Reference 1 - 1.24% Coverage

Monthly reports shall be provided to assess trends, accruals, commitment and expenditure against budget. The budget shall be reviewed monthly and set annually to include cost improvement programme (CIP) targets and the reporting of cost pressures.

<Internals\\HM-14> - § 1 reference coded [0.06% Coverage]

Reference 1 - 0.13% Coverage

resources,

<Internals\\HM-15> - § 2 references coded [0.28% Coverage]

Reference 1 - 0.28% Coverage

reviews of maintenance needs are undertaken at intervals not exceeding 12 months.

Reference 2 - 0.29% Coverage

adequate resources are made available for the effective achievement of this Policy.

<Internals\\HM-8> - § 5 references coded [1.14% Coverage]

Reference 1 - 0.37% Coverage

obtains cost effective and professional maintenance services, which make best use of available funds;

Reference 2 - 0.74% Coverage

regularly reviewing the condition of NHS Plymouth buildings services and infrastructure to feed into investment programmes and discussions on the maintenance investment needed to maintain the estate;

Reference 3 - 0.16% Coverage

annual reviewing of maintenance activities.

Reference 4 - 0.28% Coverage

Monthly reports shall be provided to assess trends, accruals, commitment and

Reference 5 - 0.74% Coverage

Undertake an ongoing review of the SLA and contract arrangements in place to take account of changes in assets and legislation, and to ensure equipment failures shape future maintenance arrangements;

1 / 1

Figure 4-4: Coding of Themes in the 'Resources' Node

4.6.3.3 Selective Coding – Categorisation of CSFs and Performance Measures

The process of selective coding involves integrating parent and child nodes with a central concept, and providing sufficient detail and density for the evolving theory (Bitsch, 2005: 79). The 'child nodes' that were developed in this research helped provide deeper understanding and clarity about the 'parent nodes'.

In this research study, the eight 'parent nodes' (i.e. resources and maintenance strategies, etc) identified through QRS NVivo7 were interpreted as the CSFs in HM in the control of HAIs. Conversely, the themes coded therein are considered as the performance measures. However, as shown Table 5-4, the CSFs and performance measures identified in the literature were subsequently modified. In total, fifty-six performance measures were identified in the literature. The process of selective coding suggested categorising the CSFs and performance measures according to the four perspectives of the balanced scorecard (BSC). These four perspectives are financial, internal business processes, innovation and learning, and customers. The four perspectives of the BSC are discussed in detail in Chapter 5.

4.7 THE CASE STUDY METHODOLOGY

After the identification of the CSFs and performance measures, the next step in the research process was piloting the research and interview questions. The pilot study was conducted through the application of the case study methodology. Yin (1989) defines the case study as an "*empirical inquiry that investigates a contemporary phenomenon within its real life context using multiple sources of evidence*". In a case study, it is important to define the 'case' right at the beginning of the research. A 'case' refers to an event, entity, individual, or a unit of analysis. In many social science research projects, it denotes a small geographical area or number of individuals (Zainal, 2007). According to Flyvbjerg (2006), the generalisability of case studies can be increased depending on the strategic selection of cases. This author identifies two main strategies in the selection of cases: random selection and information-oriented selection.

The rationale for random selection is to avoid systematic biases in the sample. Random selection can be either random or stratified. Whereas in random sampling findings may be generalised for the entire population, in stratified sampling they may only be generalized for a specially selected sub-group of the population. In information-oriented selection, small samples and single cases are selected based on the amount of information they hold. Once the case(s) have been identified and the decision to use case study to answer the research questions has been made, Baxter and Jack (2008) recommend that the case(s) be 'ring fenced'. Boundaries could be delimited according to time, place, activity, definition or context. This helps the researcher save time, and indicates the breadth and depth of the research study.

It is also important at this stage to decide on the type of case study. According to Yin (1993: 5), researchers should ask themselves the following questions: is the study describing, exploring, or comparing two cases? There are three types of case study, namely descriptive, exploratory, and explanatory (Yin, 1993). A descriptive case study is suitable in investigating particular issues or behaviour, with the aim of providing better understanding of occurrences. According to Yin (1993: 5), a descriptive case study is "*... used to describe an intervention or phenomenon and the real-life context in* *which it occurred*". Because descriptive case studies sometimes face the challenge of credibility, it is necessary for researchers to back up the data collected with some form of descriptive theory (Zainal, 2007). This will inevitably provide rigour to the data used to describe the phenomenon under study.

The exploratory case study is used to "*explore those situations in which the intervention being evaluated has no clear, single set of outcomes*" (Yin, 1993: 5). The exploratory case study is also used to describe a process in which the researcher conducts fieldwork and collects data, prior to the final definition of the research question and hypothesis (Yin, 1993). Employing the exploratory case study to conduct a pilot study does not necessarily mean that it will be used to investigate the final research questions and hypotheses. Preliminary results of the pilot study may indicate the need for a research method that is completely different from the case study. Although the exploratory case study is useful in preparing the research framework and protocol, Yin (1993) blames it for the notorious reputation suffered by all case study research. Unlike an exploratory case study, the explanatory case study is used to provide answers to "*research questions that sought to explain the presumed causal links in real-life interventions that are too complex for the survey or experimental strategies*" (Yin, 1993: 5). The examination of the data in an explanatory case study is done at the surface and deep levels, in order to explain a phenomenon within the data (Zainal, 2007).

Another important task in case study research is deciding whether the phenomenon under investigation is best understood through single or multiple case studies. According to Yin (1994, as cited in Darke *et al*., 1998) a single case study is suitable for research that represents "*a critical case (where it meets all the necessary conditions for testing a theory), where it is an extreme or unique case, or where it is a revelatory case*". Research of this nature, for which there are no other cases for replication, is called a holistic single case study (Yin, 2003). However, it may also be called a holistic case study with embedded units if the researcher also examines the sub-units within the larger case (Yin, 2003). This allows data in the different units to be analysed separately (within case analysis), between the different sub-units (between case analysis) or across all of the sub-units (cross-case analysis) (Baxter and Jack, 2008).

In research that looks at more than one case, Jack and Baxter (2008) recommend the use of multiple-case studies. There are no simple answers to the number of cases to be included in a multiple-case study (Rowley, 2002). Because multiple-case studies allow researchers to analyse within each setting and across settings, there is a better understanding of the similarities and differences that exists between the cases. According to Yin (2003, as cited in Jack and Baxter, 2008: p. 550), multiple-case studies can be used either "(*a) [to] predict … similar results (a literal replication) or (b) [to] predict… contrasting results but for predictable reasons (a theoretical replication)*". Although carrying out multiple-case studies is time-consuming and expensive, the results obtained are often considered robust and reliable (Jack and Baxter, 2008).

Case study research uses quantitative and/or qualitative approaches (Rowley, 2002). In a case study, data may be gathered through the application of one of the following techniques: interviews, observations, questionnaires, or document and text analysis (Darke *et al*., 1998). In this research study, the decision was between the following interview designs: structured, semi-structured, and unstructured interviews. According to Polit and Beck (2006, as cited in Whiting, 2008: p. 35), an interview is "*a method of data collection in which one person (an interviewer) asks questions of another person (a respondent)...*" In the unstructured interview, the researcher has a plan of action, but little control over the respondent answers. Although unstructured interviews may lead to the collection of rich data, they may also lead to the collection of a large amount of undesired data. In an exploratory study of this nature, with limited time, unstructured interviews may not be a suitable option. In contrast, structured interviews use a questionnaire format to ask respondents fixed questions, in a specific order. According to Harrell and Bradley (2009: 27), "*semi-structured interviews are often used when the researcher wants to delve deeply into a topic and to understand thoroughly the answers provided*".

Despite the advantages of the case study, it has received some criticisms. Many have accused the case study methodology of a lack of rigour and a basis for scientific generalisation. Most case studies only employ a small number of cases, which makes generalisation difficult.

4.7.1 Data Collection and Analysis

In a study of this nature, which attempts to gain answers to 'why' and 'how' questions, and in which the researcher cannot manipulate the behaviour of participants, Yin (1989) recommends the use of the case study approach. The case study approach makes it possible for a research topic to be seen through many lenses. Through the application of the case study, it is hoped that the researcher will be able to unveil many of the complex issues surrounding the performance of HM services in the control of HAIs in the NHS. Information gathered through this process helped in the further refinement of the research and interview questions. As pointed out earlier, there are not many research materials focusing on this research topic. The research is also multidisciplinary in nature, and research materials are collated from many sources, i.e. clinical and non-clinical.

In this research study, two NHS Acute hospitals in the North West were randomly selected for conducting the pilot study. As this was only a pilot study, the two pilot cases were selected from the North West for the sake of convenience. The decision to select multiple cases was to check whether the phenomena under investigation were consistent across NHS Acute hospitals. Both NHS Acute hospitals have a capacity of over six hundred beds, and employ over thirty HM staff. The pilot study was designed to solicit information from members of the infection control team (ICT) and HM managers. However, the pilot study started with HM managers, to assess their level of understanding of IC issues.

In research of this nature, with little literature, the application of the exploratory case study helped the researcher gather preliminary knowledge about the phenomenon under investigation. Data was collected in the pilot study through semi-structured interviews. The choice of semi-structured interviews over structured interviews is because of the flexibility it offers researchers. Through its application, researchers are able to approach respondents differently, while at the same time covering the same area of data collection (Noor, 2008). The pilot interviews were conducted face-to-face at the respondents' place of work and recorded digitally. Table 4-3 shows the four research questions and seventeen interview questions employed in the exploratory case study.

Table 4-3: Research and Interview Questions

Research Questions identified from the literature review	**Interview questions**
A. Do HM managers manage the performance of their services in infection control?	1. Can you describe the vision, strategy, and objectives of your NHS trusts in infection control? 2. Can you describe the vision, strategy, and objectives of the FM directorate in infection control, and how are they aligned to those of the NHS trust? 3. Does the HMS have a mission statement in infection control? 4. What are the key issues in infection control addressed by the mission statement? 5. How are these issues addressed in the mission statement aligned to the strategy of NHS trust/FM directorate in infection control?
B. Do HMUs have performance management frameworks to measure performance in infection control? C. What form of PMF will HMUs adopt in infection control?	6. Has the healthcare maintenance unit (HMU) identified its maintenance activities in infection control? 7. Can you identify these maintenance activities? 8. Does the healthcare maintenance division categorize critical success factors and measures according to the four perspective of the BSC? 9. What are the critical success factors in healthcare maintenance in infection control? 10. List the performance measures in infection control for each key performance indicator
D. What are the key performance management goals and measures in HM in the control of HAIs in the NHS?	11. Has the healthcare maintenance division formulated goals for the performance indicators and measures? 12. What are the goals of the HMU for the different performance indicators and measures in infection control? 13. How are these goals aligned to the overall strategy of the NHS trust/FM directorate in infection control? 14. Has the HMU set strategic objectives and targets to be met in line with the different performance indicators in infection control?
E. Do the HMU liaise with other stakeholders in the identification of CSFs and performance measures in IC?	15. Does the healthcare maintenance division liaise with relevant stakeholders in developing performance indicators and measures? 16. Who are these relevant stakeholders? 17. What role do they play in identifying performance indicators and measures in infection control?

To capture all relevant information derived from the interviews, conversations were digitally recorded. In order to facilitate reference and compilation, the interviews were labelled according to date, job description, and name of NHS Trust. The recorded data was then transcribed and stored in a Word document. Because of the small number of cases, the results obtained from the pilot case study were analysed manually. The results of the pilot case study pointed to two important issues. Firstly, it revealed that some HM managers did not have the required knowledge in IC to participate in this research study (see Table4-4). For example, two HM managers interviewed in the pilot study could not state the vision of their respective NHS Trusts in IC. In addition, in both NHS Acute hospitals, managers did not measure performance in IC. They only applied minimum levels of performance measurement for IC, in order to achieve legislative compliance.

Table 4-4: Analysis of the Pilot Case Study Results

	Case 1				**Case 2**			
Interview questions	**No**	**Yes**	**Some**	**Remark/indicators/measures**	**No**	**Yes**	**Some**	**Remark/indicators/ measures**
A1	√			According to respondents, this was the responsibility of members of the infection control team	√			Manager generally did not understand the meaning of 'vision', 'mission statement' and 'objectives'
A2	√				√			
A3	√				√			
A4	√				√			
A5	√				√			
B6			√		√			
B7			√	Hand-washing compliance, legislative compliance	√			
B8	√				√			
B9	√				√			
B10	√				√			
C11	√				√			
C12	√				√			
C13	√				√			
C14	√				√			
D15	√				√			
D16				Infection control team				Infection control team
D17			√	Advice on infection control, organise workshop on legionnaires 'disease			√	Advice on infection control issues

The results of the pilot study also showed the extent of what this research study was trying to achieve within a very limited period. Thus, instead of trying to address all the gaps identified in the literature and thus develop a performance measurement framework (PMF), the decision was taken to focuses on identifying the CSFs and performance measures in HM in IC. This was achieved through the application of the Delphi technique. The Delphi technique mitigates some of the weaknesses of the case study approach by making it possible for researchers to select the research participants (i.e. HM managers) according to their level of professional experience and knowledge in IC.

4.8 THE DELPHI APPROACH

Gupta and Clarke (1996: 185) define Delphi as "*a qualitative, long-range forecasting technique, that elicits, refines, and draws upon the collective opinion and expertise of a* *panel of experts*". Named after the Greek oracle, the popularity of the Delphi technique has since grown, following the work of Helmer and Dalkey in 1963. Currently the Delphi technique is widely applied across many disciplines, in the private and public sectors (Gordon, 1994). Areas identified by Gupta and Clarke (1996) for the application of the Delphi technique include, but are not limited to business, education, healthcare, real estate, engineering, environment, social science, tourism and transportation.

Since 1963, the Delphi technique has undergone a number of modifications. According to Collier (2006), significant modifications have produced three types of Delphi: numeric, policy, and historic. Others writers like Hanafin (2004) refer to classical, policy and decision Delphi. The word 'hybrid' Delphi is also used by Faucher *et al*. (2008) to describe a combination of any of these three types of Delphi.

In a classical Delphi, there is anonymity, iteration, controlled feedback, statistical group response, and stability in the responses experts provide on a specific issue. The classical Delphi is similar to the numeric Delphi described by Collier (2006). The central thesis of the policy Delphi is to not only reach consensus, but also rather, to generate policy alternatives through structured public dialogue. In the policy Delphi, there are polarised group responses and structured conflict (Hanafin, 2004). As the name implies, decision Delphi is concerned with decisions relating to social development. Participation in the decision Delphi depends on one's position in the hierarchy. Although questionnaire responses are anonymous in decision Delphi, participants know the names of all those participating in the study.

Despite trivial differences, all three types of Delphi share some common features. According to Faucher *et al*. (2008), it is an expert-based process, a managed process, an anonymous process, an indirect interactive process, an iterative process, a controlled feedback process, an aggregative process, and a potentially asynchronous process. Since this research aims at identifying the key performance measures in HM in IC, it was conducted through the classical Delphi approach.

Although Delphi started as a technique for futures research, many researchers use it today to deal with complex issues (Linstone and Turloff, 1975, as cited in Green *et al*., 1990). The fact that Delphi is an adaptable and flexible research method means that it can be applied across many disciplines (Skulmoski *et al*., 2007). Nonetheless, researchers have to make sure Delphi suits their research needs. According to Perez and Schuler (1982: p. 160), Delphi is appropriate in research where there is the lack of solid information about the research phenomenon or problem under investigation. In this research, a thorough search of the databases did not identify many studies on the subject of performance measurement in HM in IC in the NHS. Where researchers have investigated this area, they have mostly focused on clinical and financial issues. This is corroborated by the findings of the pilot study, which found HM managers did not measure performance in IC. In contrast to the case study, the Delphi approach allows researchers to recruit professionals who then "*focus their collective human intelligence on the problem at hand*" (Linstone and Turloff, 1975, as cited in Skulmoski *et al*., 2007: p. 2). Besides offering anonymity to respondents, Delphi also makes it possible for researchers to recruit professionals from a wide geographical area. According to Kalaian and Kasim (2012: p. 2), this "*provides in-depth anonymous information about the problem or issue under consideration*".

4.9 THE DESIGN OF THE DELPHI STUDY

The Delphi process started with the in-depth literature review in order to develop the Delphi instrument. The various steps in identifying and developing the Delphi instrument are discussed in sections 4.6.2 and 4.6.3. After the research instrument had been piloted and refined, the Delphi exercise itself started. A review of the literature suggests that the numbers of rounds in most Delphi studies are variable. According to Skulmoski *et al*. (2007) and Keeney *et al*. (2001), this depends on the time, purpose and nature of the study. Typically, three rounds of Delphi would be suitable for most studies (Delbecq *et al*. (1975, as cited in Skulmoski *et al*., 2007). In their studies, researchers like Dixon *et al*. (2009), Mcintyre *et al*. (2010), Smart *et al*. (2010), Landeta (2006) and Dixon *et al*. (2006) conducted three rounds of Delphi exercises. Since a three round Delphi appears ideal for most studies, this research study also had three Delphi rounds.

Figure 4-5 shows the various processes involved in the application of Delphi in this research study. There are three Delphi rounds for identifying the CSFs and performance measures in HM in IC. The first round of the Delphi exercise solicits qualitative responses, while the second and third solicit quantitative responsive from the Delphi participants (see Appendixes D, F, and H).

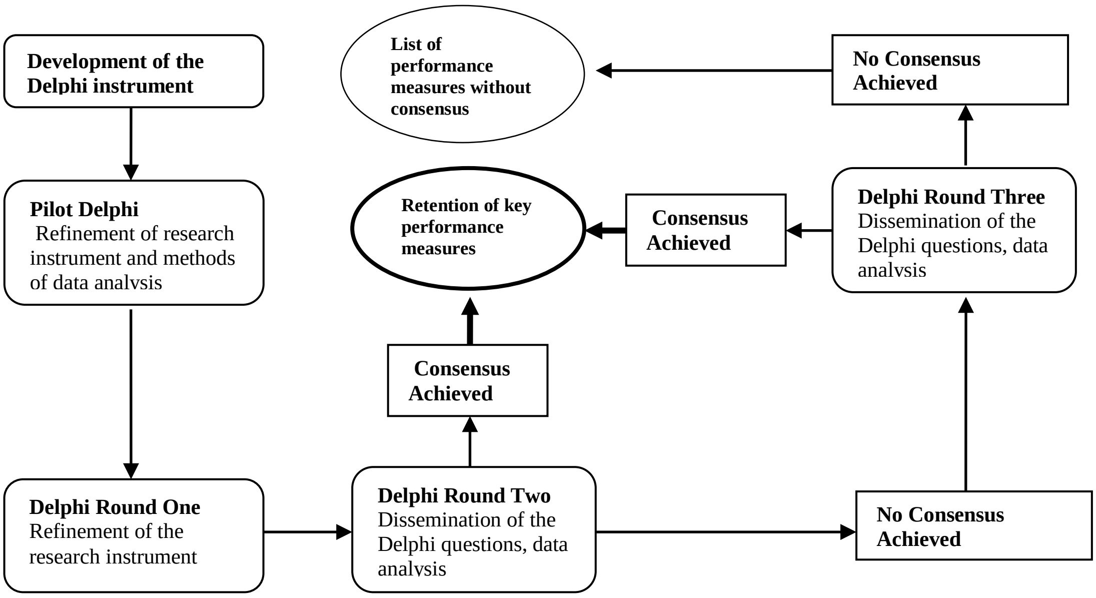

Figure 4-5: A Three-Round Delphi Process

4.9.1 The Construction of the Delphi Instrument

The design of the data collection instrument plays a critical role "*for both the exploration and distillation*" phases of the Delphi exercise (Day and Bobeva, 2005: 109). According to Day and Bobeva, creativity ensures that the Delphi questions meet the communication needs of the Delphi participants. Obviously, particular attention should also be given to the structure, length, and content of the Delphi instrument.

There are two main methods in developing the Delphi research instrument. The first method is an inductive approach, whereby members of the panel freely generate new ideas about the topic (Powell, 2003). According to Millar (2000, as cited in Hanafin, 2004) this method takes too much time to analyse, and does not generate the kind of rich information that an in-depth literature review would do. In the second method, the researcher generates ideas through the application of a qualitative research method like a literature review. As shown in Appendix D, the round one Delphi questions were developed mainly from the literature. This method saves time, and acts as a stimulus for the Delphi participants to identify new CSFs and performance measures. The performance measures identified from the literature were categorised under eight CSFs. These were then used to develop the Delphi instrument, which was piloted with healthcare maintenance managers (HM managers) and infection control members with the required knowledge of the subject matter. The purpose of the pilot Delphi study was to solicit suggestions about the presentation, wording and structure of the Delphi instrument. Through the pilot study, it was possible to test the appropriateness of the data analysis technique. The results obtained from the pilot study were used to improve the overall quality of the Delphi instrument. The three rounds of the Delphi instrument used with the participants were accompanied with detailed instructions on how to complete and return the Delphi instruments. Because the Delphi participants came from varied professional areas, the instruction notes also contained the definition of key words used in the Delphi instrument (copies of the Delphi instructions are provided in Appendixes C, E, and G).

The first round Delphi instrument was designed to elicit qualitative responses from the Delphi participants. The Delphi instrument was divided into three main sections. In the first section, the Delphi participants were asked questions about their professional experience and area of specialisation. One of the main criteria for nominating the Delphi participants was length of professional experience. The second section contained a list of performance measures, which were categorised according to the eight CSFs in HM in IC. To provide better understanding and clarity, some of CSFs were divided into sub-categories. For example, the CSF called ‘infection control practice’ has three sub-categories of performance measures: cleaning, transport, and administrative requirements. The Delphi participants were provided with a list of CSFs and performance measures in HM in IC, and given the task of identifying new ones. Section three of the round one Delphi instrument also solicited feedback from the Delphi participants on the design, presentation, and wording of the Delphi instrument. Information gathered from the round one Delphi exercise was used to modify the second Delphi instrument. Rounds two and three of the Delphi instrument were designed to elicit quantitative responses from the Delphi participants.

4.9.2 The Selection of the Delphi Participants

One of the most important steps in a Delphi study concerns the nomination of participants (Hallowell and Gambatese, 2010). This is because the credibility and reliability of Delphi studies depends on the quality of the participants selected (Keeney *et al.*, 2000). However, it appears there are no exact criteria listed in the literature for the nomination of the Delphi participants (Hsu and Sandford, 2007). Hallowell and Gambatese (2010) describe the characteristics used to define 'experts' as equivocal in nature. One criterion used commonly by researchers is level of expertise.

Generally, Delphi participants are supposed to be individuals who are directly affected by the research, have knowledge and experience, and are facilitators in the field of study (Day and Bobeva, 2005). Criteria proposed by Day and Bobeva include authorship, conference presentations and committee membership, etc. Irrespective of the nomination criteria employed in a study, researchers still have to make sure the Delphi participants are unbiased, as this has the potential to affect the generalisability of the results (Hallowell and Gambatese, 2010).

In this research study, the Delphi participants were purposively selected on the basis of their experience and knowledge of HM and IC. Since Delphi relies on expert opinion for credibility, stringent criteria were used for the selection of prospective Delphi participants. Prospective Delphi participants were considered eligible if:

1. They were people who were experiencing and labelling the reality under investigation. In this research study, this includes HM managers and infection control members (i.e. infection control nurses and microbiologist).
2. They occupied the position of HM manager or IC member in an Acute NHS Trust, and had work experience in the same role for at least five years.

After stating the criteria for the selection of the Delphi participants, the next step was deciding on the number of Delphi participants. It appears that no consensus exists on the optimum number of Delphi participants in a study (Hsu and Sandford, 2007). According to Hallowell and Gambatese (2010), the characteristics of the Delphi study (i.e. available experts) should dictate the number of the Delphi participants. The lack of a standard for the number of participants means "*…representativeness in Delphi is assessed on the qualities of the expert panel rather than its numbers*" (Powell, 2003: 378).

The contact details of prospective Delphi participants (i.e. HM managers and IC members) were located through professional databases and networking sites. In order to contact IC members, the database of the Infection Prevention Society (IPS) was utilised.

One of the business functions of the IPS is influencing and promoting evidence-base research for infection prevention practice worldwide. In search the IPS database, contact details were sought only for its UK members who specifically stated their profession and worked for Acute NHS Trusts in England. In total, 150 IC members were invited to participate in this Delphi study. As a basis for contacting HM managers, an online database containing the contact details of NHS estates and maintenance managers was purchased from Binley (2013 version). Binley is an organisation that specialises in making available healthcare databases to the public. A search of their database produced the contact details of 170 HM managers working for Acute NHS Trusts.

The information gathered about the Delphi participants was used to create two Excel spreadsheets containing the titles, names, addresses, and telephone numbers of HM managers and IC members. With the help of the Microsoft Word mailing function, 320 invitation letters were despatched via post to prospective Delphi participants across the North West of England. A copy of the initial invitation letter sent to the Delphi participants is provided in Appendix A. The letter stated amongst other things the purpose and benefit of the study, as well as explaining issues of confidentiality and eligibility. Included with the invitation letter were self-addressed stamped envelopes, with a form for the Delphi participants to state their level of professional experience and email address (see Appendix B). In order to increase participation, prospective Delphi participants were also asked to nominate colleagues for the Delphi exercise by stating their email addresses. After the Delphi participants provided email addresses, all subsequent correspondence was conducted via email. Besides the advantage of speed, ‘email Delphi’ enables researchers and Delphi participants to stay focused on the subject matter. For example, trivial issues like reminder notes can speedily be dispatched to the participants within seconds.

Out of the 320 invitations sent to prospective Delphi participants via post, only 40 (13%) were returned. However, because of issues with the returned forms, only 27 (8.4%) IC members were nominated for participation in this research study. Out of the other 13 Delphi nominees, four did not have the required level of work experience, which had been set at five years. In three of the forms, it was reported that the individuals had retired or no longer worked for the NHS hospital. The last six forms contained email addresses that could not be read by the researcher. Attempts to match the email addresses with names on the inventory did not help.

In order to increase the response rate, selected participants were contacted via telephone (those who did not return their self-addressed stamped envelopes). After waiting for another week, the decision was taken to proceed with the Delphi study. Most Delphi studies only have between 8 and 16 participants (Hallowell and Gambatese, 2010). Therefore, 27 Delphi participants were considered enough. Out of the 27 Delphi participants, 14 (52%) were IC members and 13 (48%) were HM managers. The information provided by the 27 Delphi participants was used to create an Excel spreadsheet containing the names of the Delphi nominees, email addresses, and the telephone numbers of their hospitals. Each Delphi nominee was identified by a unique code, which was then used to code the Delphi instruments in rounds 1, 2, and 3 of the Delphi exercise.

4.9.2.1 The First Round of the Delphi Exercise

Although 27 NHS professionals accepted to take part in this research, not all of them returned the first round Delphi instrument. In total, only 20 (70%) Delphi participants returned the first round Delphi instrument. Out of this number, there were 11 (55%) IC members and 9 (45%) HM managers. As shown in Table 4-5, there were five IC nurses and six consultant microbiologists in the IC list. One of the consultants is a professor of microbiology, and another the director of an IC department in an Acute NHS Trust. On average, the work experience the IC members was ten years, and that of the nine HM managers about nine years. One of the HM managers who participated in the Delphi exercise was also head of facilities in an NHS Trust. The professional experience of the Delphi participants was more than the five initially set for this research study. Thus, logically, it can be said that the Delphi participants had the required level of professional experience and knowledge to participate in this study.

According to Somerville (2007), Delphi studies of this nature, with a diverse group of participants, produce better results. The round one Delphi instrument contained fifty-six performance measures grouped under eight CSFs. The first section of the round one Delphi instrument was about the Delphi participants' generic information. In the second section, participants were provided with a list of performance measures grouped under eight CSFs. The Delphi participants were then given the task of identifying new ones.

To allow the Delphi participants enough time to complete the exercises, they were given two weeks.

Table 4-5: Composition of Infection Control (IC) Members

Delphi Participant	Profession/Position	Delphi Nominees (years)	1st round	2nd round	3rd round
ICM-1	Infection Control Nurse	12	✓		
ICM-2	Infection Control Nurse	18		✓	✓
ICM-3	Head of Nursing – Infection Prevention	8	✓	✓	✓
ICM-4	Lead Infection Prevention and Control Nurse	10	✓	✓	✓
ICM-5	Infection Control and Prevention practitioner	5	✓	✓	✓
ICM-6	Clinical Lead Infection Prevention and Control	12	✓		
ICM-7	Professor/Consultant Microbiologist	14	✓	✓	✓
ICM-8	Director/Consultant Microbiologist	6		✓	✓
ICM-9	Consultant Microbiologist	9	✓		
ICM-10	Consultant Microbiologist	16	✓	✓	✓
ICM-11	Consultant Microbiologist	16	✓	✓	✓
ICM-12	Consultant Microbiologist	6	✓		
ICM-13	Consultant Microbiologist	5			
ICM-14	Consultant Microbiologist	7	✓	✓	✓
Total number of participants			***11***	***9***	***9***
ICM Average length of professional experience		***10 yrs***	***10yrs***	***11yrs***	***11yrs***

Table 4-6: Composition of Healthcare Maintenance Managers (HMMs)

Delphi Participant	Profession/Position	Delphi Nominees (years)	1st round	2nd round	3rd round
HM-15	Head of Facilities/Maintenance	7	✓		
HM-16	Estates Operations Manager	10		✓	✓
HM-17	Maintenance Manager	5	✓		
HM-18	HM Manager	8	✓		
HM-19	HM Manager	16	✓	✓	✓
HM-20	HM Manager	10		✓	✓
HM-21	HM Manager	5	✓		
HM-22	HM Manager	14		✓	✓
HM-23	HM Manager	10	✓		
HM-24	HM Manager	6	✓		
HM-25	HM Manager	13	✓	✓	✓
HM-26	HM Manager	5	✓		
HM-27	HM Manager	9		✓	✓
Total number of participants			***9***	***6***	***6***
HM Average length of professional experience		***9yrs***	***9yrs***	***12yrs***	***12yrs***

4.9.2.2 *Subsequent Delphi Rounds*

The results of the first round Delphi exercise (mainly section two) were used to modify the second round Delphi instrument. In round one, the Delphi participants identified eleven new performance measures in HM in IC. However, only six new performance measures were added in the second round of Delphi questions. Some of the round one Delphi instruments were received after the start of the second round of the Delphi exercise. Analysis of the Delphi instruments reveals five new performance measures. Since the second round Delphi exercise had already started, these performance measures could only be included in the third round questions. Therefore, in round two of the Delphi exercise, there were sixty-two performance measures grouped under eight CSFs.

In the second round of the Delphi exercise, participants were asked to rate on a likert scale of four the importance of different performance measures in HM in IC. In a similar study, Moravec (2007) also used a four point likert scale to rate items in the Delphi instrument. According to Garland (1991: p. 4), "... *the explicit offer of a mid-point is largely one of individual researcher preference*". In the second round of the Delphi exercise, participants were also given two weeks to return their responses via email. In an attempt to increase the respond rate, the round two Delphi instrument was emailed to all those (twenty-seven Delphi nominees) who initially agreed to take part in this research study. The Delphi participants were provided with clear instructions on how to complete the round two Delphi exercises (see Appendixes E and F for the round two Delphi instructions and instrument).

Two days prior to the deadline for completing the second round Delphi exercise, reminder letters were despatched to all twenty-seven Delphi participants. After the deadline for completing the round two Delphi exercises had elapsed, follow-up calls were made to those who had failed to submit the round two Delphi instrument. By the time the decision was taken to end the second round Delphi exercise, only fifteen responses had been received. Out of the fifteen responses, nine came from IC members, and six from HM managers. The completed round two Delphi returns were assigned the same unique numbers as in round one according to participants. These were then saved in a folder entitled 'round two Delphi answers'. The performance measures were recorded using statistical software called Statistical Package for Social Sciences Statistics (SPSS) version 21, and analysed through descriptive statistics.

Performance measures which are interpreted as very important or important, and for which the Delphi participants arrived at a high-level of consensus were retained in the second round of the Delphi exercise. However, those with low-level consensus were re-submitted to the Delphi participants for re-rating in round three of the Delphi exercise. The third round of the Delphi exercise contained twenty-five performance measures.

For each of these performance measures, the Delphi participants were provided with their responses and the percentage score of the entire group in round two. They were then given the choice of either maintaining or re-rating the performance measures on a likert scale of 1–4. The third round Delphi exercise lasted for two weeks. The participants were the same as those who rated the round two Delphi questions. A copy of the round three Delphi instructions and instrument is provided in Appendixes G and H.

4.10 THE METHOD FOR ARRIVING AT CONSENSUS

The primary aim of the round two and three Delphi exercises was to identify the key performance measures in HM in IC. Reviews of the literature suggest that this can be achieved through the analysis of qualitative and/or quantitative data (Hsu and Sandford, 2007). In two separate PhD theses, Moravec (2007) and Wagner (2008) analysed quantitative and qualitative data respectively.

Irrespective of the type of data, there is no standard criterion for defining and determining consensus in Delphi (Boote *et al*., 2006). According to Boote *et al.* (2006), "*the criterion for determining consensus appears …to be an issue for the research team and their advisors*". Therefore, in Delphi, authors apply several parametric and non-parametric statistical methods to arrive at consensus. According to Kalaian and Kasim (2012), Delphi studies with more than thirty participants should apply parametric statistical methods such as the Coefficient of Variation (CV), F-ratio, Pearson correlation coefficient and the Paired t-test. In contrast, Delphi studies with fewer than thirty participants should apply non-parametric statistical methods such as McNemar, Spearman's Rank Correlation Coefficient, and the Wilcoxon Paired Signed-Ranks T Test. It is however beyond the scope of this research study to discuss all of these statistical methods.

Despite the aforementioned statistical methods, most Delphi studies apply statistical methods like the mean, median, mode, standard deviation, and inter-quartile deviation (IQD) to arrive at consensus (Hasson *et al*., 2000). The inter-quartile deviation "*is calculated by dividing absolute value of the inter-quartile range (difference between 75th and 25th percentiles of responses for a variable) by two*" (Moravec, 2007: 67). The IQD is often used in conjunction with a second statistical method. This is often where an item achieves consensus by having an IQD of 1.00 or less than one (≤ 1). Items with smaller IQDs (e.g. IQD = 0.00) have greater consensus than those with bigger IQDs (i.e. IQD = 1.00). According to Rayens and Hahn (2000), an item with an IQD of 1.00 may not necessarily reflect consensus amongst the Delphi participants. As a result, Rayens and Hahn propose the further scrutiny of items with an IQD of 1.00. For such items with an IQD of less than one, these authors recommend analysing the proportion of responses using a 60% (positive or negative response) cut off. However, other authors too have scrutinised the IQD using different statistical techniques. For example, Mcintyre *et al*. (2010) scrutinised the IQD using the median.

Not every Delphi study applies the IQR to arrive at a consensus. Researchers like Smart *et al*. (2010) and Snyder-Halpern (2001) only applied percentage scores to establish consensus. However, these studies only solicit yes or no responses. In such Delphi studies, Boote *et al*. (2006) recommend a consensus range from 51% (a simple majority) up to 80%. From the foregoing discussion, it is clear that no clear guideline exists for achieving consensus in Delphi (Powell, 2003; Rayens and Hahn, 2000).

In this research, for a performance measure to be retained in a Delphi round, it needed to be interpreted as either very important or important in IC. Unimportant performance measures in IC were not retained in this Delphi study. In rounds two and three, participants were given the task of rating the level of importance of the different performance measures in HM in IC. The rating was based on a four point likert scale. Scales 1 and 2 (very important + important) represented the positive category, while scales 3 and 4 (unimportant + very unimportant) represented the negative category. Thus, the following criteria were used to interpret the performance measures:

- **Very important -** at least 90% in the positive category
- **Important -** 80% to 89% in the positive category
- **Unimportant** - 70% - 79% in the positive category
- **Very unimportant –** 69% or below in the positive category

Although a performance measure might be interpreted as very important or important, it was not immediately retained in a Delphi round. The Delphi participants needed to arrive at a consensus that the performance measure is important in HM in IC. Having examined the different statistical techniques, consensus in this research study was achieved through the application of the arithmetical mean (hereafter the mean). McDonald (2009) defines the mean as "*the sum of the observations divided by the number of observations*". The popularity of the mean as '*the most commonly used statistics of central tendency*' (McDonald, 2009) makes it a suitable technique for establishing consensus in Delphi. Unlike other measures of central tendency, the mean takes into account every variable in the dataset (McDonald, 2009). The only disadvantage of the mean is that it might not be a suitable technique for much skewed data. Skew describes the tilt in a distribution. The datasets in this research does not exceed +2 and -2. According to Garson and Statistical Associates Publishing (2012), the skew or kurtosis for normally distributed data should be within the +2 and -2 range. A number of Delphi researchers, including Boote *et al*. (2006) and Green *et al*. (1990), also applied the mean to determine consensus in Delphi studies.

Table 4-6 shows the different mean scales for determining consensus in this research study. The scale ranges have been established by a method similar to that used by Moravec (2007). It has been established by dividing the likert scale range by the number of points on the likert scale (3/4). This produces an interval of approximately 0.75. However, a more stringent interval of 0.72 is set for the high consensus level. For a performance measure to be retained in a Delphi round, the Delphi participants needed a group mean score of at least 3.28. Any performance measure with a group mean score of less than 3.28 was re-submitted to the Delphi participants for re-rating.

Table 4-7: The Mean Scale for Determining Consensus

Levels of consensus	Mean scores	
	Low	High
High consensus	**3.28**	**4**
Medium consensus	2.52	3.27
Low consensus	1.76	2.51
No consensus	1	1.75

4.10.1 The Mann-Whitney U Test

As there were two groups of Delphi participants, i.e. HM managers and IC members, it was necessary to investigate how they rated the performance measures in HM in IC. This was achieved through the application of the Mann-Whitney U test. The Mann-Whitney U test is a suitable technique for the comparison of samples that are not normally distributed (Wheater and Cook, 2005). The Mann-Whitney U test shows the difference in the medians between two datasets (ibid). If significant differences exist in the way the two groups rate performance measures, then high and low ranks will belong to two separate groups. The rank totals for the two groups, i.e. IC members and HM managers, will be different. The level of statistical significance in this study was set at $p = < 0.05$.

4.11 LIMITATIONS OF THE DELPHI METHOD

Despite enabling researchers to reach consensus on difficult issues, Delphi still faces criticisms. According to Hanafin (2004), some authors question the reliability, validity, and credibility of the Delphi methodology. Delphi is criticised for depending too much on the quality of the research subjects, and on the technique employed to reach consensus (Hsu and Sandford, 2007). Other issues concern the application, design, administration, and the selection of participants in Delphi (Gupta and Clarke, 1996). Since its inception, Delphi has undergone a number of modifications in its methodology. Presently, variations exist in the number of Delphi participants, selection criteria, and the method of data analysis, etc.

The lack of standard procedure for applying Delphi has led to confusion about the paradigmatic position of this method. According to Hasson and Keeney (2011), the position of the technique between positivism and the naturalistic paradigms leave some calling for its abandonment as a research method (Hasson and Keeney, 2011). Despite these criticisms levied against Delphi, it remains a useful research method for investigating issues with limited empirical data. Part of the solution to counteract some of the weaknesses and challenges of Delphi is for the researcher to define precisely the method (i.e. design and administration of Delphi questions, participant selection, data analysis etc) (Hanafin, 2004). Every effort has been made in this research study to address these issues adequately.

4.12 SUMMARY

Chapter 4 provides an in-depth account of the various steps undertaken in identifying the CSFs and performance measures in HM in IC. Considering what this research study plans to achieve, its research position is associated with interpretivism. In the interpretative paradigm, the researcher works closely with the research participants, identifying issues related to the research phenomenon under investigation. In this case, these issues are the CSFs and performance measures in HM in IC.

The choice of research paradigm adopted in a study influences the researcher's choice of research methodology and methods. From the literature review, it is clear that research methodologies like phenomenology and ethnography, etc were unsuitable for this research study. This research study was conducted through the application of grounded theory methodology. In grounded theory, the researcher is able to move back and forward, revising and adjusting key elements of the research. Grounded theory made it possible for the researcher to identify the key documents in HM in IC. The documents were then analysed using grounded theory approaches like open, axial, and selective coding. This processes led to the identification of the CSFs and performance measures.

The research and interview questions were also identified from the literature. However, a pilot study conducted with two NHS hospitals exposed the weakness of the case study. HM managers interviewed in the pilot study had limited knowledge and understanding of IC issues. Because of this, the decision was taken to employ the Delphi approach. Through Delphi, it was possible to select the Delphi participants i.e. IC members and HM managers based on their level of experience and knowledge about HM and IC.

CHAPTER 5 : THE CONTROL OF HAIs IN HM – THE DEVELOPMENT OF CSFs AND PERFORMANCE MEASURES

5.1 INTRODUCTION

This chapter is divided into five main sections. In the first section, performance measurement and performance management are examined in detail. The research moves on to investigate traditional performance measures and performance measurement systems applicable in healthcare maintenance (HM). After examining the strengths and weaknesses of the such performance measurement systems, a rationale for applying the balanced scorecard (BSC) in this research study is provided. In this research study, the critical success factors (CSFs) and performance measures are categorised according to the four perspective of the BSC. A brief review is also provided of the methodology used in identifying the CSFs and performance measures in HM in IC. The eight CSFs and fifty-six performance measures identified in the literature are also discussed.

5.2 PERFORMANCE MANAGEMENT AND MEASUREMENT

The term 'performance' remains elusive (Smith, 2002), and attempts to define it are frustrating (Lebas, 1995). This is because the word 'performance' means so many different things. In management terms, it can mean anything "*from efficiency, to robustness or resistance or return on investment, or plenty of other definitions never fully specified*" (Lebas, 1995: 23). Despite these limitations, the subject of performance continues to attract the attention of practitioners and academics (Tangen, 2004). In recent years, researchers including Tangen (2004), Lai (2007) and Amaratunga *et al*. (2002) have all been attracted to performance measurement and measurement.

Neely *et al. (*1995) define performance measurement (PM) as the "*process of quantifying the efficiency and effectiveness of action*". According to Striteska and Spickova (2012), the definition stresses the importance of efficiency and effectiveness. Nutt and McLennan (2000) and Muchiri *et al*. (2010) note that PM is the first business requirement of maintenance. It is an integral part of the process driving positive change within organisations. Organisations use PM for planning, screening, control and diagnostics - says Cupello (1994, as cited in Kutucuoglu, 2001). Through PM, managers are able to align different functional areas with the strategic plan of the organisation. It narrows the gap between top management officials and organisational staff, making it easy for management to coordinate, monitor, and diagnose issues within the business (Atkinson *et al*., 1997, as cited in Myeda *et al*., 2011). Based on the results achieved, strategies maybe maintained or new ones developed for the continuous improvement of maintenance services (Lavy *et al*., 2010). PM also improves the performance of individual employees, machines, products, services, communication etc.

For an organisation to make use of their PM outcomes, they will have to move from PM to performance management (Amaratunga and Baldry, 2002: p. 218). According to these authors, "*measurement is not an end to itself, but a tool for more effective management*". Smith (2002: p. 105) defines performance management in the NHS as a "*set of managerial instruments design to secure optimal performance of the health care system over time, in line with policy objectives*". This definition indicates a difference between performance in the private and public sectors. The definition stresses managerial as opposed to external pressure (i.e. customers), the time dimension, and the duty of management to establish policy objectives. Through performance management, managers are able to anticipate changes in the strategic direction of the business, and put in place initiatives for effecting strategic change.

From the foregoing discussion, it is clear that performance measurement is an important tool for effective performance management. Without performance measurement, it will be difficult for management to ascertain the performance of certain programs, e.g. in IC. A number of studies appear to indicate that there is a lack of performance measurement in HM, especially in IC. Therefore, this research aims to identify the CSFs and performance measures in HM in the control of HAIs in the NHS.

5.3 THE NEED FOR PERFORMANCE MEASUREMENT IN HM IN IC

The maintenance of the healthcare built environment is important in preventing the transmission of HAIs in hospitals. However, as indicated by the results of a pilot study, HM services generally do not measure performance in IC. HM managers appear to carry out performance measurement on ad hoc basis in IC to ensure legislative compliance. Besides the lack of CSFs and performance measures, HM managers also do not know the strategy of NHS hospitals in relation to IC. According to Kutucuoglo *et al*. (2001), the gap between maintenance and top management at the strategic level may hinder organisational efficiency. In most organisations, the maintenance units function as separate entities, with staff relying on their technical experience and behaviour (Lee and Scott, 2008). Some HMUs in the NHS do not even have a strategy (mission, vision, goals, and objectives) for IC. Instead of linking the operation of the HMU to the core business strategy of the NHS, i.e. patient wellbeing, some HM managers spend considerable time, energy focusing on reactive measures to reduce costs. This may of course lead to customer dissatisfaction, non-compliance, health and safety problems, etc (Lam, 2007).

Following criticisms of the performance of HM services in IC, some NHS hospitals have formulated policies to minimise the risk of maintenance-associated HAIs. However, it appears that no effective procedures exist to measure the effectiveness of these policies in IC. According to Healthcare Facilities Scotland (2007), there are problems with the effective dissemination and implementation of existing policies and guidelines, etc. In addition, the low level of integration between clinical and non-clinical staff (Liyanage and Egbu, 2005) may also hinder the dissemination of new government policies and guidelines on IC among HM staff. According to Unison (2005), this is likely to affect contracted staff the most.

The lack of performance measurement in HM does not eliminate its role in IC. An important step in reducing the incidence of maintenance-associated HAIs in the NHS will be to identify the CSFs and performance measures in HM in IC. This will demonstrate the importance of the HMU in IC. According to Tsang (1998: p. 87), "*considering maintenance a purely tactical matter is myopic*". Linking the CSFs and performance measures of the HMU to the strategy of the NHS Trust will improve performance in IC.

5.4 PERFORMANCE MANAGEMENT (PM) IN HM

Performance measurement in present day maintenance services is different from what it used to be many years ago. According to Parida and Kumar (2006), prior to the 1900s, most organisations saw the business of maintenance as an unavoidable evil. Since technology was rudimentary, failures/break-downs were inevitable. As a result, managers simply accepted the fact that 'maintenance costs what it costs' (Parida and Kumar, 2006). However, following advances after the Second World War, maintenance became established as an important support function in production and manufacturing. Attention moved from salvaging 'run-down buildings' to providing spacious new buildings with gardens in the 'suburbs'. In the healthcare sector, scarce resources were devoted to the building of new hospitals and the acquisition of the much needed equipment and staff. Organisations also started applying corrective, preventive, and condition-based maintenance strategies to manage buildings (Wood, 2005). The purpose of performance measurement using these maintenance strategies was to increase the reliability and availability of equipment (minimise the number outages during a specified period of production or manufacturing).

Today's business environment is much more dynamic than it used to be many years ago. Besides stiff competition from rivals, organisations also face the challenges of meeting the needs of their stakeholder. HMUs in the NHS are no exception to some of these challenges. The widespread mechanisation and automation of companies reduced the number of production personnel, and increased the capital employed in production equipment and civil structures. Consequently, the proportion of maintenance staff has grown alongside the fraction of total operational costs spent on maintenance. The technological needs associated with the better understanding of the causes of diseases, and an ever-increasing number of susceptible patients revolutionised the process of healthcare maintenance. Today's healthcare maintenance has to grapple with complex electrical, heating, plumbing, air conditioning, mechanical and medical devices, etc in order to meet the needs of the NHS. In recent years, some of these challenges have been met through the application of performance measurement systems (PMSs). Through the application of PMSs, managers gain a better understanding of organisational processes, and measure the success or failure of the organisation in terms of meeting the needs of their customers or stakeholders.

Amaratunga *et al.* (2002) define PMS as a tool for delivering the strategic objectives of an organisation. A good PMS should cover all the CSFs identified and agreed by the organisation. According to Tangen (2004: 728) PMS should "*focus on short and long term measures, as well as on different types of performances (e.g. cost, quality, delivery, flexibility and dependability), various performance perspectives (e.g. the customer, the shareholder, the competitor, the internal and the innovativeness perspective), and various organisational levels (e.g. global and local performance)*". Despite its usefulness, only a small number of organisations consider applying PMSs in FM services (Amaratunga and Baldry, 2002; Toni *et al*., 2007). Even when this is done, the focus of the PMSs is on technical or financial issues.

The above discussion suggest that performance measurement in maintenance can be conducted through traditional performance measures (i.e. corrective, preventive, condition-based maintenance, etc), and PMSs (e.g. performance prism). In the next section, both methods for measuring performance in maintenance are reviewed.

5.4.1 Traditional Performance Measures in HM

Traditional maintenance strategies like corrective maintenance, preventive maintenance, and condition-based maintenance are still being applied across the industry (Zulkanarnian *et al*., 2011) to measure performance. As Wood (2005) noted, these traditional performance measures are applied to increase the availability and reliability of equipment, i.e. to reduce the number of stoppages over a given period. Over the years, criticisms of some of these maintenance strategies have led to the birth of maintenance strategies like Reliability-Centred Maintenance and Total Productive Maintenance.

5.4.1.1 Corrective Maintenance

The term corrective maintenance is also referred to as responsive, breakdown, day-to-day, failure-based, or unplanned maintenance. In corrective maintenance, a request for work is made only after an item or component in the building has broken down. The request for corrective maintenance is usually at short notice, and requires an urgent response. The emergency call out might be in response to work relating to serious electrical or plumbing problems in terms of potential cost implications and/or the safety of healthcare users. It could also relate to a standard and straightforward job such as the replacing of a light bulb. Although corrective maintenance in the NHS appears to be clear-cut, Al-Zubaidi (1997) has noted that it consumes a significant proportion of the building maintenance time and budget. Corrective maintenance also represents the face of the maintenance division. Those who request emergency maintenance work are more likely to judge the performance of maintenance services on response time.

Corrective maintenance is one of the oldest and most reactive forms of maintenance. A study by Mobley (1990, as cited in Chan *et al.*, 2005) found that corrective maintenance was about three times more expensive than the same maintenance work carried out under the preventive mode. Horner *et al.* (1997) have advanced two reasons why corrective maintenance is expensive:

- The act of waiting for a component to fail before carrying out maintenance work might often wear or damage other related components; leading to greater repair costs.
- Breakdowns might also occur at a time that is not convenient to both the user and the maintenance authority. This of course could mean that planning work and obtaining spares are extremely difficult. Disruptions caused by such shortages could result in significant financial losses.

5.4.1.2 Preventive Maintenance

According to Horner *et al.* (1997), the main purpose of preventive maintenance is to curb the disadvantages associated with corrective maintenance. Preventive maintenance is concerned with reducing the probability of the occurrence of a sudden failure that might disrupt business. Preventive maintenance subsumes terms such as time-based maintenance, planned maintenance or cyclic maintenance. In preventive maintenance, fixed dates on the calendar or equipment run-time may be used to scheduled maintenance work. This is a slightly better method than corrective maintenance, because technicians only attend to a piece of equipment at a time when it is just starting to show signs of wear. According to Chalifoux and Baird (1999: p. 10), "*performing preventive maintenance based on equipment run time makes sense*". Since time is linked to wear, it is logical that maintenance should be performed only after an item has been used for a certain time.

The task of preventive maintenance might simply involve the replacing, overhauling or remanufacturing of an item. Although preventive maintenance ensures reliability, safety and convenience, it nonetheless has been criticised for wasting valuable resources. In preventive maintenance, a piece of equipment may be replaced or remanufactured regardless of its working condition at the time. In addition to requiring a large workforce and stock of spares, preventive maintenance does not necessarily eliminate all breakdowns. The limitations of preventive maintenance and the need to cut maintenance cost have increased the use of technology to detect the failure mode associated with different components and/or assets, and the likely effect of a breakdown on system productivity. In the next section, we examine a third maintenance strategy called condition-based maintenance.

5.4.1.3 Condition-Based Maintenance

Kelly and Harris (1978, as cited in Horner *et al.*, 1997: 275) define condition-based maintenance as "*maintenance carried out in response to a significant deterioration in a unit as indicated by a change in monitored parameter of the unit condition or performance*". This normally involves the installation of sensors in different parts of an asset to detect critical signals of potential failure (e.g. increase in vibration or temperature) (Bivona and Montemaggiore, 2005). Signs of potential failure might be apparent from knowledge gathered from the routine and continuous monitoring of building elements such as walls or floors, etc and service equipment such as boilers, pumps, and heating systems. Although condition-based maintenance appears straightforward, it is not cost effective. According to Bivona and Montemaggiore (2005), condition-based maintenance requires a tremendous amount of resources, time, and energy. In addition, it is not possible to use technology to detect the deterioration of all building components or systems; and in some instances, the technology might not exist.

From the foregoing discussion, it is clear that no single maintenance strategy can successfully predict breakdowns of machines and deterioration of buildings. Nowadays companies are applying integrated maintenance strategies, which combine the strengths of corrective, preventive, and condition-based strategies. Examples of integrated maintenance strategies include Reliability-Centred Maintenance (RCM) and Total Productive Maintenance (TPM).

5.4.1.4 Reliability-Centred Maintenance (RCM)

Reliability-Centred Maintenance (RCM) represents a new way of thinking about maintenance. It requires maintenance decisions to be supported by a sound technical and economic justification (National Aeronautics and Space Administration (NASA), 2008). RCM combines the strengths of different maintenance strategies (i.e. corrective, preventive, and condition-based) to maximise the time that a piece of equipment functions in the required manner (Chalifoux and Baird, 1999). Table 5-1 provides guidance on RCM development by equipment application. Rather than focusing entirely on preventing failure in all cases and at all cost, RCM tries to prevent and avoid the consequences of failure (Blann, 2012). It regards a piece of equipment or facility as a function having systems, subsystems, components, and subcomponents. The selection of a system in RCM is based on the following factors: mean time between failures (MTBF), total maintenance cost, mean time to repair (MTTR) and availability (Afefy, 2010).

Table 5-1: Reliability-Centred Maintenance Element Applications

Reliability Centred-Maintenance Hierarchy		
Reactive Element Applications	**Preventive Element Applications**	**Condition-based Element Applications**
Small parts and equipment	Equipment subject to wear	Equipment with random failure patterns
Non-critical equipment	Consumable equipment	Critical equipment
Equipment unlikely to fail	Equipment with known failure patterns	Equipment not subject to wear
Redundant systems	Manufacturer recommendations	Systems in which failure may be induced by incorrect preventive maintenance

(Source: US Department of Energy, 2010)

After selecting a system, the next step is to gather data relating to the system components. One way of doing this is to apply a RCM technique, based on rigorous Failure Modes and Effects Analysis (FMEA), complete with historical data, experimental data, probability functions (statistical methods), risk analysis, common sense, intuition, and modelling (NASA, 2008). NASA divides this approach into two categories: Rigorous (also called classical RCM) and Intuitive (called streamlined RCM). The decision of which FMEA approach to adopt should be based on the consequences of failure, probability of failure, historical data, and risk tolerance (mission criticality).

Stanley Nowlan and Howard Heap proposed and developed the first version of the Rigorous RCM. Rigorous RCM is very comprehensive in nature. It involves the gathering of comprehensive knowledge and data concerning system functions, failure modes, and maintenance actions to address functional failures (NASA, 2008: 3-2). Rigorous RCM uses the principles of FMEA, and involves calculating the probability of failure and system reliability. This allows for the appropriate identification of maintenance tasks or redesign requirements to address each of the identified failure modes and their consequences (NASA, 2008). The detailed documentation and analysis of Rigorous RCM makes it suitable for the aircraft, space, defence, and nuclear industries. This is because any functional failure in any of these systems may result in a large loss of life, breach of national security, or have extreme environmental implications.

Although the effectiveness of Rigorous RCM is well documented (Blann, 2012), NASA nonetheless criticises it for being labour-intensive, and for often postponing the implementation of obvious predictive testing and inspections. In addition, the methodology used in Rigorous RCM is complex, expensive and resource-intensive (Blann, 2012). The successful application of Rigorous RCM therefore needs strong management support, organisational discipline and leadership. For these reasons, Rigorous RCM is unsuitable for most facilities. According to NASA (2008; 3-3), Rigorous RCM is suitable where the consequences of failure may "…*result in catastrophic risk in terms of environment*, *health*, *safety or complete economic failure of the business unit*".

The application of Intuitive RCM is justified because of the high cost associated with the application of Rigorous RCM. Equally, system failure in Intuitive RCM does not pose significant risks to health, safety, the environment or security. In Intuitive RCM, not all the failure modes in a system are analysed, and the implementation of condition-based maintenance is based on minimal analysis (NASA, 2008). It also draws on data gathered from previous incidences as well as input from maintenance personnel to eliminate low-value maintenance tasks.

5.4.1.5 Total Productive Maintenance (TPM)

The development of Total Productive Maintenance (TPM) in Japan arose because of the numerous problems faced by maintenance services in Japan (Chan *et al.*, 2005). The poor performance of maintenance services, especially in the manufacturing sector, was associated with low productivity and high production cost. The application of TPM was because of the failure of traditional maintenance strategies like corrective, preventive and condition-based maintenance to tackle the problem of equipment breakdown. Originally developed in the 1950s, the principles of Total Productive Maintenance are synonymous with those of preventive maintenance (Wireman, 2004). TPM uses information gathered from maintenance guidelines and recommendations provided by manufacturers to fix or reduce breakdowns in equipment or assets. Over the years, manufacturers have used this data to design, build and construct equipment that is more reliable. The evolution of TPM in the 1970s was therefore to improve the manufacturing, usage and maintenance of machines.

Wireman (2004: 1) defines Total Productive Maintenance (TPM) as "*maintenance activities that are productive and implemented by all employees*". The primary motive of TPM is to reduce machine stoppages, speed losses/reductions arising from failures and adjustments, as well as wastage and defect losses (Chan *et al.*, 2005). This ensures the optimisation of the use of machines and equipment. According to Wireman (2004), it is important that operators and maintenance staff follow the specifications and guidelines provided by the manufacturers of equipment. This relates to the design speed at which a piece of equipment is supposed to produce a certain quantity and quality of products. Companies who do not understand these issues are more likely to set up arbitrary production quotas, and adjust machine speeds to compensate for the emerging need for repairs.

TPM requires a synergistic relationship between the maintenance unit and the other business functions of the organisation. According to Chan *et al.* (2005: 74), "*an efficient TPM depends on both production and maintenance activities*". As shown in Figure 5-1, when different organisational units work together, they easily identify those areas of the business operation that may contribute to the continuous improvement of product quality, operational efficiency, and capacity assurance (Chan *et al.*, 2005). To achieve this, it is imperative to provide all the staff concerned with the necessary skills and training to detect the early signs of wear, maladjustment, oil leaks and loose parts, etc. Staff preserve the reliability and availability of equipments under their control by carrying out preventive maintenance tasks like cleaning, oiling, tightening of nuts on bolts, and inspection of machines and equipment.

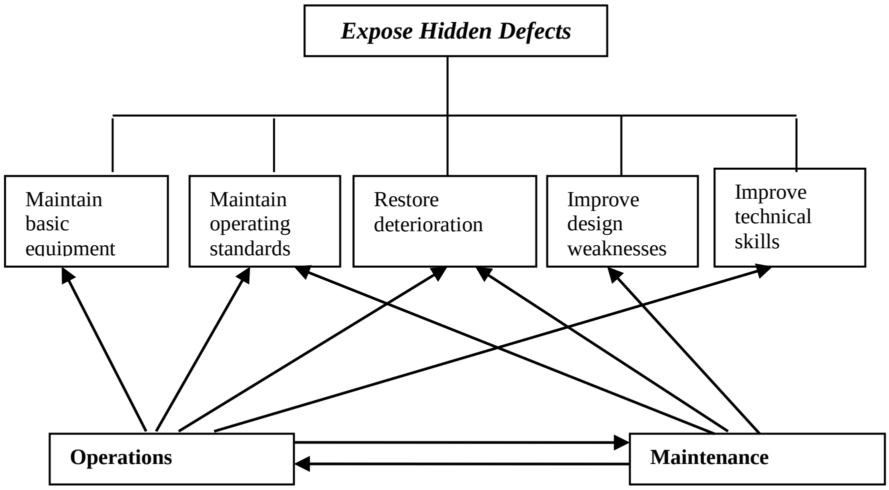

Figure 5-1: The Relationship between Operations and Maintenance
(Source: Chan et al., 2005: P. 75)

One of the goals of TPM is ensuring the maintenance of equipment at reasonable and affordable prices. To avoid maintenance costs in the first place, staff need to have a thorough understanding of the benefit of maintenance planning and scheduling. This increases reliability, and reduces waste in the maintenance process. For TPM to succeed, it must receive top management support. According to Eti *et al.* (2004), it is the responsibility of top management to set TPM goals, educate and train staff, and measure the effectiveness of TPM. Supervisors and members of trade unions should also assist management in carrying out remedial actions to reduce defects in equipment, etc (Eti *et al*., 2004).

5.4.2 An Integrated HM Strategy to Reduce HAIs

HM managers face difficulties in selecting the right mix of maintenance strategies to reduce failure modes in different machine components in hospitals. The challenge for HM managers is getting a mix of maintenance strategies that takes into consideration health, environment and cost. As indicated earlier, maintenance strategies like RCM and TPM are unsuitable for application in the NHS. Because these maintenance strategies are tailored for large manufacturing companies, they also are too expensive and complicated for application in hospitals. A snap shot analysis of healthcare maintenance policies suggests that HMUs apply corrective, preventive, and condition-based maintenance strategies.

In this research study, an integrated HM strategy has been developed for application in NHS hospitals. As shown in Figure 5-2, the first consideration in the application of maintenance strategies should be its relevance to HAI-significant items. Thereafter, the second and third considerations should be on environmental and cost-significant items respectively. In order to reduce the risk of maintenance-associated HAIs, a multidisciplinary team of experts should be appointed to identify all the maintenance elements and components that may expose healthcare users to the potential risk of acquiring HAIs. The team of experts should include HM managers, IC members, and any other relevant stakeholders. However, where necessary, officials should draw on the experience of maintenance operatives.

The main function of the multidisciplinary team of experts will be to identify and categorise maintenance elements and components into significant and non-significant items in IC. A typical HMU has the following maintenance elements: hot and cold water systems, ventilation systems, medical gas pipelines, etc (see Figure 5-2). A simple FMEA (Failure Modes and Effects Analysis) could be used to map the different maintenance systems and components in IC. An inventory should be created for use by HM staff and relevant parties in the prevention of HAIs in NHS Trusts.

Since some maintenance systems and components may pose a risk of HAIs, steps must be taken to avoid this occurring. It is not always possible to use technology to monitor all ‘HAI-significant systems and components’ for faults that may jeopardise quality and expose patients to HAIs. For those items that can be monitored by technology, it might be appropriate for managers to consider the application of a condition-based maintenance strategy. However, for those items that cannot be monitored with technology, two options are available. In the first option, preventive maintenance is recommended for those items which are verifiable by periodic testing. However, where periodic testing is not possible, managers could organise the regular testing of the systems and components. Any unexpected failure of a ‘HAI-significant system or component’ should be corrected immediately. Because non-significant items pose no risk of HAIs, elements, systems or components may be allowed to run-to-failure – i.e. corrective maintenance is appropriate. Records should be kept of the number of failures and incidences for future use. It is also from such records that managers are able to gauge the performance of the HMU in IC.

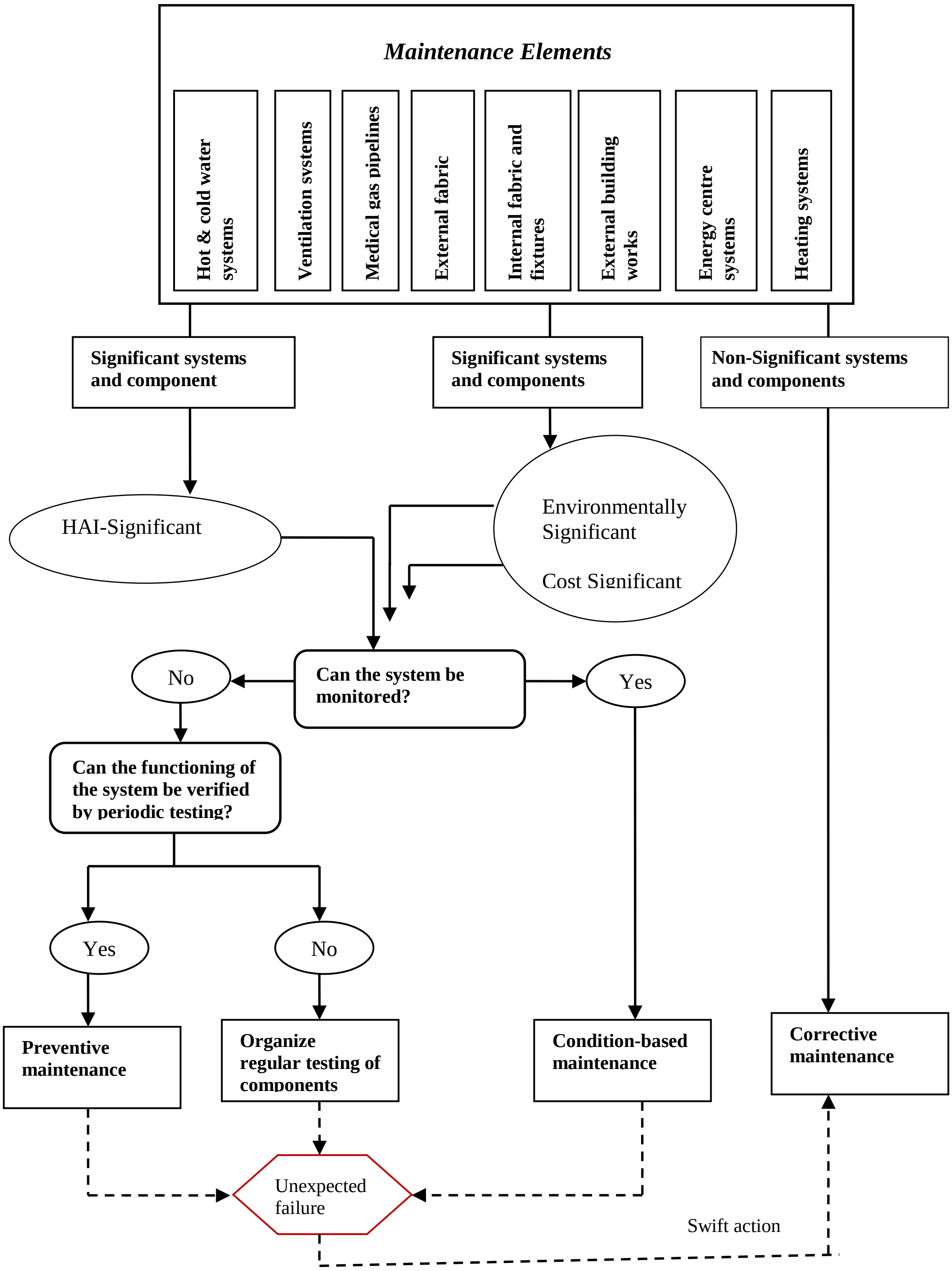

Figure 5-2: An Integrated HM Strategy to Reduce HAIs

5.4.3 Performance Measurement Systems (PMSs) in HM

In a review conducted by Kutucuoglu *et al.* (2001), the following performance measurement systems (PMSs) are identified in HM: the European Foundation for Quality Management (EFQM), the Performance Management Matrix (PMM), the Result and Determinant Framework, the Performance Pyramid System (PPS), and the Performance Prism (PP) (Kutucuoglu *et al.*, 2001). In the next section, these PMSs are described in details.

5.4.3.1 The European Foundation for Quality Management (EFQM)

Founded in 1988, the primary aim of the European Foundation for Quality Management (EFQM) is promoting quality in organisations in Europe. The EFQM receives support from the European Organisation for Quality (EOQ) and the European Commission (EC). The EFQM business model is non-prescriptive, and helps organisations (private, public and non-governmental) assess their progress towards excellence and continuous improvement (McCarthy *et al.*, 2002).

As shown Figure 5-3, there are two distinct subsets of performance measures in the EFQM business excellence model, which are classified as enablers (or implementation factors) and results (Neely *et al.*, 2000). Enablers are the levers that management uses to effect change or deliver future results. The five enabling activities of the EFQM business model are leadership, people, policy and strategy, partnership and resources, and processes. These enabling activities supposedly drive the four sets of results: people, customer, society, and key performance. The methodology used to assess EFQM organisations is a five-step process called RADAR (Striteska and Spickova, 2012). The RADAR logic means that organisations have to focus on the following: determine the required *results*, plan and develop *approaches*, *deploy* approaches, *assess* and *review* achieved results.

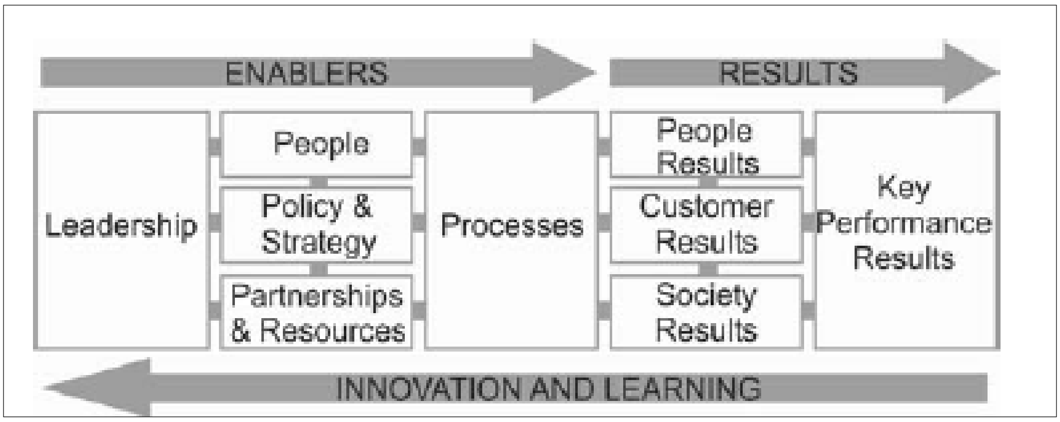

Figure 5-3: The EFQM Business Excellence Model
(Sources: McCarthy et al., 2002: p.1)

The EFQM is a practical tool that helps drive performance in organisations. On its webpage, the British Quality Foundation (2013) affirms that the EFQM improves business performance by allowing organisations to gain competitive advantage over their competitors. In addition, it increases productivity and profitability, raises employee engagement, customer satisfaction, and continuous improvement. Despite these claims, and the wide application of the EFQM across Europe, it has nonetheless faced some criticisms. One of the criticisms, advanced by Neely *et al.* (2000), is that the EFQM business model is difficult to use. In addition, it is not suitable as a strategic management tool, nor does it encourage enterprise communication (Striteska and Spickova, 2012). It is bureaucratic in nature and does not provide detailed guideline on how to design and conduct effective performance measurement (Striteska and Spickova, 2012).

5.4.3.2 The Performance Management Matrix (PMM)

In 1989, Keegan *et al.* introduced the Performance Measurement Matrix (PMM) (Purbey *et al.*, 2007). This was to counteract some of the weaknesses of traditional PMSs, which focus on financial indicators to measure the performance of organisations. As shown in Figure 5-4, PMM examines both cost and non-cost performance indicators, which are categorised according to internal and external performance perspectives. However, these performance perspectives have been criticised for not linking the different dimensions of business performance (Neely *et al.*, 2000). According to Striteska and Spickova (2012), the PMM does not include customers or human resources as dimensions of performance. According to these authors, it could not provide a balanced view of performance.

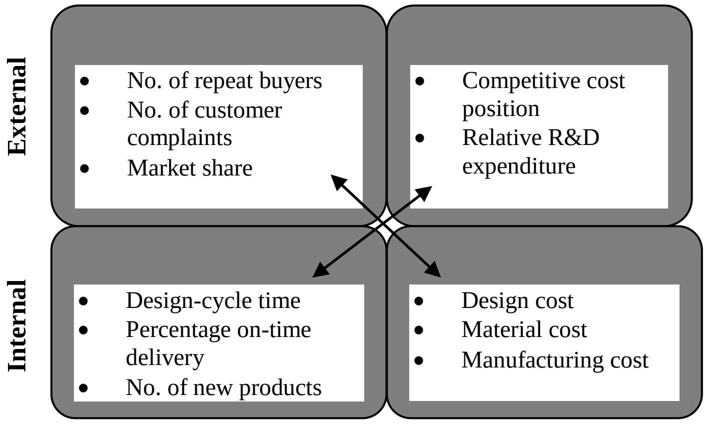

Figure 5-4: The Performance Measurement Matrix
(*Source: Keegan et al., 1989)*

Because of the criticisms of the PMM, in 1991, Fitzgerald and colleagues developed a modified version of the PMM called the Results and Determinant Framework. As shown in Table 5-2, in this framework performance measures are divided into two categories: results and determinants. The results category includes factors like competitiveness and financial performance, while the determinants category includes factors such as quality, flexibility, resource utilisation, and innovation (Neely *et al.*, 2000). The determinants are the leading indicators while the results are the lagging indicators.

Besides being a simple model, the PMM has been commended for detailing clearly what the performance perspectives are. However, others have criticised it for failing to include customers or human dimensions as performance perspectives. As a result, Striteska and Spickova (2012) noted that the PMM does not give a truly balanced picture of performance in an organisation.

Table 5-2: The Results and Determinant Framework

Results	Financial performance
	Competitiveness
Determinants	Quality
	Flexibility
	Resource utilisation
	Innovation

(Source: Fitzgerald et al., 1991)

5.4.3.3 The Performance Pyramid System (PPS)

The Performance Pyramid System was developed by Lynch and Cross to measure the business operating systems of companies (Lai, 2007). The PPS "*ties together the hierarchical view of business performance measurement with the business process view*" (Neely *et al.*, 2000: p. 1125). At the strategic level of PPS, the decision to formulate the company's vision rests with top management. As shown in Figure 5-5, the formulation of a company's vision encompasses the market and financial considerations of the company. It also provides strategic direction towards the realisation of a company's objectives (Lai, 2007). Objectives cascade from top management to bottom management levels of the organisation. It is concerned with achieving external effectiveness and internal efficiency.

The PPS requires organisations to focus on all their business operating systems relating to customer satisfaction, flexibility, and productivity (Lai, 2007). Sometimes, this may mean crossing departmental and functional boundaries. For example, if the maintenance department is to improve on its performance in infection control, it will have to work closely with the infection control unit (ICU), contracted staff, domestics etc. To measure whether an organisation's business operating systems are achieving the desired objectives, i.e. in IC, the architects of PPS list four non-financial indicators at the bottom level of the pyramid. The purpose of these indicators, which organisations have to identify, is to monitor the quality, delivery, cycle time and waste during service delivery (Purbey *et al.*, 2007). In PPS, quality and delivery relate to external effectiveness, while cycle time and waste relate to internal efficiency.

A key strength of the PPS is that it attempts to integrate the corporate objectives of an organisation with its operational performance indicators (Striteska and Spickova, 2012). Thus the PPS makes it easy for managers to focus the different functional units of the organisation on the same goals and objectives. Despite the aforementioned advantages of the PPS, it has been criticised for not providing adequate suggestions on how organisations could identify performance indicators. Without appropriate performance indicators, it will be difficult for organisations to realise their vision (Metawie and Gilman, 2005).

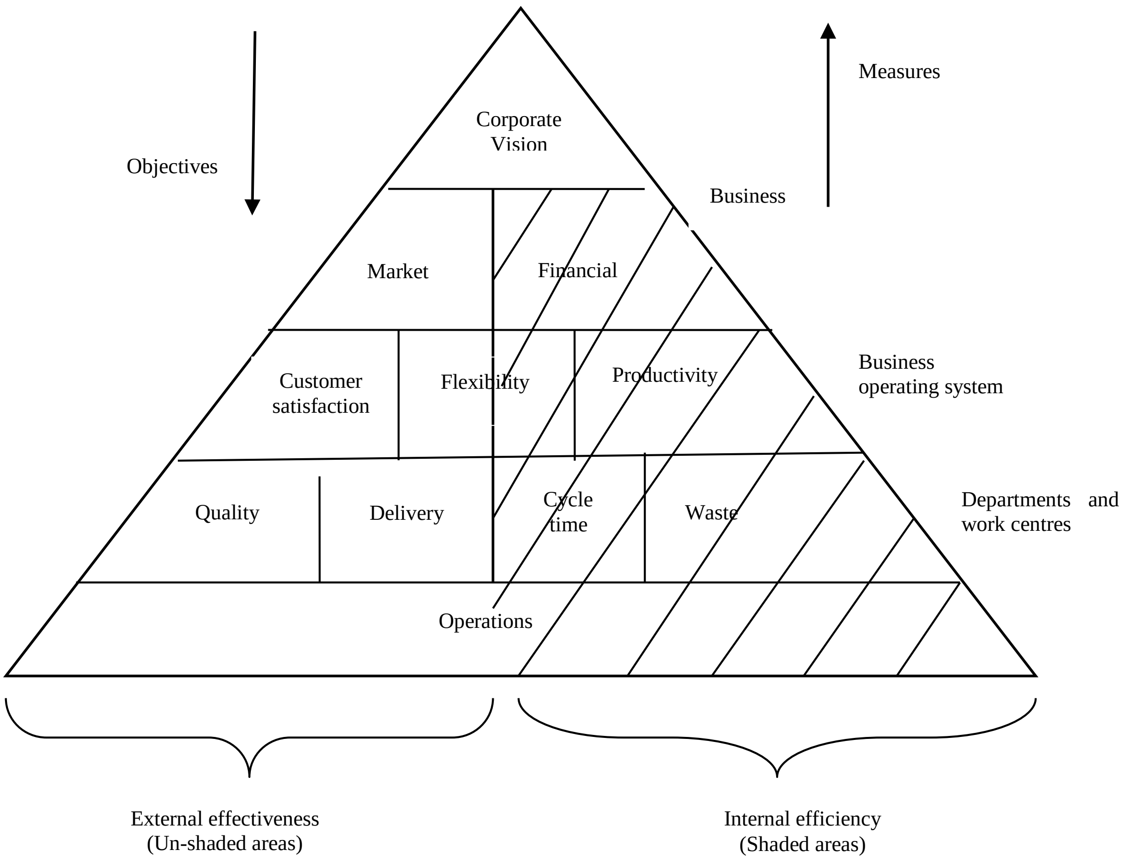

Figure 5-5: The Performance Pyramid System
(Source: Lynch and Cross, 1991, as cited in Lai, 2007: 15)

5.4.3.4 The Performance Prism (PP)

According to Neely *et al*. (2001), the architects of PP, performance measurement and management are a very complex business. They compare performance measurement and management to a refracted light, i.e. white light passing through a prism. They describe the PP as a second-generation PMS, which should replace first-generation PMSs like the BSC (Association of Chartered Certified Accountants (ACCA), 2012). They criticise some of these first-generation PMSs for focusing too much attention on the needs of stakeholders (owners or customers). At the same time, some of these PMSs fail to verify whether the very stakeholders are fulfilling their commitment to the organisation.

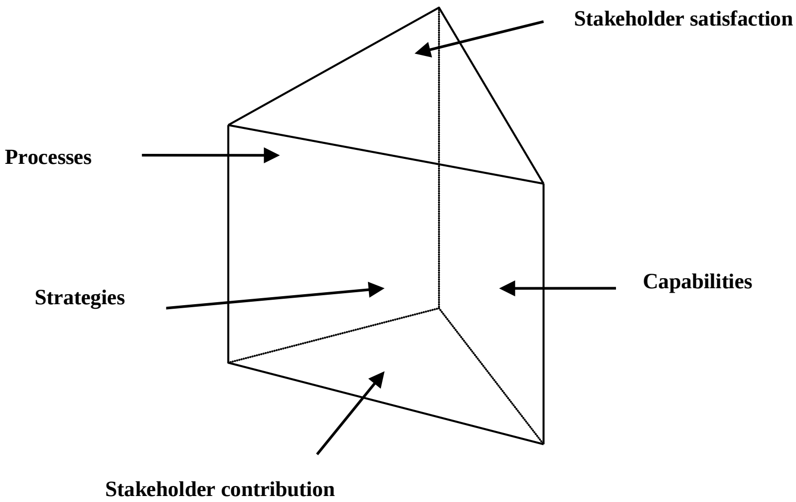

Figure 5-6: The Performance Prism
(Source: ACCA, 2012: p. 2)

Designed as a flexible tool, the PP is suited for large and small commercial or non-profit organisations (ACCA, 2012). As shown in Figure 5-6, the PP consists of five distinct but linked perspectives on performance (ACCA, 2012):

1. **Stakeholder satisfaction**: the best way for organisations to survive in today's business environment is to identify what stakeholders consider to be value and to deliver it. In the information rich-society of today, focusing on a subset of seemingly more influential stakeholders (i.e. shareholders and customers) and ignoring the needs of the rest of the customers is short-sighted and naive (Epstein, 2001). Compared to PMSs, the PP has a much more comprehensive view of stakeholders. The PP argues against the common belief of strictly deriving performance measures from the strategy (Tangen, 2004). According to Neely *et al*. (2001), the needs and wants of stakeholders should be considered first. The stakeholders of the PP include employees, suppliers, consumers, regulators, legislators, activists, alliance partners and intermediaries, etc; these are often neglected when organisations devise performance measures.
2. **Stakeholder contribution**: over the years, organisations have become increasingly demanding of what they expect of their stakeholders. Thus, the second facet of the PP requires organisations to identify and measure their stakeholder requirements. A PMS like the BSC asks the question 'what do our

customers want from us?' They fail to identify the contributions of stakeholders to the organisation. Loyalty and profits are just some of the contributions stakeholders to an organisation. Presently, organisations are conducting customer profitability analysis, to identify the sort of contributions their stakeholders could bring. ACCA (2012) and Epstein (2001) have identified different stakeholder groups with the following contributions:

- *Investors* – capital for growth, and the willingness to take on more risk
- *Employees* – flexibility, multiple skills, antisocial hours, suggestions
- *Regulators* – better understanding of the business sector, ability to regulate informal advice, early involvement across borders
- *Suppliers* – more outsourcing, fewer vendors, total solutions, integration
- *Communities* – skilled employment pool, grants, support, integration
- *Pressure Groups* – closer co-operation, shared research, co-branding
- *Alliance Partners* – cross-selling, co-development, cost sharing

3. **Strategies:** in PP, a strategy describes the route an organisation plans to take to reach its goals, not the goal itself. On the other hand, a goal refers to the first two facets of the PP – stakeholder satisfaction and stakeholder contribution. The aim of the strategy facet of PP is to identify the strategies to satisfy an organisation's stakeholders, and meet its own business requirements. With the right strategies in place, organisations can devise meaningful performance measures. Performance measures allow organisations to communicate and implement strategies, as well as evaluating their outcomes.
4. **Processes:** the next step in the PP is finding out whether organisations have the right business processes to support the strategies. According to ACCA (2012), most organisations classify processes into the following categories: develop products and services**,** generate demand**,** fulfil demand**,** plan, and manage the enterprises. For each of these processes, companies are required to create sub-process and delegate responsibility to a process owner.
5. **Capabilities:** capabilities refer to people, practices, technologies and infrastructures required to enable a process to work (ACCA, 2012). Capabilities are important in that they support the functioning of the processes and sub-processes. It is important, therefore, for management to select the most critical capabilities, and develop performance measures to show how well these capabilities are performing.

As one of the newly developed PMSs, the PP has introduced new stakeholders like employees, suppliers, alliance partners or intermediaries which are often neglected when organisations develop performance measures (Striteska and Spickova, 2012). By recognising the contributions of these stakeholders, managers are able to focus on the key issues which drive performance in the organisation. Despite being considered by some as a second-generation PMS, the PP has been criticised for not clearly detailing how the performance measures will be realised (Tangen, 2004). It lacks a proper framework detailing how the various performance perspectives could be adopted in the real world (Lai, 2007). Even so, Lai notes that the performance perspectives are too broad for any practical implementation.

5.4.3.5 The Balanced Scorecard (BSC)

Proposed by Kaplan and Norton in 1992, the BSC derives performance metrics from the financial, customer, internal business, and innovation and learning perspectives. According to Lai (2007), the strength of the BSC is in these four perspectives. Combining the perspectives, as suggested by Kaplan and Norton, enables managers to understand the intricate link and trade-offs between alternative performance dimensions in an organisation (Banker *et al.*, 2004). Thus, they are able to improve their decision-making and problem solving processes (Banker *et al.*, 2004). The four perspectives of the BSC are shown in Figure 5-7.

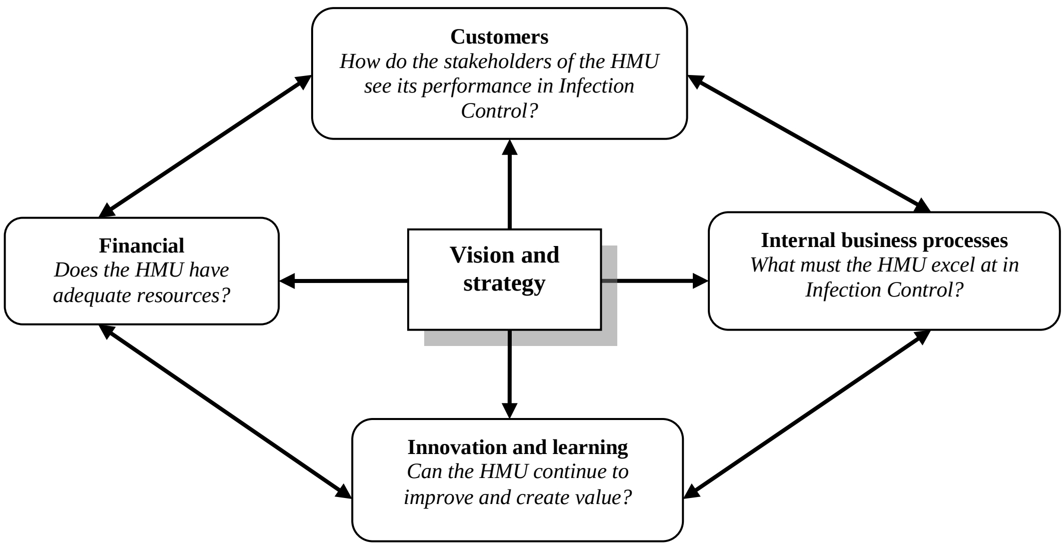

Figure 5-7: Translating Vision and Strategy: the Four Perspectives of the BSC
(Adapted from: Kaplan and Norton, 1992: p. 4)

1. **Financial Perspective:** performance measures gathered in this perspective represent the financial issues of the organisation. According to Kaplan and Norton, the financial perspective is like a must-have thing for organisations (Lai, 2007). This is because financial measures provide officials with information to verify whether the implementation and execution of the organisation's strategy are contributing to bottom-line improvements. It also enables organisations track the progress they are making towards achieving pre-defined sets of financial goals and objectives, i.e. profitability, growth, and shareholder value, etc. According to the Procurement Executives' Association (1998), there is a difference between the financial perspective of public and traditional private organisations. Whilst private organisations gear their financial objectives towards attaining long- range financial profits, public firms do not. Value-for-money in public organisations is measured, for instance, by the quality of service received by the public. In the case of the NHS, one aspect of the quality of care received by patients is reductions in the rate of HAIs.
2. **Customer Perspective:** this perspective shows how an organisation is performing from its customers' viewpoint. Under this perspective, managers are required to identify those factors that matter the most to customers. The BSC requires managers to "*translate the general mission statement on customer service into specific measures that reflect the factors that really matter to customers*" (Lai, 2007: 20). Kaplan and Norton group the concerns of customers into the following categories: time, quality, performance and service, and cost (Lai, 2007). In the BSC, time refers to the duration taken by organisations to respond to the needs of customers, e.g. the time taken by the HMU to respond to calls logged by nurses, doctors etc. As well as responding to time, organisations must also ensure that the quality of goods and services they produce meets customer requirements. For this to occur, organisations will have to do things like tracking and reducing the volume of defective products customers receive. The measure of performance and service focuses on whether the organisation's customers are getting value from the goods and services they purchase. Organisations therefore need to measure the cost of the supply of goods and services to their customers. In addition, they are supposed to measure their supplier-driven cost such as ordering, delivering, handling, storing and obsolescence, etc. Reducing the supplier-driven cost may lower the price of the

goods and services to customers, and give the organisation a competitive edge over its rivals.

3. **Internal Business Perspective:** this perspective requires managers to analyse the internal business operations of the organisation. The purpose of this perspective is to identify processes and competencies which the organisation must excel at, and for which measures ought to be stipulated (Lai, 2007). According to Amaratunga and Baldry (2002), the identification of these issues should involve the judgment of top management. This increases the level of communication throughout the organisation, and enables the organisation to link its internal business measures to its objectives (Kaplan and Norton, 1992). The organisation is thus able to achieve its overall business goals (Kaplan and Norton, 1992). Organisations that focus on their critical internal business operations achieve customer satisfaction and financial success (Amaratunga and Baldry, 2002). It is therefore important for managers to pay particular attention to monitoring these issues. Examples of critical internal measures needing the attention of managers include cycle time, quality, employee skills, and productivity (Kaplan and Norton, 1992).
4. **Innovation and Learning Perspective:** customers and internal business measures are two important issues affecting the competitiveness of organisations (Amaratunga and Baldry, 2002: 142). However, faced with intense competition and ever changing customer needs, organisations have to continually adopt new strategies to meet some of these challenges. Organisations need to continuously make improvements in their existing products and introduce new processes, which expands their core capabilities (Kaplan and Norton, 1992). This creates more value for the customer, and opens up new markets for the organisation, which leads to more profit for the shareholders. The innovation and learning perspective, therefore, examines issues relating to "…*the ability of employees, quality of information systems and the effects of organisational alignment in supporting accomplishment of organisational goals*" (Amaratunga and Baldry, 2002). For an organisation to be innovative, and create value for its customers, it must have the right mix of competent staff. Sometimes, this may entail hiring experts, training, or retraining staff on existing or new technologies and processes.

The key strength of the BSC is in the fact financial measures and non-financial measures are used to drive performance. According to the architects of the BSC, deriving performance measures from the four perspectives of the BSC helps reduce information overload by reducing the number of performance measures used (Tangen, 2004). In the BSC, managers focus on crucial performance measures that drive overall business performance. Although the BSC is commended by many, it too faces a number of criticisms. Because the BSC is designed to provide top management with an overall view of performance, it is not suitable for application at the factory operation level (Ghalayini *et al*., 1997, as cited in Tangen, 2004). Striteska and Spickova (2012) also argue that the BSC is constructed as a monitoring and controlling tool rather than an improvement tool. Little guidance is provided by the BSC on the identification and implementation of performance measures (Neely *et al*., 2000). Despite the criticisms levied against the BSC, it remains one of the most useful PMSs to drive organisational performance. In the next section, the focus is on the rationale for the application of the BSC in this research study.

5.5 RATIONALE FOR ADOPTING THE BALANCED SCORECARD PERSPECTIVES

The tradition of organisations relying heavily on financial and accounting data to measure their performance is outdated. Relying too much on financial measures may not reflect the true picture of the performance of an organisation. Unfortunately, this seems to be the case with maintenance services in most organisations. According to Tsang (1998), most organisations restrict performance measurement in maintenance to the tracking of direct costs or their surrogates such as the headcount of tradesmen, etc. Organisations that focus on these issues, "*ignore the softer less measurable performance indicators, as well as the relationship between different business units and their variable objectives*" Kaplan and Norton (1992). According to Amaratunga *et al.* (2002), this may affect the level of satisfaction offered by an organisation to its customer. The need to counteract some of the limitations of traditional PMSs has created a proliferation of new models. Examples include PMSs like the Performance Measurement matrix (PMM), Performance Pyramid (PP), and the Balanced Scorecard (BSC), etc.

Of all these PMSs, the BSC, developed by Robert Kaplan and David Norton in the 1990s, is probably the most widely recognised (Neely *et al*., 2000). The BSC provides organisations with a comprehensive framework for the translation of strategic objectives into a coherent set of performance measures (Thakker *et al.*, 2006). Tsang (1998) advised against considering maintenance as a purely tactical issue. The BSC allows data to be collected on financial and non-financial performance measures. According to Amaratunga and Baldry (2002), the gathering of critical non-financial data, as advocated in the BSC, enables organisations to pinpoint problems, improve processes, and achieve pre-set goals in performance. Through the application of the BSC, managers are able to gather rich information to gauge the effectiveness of their strategy, as well as direct consistent staff behaviour towards the realisation of the desired strategy, i.e. by upgrading the knowledge and skills of staff, etc (Thakker *et al*., 2006). As opposed to other PMSs, the BSC allows managers to select CSFs from all areas of the organisation, which collectively play a critical role in its future success (Tsang, 1998).

Currently, its application spans many business, private, government, and non-governmental sectors (McDonald, 2012). The popularity of the BSC has led to its widespread application across the globe. Worldwide companies like Pepsi, Apple, the US Army and Nike, etc have all adopted the BSC (Toni *et al*., 2007). A review conducted MIn order to identify the most relevant PMSs in FM, Toni *et al*. (2007) carried out a comprehensive search of the literature about companies' measurement systems. They examined 102 case studies from 85 papers issued between 1993 and 2006. The most representative PMSs included the Balanced Scorecard (BSC), the European Foundation for Quality Management (EFQM), the Business Excellence Model, the Results and Determinants, and the Performance Prism. The BSC was further divided in the Services Balanced Score Card, the Business Balanced Score Card and the Holistic Balanced Score Card. The PMSs were categorised according to use in the production, service and FM sectors. As shown in Table 5-3, the BSC was the most popular PMS, accounting for 76 out of the 102 cases. However, in relation to FM, there were only four cases of BSC, and one case of the EFQM. The results of this study led Toni *et al*. (2007: 426) to conclude that:

- Performance measurement in FM is still in its infancy;

– The BSC is the reference model for all application environments;
– The BSC is the most popular in the facility management field; and
– The BSC is probably the best solution for facility management even if its applications are still limited.

The foregoing discussion suggests that the Balanced Scorecard is probably the favoured PMSs in this field. Amaratunga *et al*. (2002) noted that the "*…BSC …is the essential ingredient of business success*". Thus, instead of re-inventing the wheel, this research will focus on identifying the CSFs and key performance measures in HM in IC. This appears lacking in the control and prevention of HAIs in HM.

Table 5-3: Number of Case Studies on PMS Applications in FM

			PMS frameworks							
			Balanced Scorecard				EFQM Business Excellence Model	Results and Determinants	Performance Prism	Total
			Main Model	Service Balanced Scorecard	Balanced Business Scorecard	Holistic Balanced Scorecard				
Business industry	Manufacturing		25	0	2	1	12	0	0	40
	Service		41	0	3	0	8	3	2	57
		Facility Management	3	1	0	0	1	0	0	**5**
	Total		**69**	1	5	1	21	3	2	**102**

(Sources: Toni *et al*., 2007: p. 427)

5.6 THE APPLICATION OF THE BSC TO THE CONTROL OF HAIs IN HMS

Before embarking on the process of identifying the CSFs and performance measures in HM in IC, it is necessary to examine relevant performance issues in the development of the BSC. Although some of these performance issues are drawn from the literature, e.g. Amaratunga *et al*. (2002), they are based on a number of case studies, e.g. Rockwater (Kaplan and Norton, 1993). It is possible that there will be variations in the ways different HMUs apply the BSC.

As mentioned earlier, HM managers often do not understand or pursue the strategic agenda of the organisation under which they operate. In order for HM managers to improve performance in IC, they need to have a thorough understanding of the vision and strategy of the FM division and NHS Trust under which they operate. Failure to derive the PMS from the organisation's strategy may result in actions that are not congruent with those laid down in the strategy (Tangen, 2004). Therefore, HM managers have to identify those aspects of their business operations that support the NHS Trusts' vision and strategy in IC. This can be done by soliciting information from the principal stakeholders of the HMU in IC. So far, the principal stakeholders of the HMU in IC are patients, the infection control team (ICT), nurses, microbiologist and DH, etc.

Liaising with these stakeholders could help the HMU identify some pertinent strategic issues in IC. It could assist HM managers to understand the extent to which they can stretch the HMU in terms of action for IC. Junior maintenance staff should not be excluded from discussions relating to maintenance operations. According to Hicks (2004: 1), they could participate in a series of internal meetings or interviews "… *to identify the …opportunities and challenges that exist operationally within the* [maintenance] *department*". Any decision about actions to adopt in HM in IC should be evaluated against the internal and external business requirements of the HMU, i.e. in terms of impact, cost and resource requirements, and ease of implementation (Al-Turki, 2011).

The process involved in the formulation of the strategy of the NHS Trust in IC is an on-going one. Given the business climate of today, where competition and stakeholder demands are top on the agenda, one would expect the strategy of the NHS Trust to change often. Thus, as strategic issues change, the HMU must also be in a position to re-align itself. With a thorough understanding of the strategy of the NHS Trust in IC, the HMU could then move on to address its mission statement. The mission statement is a platform for the HMU to demonstrate to its stakeholders that it understands and supports the vision of the NHS hospital in IC. The mission statement reflects the values, beliefs, and philosophy of the HMU in IC. It also demonstrates the seriousness with which the HMU is taking the NHS's objective of reducing the spread of HAIs. In order to give credibility to the mission statement, it is imperative for the HMM to get it approved by top NHS Trust officials. The mission statement should be written in such a way that it is clearly understood by all the departmental units in the NHS Trust. All the stakeholders of the HMU (especially maintenance staff) should identify with the mission statement, and see their contribution in controlling HAIs in the NHS.

Merely stating the mission of the HMU in IC would not drive performance. HM managers will need to identify those CSFs that drive performance in HM in IC. According to Caralli (2004: p. 2), CSFs are "…*key areas of performance that are essential for the organisation to accomplish its mission* [goals, objectives, or projects]". These are specific areas of the HMU where excellence is needed for it to excel in IC. Since CSFs determine success or failure in IC, it is important for HM managers to spend sufficient time identifying and collecting information about them. In this research study, the CSFs in HM in IC are categorised according to the four perspectives of the BSC: finance, internal business processes, innovation and learning, and customers (see Table 5-4).

Having identified and categorised the CSFs, the next step for the HMM is to identify the key performance measures in HM in IC. Performance measure are "… *specific standards which allow the calibration of performance for each critical success factor, goal, or objective*" (Bullen and Rockart, 1981, p. 8). Performance measures therefore help HM managers understand and manage the performance of the HMU effectively. Through the application of performance measures, managers are able to collect valuable information that lets them make intelligent decisions about the short- and long-term futures of their organisation (U.S Department of Energy, 1995). The performance measures in HM in IC are listed in Table 5-4.

For every performance measure in HM in IC, managers will need to set the goals they are aiming to achieve in IC. Performance goals are "*broad, measurable, aims that support the accomplishment of a mission*" (Gates, 2010: 5). Goals should be linked to the mission of the HMU, as well as to the vision of the NHS Trust in IC. They should contribute towards the provision of safe patient care in the NHS. Goals are expected to cover a reasonable period. They give a picture of what the long-term plans of the HMU are in IC. Goals are vague to be useful in any meaningful short-term planning. The goals of the HMU in IC could be developed from the CSFs.

In order to plan and evaluate progress towards pre-set goals in IC, the HMU will also have to develop performance objectives. According to Al-Turki (2011: p. 158) performance objectives are "*...the highest level measure of mission achievement…*" Performance objectives provide management with unique ways of enhancing the performance of maintenance staff and the entire maintenance department in IC. However, the challenge lies with the selection of the right set of performance measures for achieving the performance objectives of the HMU in IC. For every performance measure, actions will need to be identified to drive performance towards a pre-set goal and objective in IC. The process of identifying actions to drive performance should not be left in the hands of HM managers alone. The process should be an inclusive one involving all the stakeholders of the HMU in IC, i.e. the ICT. Often, the process goes on without the participation of maintenance staff at the operational level. According to Hicks (2004), operational staff hold valuable information that could contribute to the identification of actions to drive performance in the HMU. Once actions have been identified, the HMU will need to turn them into a set of programs that can easily be monitored and adjusted.

HM managers need to state the metrics and frequency of measurement they will use to measure performance. This is because metrics enable managers to establish the gap between the current state and future desired ambition of the HMU in infection control. On the other hand, the frequency of measurement serves as an early warning indicator to managers about the HMU achieving its pre-set goals and objectives in IC. It is important for managers to consider quantitative and qualitative metric of measurements. The frequency of measuring performance should provide managers with enough time to either maintain or change tactics/strategy for attaining the goals and objective of the HMU in IC.

In order to demonstrate commitment in IC, HM managers need to be in full control of performance management. Managers need to establish clear roles and responsibilities for maintenance staff in IC. Competent and dedicated individuals should be appointed for collecting data on selected performance measures. These individuals should know where to collect, as well as who to contact for information relating to performance measures. Other departments and units with relevant information should be contacted. Those collecting data may not be the ones who make use of the information. Thus it is necessary to identify all those who need to use of the data. Valuable time should not be spent collecting data that will not be used to drive performance in IC. The value of performance measurement is diminished if managers do not record and evaluate the results of key performance measures against pre-set goals and objectives. A system should also be put in place for the continuous improvement of the performance of HM services in IC.

As demonstrated above, there are key performance issues to consider in the application of the BSC. However, given the scope of this research study, it will not be possible to address all of these performance issues. In addition, because of variations across NHS Trusts, some of these performance issues are better addressed at the level of individual HMUs. The focus of this research study is on the identification of the CSFs and performance measures in HM in IC. In the following section, the CSFs and performance measures identified in the literature are discussed.

5.6.1 An Overview of the CSFs and Performance Measures in HM in IC

The CSFs and performance measures in HM in IC were gathered through an in-depth literature review process (see section 4.6.3). The research materials were drawn from a wide range of sources, i.e. government policies, HM policies, and clinical research materials. As shown in Table 5-4, 27 documents were analysed for the CSFs and performance measures in IC. A complete list of all the 27 documents showing dates of publication and names of authors is provided in Table 4-2.

The initial aim of this research study was to develop a conceptual framework for HM in IC. However, the results of the pilot study brought to light a number of important issues. It revealed the broad nature of what this research study was trying to achieve within a limited period. More importantly, the results showed that the problem was not with the development of a HM conceptual framework in IC. As shown section 5.4.3, PMSs abound in HFM and HM. So far, the problem is therefore with the identification of the CSFs and performance measures in IC.

The results of the pilot study show that some HM managers did not have the required knowledge in IC to participate in this research study. As a result, the decision was taken to apply the Delphi approach. A key strength of Delphi is the selection of participants based on professional knowledge and experience. In the next section, the CSFs and performance measures in HM in IC identified in the literature are examined. This includes eight CSFs and 56 performance measures (see table 5-4). These are described briefly below.

Table 5-4: The CSFs and Performance Measures Identified in the Literature

(A) BSC Perspective (n = 4)	(B) CSFs (n = 8)	(C) Performance Measures (n = 56)	Documents (D) (n = 27) GD-1	GD-2	GD-3	GD-4	GD-5	GD-6	GD-7	HM-8	HM-9	HM-10	HM-11	HM-12	HM-13	HM-14	HM-15	HM-16	HM-17	CR-18	CR-19	CR-20	CR-21	CR-22	CR-23	CR-24	CR-25	CR-26	CR-27	Frequency (F)	% (F/D * 100%)
Internal Business Processes	**Liaise & Communicate with the Infection Control Team (ICT)**	1. Early consultation & authorisation from the Infection Control Team before commencement of any maintenance work posing the risk of HAIs.			x						x	x						x												4	15%
		2. Seek the advice of the Infection Control Team (ICT) on such matters concerning infections.			x		x		x	x	x		x	x	x			x												9	33.3%
		3. Liaise with person in charge of area where maintenance is to be carried out.		x								x							x											3	11%
		4. Put in place a system for maintenance staff to liaise with domestic staff regarding cleaning during and on completion of work.							x																					1	4%
		5. Establish communication channel between maintenance staff and contracted staff.		x									x					x												3	11%
		6. Regularly meet with Infection Control and Clinical representatives to ensure maintenance processes complement clinical care.		x					x			x											x							4	15%
	Infection Control Practices																														
	– ***Cleaning Requirements***	1. Provide active means to prevent airborne dust from dispersing into high risk patient areas.					x					x						x		x	x	x	x	x	x	x	x	x	x	13	48%
		2. Compliance with hand hygiene whilst working in clinical areas.	x		x		x	x			x								x			x								7	26%
		3. Compliance with the use of personal protective equipment as required.		x			x		x			x							x											5	19%
		4. Report any injury especially if 'sharp'-related, cover wounds or sores.		x							x		x						x											4	15%
		5. Maintenance staff must not work in clinical areas if any symptoms of infection exist, e.g. diarrhoea or vomiting (seek advice from the ICT).									x																			1	4%
		6. Conduct maintenance work in a manner that facilitates cleaning.	x	x	x	x			x		x	x	x			x							x							10	37%
		7. Provide temporary hand-washing facilities for maintenance staff working in high risk patient areas.																x												1	4%
		8. Wash and sanitise drainage equipment after use.		x																										1	4%
	– ***Administrative Requirement***	1. Inform Charge Nurse before commencement of maintenance work.																												0	-
		2. Maintain and review infection control policies and		x	x	x		x	x	x	x	x	x	x	x	x	x	x	x											15	56%

		procedures.																													
	3.	Before commencement of maintenance work, obtain infection control permit, and assess patients for risk of maintenance-associated HAIs.																												0	-
	4.	Put in place safe working system for maintenance staff in infection prevention.						x		x	x	x	x	x	x	x		x	x											10	37%
	5.	Pre-employment health check and immunisation programme for all in-house and contracted maintenance staff.	x	x															x											3	11%
– ***Transport Requirements***	1.	Health & safety signage used.										x																		1	4%
	2.	Contain construction waste before transport in tightly covered containers.										x																		1	4%
	3.	Transport clean and sterile equipment to storage areas via route that minimises contamination.					x					x																		2	7%
	4.	Redirect pedestrian traffic from work area.										x						x												2	7%
– **SLA Agreement**																															
– ***Contract Requirements with External Providers***	1.	Contractor should have safe record keeping, and adhere to mandatory code of conduct in infection control.							x		x	x	x					x												5	19%
	2.	Contractor should have arrangement to respond to emergency calls.									x																			1	4%
	3.	Take into account changes in assets and legislation when renewing contracts.										x	x																	2	7%
	4.	Contractor should have procedure to supervise maintenance work and variables, e.g. spares, etc.									x																			1	4%
	5.	Select contractors for strong technical, resource, managerial, and communication capabilities.								x	x				x			x												4	15%
	6.	Customer satisfaction survey should be part of service level agreement with contractors.											x	x																2	7%
– ***Contracted Staff Requirements***	7.	Contractors have to take responsibility for any unsafe equipment or practice posing risk of infection.								x	x	x		x					x											5	19%
	8.	Contracted workers must attend all mandatory induction and training in infection control.									x		x																	2	7%
– **Maintenance Strategies**	1.	Ensure the timely execution of all planned maintenance work posing risk of infection.		x						x	x	x			x	x	x	x												8	30%
	2.	Keep account of the effectiveness of all critical maintenance equipment/assets that may cause HAIs.								x	x	x	x		x		x	x												7	26%
	3.	Use a computer-based maintenance system (i.e. reliability-centred maintenance) to coordinate all maintenance work.																												0	-
	4.	Daily check of all critical maintenance systems posing the risk of HAIs.								x		x																		2	7%
	5.	Categorize hospital assets and maintenance equipment into significant and non-significant items in terms of infection control.								x		x			x		x													4	15%

	– **Risk Assessment**	1. Involve all stakeholders in risk identification and response (i.e. the ICT).		X			X			X	X	X			X			X												7	26%
		2. Educate staff and set clear lines of individual responsibility for managing the risk of maintenance-related infections.		X							X	X			X	X			X											6	22%
		3. Process for reporting, managing, and analysing complaints and incidences in infection control.		X						X	X																			3	11%
		4. Use a recognised risk assessment tool (i.e. infection control risk assessment – ICRA) to match the level of risk associated with maintenance work.										X					X	X												3	11%
Financial	**Maintenance Resource Availability**	1. Secure adequate resources for mandatory and operational compliance of the healthcare maintenance unit in infection control.		X			X		X		X		X					X												6	22%
		2. Review the condition of hospital building services and infrastructure to feed into investment program.		X						X	X	X	X		X		X													7	26%
		3. The purchase of quality maintenance materials and products from reliable suppliers.		X																										1	4%
		4. Conduct monthly review of expenditure against budget in IC.								X					X															2	7%
Innovation and Learning	**Staff Education**																														
	– ***Staff Training***	1. Provide all maintenance staff with information on statutory and technical guidance on infection control.		X	X		X			X	X	X	X	X	X	X	X													11	41%
		2. Employ skilled and competent staff to ensure safe and efficient maintenance operations.									X		X																	2	7%
		3. Conduct annual review of staff training.		X					X						X		X													4	15%
		4. Conduct site induction on infection control within first few weeks of employment.		X			X		X	X	X																			5	19%
	– ***Staff Development***	1. The maintenance department should be represented in infection prevention & control, risk/governance committees.									X																			1	4%
		2. The education of maintenance staff on assessing and managing the risk of maintenance-associated hospital-acquired infections (HAIs).		X					X																				X	3	11%
		3. Maintenance staff team briefings and appraisal schemes in infection control.					X																							1	4%
		4. Equal access, and improve working lives for staff.																													-
Customer Satisfaction	**Customer Satisfaction**	1. System to review, analyse complaints against maintenance services, and recommend improvement.								X			X		X															3	11%
		2. Measure the speed to response to maintenance request.									X		X																		7%
		3. Measure the number of maintenance products that do not conform to the request.																												0	-
		4. Make available complaint boxes/leaflets to enable people to raise issues related to quality of maintenance services								X																				1	4%

5.6.1.1 Liaison and Communication with the ICT

Under 'liaison and communication with the ICT', issues relating to the working relationship between the HMU and the Infection Control department are examined. Table 5-4 show the 56 performance measures that were identified in the literature. Since the issue of IC is directly under the auspices of the ICT, their input on the control of maintenance-associated HAIs is vital. Early consultation must be established with ICT on matters such as maintenance works posing the risk of HAIs. HM managers must also seek the advice of the ICT on IC issues. Other issues addressed under this CSF concern the collaboration between HM staff and contracted staff in IC. Cleaning staff also need to work closely with HM staff regarding cleaning during and after maintenance work in patient areas. Under this CSF, there are six performance measures.

5.6.1.2 Infection Control Practices

A number of performance measures were identified in the literature for the control of maintenance-associated HAIs in hospitals. Infection control practices in HM could be divided into three categories: cleaning, transport, and administrative requirements. The cleaning requirement refers to routine cleaning practices to prevent HAIs in hospitals. Transport requirements on the other hand refer to transportation activities to prevent dust contamination emanating from maintenance work in hospitals. Administrative requirements refer to those actions which are initiated at top management level to minimise the risk of HAIs. In total, there are 17 performance measures under infection control practices.

As shown in Table 5-4, the prevention of dust contamination in hospitals is an important performance measure in IC. Therefore, it is necessary that maintenance work be conducted in a manner that facilitates cleaning. Given the technical nature of maintenance operations, managers have to make sure HM staff understand and abide by all necessary policies and procedures.

5.6.1.3 Service-Level Agreements (SLA) with Contractors

The manner in which HM services are provided in the NHS has changed over the years. Presently, HM services are provided both in-house and by contractors. Eight performance measures are identified under this CSF. Amongst them are issues related to the technical ability of contractors to minimize the risk of maintenance-associated HAIs. Contractors are to take responsibility for any unsafe equipment that exposes patients to the risk of HIAs. Contracted staff working in close proximity to patients are also required to undergo mandatory training in IC, and be immunized against infectious diseases such as tuberculosis.

5.6.1.4 Maintenance Strategies

These are strategies that may be applied in HM to reduce the rate of failure of critical maintenance equipment or components that may expose healthcare users to the risks of HAIs. Maintenance strategies commonly applied in the NHS include corrective, preventive, and condition-based maintenance strategies. The timely execution of planned maintenance work is identified in the literature as a key performance measure to reduce maintenance-associated HAIs. HM managers are also required to keep records of the effect of all critical equipment that may expose patients to the risk of HAIs. It appears that the cost associated with application of computer-based maintenance systems has reduced their application in the NHS Trusts.

5.6.1.5 Risk Assessment

Risk assessments are actions by the HMU to identify and manage the risk of HAIs in HM. In total, four performance measures are identified under this CSF. These actions are to be taken by the key players of the HMU in IC. Information related to risk identification and management should be disseminated to all HM staff. HM managers need to have a process for reporting, managing, and analysing complaints against the HMU in IC. The ICRA (infection-control risk assessment) is an important tool in controlling the risk of maintenance-associated HAIs in the NHS.

5.6.1.6 Maintenance Resource Availability

These resources are allocated to the HMU for the safe execution of maintenance-related work in hospitals. Maintenance resources include money allocated to the HMU for the purchase of spare parts, equipment, staff education (staff training and development), incentives, etc. Once maintenance resources are allocated to the HMU, it is the expectation of top management that maintenance work will be carried out in a prudent fashion, i.e. considering patient safety, environment, and cost. There are four performance measures under maintenance resource availability. In order for the HMU to achieve compliance in IC, it must secure adequate resources from top management. The HMU also has to review the condition of the hospital building and feed the information into an investment program. This is necessary to predict future resource needs and to utilise maintenance resources in an efficient manner.

5.6.1.7 Staff Education

The CSF staff education is divided into staff training and staff Development. Under each of these categories, there were four performance measures. This is related to such issues as the induction of HM staff in IC, and statutory guidance on IC. Employing competent and highly skilled maintenance staff could help improve the overall performance of maintenance services in the NHS. Staff development refers to those programmes that help enhance the performance of HM staff in IC. An example of a performance measure under this category is equal access, and improved working lives for staffs in the NHS. There are eight performance measures under staff training and development.

5.6.1.8 Customer Satisfaction

There were four performance measures under customer satisfaction. As shown in Table 5-4, it appears the issue of customer satisfaction has not been taken seriously in HM. Amongst the performance measures identified here is that about a system to review and analyse complaints, and recommend improvement in the performance of the HMU in IC. Others include the speed of the HMU in responding to emergency calls, as well as the number of defective products, etc.

5.7 SUMMARY

The business of measuring performance in IC in the NHS should not be restricted to clinical services alone. As demonstrated in this research study, the poor performance of HM services in IC can also cause HAIs. Therefore, to tackle the high rate of HAIs in the NHS, officials should consider making performance measurement and management a key requirement in HM in IC. Presently, it appears that there are few PMSs to measure performance in HM in IC. The few performance measures that have been developed in HM focus mainly on cost.

As this research study has shown, the problem is not with the development of an HM-BSC framework, but rather with the identification of the CSFs and performance measures in HM in IC. Eight CSFs and 56 performance measures are identified in this research. These are also categorised according to the four perspectives of the BSC. The BSC is one of the most popular performance measurement systems for HM. Performance measurement is not only about CSFs and about performance measures. HM managers need to have a thorough understanding of the strategy of the NHS Trust in IC. This involves having thorough understanding of the Trust's mission statement, goals and objectives for the control of HAIs.

CHAPTER 6 : CONSENSUS ON CSFs AND PERFORMANCE MEASURES – THE RESULTS OF DELPHI ROUNDS 1 AND 2

6.1 INTRODUCTION

According to the CSFs and performance measures in HM in IC, identified in chapter 5, the purpose of the next stage of the study was to identify the level of importance of the CSFs and performance measures in HM in IC. To achieve this aim, a three-round Delphi exercise was carried out. In this chapter, only the findings of the first two rounds of the Delphi exercise are presented. In section one, the results of the first round of the Delphi exercise are presented. The main aim of the first-round Delphi exercise was to identify other CSFs and performance measures in HM in IC, if any were not captured in the previous chapter. Thus, the results are presented in a qualitative form. Section two deals with the task of identifying the key performance measures in HM in IC by the Delphi participants. The results are presented according to the identified CSFs in HM in IC. Finally, a summary is also provided of how the HM managers and Infection Control personnel rated the different performance measures in HM in IC.

6.2 THE RESULTS OF DELPHI ROUND 1

As shown in Table 4-5 and 4-6, 27 Delphi nominees agreed to take part in this research study to identify the CSFs and performance measures in HM in IC. At the end of the first round of the Delphi exercise, 20 (74%) participants returned the Delphi instruments (a copy of the round one Delphi instrument is provided in Appendix D). However, not every Delphi participant completed the section ‘performance issues’. In a few instances, the Delphi participants simply re-wrote what had already been identified. Others simply returned the Delphi instrument, saying that they were unable to identify any new issues. Worst still, those who failed to read the Delphi instructions properly went on to provide yes and no answers to the Delphi questions. Despite these shortcomings, the Delphi participants were able to identify additional performance measures, and provide positive comments and suggestions.

The Delphi participants provided comments and suggestions that led to re-wording, and in some instances, the re-structuring of sections of the Delphi instrument. Because of the small number of responses, the Delphi instruments were analysed manually. The results of the Delphi round one exercise are presented here according to the CSFs.

6.2.1 Maintenance Resource Availability

There were four performance measures under maintenance resource availability. One of the Delphi participants suggested that the word 'regularly' used in one of the performance measures under resources was ambiguous. In the first round of the Delphi exercise, the performance measure read '*regularly review the condition of hospital building services and infrastructure, and feed into investment program'*. One of the Delphi participants noted that it would be too expensive for PFI hospitals to review the condition of hospital buildings on a regular basis. Following this suggestion, in the second round of the Delphi exercise, the performance measure was re-worded as '*review of the condition of hospital building services & infrastructure to feed into investment program*'. Concerning the frequency with which the condition of hospital services and infrastructure is reviewed, a HM mentioned that "*each year we visit the five-facet survey to get all our buildings and plant to an A or B rating from C or D capital investment funding*".

On the provision of adequate maintenance resources in IC, an IC member commented that *"… funding will never be available to resource all* [maintenance] *needs …*" "*This is difficult as there are no national standards to indicate what is adequate in this context*". For example, "*the Code of Practice (Health Act) states that healthcare providers should provide adequate isolation facilities, but adequate is not defined*". One HM manager even criticised the fact that guidance on the provision of resources to the HMU in IC was an emerging issue. According to this participant, "*the condition of the estate in relation to infection control needs to be risk assessed by the HMU and the IC department… for resource needs*". On the other hand, one of the HM managers noted, "*I take guidance from IC who will have confirmed costs and funding*".

The performance measure on the purchase of quality materials and products was criticised for being too subjective. According to one of the Delphi participants, this performance measure should be considered as "*an aim rather than a performance measure*". Further, it was also suggested that the HMU did not handle the business of purchasing HM materials and products. One HM manager noted, "*I do not hold this budget...*" In most NHS Trusts, this has *"been outsourced by the procurement and logistics department to the EROS e-Procurement system"*. In another case, one of the Delphi participants noted that the "*purchasing department was often driven by lowest cost …but in relation to infection control, not all of the cheapest products are the best"*.

Under the CSF maintenance resource availability, the Delphi participants identified three performance measures as follows:

1. Use risk assessment in maintenance-associated HAIs to direct maintenance resources to highest-risk activities.
2. Involve the HMU and IC department in the purchase of maintenance materials and products.
3. Develop processes to control the introduction of new equipment/fabric that can be maintained efficiently and reduce the risk of HAIs (cheap capital purchases may be more expensive to maintain in the long term and pose a risk of HAIs).

6.2.2 Maintenance Strategies

There were initially five performance measures under maintenance strategies. The Delphi participants were asked to comment, and identify any new CSFs or performance measures under maintenance strategies. On the performance measure concerning the daily check of all critical maintenance activities posing risk of HAIs, an IC member thought it "*might not be good use of resources, as it may overkill the HMU*". However, other microbiologists thought that a daily check of critical maintenance systems posing the risk of HAIs might be useful, but that it was currently unavailable. An HM manager pointed out that "*...all critical maintenance systems are monitored through a BMS system*". A BMS (Building Management System) is a computer-based system that is installed in a building to monitor the building's mechanical and electrical equipment, e.g. heating, ventilation. According to this HM manager, it is important that "*preventive maintenance in the BMS be conducted according to various frequencies to meet* *manufacturers' maintenance requirements and compliance with statutory requirements... "*. The Built Environment Group is responsible for keeping records of the effectiveness of all critical maintenance equipment/assets that may cause HAI.

Although it was important to categorise hospital assets and maintenance equipment into significant and non-significant items, it was unnecessary in every area of the hospital, noted a microbiologist. According to this microbiologist, "*certain areas of the hospital will, by its nature, pose a higher risk to patients e.g. augmented care areas (ICU Neonatal, renal, cancer units & burns units) ...water systems and equipment are of a higher risk in these areas than in lower risk area, even though the equipment and services used are the same"*. In order to uphold high standards in critical patient areas, this microbiologists recommended hospital assets and maintenance equipment be validated, verified, monitored and tested. In this way, authorities can "... *prove the effectiveness of the maintenance programme and ensure that equipment parameters are all maintained within specification*"

Following the comments and suggestions provided by the Delphi participants, three new performance measures were included under maintenance strategies. These are:

1. Prioritise and respond to building defects on time to minimise the risk of HAIs.
2. Introduce computer system that promotes mobility and allows maintenance staff to carry all the information they require, and communicate back to coordinators when job cannot be completed first time (so that parts/people can be planned in swiftly for revisit).
3. Both the HM and IC teams to develop a water safety plan (reviewed annually) to identify, manage and control risks of waterborne infections associated with maintenance activities.

6.2.3 Infection Control Practices

The CSF 'infection control practice' is divided into cleaning, transport, and administrative requirements. In total, there were seventeen performance measures under this CSF. On one of them on the prevention of dust contamination, a microbiologist noted that "*any building site/ or building should be double screened to stop dust entering hospital streets wards*". Before commencing any maintenance with the potential of generating dust, contractors should be inducted on dust abatement techniques, and provided with personal protective equipment. Besides protecting HM staff from HAIs, it is also necessary to prevent HM staff from transmitting HAIs in hospitals. At the moment, according to one of the HM managers, there is no system in place for preventing "*contracted staff with the symptom of an infection e.g. diarrhoea working in a clinical area*". One of the HM managers, with over 32 years of experience doubted the value of the immunisation of HM in IC. According to this official, "*the cost of this immunisation programme would be significant and also impossible to manage and control given the number of contractors on site every year*". An IC member noted that "*... good infection control practice and hygiene practice in* [maintenance] *should be sufficient to ensure adequate HAI controls*".

Analysis of Delphi round one resulted in the identification of three new performance measures under infection control practices. All the three newly identified performance measures were under the sub-category 'administrative requirements'. The following performance measures were identified:

1. Ensure in-house staff and contractors work on the same clear guidelines.
2. Have an agreed HAI plan to control all construction on site. This needs to be reviewed annually to monitor/review/assess level of compliance and provide annual improvement action plan based on benchmark findings (based on previous years).
3. Develop a work culture that supports prioritisation of maintenance work in infection control.

6.2.4 Liaison and Communication with the Infection Control Team (ICT)

Most Delphi participants agreed that 'liaison and communication with the ICT' is an important CSF in HM to control HAIs. One HM manager even suggested for "*estates staff and infection control staff to meet on a weekly basis to review all estates works programmes and agree all HAI control measures during all works*". This could also allow them to "*review trends or concerns in relation to microbiological monitoring*". The organisational structure for HM in IC has to be led by the IC, since they are the experts in the field of IC. Under liaison and communication with the ICT, the Delphi participants did not identify any new performance measure.

6.2.5 Service Level Agreement

In order to draw up service level agreements (SLAs) that consider IC, HM managers and IC members should work closely together. Unfortunately, this is not always the case. According to an infection control nurse, "... *infection control team members are rarely informed about maintenance contracts*". One HM manager suggest that because "*the selection of contractors is based on European legislation, all contracts will no doubt meet the requirements of the areas mentioned*". Presently, issues relating to arrangements to respond to emergency calls, procedures to supervise maintenance work and variables, contractors' safe record keeping are currently, according to one HM manager, not being considered in SLAs. Instead of selecting contractors based on strong technical, resource, managerial, and communication capabilities, NHS Trusts always "... *run for the cheap option*", says a microbiologist.

In order to improve the performance of the HMU in IC, one of the HM managers proposed a number of criteria for the selection of contractors. These include, for example, evidence that the contractor has successfully executed a similar contract in an NHS Trust, association with a professional body or organisation (Legionella Control Association, UKAS accredited body). The comments and suggestions under SLA led to a deeper understanding of the performance measures. The Delphi participants did not identify or provide comments on staff education. However, for customer satisfaction, they identified two new performance measures:

1. Ensure visual display of response to complaints.
2. Measure the number of completed maintenance jobs that failed to meet the required standard in infection control.

In total, eleven new performance measures were identified in the first round of the Delphi exercise. However, because of late submission, only six of these new performance measures were added to the second round Delphi questions. The remaining five performance measures were then added to the round three Delphi question for rating by the Delphi participants.

6.3 THE RESULTS OF DELPHI ROUND 2

In the first round of the Delphi exercise, there were 20 participants. However, in the second round, the number was reduced to 15 participants (See Section 4.9.2). Therefore, the rate of attrition from the first to the second Delphi rounds was 25%. In the next section, the results of the second round Delphi exercise are presented according to the eight CSFs in HM in IC. In section 4-10, the criteria for interpreting as well as arriving at consensus on the performance measures are provided.

6.3.1 Maintenance Resource Availability

Under maintenance resource availability, there were five performance measures in the second round of the Delphi exercise. Of these performance measures, the Delphi participants achieved consensus on four. The securing of adequate maintenance resources for mandatory and operational compliance in IC was ranked the most important performance measures under maintenance resource availability. As shown in Table 6-1, all the Delphi participants rated this performance measure in the positive category (i.e. very important or important). In terms of consensus, the mean score for IC members was 4.000, while for HM managers it was 3.833. Overall, both groups arrived at a high level of consensus of 3.933 that this performance measure was very important in IC. As a result, the performance measure was retained in the second round of the Delphi exercise.

The review of the condition of hospital buildings to feed into an investment program was ranked second under maintenance resource availability. Since this performance measure achieved was placed by 100% of participants in the positive category, it was interpreted as very important in IC. The mean scores for HM managers and IC members for this performance measure were 4.000 and 3.7778 respectively. Since both groups achieved a mean score of 3.8667 (high-level consensus), the performance measure was retained in the second round of the Delphi exercise.

The development of processes to control the introduction of new equipment/fabric was considered by the Delphi participants to be very important in IC. Out of the 15 Delphi participants, 13 (86.7%) rated this performance measure as very important, and two (13.3%) rated it as important. Therefore, this performance measure was interpreted as very important in IC. There was also strong consensus between HM managers and IC members on the importance of this. The mean score for IC members was 3.8889, and for HM managers it was 3.8333. With a combined mean score of 3.866, the performance measure was retained in round two of the Delphi exercise.

Purchasing quality maintenance materials and products from reliable suppliers was rated as very important or important in IC by most of the Delphi participants, with the exception of for one Delphi participant who rated it as unimportant. With a score of 93.3% in the positive category, the performance measure was interpreted as very important in IC. There was also a high-level of consensus between HM managers and IC members, with each group achieving a mean score of 3.3333. As it also had a grouped mean score of 3.333, the performance measure was retained in round two of the Delphi exercise.

The last performance measure under maintenance resource availability concerned the monthly review of maintenance expenditure against budget in IC. None of the 15 Delphi participants rated this performance measure as very important. Only nine (60%) of the Delphi participants rated this performance as important in IC. The remaining six (40%) Delphi participants rated this performance measure as unimportant in IC. Thus, with a vote of only 60% in the positive category, this performance measure was interpreted as very unimportant in IC. The mean score for HM managers was 2.6667, and for IC members it was 2.5556. With a combined mean score of 2.6000, the performance measure was re-submitted to the Delphi participants for re-rating in round three.

Table 6-1: Maintenance Resources - Levels of Importance and Degrees of Consensus

Performance Measures	Response	*N*	%	Category Total %	Interpretation	Mean HMM	Mean ICM	Combined Mean (HMM+ICM)	Mann-Whitney U test (*p*)	Consensus	σ	Retention
1. Secure adequate resources for mandatory and operational compliance of the healthcare maintenance unit in infection control.	Very important	14	93.3	100	**Very important**	3.833	4.000	3.933 (1)	.221	**High**	.2582	**Yes**
	Important	1	6.7									
2. Review condition of hospital building services & infrastructure to feed into investment program	Very important	13	86.7	100	**Very important**	4.0000	3.7778	3.8667 (2)	.231	**High**	.35187	**Yes**
	Important	2	13.3									
3. Develop processes to control the introduction of new equipment/fabric that can be maintained efficiently and reduce the risk of HAIs.	Very important	13	86.7	100	**Very important**	3.8333	3.8889	3.8667 (2)	.765	**High**	.35187	**Yes**
	Important	2	13.3									
4. Quality maintenance materials and products to be purchased from reliable suppliers	Very important	6	40.0	93.3	**Very important**	3.3333	3.3333	3.3333 (4)	.842	**High**	.61721	**Yes**
	Important	8	53.3									
	Unimportant	1	6.7		-							
5. Conduct monthly review of expenditure against budget in infection control.	Important	9	60	60	**Unimportant**	2.6667	2.5556	2.6000 (5)	.678	**Medium**	.50709	**No**
	Unimportant	6	40									

Results are statistically significant at $p < 0.05$ level
(HMM-Healthcare Maintenance Managers; ICM – Infection Control Member)

6.3.2 Maintenance Strategies in IC

In round two of the Delphi exercise, there were seven performance measures under maintenance strategies. Of these seven performance measures, only three were retained in round two of the Delphi exercise. The remaining four were included in the third round Delphi questions for re-rating. One of the performance measures that was retained in round two of the Delphi exercise concerned the timely execution of all planned maintenance work posing a risk of HAIs. All 14 Delphi participants who rated this performance measure did so in the positive category. As shown in Table 6-2, the total percentage score for the positive responses was 93.4%. The mean score for HM managers was 3.8333, and for IC members it was 3.6250. With a combined mean score of 3.7143, the performance measure was very important for HM in IC. Thus, the performance measure was retained in round two of the Delphi exercise.

The performance measure on prioritising and responding to building defects within the in time-critical period ranked second under maintenance strategies. The total percentage score in the positive category was 100%, and both groups of Delphi participants achieved high-level consensus that this performance measure was very important in IC. The mean score for IC members was 3.6667, and for HM managers it was 3.5000. Thus, the groups achieved a combined mean score of 3.6000, and the performance measure was retained in the second round of the Delphi exercise.

The introduction of a computer system to facilitate the coordination of maintenance staff and equipment around hospital wards achieved 93.3% in the positive category. Thus, this performance measure was interpreted as very important in IC. However, the two groups of Delphi participants failed to achieve the same level of consensus. As shown in Table 6-2, the mean score for HM manager was 3.6667 (high-level consensus), and for IC members it was only 3.1111 (medium-level consensus). The Mann Whitney U test ($p = 0.084$) also reveals slight difference between the two groups of Delphi participants. Since the overall mean score for both groups was 3.3333, the performance measure was retained in round two of the Delphi exercise.

The performance measure concerning keeping account of the effectiveness of all critical maintenance equipment/assets achieved 100% in the positive category. Out of 15 Delphi participants, 4 (26.7%) rated this as very important, and 11 (73.3%) rated it as important in IC. The mean score for IC members on this performance measure was only 3.111 (medium consensus), while for HM managers it was 3.5000 (high consensus). However, with a combined mean score of 3.2667, the performance measure was not retained in round two of the Delphi exercise. Instead, it was re-submitted to the Delphi participants for re-rating in the third round of the Delphi exercise.

All 15 Delphi participants who rated the use of a computer-based maintenance system (i.e. reliability centred maintenance) to coordinate maintenance work did so in the positive category. Therefore, the performance measure was interpreted as very important in IC. However, the two groups of Delphi participants failed to achieve the same level of consensus on this. Whilst the mean score for maintenance managers was 3.667 (indicating high consensus), for IC members it was 3.0000 (indicating medium consensus). The Mann-Whitney U test (see Table 6-2) revealed a significant difference (p = .006) between HM managers and IC members on this issue. Nonetheless, with a combined mean score of 3.2667, the performance measure was not retained in the second round of the Delphi exercise. It was included in the third round Delphi questions for re-rating.

The performance measure regarding the daily check of all critical maintenance equipment posing a risk of HAIs was rated by 93.3% of the Delphi participants in the positive category. One Delphi participant rated this performance measure as unimportant in IC. As shown in Table 6-2, the level of consensus for this performance measure was not the same for ICM and HM managers. With a mean score of 3.6667, IC members showed a high-level of consensus that this performance measure was very important in IC. On the other hand, the mean score for HM managers was 3.000, indicating a medium-level of consensus that this performance measure was important in IC. The Mann-Whitney U test also revealed a significant difference (p = .029) between maintenance managers and IC members. Thus, with a combined mean score for of 3.2667 (medium level consensus), the performance measure was not retained in the second round of the Delphi exercise. It was included in the third round Delphi questions for re-rating.

Ranked last under maintenance strategies was the performance measure on the categorisation of hospital assets and maintenance equipment into significant and non-significant items in IC'. While 73.3 % of Delphi participants rated this performance measure in the positive category, the remaining 4 (26.7%) Delphi participants put it in the negative category. Thus, the performance measure was interpreted as unimportant in IC. The Delphi participants also failed to arrive at a consensus: the mean score for IC members was 3.0000, while for maintenance managers it was 2.8333. The combined mean score was 2.9333, and the performance measure was not retained in the second round of the Delphi exercise. It was included in the third round Delphi questions.

Table 6-2: Maintenance Strategies - Levels of Importance and Degrees of Consensus

Performance Measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention
7. Ensure the timely execution of all planned maintenance work posing risk of infection.	Very important	10	66.7	93.4	**Very important**	3.8333	3.6250	3.7143 (1)	.411	**High**	.46881	**Yes**
	Important	4	26.7									
	Missing	1	6.7									
8. Prioritise and respond to building defects within time-critical period to minimise the risk of HAIs	Very Important	9	60	100	**Very important**	3.5000	3.6000	3.6000 (2)	.533	**High**	.35187	**Yes**
	Important	6	40									
9. Introduce computer system to promote mobility and allow maintenance staff to carry all the information they require, and communicate back to coordinators when job cannot be completed first time.	Very important	6	40	93.2	**Very important**	3.6667	3.1111	3.3333 (3)	.084	**High**	.61721	**Yes**
	Important	8	53.3									
	Unimportant	1	6.7									
10. Keep account of the effectiveness of all critical maintenance equipment/assets that may cause HAI.	Very important	4	26.7	100	**Very important**	3.5000	3.1111	3.2667 (4)	.107	**Medium**	.45774	**No**
	Important	11	73.3									
11. Use a computer-based maintenance system (i.e. reliability-centred maintenance) to coordinate all maintenance work.	Very important	4	26.7	100	**Very important**	3.6667	3.0000	3.2667 (5)	.006*	**Medium**	.45774	**No**
	Important	11	73.3									
12. Conduct daily check of all critical maintenance systems posing the risk of HAIs	Very important	5	33.3	93.3	**Very important**	3.6667	3.0000	3.2667 (6)	.029*	**Medium**	.59362	**No**
	Important	9	60									
13. Categorise hospital assets and maintenance equipment into significant and non-significant items in infection control	Very important	3	20	73.3	**Unimportant**	2.8333	3.0000	2.9333 (7)	.697	**Medium**	.70373	**No**
	Important	8	53.3									
	Unimportant	4	26.7									

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Managers; ICM – Infection Control Member)

6.3.3 Infection Control Practices

Infection control practices in HM in IC have been divided into three sections: cleaning, transport, and administrative requirements. In total, 18 performance measures were proposed for these three headings (see Appendix F).

6.3.3.1 Cleaning Requirements

There were eight performance measures under the category 'cleaning'. The first performance measure under this category was about the 'prevention of airborne dust dispersing into high-risk patient areas in hospitals'. As shown in Table 6-3, all 15 (100%) Delphi participants in this study rated this performance measure as very important in IC. The two groups of Delphi participants also achieved a high level of consensus, with a mean score of 4.0000. The Mann-Whitney U test (p = 1.000) also shows strong agreement between the two groups. Therefore, the performance measure was retained in the second round of the Delphi exercise.

The Delphi participants also rated 'compliance with hand hygiene' as very important in IC. All 15 Delphi participants (100%) rated this performance measure in the positive category. Thus, the performance measure was interpreted as very important in IC. There was unanimous agreement amongst HM managers that this performance measure was very important in IC. The level of consensus for HM managers was 4.0000, and for IC members it was 3.7778. With a combined mean score of 3.8667, the performance measure was retained in the second round of the Delphi exercise.

Delphi participants also considered 'compliance with the use of personal protective equipments' as very important in IC. All the Delphi participants (100%) rated this performance measure in the positive category. Therefore, the performance measure was interpreted as very important in IC. It also achieved a high level of consensus amongst the Delphi participants. With a combined mean score of 3.8667, this performance measure was retained in round two of the Delphi exercise.

The reporting of injuries (especially if sharp-related) and the covering of wounds and sores was rated as very important in IC by all the Delphi participants (100%). The two groups of Delphi participants achieved a high level of consensus that this performance measure is very important in IC. With a combined mean score of 3.6667, the performance measure was retained in the second round of the Delphi exercise.

The performance measure 'restricting maintenance staff with infectious diseases from working in clinical areas' was also considered very important by all the Delphi participants. One Delphi participants did not rate this performance measure. Out of the 14 remaining Delphi participants who rated this performance measure, 13 did so in the positive category (see Table 6-3). One of the Delphi participants rated this performance measure as unimportant in IC. On this performance measure, IC members had a stronger level of consensus than maintenance managers did. The mean score for IC members was 3.8889 (high consensus), while that for maintenance managers was 3.2000 (medium consensus). However, because the combined mean score for the two groups was 3.4629, the performance measure was retained in the second round of the Delphi exercise.

The last performance measure that was retained in round two covered the 'carrying out of maintenance work in a manner that eases the cleaning of hospitals'. The 14 Delphi participants who rated this performance measure did so in the positive category. The performance measure was therefore considered very important in IC. The two groups of Delphi participants also achieved a high level of consensus. With a combined mean score of 3.4000, the performance measure was retained in round two of the Delphi exercise.

The 'washing and sanitising of drainage equipment' was rated by 85.8% of the Delphi participants in the positive category. However, the mean score for HM managers was 3.5000 (high-level consensus), but was only 3.0000 (medium-level consensus for IC members. With a combined mean score of 3.2143, the performance measure was re-submitted to the Delphi participants for re-rating.

The 'provision of temporal hand washing facilities for maintenance staff working in clinical areas' was the only performance measure that was rated unimportant in IC. 11 (73.4%) Delphi participants rated this performance measure in the positive category, the other four (26.7) rated it in the negative category. Therefore, the performance measure was interpreted as unimportant in IC. Both HM managers and IC members agreed that this performance measure was unimportant in IC. The mean scores for HM managers and IC members were 3.1667 and 2.8889 respectively. The combined mean score for this performance measure was 3.0000. Ranked eighth in the list, this performance measure was not retained in round two of the Delphi exercise. It was included in the third round Delphi questions for re-rating

Table 6-3: Cleaning - Levels of Importance and Degrees of Consensus

Performance measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention
1. Provide active means to prevent airborne dust from dispersing into high risk patient areas.	Very important	15	100	100	**Very important**	4.0000	4.0000	4.0000 (1)	1.000	**High**	.00000	**Yes**
2. Compliance with hand hygiene whilst working in clinical areas	Very important	13	86.7	100	**Very important**	4.0000	3.7778	3.8667 (2)	.231	**High**	.35187	**Yes**
	Important	2	13.3									
3. Compliance with the use of personal protective equipment as required.	Very important	13	86.7	100	**Very important**	4.0000	3.7778	3.8667 (2)	.231	**High**	.35187	**Yes**
	Important	2	13.3									
4. Report any injury especially if 'sharp' related, cover wounds or sores.	Very important	10	66.7	100	**Very important**	3.8333	3.5556	3.6667 (4)	.280	**High**	.48795	**Yes**
	Important	5	33.3									
5. Maintenance staff must not work in clinical areas if any symptoms of infection exist i.e. diarrhoea or vomiting (seek advice from the ICT).	Very important	11	78.6	92.9	**Very important**	3.2000	3.8889	3.6429 (5)	.193	**High**	.84190	**Yes**
	Important	2	14.3									
	Very unimportant	1	7.1									
	Missing	1										
6. Conduct maintenance work in a manner that eases cleaning.	Very important	7	46.7	93.4	**Very important**	3.3333	3.4444	3.4000 (6)	.598	**High**	.63246	**Yes**
	Important	7	46.7									
	Missing	1	6.7									
7. Wash and sanitize drainage equipment after use.	Very important	6	42.9	85.8	**Important**	3.5000	3.0000	3.2143 (7)	.400	**Medium**	.89258	**No**
	Important	6	42.9									
	Unimportant	1	7.1	14.2								
	Very unimportant	1	7.1									
	Missing	1										
8. Provide temporal hand washing facilities for maintenance staff working in high risk patient areas.	Very important	4	26.7	73.4	**unimportant**	3.1667	2.8889	3.0000 (8)	.486	**Medium**	.75593	**No**
	Important	7	46.7									
	Unimportant	4	26.7									

Results are statistically significant at $p < 0.05$ level,
(HMM - Healthcare Maintenance manager; ICM – Infection Control Member

6.3.3.2 Transport Requirements

The category 'transport requirements' contains four performance measures. Only one of the performance measures under this category was not retained in round two of the Delphi exercise. The first performance measure that the Delphi participants achieved consensus on was 'the use of health and safety signage during maintenance work in the hospitals'. Except for one Delphi participant who rated this performance measure as unimportant in IC, all rated it in the positive category (see Table 6-4). Both groups of Delphi participants, i.e. HM managers and IC members, arrived at high-level consensus that this performance measure was very important in IC. With a combined mean score of 3.4667, the performance measure was retained in the second round of the Delphi exercise.

The Delphi participants also considered 'maintenance waste in tightly sealed containers before being transported off site' very important in IC. All 15 Delphi participants rated this performance measure in the positive category. Both HM managers and IC members also arrived at a high-level of consensus. The combined mean score for the two groups was 3.4000. Therefore, the performance measure was retained in round two of the Delphi exercise.

The Delphi participants considered the 'transportation of clean and sterile equipment via routes that minimise contamination' as very important in IC. All 15 (100%) Delphi participants rated this performance measure in the positive category. The two groups of Delphi participants achieved a high level of consensus. The combined mean score was 3.4000, and the performance measure was retained in the second round of the Delphi exercise.

The Delphi participants did not think 're-directing pedestrians from maintenance work areas' was either very important or important in IC. Since the total score for the positive category was 80%, no consensus was reached amongst the Delphi participants. With a mean score of 2.7778 for HM managers, and 2.8667 for IC members, the performance measure was not retained in the second round of the Delphi exercise. It was included in the third round of the Delphi exercise for re-rating.

Table 6-4: Transport Requirements - Levels of Importance and Degrees of Consensus

Performance measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICP	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention
1. Health & safety signage used	Very important	8	53.3	93.3	**Very important**	3.4444	3.4667	3.4667 (1)	1.000	**High**	.63994	**Yes**
	Important	6	40									
	Unimportant	1	6.7									
2. Contain construction waste before transport in tightly covered containers.	Very important	6	40	100	**Very important**	3.5556	3.4000	3.4000 (2)	.146	**High**	.50709	**Yes**
	Important	9	60									
3. Transport clean and sterile equipment to storage areas via route that minimises contamination.	Very important	6	40	100	**Very important**	3.5556	3.4000	3.4000 (2)	.678	**High**	.50709	**Yes**
	Important	9	60									
4. Redirect pedestrian traffic from work area.	Very important	2	13.3	80	**Important**	2.7778	2.8667	2.8667 (4)	.673	**Medium**	.61721	**No**
	Important	10	66.7									
	Unimportant	2	13.3	20	-							
	Very Unimportant	1	6.7									

Results are statistically significant at $p < 0.05$ level
(HMM – Healthcare Maintenance Manager; ICM – Infection Control Member)

6.3.3.3 Administrative Requirements

There were six performance measures under ‘administrative requirements’. Only one performance measure was not retained (see Table 6-5). The first performance measure under this category was about ‘maintenance staff informing charge nurses before commencing maintenance work’. All the Delphi participants rated this performance measure in the positive category, and it was interpreted as very important in IC. HM managers and IC members achieved a high level of consensus. Since the combined mean score was 3.9333, the performance measure was retained in the second round of the Delphi exercise.

The next performance measure concerned ‘in-house and contracted staffs working to the same clear guidelines’. Out of the 15 Delphi participants, 12 (80%) rated this performance measure as very important. The remaining 3 (20%) Delphi participants also rated this performance measure as important. Because this performance measure was rated by all the Delphi participants in the positive category, it was interpreted as very important. The combined mean score for the two groups of Delphi participants was 3.8000; and the performance measure was retained in round two of the Delphi exercise.

The third performance measure was about ‘maintaining and reviewing infection control policies and guidelines in IC’. Apart from 2 (13.3%) Delphi participants who rated this performance measure as unimportant, the remaining 13 (86%) put it in the positive category. As a result, the performance measure was interpreted as an important performance measure in IC. Overall, the combined mean score for the two groups of Delphi participants was 3.6000. Therefore, the performance measure was retained in round two of the Delphi exercise.

The performance measure requiring ‘maintenance managers to obtain infection control permits and assess patients for risks of maintenance-associated HAIs’ was rated by 4 (93.4%) Delphi participants in the positive category. One Delphi participant rated this performance measure as unimportant in IC. Although this performance measure was interpreted as very important in IC, there was disagreement between HM managers and IC members. The Mann-Whitney U test revealed a significant difference (p = .028) between the groups. As shown in Table 6-5, the mean score for IC members was 3.8889 (high-level consensus), and for HM managers it was 3.1667 (medium consensus). However, since the combined mean score was 3.6000, the performance measure was retained in the second round of the Delphi exercise.

All 15 Delphi participants rated the performance measure ‘putting in place a safe working system for maintenance staff in IC’ in the positive category. Thus, the performance measure was interpreted as very important in IC. However, there was a high level of disagreement between HM managers and IC members (P = .066). The mean score for HM managers was 3.8333, and for IC members, it was 3.3333. However, since the two groups achieved a combined mean score of 3.5333, the performance measure was retained in round two of the Delphi exercise.

The final performance measure under this category was about a ‘pre-employment health check and immunisation program for all in-house and contracted maintenance staff’. Since 13 (86.7%) of the 15 Delphi participants rated this performance measure in the positive category, it was interpreted as important in IC. Although HM managers achieved a high level of consensus, IC members did not. Thus, the combined mean score was only 2.6667, and the performance measure was not retained in the second round of the Delphi exercise. It was re-submitted to the Delphi participants for re-rating in round three.

Table 6-5: Administrative Requirements - Levels of Importance and Degrees of Consensus

Performance measures	Response	*N*	%	Total %	Interpretation	Mean MM	Mean IC	Mann-Whitney U test (*P*)	Grouped Mean/ Rank	σ	Consensus	Retention
1. Inform Charge Nurse before commencement of maintenance work.	Important	1	6.7	100	**Very important**	4.0000	3.8889	.414	3.9333 (1)	.25820	**High**	**Yes**
	Very important	14	93.3									
2. Ensure in –house and contractors work to same clear guidelines	Important	3	20	100	**Very important**	3.8333	3.7778	.799	3.8000 (2)	.41404	**High**	**Yes**
	Very important	12	80									
3. Maintain and review infection control policies and procedures.	Important	2	13.3	86.6	**Important**	3.6667	3.5556	.595	3.6000 (3)	.73679	**High**	**Yes**
	Very important	11	73.3									
	Unimportant	2	13.3									
4. Before commencement of maintenance work, obtain infection control permit, and assess patients for risk of maintenance-associated HAIs.	Important	4	26.7	93.4	**Very Important**	3.1667	3.8889	.028*	3.6000 (3)	.63246	**High**	**Yes**
	Very important	10	66.7									
	Unimportant	1	6.7		-							
5. Put in place safe working system for maintenance staff in infection prevention.	Important	7	46.7	100	**Very Important**	3.8333	3.3333	.066*	3.5333 (5)	.51640	**High**	**Yes**
	Very important	8	53.3									
6. Pre-employment health check and immunization program for all in-house and contracted maintenance staff.	Important	7	46.7	86.7	**Important**	3.3333	3.2222	.699	3.2667 (6)	.70373	**Medium**	**No**
	Very important	6	40									
	Unimportant	2	13.3									

Results are statistically significant at $p < 0.05$ level
(HMM- Healthcare Maintenance Manager; ICM – Infection Control Member)

6.3.4 Risk Assessment

Of the four performance measures under risk assessment, three were retained in round two of the Delphi exercise. There were also no significant differences in the way HM managers and IC members rated the performance measures (see Table 6-6). The first performance measure under this CSF was about ‘involving the stakeholders of the HMU in risk identification and response’. All the Delphi participants rated this performance measure in the positive category. Thus it was interpreted as very important. The two groups of Delphi participants also achieved high consensus that this performance measure was very important in IC. With a combined mean score of 3.6667, the performance measure was retained in the second round of the Delphi exercise.

‘Education of maintenance staff and setting clear lines of individual responsibility in managing the risk of maintenance-associated HAIs’ was the next performance measure under risk assessment. All 15 Delphi participants rated this performance measure in the positive category, and it was interpreted as very important. The performance measure also achieved high consensus amongst the Delphi participants. HM managers and IC members achieved a combined mean score of 3.4667, and the performance measure was retained in the second round of the Delphi exercise.

The performance measure ‘the development of a process for reporting, managing, and analysing complaints and incidences in IC’ was rated by all 15 Delphi participants in the positive category. The two groups of Delphi participants arrived at a high level of consensus that this performance measure was important in IC. As shown in Table 6-6, HM managers and IC members achieved a combined mean score of 3.4000, and the performance measure was retained in round two of the Delphi exercise.

Although the performance measure concerning the ‘application of risk-assessment tools in maintenance’ was interpreted as very important, it failed to achieve high-level consensus amongst the Delphi participants. As shown in Table 6-6, the mean scores for HM managers and IC members were 3.1667 (medium-level consensus) and 3.2222 (medium-level consensus) respectively. With a combined mean score of 3.2222, the performance measure was not retained in the second round of the Delphi exercise. It was included in the third round Delphi exercise for re-rating by the Delphi participants.

Table 6-6: Risk Assessment - Levels of Importance and Degrees of Consensus

Performance measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention
1. Involve all stakeholders in risks identification and response (i.e. the ICT).	Very important	10	66.7	100	**Very important**	3.5000	3.7778	3.6667 (1)	.280	**High**	.48795	**Yes**
	Important	5	33.3									
2. Educate staff and set clear lines of individual responsibility in managing the risk of maintenance-related infections.	Very important	7	46.7	100	**Very important**	3.5000	3.4444	3.4667 (2)	.837	**High**	.51640	**Yes**
	Important	8	53.3									
3. Process for reporting, managing, and analyzing complains and incidences in infection control.	Very important	6	40	100	**Very important**	3.5000	3.3333	3.4000 (3)	.533	**High**	.61721	**Yes**
	Important	9	60									
4. Use a recognised risk assessment tool (i.e. infection control risk assessment – ICRA) to match the level of risk associated with maintenance work.	Very important	4	26.7	93.4	**Very important**	3.1667	3.2222	3.2000 (4)	.943	**Medium**	.56061	**No**
	Important	10	66.7									
	Unimportant	1	6.7		-							

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Manager; ICM – Infection Control Member)

6.3.5 Liaison and Communication with Stakeholders

Five performance measures were listed under ‘liaison and communication with stakeholders’. As shown in Table 6-7, there were no significant differences between the groups of Delphi participants. The first performance measure relates to ‘the HMU seeking early consultation and authorization with the IC department’. All 15 Delphi participants who rated this performance measure put it in the positive category. Thus the performance measure was interpreted as very important. There was also strong agreement amongst the Delphi participants that this performance measure was very important. The combined mean score for the two groups of Delphi participants was 4.000. The performance measure was ranked first under this category, and retained in the second round of the Delphi exercise.

The Delphi participants also agreed that the ‘HMU should seek the advice of the IC team on matters relating to IC’. All 15 Delphi participants rated this performance measure in the positive category. The performance measure was therefore interpreted as very important in IC. In terms of consensus, the two groups of Delphi participants achieved a combined mean score of 3.9333, and the performance measure was retained in round two of the Delphi exercise.

All the Delphi participants rated the performance measure ‘requiring maintenance staff to liaise with individuals in charge of the areas’ in the positive category. Thus the performance measure was interpreted as important. There was also high-level consensus between the two groups of Delphi participants. The mean scores for HM managers and IC members were 3.8333 and 3.6667 respectively. Thus the performance was retained in the second round of the Delphi exercise.

The performance measure relating to a ‘system for maintenance staff to liaise with domestic staff regarding cleaning during and on completion of maintenance work’ was rated by all the 15 Delphi participants in the positive category. Thus it was interpreted as very important in IC. The two groups of Delphi participants also achieved high-level consensus. The combined mean score was 3.5333, and the performance measure was retained in the second round of the Delphi exercise.

In the NHS, in-house and/or contracted staff often carry out maintenance work. One of the performance measures in this research was therefore about 'the setting up of a communication channels between in-house and contracted maintenance staff'. Only 1 (6.7%) Delphi participant thought this performance measure was unimportant in IC. The other 14 (93.3%) Delphi participants rated this performance measure in the positive category. The performance was therefore interpreted as very important in IC. However, the level of consensus was not the same for HM managers as for IC members. As shown in Table 6-7, the mean score for HM managers was 3.1667 (medium consensus), while that for IC members was 3.6667 (high-level consensus). However, because the combined mean score was 3.3333, the performance measure was retained in round two of the Delphi exercise.

One performance measure was not retained under 'liaison and communication with members of the ICT'. 2 (13.3%) Delphi participants rated this performance measure as unimportant. On the other hand, 13 (86.6%) rated it in the positive category. Although the performance measure was interpreted as important, the Delphi participants failed to arrive at a high level of consensus. Although HM managers achieved high-level consensus on this performance measure, IC members did not. With a combined mean score of 3.2000, the performance measure was not retained in the second round Delphi exercise. It was included in the third round Delphi questions for re-rating by the Delphi participants.

Table 6-7: Liaison and Communication - Levels of Importance and Degrees of Consensus

Performance measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention
1. Early consultation & authorization from the Infection Control Team before commencement of any maintenance work posing the risk of HAIs.	Very important	15	100	100	**Very Important**	4.000	4.0000	4.0000 (1)	1.000	**High**	.00000	**Yes**
2. Seek the advice of the Infection Control Team (ICT) on such matters concerning infections.	Very important	14	93.3	100	**Very important**	3.8333	4.0000	3.9333 (2)	.221	**High**	.25820	**Yes**
	Important	1	6.7									
3. Liaise with person in charge of area where maintenance is to be carried.	Very important	11	73.3	100	**Very important**	3.8333	3.6667	3.7333 (3)	.490	**High**	.45774	**Yes**
	Important	4	26.7									
4. A system for maintenance staff to liaise with domestic staff regarding cleaning during and on completion of work.	Very important	8	53.3	100	**Very important**	3.3333	3.6667	3.5333 (4)	.221	**High**	.51640	**Yes**
	Important	7	46.7									
5. Set communication channel between maintenance staff and contracted staff.	Very important	6	40	93.3	**Very important**	3.1667	3.4444	3.3333 (5)	.465	**High**	.61721	**Yes**
	Important	8	53.3									
	Unimportant	1	6.7									
6. Regularly meet with infection Control and Clinical representatives to ensure maintenance processes complement clinical care.	Very important	5	33.3	86.6	**Important**	3.3333	3.1111	3.2000 (6)	.601	**Medium**	.67612	**No**
	Important	8	53.3									
	Unimportant	2	13.3									

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Managers; ICM – Infection Control Member)

6.3.6 SLA with Contractors

The CSF Service level agreement (SLA) was divided into two main sections: the contract and contracted staff requirements. Contract requirements concern the external providers of maintenance services in an NHS Trust. On the other hand, contracted staff requirements relate to HM staff employed by the external providers.

6.3.6.1 Contract Requirement with External Providers

As indicated in Table 6-6, there were six performance measures under 'contract requirements with external providers'. The first performance measure was related to 'safe record keeping, and adherence to mandatory codes of conduct in IC'. All the Delphi participants rated this performance measure in the positive category. There was also high-level consensus between the two groups of Delphi participants. With a combined mean score of 3.7333, the performance was retained in the second round of the Delphi exercise.

The second performance measure under this category related to 'external providers of maintenance in the NHS having arrangements to respond to emergency calls'. One Delphi participant rated this performance as unimportant in IC. However, the other 14 (93.3%) put it in the positive category. Thus the performance measure was interpreted as very important in IC. The two groups of Delphi participants, i.e. HM managers and IC members, also achieved high-level consensus. Overall, they achieved a combined mean score of 3.5333. As a result, the performance measure was retained in the second round of the Delphi exercise.

The performance measure requiring 'the external providers of maintenance services to have procedures to supervise maintenance works and variables' was rated by all 15 Delphi participants in the positive category. Since all the Delphi participants rated this performance measure in the positive category, it was interpreted as very important in IC. The combined mean score for HM managers and IC members was 3.3333, and the performance measure was retained in the second round of the Delphi exercise.

The next performance measure was about 'the selection of the external providers of HM services on the basis of technical, resource, managerial and communication capabilities'. 14 Delphi participants rated this performance measure in the positive category. One Delphi participant did not rate this performance measure. Although there was no significant difference between HM managers and IC members, the latter achieved only achieved medium-level consensus (3.1250). Nonetheless, the combined mean score for HM managers and IC members was 3.2857, and the performance measure was retained in round two of the Delphi exercise.

The Delphi participants did not arrive at a consensus on the performance measure 'requiring authorities to take into account changes in assets and legislation in renewing contracts'. Out of the 15 Delphi participants, 2 (13.3%) rated this performance measure as unimportant. The remaining 13 (86.7%), however, put it in the positive category. Although the performance measure was interpreted as important, the two groups of Delphi participants failed to arrive at high-level consensus. With a combined mean score of 3.1333 (3.1667 for HM managers and 3.1111 for IC members) the performance measure was not retained in round two of the Delphi exercise. It was re-submitted to the Delphi participants in round three for re-rating.

Delphi participants also did not agree on a 'customer satisfaction survey on IC being part of the SLA'. Although four (26.7%) Delphi participants rated this performance measure as unimportant, 11 (73.3%) put it in the positive category. Thus the performance measure was interpreted as unimportant in IC. The two groups of Delphi participants agreed that this performance measure was unimportant in IC. As shown in Table 6-8, the mean score for HM managers was 2.8333 (medium-level consensus), and 2.8889 (medium level consensus) for IC members. The combined mean score was only 2.8667, and the performance measure was therefore not retained in the second round of the Delphi exercise.

Table 6-8: Contract Requirements with External Providers - Levels of Importance and Degrees of Consensus

Performance measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Grouped Mean/ Rank	Mann-Whitney U test (*P*)	Consensus	σ	Retention
1. Contractor should have safe record keeping, and adhere to mandatory code of conduct in infection control.	Very important	11	73.3	100	**Very Important**	3.8333	3.6667	3.7333 (1)	.490	**High**	.45774	**Yes**
	Important	4	26.7									
2. Contractor should have arrangement to response to emergency calls.	Very important	9	60	93.3	**Very important**	3.6667	3.4444	3.5333 (2)	.586	**High**	.63994	**Yes**
	Important	5	33.3									
	Unimportant	1	6.7									
3. Contractor should have procedure to supervise maintenance work and variables i.e. spares etc.	Very important	5	33.3	100	**Very important**	3.5000	3.2222	3.3333 (3)	.280	**High**	.48795	**Yes**
	Important	10	66.7									
4. Select contractors on their strong technical, resource, managerial, and communication capabilities.	Very important	4	26.7	93.3	**Very important**	3.5000	3.1250	3.2857 (4)	.139	**High**	.46881	**Yes**
	Important	10	66.7									
5. Take into account changes in assets and legislation when renewing contracts.	Very important	4	26.7	86.7	**Important**	3.1667	3.1111	3.1333 (5)	.840	**Medium**	.63994	**No**
	Important	9	60									
	Unimportant	2	13.3									
6. Customer satisfaction surveys should be part of Service Level Agreement with contractors.	Very important	2	13.3	73.3	**Unimportant**	2.8333	2.8889	2.8667 (6)	.840	**Medium**	.63994	**No**
	Important	9	60									
	Unimportant	4	26.7									

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Manager; ICM – Infection Control Member)

6.3.6.2 Contracted Staff Requirements

There were only two performance measures under staff requirements. As shown in Table 6-9, there were also no significant differences between HM managers and IC members. The first performance measure was about ‘contractors taking responsibility for any unsafe equipment or practice posing the risk of HAIs’. Two Delphi participants did not rate this performance measure. However, the remaining 13 (86.7%) Delphi participants rated this performance measure in the positive category. The performance was therefore interpreted important in IC. With a combined mean score of 3.7692, the performance measure was retained in round two of the Delphi exercise.

The next performance measure, on ‘the mandatory training of contracted staff on IC’, did not achieve consensus amongst the Delphi participants. Although 11 (73.4%) Delphi participants rated this performance measure in the positive category, 3 (20%) put it in the negative category. With only 73.4% of the votes in the positive category, the performance measure was interpreted as unimportant in IC. HM managers arrived at a higher level of consensus than IC members. However, with a grouped mean score of 3.2143, the performance measure was not retained in the second round of the Delphi exercise. It was re-submitted to the Delphi participants for re-rating.

Table 6-9: Contracted Staff Requirements - Levels of Importance and Degrees of Consensus

Performance measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention
1. Contractors have to take responsibility for any unsafe equipment, or practice posing risk of infection.	Very important	10	66.7	86.7	**Important**	3.8333	3.7143	3.7692 (1)	.626	**High**	.43853	**Yes**
	Important	3	20									
	Missing	2	13.3									
2. Contracted workers must attend all mandatory induction and training in infection control.	Very important	7	46.7	73.4	**Unimportant**	3.5000	3.0000	3.2143 (2)	.328	**Medium**	.97496	**No**
	Important	4	26.7									
	Unimportant	2	13.3	20	-							
	Very unimportant	1	6.7									
	Missing	1	6.7									

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Manager; ICM – Infection Control Member)

6.3.7 Staff Education

As reiterated earlier, the CSF staff education is divided into two categories namely staff training and staff development. Each of these categories contained four performance measures. Three performance measures were not retained between both categories.

6.3.7.1 Staff Training

As mentioned earlier, there were four performance measures under staff training. The first performance measure was about ‘providing maintenance staff with information on statutory and technical guidance on IC’. All 15 Delphi participants rated this performance measure in the positive category. As a result, the performance measure was interpreted as very important in IC. As shown in Table 6-10, the two groups of Delphi participants achieved high-level consensus on this performance measure. Thus, with a combined mean score of 3.6000, the performance measure was retained in the second round of the Delphi exercise.

The second performance measure was about the ‘employment of skilled and competent maintenance staff to ensure safe and efficient maintenance operations in hospitals’. Of the 14 participants who rated this performance measure, 13 (86.7%) put it in the positive category. Hence, the performance measure was interpreted as important in IC. There was slight disagreement (p = 0.91) between the two groups of Delphi participants. As shown in Table 6-10, while the mean score for HM managers was 3.8333 (high-level consensus), that for IC members was only 3.2500. However, since the performance measure achieved a combined mean score of 3.5000, it was retained in the second round of the Delphi exercise.

The next performance measure was about ‘providing maintenance staff with site induction on IC’. Only one Delphi participant rated this performance measures as unimportant in IC. The remaining 14 (93.3%) Delphi participants put it in the positive category. As a result, the performance measure was interpreted as very important in IC. Although IC members failed to achieve a high level of consensus, the performance measure was nonetheless retained in the second round of the Delphi exercise. This was because the combined mean score for both groups was 3.3333.

Although the 'annual review of staff training in IC' was rated by 14 (93.3%) Delphi participants in the positive category, it failed to achieve the required level of consensus for it to be retained in round two of Delphi exercise. On this performance measure, IC members failed again to arrive at a high level of consensus. Thus, with a combined mean score of 3.2667, the performance measure was not retained in the second round of the Delphi exercise. It was included in the third round Delphi questions for re-rating.

Table 6-10: Staff Training - Levels of Importance and Degrees of Consensus

Performance measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention
1. Provide all maintenance staff with information on statutory and technical guidance on infection control.	Very important	9	60	100	**Very important**	3.6667	3.5556	3.6000 (1)	.678	**High**	.50709	**Yes**
	Important	6	40									
2. Employ skilled and competent staff to ensure safe and efficient maintenance operations.	Very important	8	53.3	86.6	**Important**	3.8333	3.2500	3.5000 (2)	.091*	**High**	.65044	**Yes**
	Important	5	33.3									
	Unimportant	1	6.7									
	Missing	1										
3. Conduct site induction on infection control within few weeks of employment.	Very important	6	40	93.3	**Very important**	3.5000	3.2222	3.3333 (3)	.426	**High**	.61721	**Yes**
	Important	8	53.3									
	Unimportant	1	6.7									
4. Conduct annual review of staff training.	Very important	5	33.3	93.3	**Very important**	3.3333	3.2222	3.2667 (4)	.785	**Medium**	.59362	**No**
	Important	9	60									
	Unimportant	1	6.7		-							

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Manager; ICM – Infection Control Personnel)

6.3.7.2 Staff Development

Of the four performance measures identified under staff development, two were retained in the second round of the Delphi exercise. The first performance measure under this category concerned ‘the representation of the HMU in infection prevention and control, risk/governance committee’. All the Delphi participants who rated this performance measure put it in the positive category. Only 1 (6.7%) Delphi participant rated this performance measure as unimportant in IC. The remaining 14 (93.3%) put it in the positive category. Thus, the performance measure was interpreted as very important in IC. As shown in 6-11, both groups of Delphi participants achieved a high level of consensus. With a combined mean score of 3.6667, the performance measure was retained in the second round of the Delphi exercise. The next performance measure was about ‘educating HM staff on the assessment and management of the risk of maintenance-associated HAIs’. Of the 15 Delphi participants, 14 rated this performance measure in the positive category. Both maintenance managers and IC members agreed that this performance measure was very important in IC. Thus, with a combined mean score of 3.4286, the performance measure was retained in round two of the Delphi exercise.

One of the performance measures that did not achieve consensus under this category concerned ‘maintenance staff team briefings and appraisal schemes in IC’. 12 (80%) Delphi participants rated this performance measures in the positive category. However, 2 (13.3%) other Delphi participants also rated this as unimportant. HM managers achieved a high level of consensus, while IC members only achieved medium-level consensus, that this performance measure was important in IC. With a combined mean score of 3.2143, the performance measure was not retained in the second round of the Delphi exercise. It was included in the third round Delphi questions. ‘Equal access, and improve working lives for staff’ was also not considered important by the Delphi participants. Only 11 (73.4%) of the Delphi participants rated this performance measure in the positive category. The other 4 (26.7%) Delphi participants rated this performance measure as unimportant in IC. The two groups of Delphi participants only arrived at medium-level consensus. The combined mean score was 3.0000, and the performance measure was not retained in the second round of the Delphi exercise.

Table 6-11: Staff Development -- Levels of Importance and Degrees of Consensus

Performance measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention
1. The maintenance department should be represented in infection prevention & control, risk/governance committees.	Very important	11	73.3	93.3	**Very important**	3.6667	3.6667	3.6667 (1)	.761	**High**	.61721	**Yes**
	Important	3	20									
	Unimportant	1	6.7									
2. Educate maintenance staff on the assessment and management of risk in maintenance-associated hospital-acquired infections (HAIs).	Very important	6	40	93.3	**Very important**	3.6000	3.3333	3.4286 (2)	.352	**High**	.51355	**Yes**
	Important	8	53.3									
	Missing											
3. Maintenance staff team briefings and appraisal schemes in infection control.	Very important	5	26.7	80	**Important**	3.3333	3.1250	3.2143 (3)	.524	**Medium**	.69929	**No**
	Important	7	73.3									
	Unimportant	2	13.3									
	Missing	1	6.7									
4. Equal access, and improve working lives for staff.	Very important	4	26.7	73.4	**Unimportant**	3.1667	2.8889	3.0000 (4)	.486	**Medium**	.75593	**No**
	Important	7	46.7									
	Unimportant	4	26.7		-							

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Manager; ICM – Infection Control Member)

6.3.8 Customer Satisfaction Requirements

There were six performance measures under customer satisfaction requirements. Only three performance measures under this category were retained in the second round of the Delphi exercise. The first performance measure related to the 'number maintenance works that failed to meet required standards in IC'. This performance measure was rated by 14 (93.4%) of the Delphi participants in the positive category. Thus, the performance measure was interpreted as very important in IC. There was also high-level consensus between the two groups of Delphi participants. With a combined mean score of 3.5000, the performance measure was retained in round two of the Delphi exercise.

Also retained under customer satisfaction requirements was the performance measure relating to 'the review and analysis of complaints against maintenance services'. Since all the Delphi participants rated this performance in the positive category, it was interpreted as very important in IC. There was also high-level consensus between the two groups of Delphi participants. The two groups of Delphi participants achieved a mean score of 3.4667, and the performance measure was retained in the second round of the Delphi exercise.

The performance measure on the 'speed of the HMU to response to work requests' was ranked third under customer satisfaction requirements. Of the 15 participants who rated this performance measure, 14 (93.4%) did so in the positive category. Only 1 (6.7%) Delphi participant rated this performance measure as unimportant in IC. The performance measure was therefore interpreted as very important. However, as shown in Table 6-12**,** IC members only achieved a medium level of consensus. However, since the combined mean score was 3.4000, the performance measure was retained in the second round of the Delphi exercise.

13 (86.7%) rated 'measurement of the number of maintenance product that does not conform to request' in the positive category. The remaining two (13.3%) Delphi participants rated this performance measure as unimportant. Since 86.7% of the Delphi participants rated this performance measure in the positive category, it was interpreted

as important in IC. The two groups of Delphi participants only arrived at medium-level consensus. The combined mean score was only 3.0667, and the performance was not retained in round two of the Delphi exercise. It was rather instead included in the round three Delphi questions for re-rating.

'Visual display of response to complaints' was not considered important by the Delphi participants. Only 12 (80%) Delphi participants rated this performance measure in the positive category. The remaining three (20%) Delphi participants rated it as unimportant. The two groups of Delphi participants arrived at a perfect consensus. Both groups of Delphi participants achieved a mean score of 3.0000. Since the combined mean score for this performance measure was 3.0000 (medium level consensus), it was not retained in round two Delphi exercise. It was included in the third round Delphi questions.

The 'provision of complaint boxes/leaflets for people to raise issues concerning the quality of maintenance services' did not also achieve consensus amongst the Delphi participants. As shown in Table 6-12, only 73.3% of the Delphi participants rated this performance measure in the positive category. Thus, the performance measure was interpreted as unimportant. This performance measure did not also achieve high-level consensus amongst the Delphi participants. With a combined mean score of 2.8000, the performance measure was not retained in round two of the Delphi exercise. It was included in the round three Delphi questions for re-rating.

Table 6-12: Customer Satisfaction - Levels of Importance and Degrees of Consensus

Performance measures	Response	*N*	%	Total %	Interpretation	Mean MM	Mean IC	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention
1. Measure the number of completed maintenance jobs that failed to meet the required standard in infection control.	Very important	7	46.7	93.4	**Very important**	3.3333	3.6250	3.5000 (1)	.298	**High**	.51887	**Yes**
	Important	7	46.7									
	Missing	1	6.7									
2. System to review, analyse complaints against maintenance services, and recommend improvement.	Very important	7	46.7	100	**Very important**	3.5000	3.4444	3.4667 (2)	.838	**High**	.51640	**Yes**
	Important	8	53.3									
3. Measure the speed to response to maintenance request.	Very important	7	46.7	93.4	**Very important**	3.6667	3.2222	3.4000 (3)	.188	**High**	.63246	**Yes**
	Important	7	46.7									
	Unimportant	1	6.7									
4. Measure the number of maintenance product that do not conform to the request.	Very important	3	20	86.7	**Important**	3.0000	3.1111	3.0667 (4)	.724	**Medium**	.59362	**No**
	Important	10	66.7									
	Unimportant	2	13.3		-							
5. Ensure visual display of response to complaints.	Very important	3	20	80	**Important**	3.0000	3.0000	3.0000 (5)	1.000	**Medium**	.65465	**No**
	Important	9	60									
	Unimportant	3	20									
6. Make available complaint boxes/ leaflets to enable people raise issues related to quality of maintenance services.	Very important	2	13.3	73.3	**Unimportant**	2.6667	2.8889	2.8000 (6)	.422	**Medium**	.77460	**No**
	Important	9	60									
	Unimportant	3	20	26.7								
	Very unimportant	1	6.7									

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Managers; ICM – Infection Control Member)

6.3 SUMMARY OF THE DELPHI ROUND TWO RESULTS

In the second Delphi instrument, there were sixty-two performance measures. Of these, the Delphi participants achieved high-level consensus on forty-two. In order for a performance measure to be retained in a Delphi round, the two groups of Delphi participants needed a combined mean score of 3.28 or above. Thus it is possible for a performance measure to be retained in a Delphi round with consensus in only one group of participants. As shown in Table 6-13, on 17 performance measures there was high-level consensus in only one group of Delphi participants. Of the 14 performance measures on which HM managers alone achieved consensus, six were retained in the second round of the Delphi exercise. Conversely, on the remaining three performance measures, high-level consensus was achieved by IC members alone. All the three performance measures were retained in the second round of the Delphi exercise.

The foregoing discussion suggests differences in the way HM managers and IC members view the issue of performance measurement in HM in IC. On one of the performance measure which was retained in round two there was a significant difference between IC members and HM managers. The performance measure in question is related to 'the HMU obtaining IC permits and assessing patients for risk of maintenance-associated HAIs'. Whilst IC members agreed strongly on this performance measure, HM managers did not (p = 0.28). Two other performance measures with a significant difference between HM managers and IC members were not retained in round two of the Delphi exercise. On the use of a computer-based maintenance system (i.e. reliability-centred maintenance) to coordinate all maintenance work (p = 0.06) HM managers agreed more strongly than IC members did. Similarly, HM managers agreed more strongly than IC members did on the daily check on all critical maintenance systems posing the risk of HAIs (p = 0.029).

Overall, in the second round of the Delphi exercise, HM managers achieved consensus on 47 performance measures, 39 of which were retained, while IC members achieved consensus on 36, all of which were retained. As mentioned earlier, in total 42 performance measures were retained in the second round of the Delphi exercise. The remaining 20 performance measures for which the Delphi participants only achieved low-level consensuses were re-sent to the Delphi participants for re-rating.

Table 6-13: Performance Measures with Consensus in only one Group of Delphi Participants

CSFs	Performance measures	HMM		ICM		Mann-Whitney U test	Retention
		Mean	Consensus	Mean	Consensus		
Maintenance Strategies	1. Introduce computer system that promotes mobility and allows maintenance staff to carry all the information they require, and communicate back to coordinators when job cannot be completed first time.	**3.6667**	**Yes**	**3.1111**	**No**	0.084*	**Yes**
	2. Keep account of the effectiveness of all critical maintenance equipment/assets that may cause HAI.	**3.5000**	**Yes**	**3.1111**	**No**	.107	**No**
	3. Use a computer-based maintenance system (i.e. reliability-centred maintenance) to coordinate all maintenance work.	**3.6667**	**Yes**	**3.0000**	**No**	.006*	**No**
	4. Conduct daily check of all critical maintenance systems posing the risk of HAIs.	**3.6667**	**Yes**	**3.0000**	**No**	.029*	**No**
Cleaning Requirements	5. Maintenance staff must not work in clinical areas if any symptoms of infection exist i.e. diarrhoea or vomiting (seek advice from the ICT).	**3.2000**	**No**	**3.8889**	**Yes**	.193	**Yes**
	6. Wash and sanitize drainage equipment after use.	**3.5000**	**Yes**	**3.0000**	**No**	.400	**No**
Administrative Requirements	7. Before commencement of maintenance work, obtain infection control permit, and assess patients for risk of maintenance-associated HAIs.	**3.1667**	**No**	**3.8889**	**Yes**	.028*	**Yes**
	8. Pre-employment health check and immunization program for all in-house and contracted maintenance staff.	**3.3333**	**Yes**	**3.2222**	**No**	.699	**No**
Liaison & Communication	9. Set communication channel between maintenance staff and contracted staff.	**3.1667**	**No**	**3.4444**	**Yes**	.465	**Yes**
Contract Requirements with External Providers	10. Contractor should have procedure to supervise maintenance work and variables i.e. spares etc.	**3.5000**	**Yes**	**3.2222**	**No**	.280	**Yes**
	11. Select contractors on their strong technical, resource, managerial, and communication capabilities.	**3.5000**	**Yes**	**3.1250**	**No**	.139	**Yes**
Contracted Staff Requirements	12. Educate staff and set clear lines of individual responsibility in managing the risk of maintenance-related infections.	**3.5000**	**Yes**	**3.0000**	**No**	.328	**No**
Staff Training	13. Employ skilled and competent staff to ensure safe and efficient maintenance operations	**3.8333**	**Yes**	**3.2500**	**No**	.091*	**Yes**
	14. Conduct site induction on infection control within few weeks of employment.	**3.5000**	**Yes**	**3.2222**	**No**	.426	**Yes**
	15. Conduct annual review of staff training.	**3.3333**	**Yes**	**3.2222**	**No**	.785	**No**
Staff Development	16. Maintenance staff team briefings and appraisal schemes in infection control.	**3.3333**	**Yes**	**3.2143**	**No**	.524	**No**
Customer satisfaction	17. Measure the speed to response to maintenance request.	**3.6667**	**Yes**	**3.2222**	**No**	.188	**Yes**
	Consensus	**14**		**03**			
	Retained	**6**		**03**			

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Managers; ICM – Infection Control Member; R – Delphi round)

CHAPTER 7 : CSFs AND PERFORMANCE MEASURES – THE RESULTS OF DELPHI ROUND 3

7.1 INTRODUCTION

Chapter 7 is similar to the previous chapter, and is divided into two main sections. The first section is organized according to the eight CSFs in HM in IC. Here, all those performance measures on which the Delphi participants could not arrive at high-level consensus are re-rated by the Delphi participants. Of the 25 performance measures in round three, five were newly introduced from round one.

In the third round of the Delphi exercise, participants were able to arrive at high-level consensus on eleven performance measures. In section two, the researcher also examines those performance measures with a consensus among only one group of Delphi participants. Unlike in round two, only two performance measures with significant difference between HM managers and IC members were retained in round three of the Delphi exercise.

7.2 RESULTS OF DELPHI ROUND THREE

In the third round of the Delphi exercise, there were 15 participants - the same participants as in round two of the Delphi exercise. Of the 25 performance measures contained in the third round Delphi instrument, 20 were re-introduced from the second round of the Delphi exercise. The remaining five performance measures were re-introduced from the first round of Delphi exercise. As pointed out earlier, some round one Delphi instruments were submitted late, after the commencement of the second round of the Delphi exercise. Of the25 performance measures contained in the third round Delphi instrument, consensus was achieved on 11. No further rounds of Delphi were conducted after this one. In the next section, the results of the round three Delphi exercise are discussed. The results are presented under the eight CSFs in HM in IC.

7.2.1 Maintenance Resource Availability

Under maintenance resource availability, there were three performance measures. Except for the last performance measures in Table 7-1, the other two were re-introduced from round one of the Delphi exercise. As shown in Table 7-1, consensus was achieved on only one of these performance measures. This relates to the 'use of risk assessment in HAIs to direct maintenance resources to highest risk activities'. Of the 15 Delphi participants, 10 (90.9%) rated this performance measure in the positive category. Only one Delphi participant rated this performance measure as unimportant. The remaining four Delphi participants did not rate this performance measure. The performance measure was interpreted as very important in IC. As shown in Table 7-1, the two groups of Delphi participants achieved high-level consensus. With a combined mean score of 3.4545, this performance measure was included in the list of key performance measures.

The second performance measure concerned the 'involvement of the HMU and IC department in the purchase of maintenance materials and products'. 11 (91.6%) Delphi participants rated this performance measure in the positive category. Thus the performance measure was interpreted as very important. However, both groups of Delphi participants failed to achieve high-level consensus on this performance measure. As shown in Table 7-1, only IC members achieved high-level consensus. Thus, with a combined mean score of 3.2500, the performance measure was not included in the list of key performance measures.

The third performance measure related to 'a formula to match monthly expenditure against budget in IC'. It was introduced from the second round Delphi exercise. Only nine (60%) Delphi participants rated this performance measure in the positive category. The remaining six (40%) Delphi participants rated this performance measure as unimportant. This performance measure was therefore interpreted as unimportant in IC. In terms of consensus, the mean score for IC members did not change between the two Delphi rounds. However, the mean score for HM managers dropped by 0.0667. In round three of the Delphi exercise, the mean score for ICM and HM managers were 2.5556 and 2.6000 respectively. The combined mean score did change between the two Delphi rounds. The combined mean score in round three was 2.6000, and the performance measure was not included in the list of key performance measures in HM in IC.

Table 7-1: Maintenance Resource Availability - Levels of Importance and Degrees of Consensus

Performance Measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention	Combined Mean R2	Difference in Combined Means R3 –R2
1. Use risk assessment in maintenance-associated HAIs to direct maintenance resources to highest risk activities.	Very important	6	54.5	90.9	**Very important**	3.4000	3.5000	**3.4545**	1.000	**High**	.68755	**Yes**	-	-
	Important	4	36.4											
	Unimportant	1	9.1	9.1										
	Missing	4												
2. Involve the HMU and IC department in the purchase of maintenance materials and products.	Very important	4	33.3	91.6	**Very important**	3.2000	3.2857	**3.2500**	.926	**Medium**	.62158	**No**	-	-
	Important	7	58.3											
	Unimportant	1	8.3	8.3										
	Missing	3												
3. Conduct monthly review of expenditure against budget in IC	Important	9	60	60	**Very unimportant**	2.6000	2.5556	**2.6000**	.678	**Medium**	.50709	**No**	2.6000	0
	Unimportant	6	40											

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Managers; ICM – Infection Control Member; R – Delphi round)

7.2.2 Maintenance Strategies

In the third round of the Delphi exercise, there were five performance measures under maintenance strategies. Four of these performance measures were re-introduced from the second round of the Delphi exercise. As shown in Table 7-2, one of the performance measures was newly introduced from the first round Delphi exercise. Of the five performance measures under maintenance strategies, the Delphi participants achieved consensus on three.

The first performance measure related to the 'development a water safety plan to identify, manage, and control the risk of waterborne infections in maintenance'. This performance measure was newly introduced to the Delphi participants in round three. The only 12 Delphi participants who rated this performance measure did so in the positive category. Therefore, the performance measure was interpreted as very important in IC. The level of consensus was also high for HM managers and IC members. The mean score for HM managers and ICM were 4.0000 and 3.8571 respectively. Overall, both groups of Delphi participants had a mean score of 3.9167. The performance measure was therefore included in the list of key performance measures.

The next performance measure related to the 'HMU keeping account of the effectiveness of critical maintenance equipment/assets that may cause HAIs'. All 15 Delphi participants in this study rated this performance measure in the positive category. Thus, the performance measure was interpreted as very important. Both groups of Delphi participants achieved high-level consensus. In round two, IC members only arrived at medium consensus. The mean score for IC members increased from 3.1111 in round two (medium consensus) to 3.3333 (high-level consensus (+ .2222) in round three. As a result, the combined mean score for both groups of Delphi participants also went up from 3.2667 to 3.4000 (+ 0.1333). Thus, the performance measure was added to the list of key performance measures.

The third performance measure concerned the 'application of a computer-based maintenance system (i.e. reliability-centred maintenance) to coordinate maintenance work in IC'. Since all 15 Delphi participants rated this performance measure in the positive category, it was interpreted as very important in IC. Although the mean score for ICM went up by 0.1111, they only attained medium-level consensus. In contrast, the mean score for HM managers went up by 0.7222, and they were able to achieve high-level consensus. The Mann-Whitney U test shows a significant difference (p = .007) between the HM managers and IC members. Despite the difference between HM managers and IC members, the combined mean score increased by 0.1333. Thus, with a combined mean score of 3.4000, the performance measure was added to the list of key performance measures.

In round two of the Delphi exercise, 93.3% of the Delphi participants rated a 'daily check of all critical maintenance systems posing the risk of HAIs' in the positive category. However, in round three, the number fell to 86.6% (-6.7%). Also in round three, the level of consensus for HM managers fell slightly (- 0.1667). However, for IC members, the level of consensus increased slightly (+ 0.1111). With a combined mean score of 3.2667, the performance was not included in the list of key performance measures.

The last performance measure under maintenance strategies concerned the 'categorisation of hospital assets and maintenance equipment into significant and non-significant items in IC'. The proportion of Delphi participants who rated this performance measure in the positive category increased from 73.3% in round two to 86.7% in round three. Thus, the performance measure was interpreted as important. Nonetheless, the two groups of Delphi participants did not achieve high-level consensus. With a combined mean score of 2.9333, the performance measure was not included in the list of key performance measures.

Table 7-2: Maintenance Strategies - Levels of Importance and Degrees of Consensus

Performance Measures	Response	*N*	%	Total %	Interp.	Mean HMM	Mean ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Ret.	Combined Mean R2	Difference in Combined Means R3 –R2
1. The development of a water safety plan (reviewed annually) by maintenance and infection control teams, to identify, manage and control risks of waterborne infections associated with maintenance activities.	Very important	11	91.7	100	**Very important**	4.0000	3.8571	**3.9167**	.398	**High**	.28868	**Yes**	-	-
	Important	1	8.3											
	Missing	3	20											
2. Keep account of the effectiveness of all critical maintenance equipment/assets that may cause HAI.	Very important	6	40	100	**Very important**	3.5000	3.3333	**3.4000**	.533	**High**	.50709	**Yes**	3.2667	0.1333
	Important	9	60											
3. Use a computer-based maintenance system (i.e. reliability-centred maintenance) to coordinate all maintenance work.	Very important	6	40	100	**Very important**	3.8333	3.1111	**3.4000**	.007*	**High**	.50709	**Yes**	3.2667	0.1333
	Important	9	60											
4. Daily check of all critical maintenance systems posing the risk of HAIs	Very important	6	40	86.7	**Important**	3.5000	3.1111	**3.2667**	.221	**Medium**	.7373	**No**	3.2667	0
	Important	7	46.7											
	Unimportant	2	13.3											
5. Categorize hospital assets, and maintenance equipment into significant and non-significant items in infection control	Very important	1	6.7	86.7	**Important**	2.8333	3.0000	**2.9333**	.500	**Medium**	.45774	**No**	2.9333	0
	Important	12	80											
	Unimportant	2	13.3											

Results are statistically significant at $p < 0.05$ level;
(HMM - Healthcare Maintenance Manager; ICM – Infection Control Member; R – Delphi round)

7.2.3 Infection Control Practices

The CSF 'infection control practices' is divided into three categories: cleaning, transport, and administrative requirements. In total, there were 18 performance measures under infection control practices.

7.2.3.1 Cleaning Requirements

The two performance measures presented under cleaning requirements were from the second round of the Delphi exercise. The first performance measure under this category related to 'the washing and sanitisation of drainage equipment after use in hospital'. In round three, the number of Delphi participants who rated this performance measure in the positive category fell by 5.8%. Nonetheless, the performance measure was interpreted as important. As shown in Table 7-3, HM managers achieved a higher level of consensus than IC members. However, in rounds 2 and 3, the combined mean score for the two groups of Delphi participants stayed the same at 3.2000. Therefore, the performance measure was not included in the lists of key performance measures.

Next under cleaning requirements was the performance measure concerning the 'provision of temporal hand-washing facilities for HM staff working in high-risk patient areas'. In round three, the number of Delphi participants who rated this performance measure in the positive category increased by 6.6%. Thus, instead of being interpreted as unimportant, as it was in round two, the performance measure was interpreted as important in round three. In round three, only HM managers achieved high-level consensus. With a combined mean score of 3.2000, the performance was not retained as a key performance measure.

Table 7-3: Cleaning Requirements - Levels of Importance and Degrees of Consensus

Performance Measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention	Combined Mean R2	Difference in Combined Means R3 –R2
1. Wash and sanitize drainage equipment after use.	Very important	6	40	80	**Important**	3.5000	3.0000	**3.2000**	.255	**Medium**	.77460	**No**	3.2143	- 0.0143
	Important	6	40											
	Unimportant	3	20											
2. Provide temporal hand washing facilities for maintenance staff working in high risk patient areas.	Very important	6	40	80	**Important**	3.3333	3.1111	**3.2000**	.569	**Medium**	.77460	**No**	3.0000	0.2
	Important	6	40											
	Unimportant	3	20											

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Managers; ICM – Infection Control Member; R – Delphi round)

7.2.3.2 Transport Requirements

In round three of the Delphi exercise, there was only one performance measure under transport requirements. This concerned the ‘re-direction of pedestrian traffic from maintenance work areas’. As shown in Table 7-4, in round three of the Delphi exercise the proportion of Delphi participants who rated this performance in the positive category increased from 80% to 86.7% (+6.7%). Thus in round three the performance measure was also interpreted as important. Although the level of consensus increased slightly in round three, the two groups of Delphi participants only arrived at a medium level of consensus. The combined mean score increased from 2.8667 in round two to 3.2000 in round three (+ 0.3333). As a result, the performance measure did not qualify to be included in the lists of key performance measures.

Table 7-4: Transport Requirements - Levels of Importance and Degrees of Consensus

Performance Measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention	Combined Mean R2	Difference in Combined Means R3 –R2
1. Redirect pedestrian traffic from work area.	Very important	3	20	86.7	**Important**	3.1667	3.0667	**3.2000**	.572	**Medium**	.77460	**No**	2.8667	0.3333
	Important	10	66.7											
	Unimportant	2	13.3											

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Manager; ICM – Infection Control Manager; R – Delphi rounds)

7.2.3.3 Administrative Requirements

As shown in Table 7-5, there were three performance measures under administrative requirements. Two of these performance measures were newly introduced in round three of the Delphi exercise. The first performance measure in this category concerned the ‘development of a work culture that supports the prioritization of maintenance work in IC’. The vast majority of the Delphi participants (91.7%) rated this performance measure in the positive category. It was thus interpreted as very important. There was also high-level consensus amongst the Delphi participants. With a combined mean score of 3.5833, the performance measure was added to the list of key performance measures in HM in IC.

The second performance measure was about the ‘pre-employment health check and immunization program for maintenance staff’’. In the third round of the Delphi exercise, 14 Delphi participants rated this performance measure in the positive category. The performance measure was therefore interpreted as very important. In addition, the level of consensus for both groups of Delphi participants also went up. For HM managers and IC members, the mean score increased by 0.1667 and 0.1528 respectively. Consequently, the combined mean score increased from 3.2667 to 3.4286. The performance measure was therefore included in the lists of key performance measures in IC.

The last performance measure under administrative requirements concerned the ‘development of a construction HAI plan to manage the activities of contracted staff in IC’. Only 10 (76.9%) Delphi participants rated this performance measure in the positive category. Besides considering it unimportant, the two groups of Delphi participants also failed to achieve high-level consensus. With a combined mean score of 3.0000, the performance measure was not included in the lists of key performance measures.

Table 7-5: Administrative Requirements- Levels of Importance and Degrees of Consensus

Performance Measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention	Combined Mean R2	Difference in Combined Means R3 –R2
1. Develop a work culture that supports prioritization of maintenance work in infection control.	Very Important	8	66.7	91.7	**Very important**	3.4000	3.7143	**3.5833**	.558	**High**	.66856	**Yes**	-	-
	Important	3	25											
	Unimportant	1	8.3											
2. Pre-employment health check and immunization program for all in-house and contracted maintenance staff.	Very important	6	42.9	100	**Very important**	3.5000	3.3750	**3.4286**	.652	**High**	.51355	**Yes**	3.2667	0.1619
	Important	8	57.1											
	Missing	1	8.3											
3. Have an agreed HAI plan to control all contract works on site. Review plan annually to see level of compliance and provide annual improvement action plan based on previous year's findings.	Very important	3	23.1	76.9	**Unimportant**	3.0000	3.0000	**3.0000**	1.000	**Medium**	.70711	**No**	-	-
	Important	7	53.8											
	Unimportant	3	23.1											
	Missing	2	13.3											

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Managers; ICM – Infection Control Member; R – Delphi round)

7.2.4 Risk Assessment

There was only one performance measure under risk assessment. This related to the 'application of a recognised risk assessment tool to minimise the level of risk of maintenance-associated HAIs'. In both Delphi rounds, 14 (93.4%) Delphi participants rated this performance measure in the positive category. Therefore the performance measure was interpreted as very important in IC. In round three of the Delphi exercise, the mean score for HMMs fell from 3.3333 to 3.0000 (- 0.3333). On the other hand, the mean score for IC members increased from 3.2222 to 3.3333 (+1111). As shown in Table 7-6, in rounds two and three of the Delphi exercises, the combined mean score stayed the same at 3.2000 (medium level-consensus). Therefore, the performance measure was not added to the lists of key performance measures.

Table 7-6: Risk Assessment - Levels of Importance and Degrees of Consensus

Performance Measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined Mean (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention	Combined Mean R2	Difference in Combined Means R3 –R2
1. Use a recognised risk assessment tool (i.e. infection control risk assessment – ICRA) to match the level of risk associated with maintenance work.	Very important	4	26.7	93.4	**Very important**	3.0000	3.3333	**3.2000**	.286	**Medium**	.56061	**No**	3.2000	0
	Important	10	66.7											
	unimportant	1	6.7											

Results are statistically significant at $p < 0.5$ level
(HMM - Healthcare Maintenance Managers; ICM – Infection Control Member; R – Delphi round)

7.2.5 Liaison and Communication with Stakeholders

Under liaison and communication with stakeholders, there was only one performance measure. This concerned ‘holding regular meetings between HM managers, IC, and clinical representatives to ensure maintenance work complements clinical care’. In the third round of the Delphi exercise, the number of Delphi participants who rated this performance measure in the positive category increased from 13 (86.6%) to 14 (93.3%). Thus, the performance measure was interpreted as very important. In the two Delphi rounds, the mean score for HM managers stayed the same, while for IC members it increased by 0.2222. Because of this slight increase, the combined mean score went up from 3.2000 in round two to 3.3333 in round three. As a result, the performance measure was included in the list of key performance measures in HM in IC.

Table 7-7: Liaison and Communication on with Stakeholders - Levels of Importance and Degrees of Consensus

Performance Measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention	Combined Mean R2	Difference in Combined Means R3 –R2
1. Regularly meet with infection control and clinical representatives to ensure maintenance processes complement clinical care.	Very important	6	40	93.3	**Very important**	3.3333	3.3333	**3.3333**	.894	**High**	.61721	**Yes**	3.2000	0.1333
	Important	8	53.3											
	Unimportant	1	6.7											

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Managers; ICM – Infection Control Member; R – Delphi rounds)

7.2.6 Service Level Agreements with Contractors

SLA was divided into two sections: contract requirements with external providers and contracted staff requirements. Of the three performance measures in these sections, the Delphi participants achieved consensus on two.

7.2.6.1 Contracted Requirements with External Providers

There were two performance measures under ‘contracted requirements with external providers’. The first concerned the ‘HMU taking into account changes in assets and legislation when renewing contracts with external providers’. Between rounds two and three of the Delphi exercise, the number of Delphi participants who rated this performance in the positive category increased from 13 to 14. One Delphi participant did not rate this performance measure. In round three, therefore, the performance measure was interpreted as very important. In terms of consensus, the mean score for HM managers increased from 3.1667 to 3.8666 (+ 0.6666) in round three. The mean score for IC members also increased, from 3.1111 to 3.2222 (medium-level consensus) in round three. As shown in Table 7-8, there was a significant difference (P = .025) between HM managers and IC members on this performance measure. The combined mean score in round two was 3.1111 (medium consensus). Despite this difference, the combined mean score for the two groups of Delphi participants increased from 3.1333 to 3.4667 (+0.3334) in round three of the Delphi exercise. Therefore, the performance measure was included in the list of key performance measures in HM in IC.

The next performance measure was the ‘need to have customer satisfaction surveys as part of SLAs’. The number of Delphi participants who rated this performance measure in the positive category increased from 11 (73%) in round two to 13 (86.7%) in round three of the Delphi exercise. Therefore, the performance measure was interpreted as important. As shown in Table 7-8, there was a slight increase in the level of consensus for HM managers. Between the two Delphi rounds, the mean score for HM managers increased from 2.8333 to 3.0000. However, for IC members, the mean score was 2.8889 for both Delphi rounds. Since the combined mean score in round three was only 2.9333 (+0.0444), the performance was not retained as a key performance measure.

Table 7-8: Contract Requirements with External Providers - Levels of Importance and Degrees of Consensus

Performance Measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention	Combined Mean R2	Difference in Combined Means R3 –R2
1. Take into account changes in assets and legislation when renewing contracts.	Very important	7	46.7	100	**Very important**	3.8333	3.2222	3.4667	.025*	**High**	.51640	**Yes**	3.1333	0.3334
	Important	8	53.3											
	Missing	1	6.7											
2. Customer satisfaction surveys should be part of Service Level Agreement with contractors.	Very important	1	6.7	86.7	**Important**	3.0000	2.8889	**2.9333**	.673	**Medium**	.45774	**No**	2.8889	0.0444
	Important	12	80											
	Unimportant	2	13.7											

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Manager; ICM – Infection Control Member; R – Delphi rounds)

7.2.6.2 Contracted Staff Requirements

In round three of the Delphi exercise, there was only one performance measure under 'contracted staff requirements'. This concerned 'mandatory induction and training of contracted staff on IC'. In the third round of the Delphi exercise, the number of Delphi participants who rated this performance measure in the positive category increased from 11 (73.4%) to 13 (92.9%). The performance measure was therefore interpreted as very important. In round three of the Delphi exercise, there was a slight increase in the levels of consensus for both HM managers and IC members. As shown in Table 7-9, between rounds two and three of the Delphi exercise, the combined mean score for HM managers and ICM increased from 3.2143 to 3.7143 (+ 0.5). Therefore, the performance measure was included in the lists of key performance measures.

Table 7-9: Contracted Staff Requirements - Levels of Importance and Degrees of Consensus

Performance Measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined Mean (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention	Combined Mean R2	Difference in Combined Means R3 –R2
1. Contracted workers must attend all mandatory induction and training on infection control.	Very important	11	78.6	92.9	**Very important**	3.8333	3.6250	**3.7143**	.653	**High**	.61125	**Yes**	3.2143	0.5
	Important	2	14.3											
	unimportant	1	7.1											
	Missing	1	6.7											

Results are statistically significant at $p < 0.05$ level
(HMM - healthcare maintenance managers; ICM – infection control personnel; R – Delphi rounds

7.2.7 Staff Education

This CSF constituted two sections: staff training and staff development. There was one performance measure under staff training, and two performance measures under staff development. In the next section, the results obtained from round three Delphi exercise are examined.

7.2.7.1 Staff Training

The only performance measure under staff training concerned 'the annual review of staff training in IC'. In the third round of the Delphi exercise, the number of Delphi participants who rated this performance measure in the positive category increased from 14 (93%) to 15 (100%). There was also a slight increase in the levels of consensus reached by the Delphi participants. As shown in Table 7-10, the mean score for HM managers and IC members increased by .1667 and .1111 respectively. Thus, with a combined mean score of 3.4000 (+0.1333), the performance measure was retained as a key performance measures.

Table 7-10: Staff Training - Levels of Importance and Degrees of Consensus

Performance Measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention	Combined Mean R2	Difference in Combined Means R3 –R2
1. Conduct annual review of staff training.	Important	9	60	100	**Very important**	3.5000	3.3333	**3.4000**	.533	**High**	.50709	**Yes**	3.2667	0.1333
	Very important	6	40											

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Managers; ICM – Infection Control Member; R – Delphi rounds)

7.2.7.2 Staff Development

There were two performance measures under staff development. The first related to ‘maintenance staff team briefings and appraisal schemes in IC’. In round three of the Delphi exercise, the number of Delphi participants who rated this performance measure in the positive category increased from 80% (important) to 92.8% (very important). There was also a slight increase in the combined mean score for HM managers and IC members. As shown in Table 7-11, the combined mean score increased from 3.2143 in round two to 3.2857 (+ 0.0714) in round three. Therefore, the performance measure was added to the list of key performance measures.

The next performance measure had to do with ‘equal access and improve working lives for staff’. In round two of the Delphi exercise, the number of Delphi participants who rated this performance measure in the positive category was 11 (73.4% - unimportant). However, in the third round of the Delphi exercise, the number increased to 12 (80% - important). Nonetheless, in both Delphi rounds, the combined mean score for HM managers and IC members stayed at 3.0000 (medium-level consensus). As a result, the performance measure was not included in the lists of key performance measures.

Table 7-11: Staff Development - Levels of Importance and Degrees of Consensus

Performance Measures	Response	*N*	%	Total %	Interpretation	Mean HMM	MM ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention	Grouped Mean R2	Difference in Combined Means R3 –R2
1. Maintenance staff team briefings and appraisal schemes in infection control.	Very important	5	35.7	92.8	**Very important**	3.5000	3.1250	**3.2857**	.270	**High**	.61125	**Yes**	3.2143	0.0714
	Important	8	57.1											
	Unimportant	1	7.1											
	Missing	1	6.7											
2. Equal access, and improve working lives for staff.	Very important	3	20	80	**Important**	3.3333	2.7778	**3.0000**	.107	**Medium**	.65465	**No**	3.0000	0
	Important	9	60											
	Unimportant	3	20											

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Manager; ICM – Infection Control Member; R – Delphi rounds)

7.2.8 Customer Satisfaction

There were three performance measures under ‘customer satisfaction’. The first had to do with ‘the measurement of the number of maintenance product that do not conform to request’. In the first round of the Delphi exercise, 13 (86.7%) of the Delphi participants rated this performance measure in the positive category. However, in the third round, the number increased to 14 (93.3%), and the performance measure was interpreted as very important. In terms of consensus, there was an increase in the level for HM managers. The mean score for IC members stayed the same for the two Delphi rounds. As shown in Table 7-12, the combined mean score for both groups of Delphi participants increased slightly (+ 0.0666) between the Delphi rounds. Nevertheless, in round three, the combined mean for the Delphi participants was only 3.1333. Therefore, the performance measure was not included in the list of key performance measures.

The next performance, on the ‘visual display of response to complaints’ also did not achieve consensus. As shown in Table 7-12, 13 (86.6%) Delphi participants rated this performance measure in the positive category. As a result, it was interpreted as important. Neither HM managers nor IC members arrived at high-level consensus. Thus, their combined mean score was only 3.0000; the same as in round two of the Delphi exercise. As a result, the performance measure was not included in the lists of key performance measures.

The last performance measure under customer satisfaction had to do with ‘making available complaints boxes and leaflets for people to raise issues about the quality of maintenance work’. In the first round of the Delphi exercise, only 11 (73.3%) participants rated this performance measure in the positive category. However, in round three, the number went up to 12 (80%), and the performance measure was interpreted as important in IC. In both Delphi rounds, participants failed to arrive at high-level consensus. In round three, the combined mean score for the Delphi participants was only 2.8667. Therefore, the performance measure was not included in the lists of key performance measures.

Table 7-12: Customer Satisfaction - Levels of Importance and Degrees of Consensus

Performance Measures	Response	*N*	%	Total %	Interpretation	Mean HMM	Mean ICM	Combined (HMM+ICM)	Mann-Whitney U test (*P*)	Consensus	σ	Retention	Combined Mean R2	Difference in combined Mean R3 –R2
1. Measure the number of maintenance products that do not conform to request.	Very important	3	20	93.3	**Very important**	3.3333	3.0000	**3.1333**	.224	**Medium**	.51640	**No**	3.0667	.0666
	Important	11	73.3											
	Unimportant	1	6.7											
2. Ensure visual display of response to complaints.	Very important	2	13.3	86.6	**Important**	3.1667	2.8889	**3.0000**	.324	**Medium**	.53452	**No**	3.0000	0
	Important	11	73.3											
	Unimportant	2	13.3											
3. Make available complaint boxes/ leaflets to enable people to raise issues related to quality of maintenance services.	Very important	2	13.3	80	**Important**	2.8333	2.8667	**2.8667**	.673	**Medium**	.74322	**No**	2.8000	.0667
	Important	10	66.7											
	Unimportant	2	13.3	20										
	Very unimportant	1	6.7											

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Manager; ICM – Infection Control Member; R – Delphi rounds)

7.3 SUMMARY OF ROUND THREE DELPHI RESULTS

In round three of the Delphi exercise, there were 25 performance measures. Of the 25 performance measures introduced in the third round of the Delphi exercise, participants achieved high-level consensus on 11. In the third round of the Delphi exercise, there were also performance measures with high-level consensus in only one group of Delphi participant. As shown in Table 7-13, there were eight performance measures on which only HM managers achieved high-level consensus. However, only two of these performance measures were retained as key performance measures in the third round of the Delphi exercise. Neither of the two performance measures on which only IC members achieved high-level consensus were considered as key performance measures in the third round of the Delphi exercise.

As shown in Table 7-13, IC members achieved high-level consensus on the performance measure 'the involvement of the HMU and ICT in the purchase of maintenance materials and products'. The other performance measure on which IC members achieved high-level consensus is related to 'the use of a recognisable risk assessment tool (i.e. Infection Control Risk Assessment Framework) to match the level of risk associated with maintenance work'. On the two performance measures on which only HM managers achieved high-level consensus, IC members disagreed significantly. The first is related to 'the use of a computer-based maintenance system (i.e. Reliability-Centred Maintenance) to coordinate maintenance work in hospitals'. Although the two groups of Delphi participants disagreed significantly (p = 0.007) about the level of importance of this performance measure, it was nonetheless retained in the third round of the Delphi exercise. The second performance measure with a significant difference (p = 0.025) between the two groups of Delphi participants had to do with 'taking into account changes in assets and legislation when renewing contracts'. This performance measure was not retained in the third round of the Delphi exercise.

HM managers also achieved high-level consensus on the performance measure relating to 'maintenance staff team briefings and appraisal schemes in HM in IC'. Although IC members achieved low-level consensus on this performance measure, it was nonetheless retained in the list of key performance measures.

Table 7-13: Performance Measures with Consensus in one Group only of Delphi Participants

Performance Measures	HMM		ICM		Mann-Whitney U test		R3 – R2	Retention
	Mean	Consensus	Mean	Consensus	Round (R) 3	Round (R) 2		
1. Involve the HMU and IC department in the purchase of maintenance materials and products.	3.2000	No	3.2857	Yes	.926	-	-	No
2. Use a computer-based maintenance system (i.e. reliability-centred maintenance) to coordinate all maintenance work.	3.8333	Yes	3.1111	No	.007*	.006*	.001	Yes
3. Conduct daily check of all critical maintenance systems posing the risk of HAIs.	3.5000	Yes	3.1111	No	.221	.029*	0.192	No
4. Wash and sanitize drainage equipment after use.	3.5000	Yes	3.0000	No	.255	.400	-0.145	No
5. Provide temporal hand washing facilities for maintenance staff working in high risk patient areas.	3.3333	Yes	3.1111	No	.569	.486	0.083	No
6. Use a recognised risk assessment tool (i.e. infection control risk assessment – ICRA) to match the level of risk associated with maintenance work.	3.0000	No	3.3333	Yes	.286	.943	-0.657	No
7. Take into account changes in assets and legislation when renewing contracts.	3.8333	Yes	3.2222	No	.025*	.840	-0.815	No
8. Maintenance staff team briefings and appraisal schemes in infection control.	3.5000	Yes	3.1250	No	.270	.524	-0.254	Yes
9. Equal access, and improve working lives for staff.	3.3333	Yes	2.7778	No	.107	.486	-0.379	No
10. Measure the number of maintenance product that do not conform to the request.	3.3333	Yes	3.0000	No	.224	.724	-0.5	No
Consensus		8		2				
Retained		2		0				

Results are statistically significant at $p < 0.05$ level
(HMM - Healthcare Maintenance Managers; ICM – Infection Control Member; R – Delphi rounds)

7.4 DISCUSSION OF THE FINDINGS

In this research study, the CSFs and key performance measures in HM in IC have been identified. However, much work is needed to show the levels of importance of the CSFs and performance measures in HM in IC. According to Tangen (2004), it costs organisations money and time to analyse many performance measures. Too many performance measures may result in an information overload. As the organisation grapples with many performance measures, it becomes difficult for them to prioritize the performance measures. As time is money, it is necessary for organisations to collect data only on meaningful performance measures, i.e. those that tell a story of the strategy.

In this research study, steps are taken to establish the level of importance of the different CSFs and performance measures in HM in IC. This was achieved through a research technique called the weighted mean. The weighted mean is different from the mean in that some data points contribute more than others do. The first requirement in the weighted mean is the categorisation of all performance measures into zones of mean scores. Since the Delphi exercises were conducted on a four point likert scale, the mean zones were established by dividing the difference between the maximum and minimum level of consensuses by four (4 – 3.28/4). This produces four mean zones with intervals of approximately 0.18. These are then linked to the CSFs, which are categorised according to the four perspectives of the BSC. If the mean score of the performance measure is X, the mean zone it belongs to is identified using the following scale ≤ 3.82 to ≥ 4, ≤3.64 to >3.82, ≤3.46 to >3.64, and ≤3.28 to >3.46, < 3.28. The mean zones are given weighted scores of between 4 and 1, where 4 and 1 represent the highest and lowest mean scores respectively. All those performance measures with a mean score of less than 3.28 are categorised in a fifth mean zone, and given a weight of zero.

For every CSF, the number of performance measures categorised under the different mean zones are multiplied by the weighted score. These are then added, and divided by the total number of performance measures for that particular CSF. The levels of importance of the CSFs are shown in Table 7-14. So far, the most important CSFs in HM in IC are liaison and communication with the ICT, infection control practices (cleaning and administrative requirements), and maintenance resource availability. On the other hand, the least important CSFs are customer satisfaction, transport requirements, staff training, and development. The information provided in Table 7-14 does not provide adequate information concerning the level of importance of the different performance measures in IC. In order to do so, all the sixty-seven performance measures identified in this research study were categorised according to the mean scales used in Table 7-14. As shown in Table 7-15, the performance measures have been grouped according to their level of importance in HM in IC. The CSFs and performance measures in HM in IC are discussed in details in the next section.

Table 7-14: Critical Success Factors and Level of Importance of Performance Measures in HM in IC

(A) BSC Perspective	(B) CSFs	(C) Performance Measures	(D) Mean Score	Mean scales and weight (W)					Weighted Mean	
				≤ 3.82 to ≥ 4	≤3.64 to >3.82	≤3.46 to >3.64	≤3.28 to >3.46	< 3.28	Total (E) Σ(C × W)/C	Answer
				W = 4	W = 3	*W = 2*	*W = 1*	*W = 0*		
	Liaison & Communication with the Infection Control Team (ICT)	1. Early consultation & authorization from the Infection Control Team before commencement of any maintenance work posing the risk of HAIs.	4.0000	**2(4) = 8**	**1(3) = 3**	**1(2) = 2**	**2(1) = 2**	**-**	**15/6**	**2.5**
		2. Seek the advice of the Infection Control Team (ICT) on such matters concerning infections.	3.9333							
		3. Liaise with person in charge of area where maintenance is to be carried.	3.7333							
		4. Put a system for maintenance staff to liaise with domestic staff regarding cleaning during and on completion of work.	3.5333							
		5. Set communication channel between maintenance staff and contracted staff.	3.3333							
		6. Regularly meet with infection Control and Clinical representatives to ensure maintenance processes complement clinical care.	3.3333							
	Infection Control Practices	**N = 20**		**4(5) = 20**	**3(3) = 9**	**5(2) = 10**	**4(1) = 4**	**4(0) = 0**	**43/20**	**2.15**
	– ***Cleaning Requirements***	1. Provide active means to prevent airborne dust from dispersing into high risk patient areas.	4.0000	*3(4)= 12*	*2(3)* = 6		*1(1)* = 1	*2(0)* = 0	*19/8*	*2.375*
		2. Compliance with hand hygiene whilst working in clinical areas	3.8667							
		3. Compliance with the use of personal protective equipment as required.	3.8667							
		4. Report any injury especially if 'sharp' related, cover wounds or sores.	3.6667							
		5. Maintenance staff must not work in clinical areas if any symptoms of infection exist i.e. diarrhoea or vomiting (seek advice from the ICT).	3.6429							
		6. Conduct maintenance work in a manner that eases cleaning.	3.4000							
		7. Provide temporal hand washing facilities for maintenance staff working in high risk patient areas.	3.2000							
		8. Wash and sanitize drainage equipment after use.	3.2000							
	– ***Administrative Requirement***	1. Inform Charge Nurse before commencement of maintenance work	3.9333	*1(4)* = 4	*1(3)* = 3	*4(2)* = 8	*1(1)* = 1	*1(0)* = 0	*16/8*	*2*
		2. Ensure in –house and contractors work to same clear guidelines.	3.8000							
		3. Maintain and review infection control policies and procedures.	3.6000							
Internal Business Processes		4. Before commencement of maintenance work, obtain infection control permit, and assess patients for risk of maintenance-associated HAIs.	3.6000							
		5. Develop a work culture that supports prioritization of maintenance work in infection control.	3.5833							
		6. Put in place safe working system for maintenance staff in infection prevention.	3.5333							
		7. Pre-employment health check and immunization program for all in-house and contracted maintenance staff.	3.4286							
		8. Have an agreed HAI plan to control all contract works on site. Reviewed plan annually to see level of compliance and provide annual improvement action plan based on previous years findings.	3.0000							
	– ***Transport Requirements***	5. Health & safety signage used.	3.4667	-	-	*1(2) = 2*	*2(1) = 2*	*1(0)* = 0	*4/4*	*1*
		6. Contain construction waste before transport in tightly covered containers.	3.4000							
		7. Transport clean and sterile equipment to storage areas via route that minimises contamination.	3.4000							
		8. Redirect pedestrian traffic from work area.	3.2000							
	– **SLA Agreement**	1. Contractors have to take responsibility for any unsafe equipment, or practice posing risk of infection.	3.7692	**-**	**3(3) = 9**	**2(2) = 4**	**2(1) = 2**	**1(0) = 0**	**15/8**	**1.875**
		2. Contractor should have safe record keeping, and adhere to mandatory code of conduct in infection control.	3.7333							
		3. Contracted workers must attend all mandatory induction and training in infection control.	3.7143							
		4. Contractor should have arrangement to response to emergency calls.	3.5333							
		5. Take into account changes in assets and legislation when renewing contracts.	3.4667							
		6. Contractor should have procedure to supervise maintenance work and variables i.e. spares etc.	3.3333							
		7. Select contractors on their strong technical, resource, managerial, and communication capabilities	3.2857							
		8. Customer satisfaction survey should be part of service level agreement with contractors.	2.9333							

	– **Maintenance Strategies**	1. The development of a water safety plan (reviewed annually) by maintenance and infection control teams, to identify, manage and control risks of waterborne infections associated with maintenance activities.	3.9167	**1(4) = 4**	**1(3) = 3**	**1(2) = 2**	**2(1) = 2**	**3(0) = 0**	**11/8**	**1.375**
		2. Ensure the timely execution of all planned maintenance work posing risk of infection.	3.7143							
		3. Prioritise and respond to building defects in time critical period to minimise the risk of HAIs.	3.6000							
		4. Keep account of the effectiveness of all critical maintenance equipment/assets that may cause HAI.	3.4000							
		5. Use a computer-based maintenance system (i.e. reliability-centred maintenance) to coordinate all maintenance work.	3.4000							
		6. Computer system that promotes mobility and allows maintenance staff to carry all the information they require, and communicate back to coordinators when job cannot be completed first time.	3.3333							
		7. Daily check of all critical maintenance systems posing the risk of HAIs	3.2667							
		8. Categorize hospital assets, and maintenance equipment into significant and non-significant items in infection control.	2.9993							
	– **Risk Assessment**	5. Involve all stakeholders in risks identification and response (i.e. the ICT).	3.6667		**1(3) = 3**	**1(2) = 2**	**1(1) = 1**	**1(0) = 0**	**6/4**	**1.5**
		6. Educate staff and set clear lines of individual responsibility in managing the risk of maintenance-related infections.	3.4667							
		7. Process for reporting, managing, and analysing complains and incidences in infection control.	3.4000							
		8. Use a recognised risk assessment tool (i.e. infection control risk assessment – ICRA) to match the level of risk associated with maintenance work.	3.2000							
Financial	**Maintenance Resource Availability**	1. Secure adequate resources for mandatory and operational compliance of the healthcare maintenance unit in infection control.	3.9333	**3(4) = 12**	**-**	**-**	**2(1) = 2**	**2(0) = 0**	**14/7**	**2**
		2. Develop processes to control the introduction of new equipment/fabric that can be maintained efficiently and reduce the risk of HAIs.	3.8667							
		3. Review the condition of hospital building services and infrastructure to feed into investment program.	3.8667							
		4. Use risk assessment in maintenance-associated HAIs to direct maintenance resources to highest risk activities.	3.4545							
		5. The purchase of quality maintenance materials and products from reliable suppliers	3.3333							
		6. Involve the HMU in the IC Department in the purchase of maintenance materials and products.	3.2500							
		7. Conduct monthly review of expenditure against budget in IC.	2.6000							
Innovation and Learning	**Staff Training & Development**	**N = 8**			**1(3) = 3**	**2(2) = 4**	**4(1) = 4**	**1(0) = 0**	**11/8**	**1.4**
	– ***Staff Training***	1. Provide all maintenance staff with information on statutory and technical guidance on infection control.	3.6000	-	-	*2(2)* = 4	*2(1)* = 2	-	*6/4*	***1.5***
		2. Employ skilled and competent staff to ensure safe and efficient maintenance operations.	3.5000							
		3. Conduct annual review of staff training.	3.4000							
		4. Conduct site induction on infection control within few weeks of employment.	3.3333							
	– ***Staff Development***	5. The maintenance department should be represented in infection prevention & control, risk/governance committees	3.6667	-	*1(3)* = 3	-	*2(1)* = 2	*1(0)* = 0	*5/4*	***1.3***
		6. The education of maintenance staff on the assessing and managing the risk maintenance-associated hospital-acquired infections (HAIs)	3,4286							
		7. Maintenance staff team briefs and appraisal schemes in infection control.	3.2857							
		8. Equal access, and improve working lives for staff.	3.0000							
Customer Satisfaction	**Customer Satisfaction**	1. The number of completed maintenance jobs that failed to meet the required standard in infection control.	3.5000	**-**	**-**	**2(2) = 4**	**1(1) = 1**	**3(0) = 0**	**5/6**	**0.8**
		2. System to review, analyse complains against maintenance services, and recommend improvement.	3.4667							
		3. Measure the speed to response to maintenance request.	3.4000							
		4. Measure the number of maintenance product that do not conform to the request.	3.1333							
		5. Speed to response to complaints about completed maintenance work.	3.0000							
		6. Make available complain boxes/ leaflets to enable people raise issues related to quality of maintenance services	2.8667							
Total		**67**		**10 (14.9)**	**9 (13.4%)**	**11(16.4%)**	**23 (34%)**	**14 (20.8)**	**-**	

Table 7-15: The HM - BSC Matrix in IC

BSC Areas	CSFs	Performance Measures – Mean Interval				
		≤ 3.82 to ≥ 4	≤3.64 to >3.82	≤3.46 to >3.64	≤3.28 to >3.46	**≤ 3.27 (20.8%)**
Internal Business Processes	***Liaison and Communication with the infection control team***	1. Early consultation & authorization from the Infection Control Team before commencement of any maintenance work posing a risk of HAIs. 3. Seek the advice of the Infection Control Team (ICT) on such matters concerning infections.	13 Liaise with person in charge of area where maintenance is to be carried out.	26. Put a system in place for maintenance staff to liaise with domestic staff regarding cleaning during and on completion of work.	46. Establish communication channel between maintenance staff and contracted staff. 46. Regularly meet with Infection Control and Clinical representatives to ensure maintenance processes complement clinical care.	
	IC Practices *(cleaning, transport, and administrative requirements)*	**Cleaning Requirements** 1. Provide active means to prevent airborne dust from dispersing into high risk patient areas. 7. Compliance with hand hygiene whilst working in clinical areas. 7. Compliance with the use of personal protective equipment as required. **Administrative Requirements** 3. Inform Charge Nurse before commencement of maintenance work.	**Administrative Requirements** 11. Ensure in –house staff and contractors work to same clear guidelines. **Cleaning Requirements** 17 Report any injury especially if 'sharp'-related, cover wounds or sores. 20. Maintenance staff must not work in clinical areas if any symptoms of infection exist i.e. diarrhoea or vomiting (seek advice from the ICT).	**Administrative Requirements** 21. Maintain and review infection control policies and procedures. 21. Before commencement of maintenance work, obtain infection control permit, and assess patients for risk of maintenance-associated HAIs. 25. Develop a work culture that supports prioritization of maintenance work in infection control. 26. Put in place safe working system for maintenance staff in infection prevention. **Transport Requirements** 31. Health & safety signage used.	**Cleaning Requirements** 38. Conduct maintenance work in a manner that eases cleaning. **Administrative Requirements** 36. Pre-employment health check and immunization program for all in-house and contracted maintenance staff. **Transport Requirements** 38. Contain construction waste before transport in tightly covered containers. 38. Transport clean and sterile equipment to storage areas via route that minimises contamination.	**Cleaning Requirements** 56. Provide temporal hand washing facilities for maintenance staff working in high-risk patient areas. 56. Wash and sanitize drainage equipment after use. **Transport Requirements** 56. Redirect pedestrian traffic from work area. **Administrative Requirements** 61. Have an agreed HAI plan to control all contract works on site. Review plan annually to set level of compliance and provide annual improvement; action plan based on previous year's findings.

	SLA ***(contract & contracted staff requirements)***		12. Contractors have to take responsibility for any unsafe equipment or practice posing risk of infection. 13. Contractor should have safe record keeping, and adhere to mandatory code of conduct in infection control. 15. Contracted workers must attend all mandatory induction and training in infection control.	28. Contractor should have arrangement to respond to emergency calls. 31. Take into account changes in assets and legislation when renewing contracts.	46. Contractors should have procedure to supervise maintenance work and variables, i.e. spares, etc. 52. Select contractors on basis of their strong technical, resource, managerial and communication capabilities.	65. Customer satisfaction survey should be part of service level agreement with contractors.
	Maintenance Strategies	6. The development of a water safety plan (reviewed annually) by maintenance and infection control teams, to identify, manage and control risks of waterborne infections associated with maintenance activities.	15. Ensure the timely execution of all planned maintenance work posing risk of infection.	21. Prioritise and respond to building defects in time-critical period to minimise the risk of HAIs.	38. Keep account of the effectiveness of all critical maintenance equipment/assets that may cause HAI. 38. Use a computer-based maintenance system (i.e. reliability-centred maintenance) to coordinate all maintenance work. 46 Computer system that promotes mobility and allows maintenance staff to carry all the information they require, and communicate back to coordinators when job cannot be completed first time.	54. Daily check of all critical maintenance systems posing a risk of HAIs. 64. Categorize hospital assets, and maintenance equipment into significant and non-significant items in infection control.
	Risk Assessment		17. Involve all stakeholders in risk identification and response (i.e. the ICT).	31. Educate staff and set clear lines of individual responsibility in managing the risk of maintenance-related infections.	38. Process for reporting, managing, and analysing complaints and incidents in infection control.	56. Use a recognised risk assessment tool (i.e. infection control risk assessment – ICRA) to match the level of risk associated with maintenance work.

Financial	**Maintenance Resource Availability**	3. Secure adequate resources for mandatory and operational compliance of the healthcare maintenance unit in infection control. 7. Review the condition of hospital building services and infrastructure to feed into investment program. 7. Develop processes to control the introduction of new equipment/fabric that can be maintained efficiently and reduce the risk of HAIs.			35. Use risk assessment in maintenance-associated HAIs to direct maintenance resources to highest risk activities. 46. The purchase of quality maintenance materials and products from reliable suppliers.	55. Involve the HMU in the IC Department in the purchase of maintenance materials and products. 67. Conduct monthly review of expenditure against budget in IC.
Innovation and Learning	**Staff Education**		**Staff Development** 17. The maintenance department should be represented in infection prevention & control, risk/governance committees.	**Staff Training** 21. Provide all maintenance staff with information on statutory and technical guidance on infection control. 29. Employ skilled and competent staff to ensure safe and efficient maintenance operations.	**Staff Development** 36. The education of maintenance staff on the assessing and managing the risk of maintenance-associated hospital-acquired infections (HAIs) **Staff Training** 46. Conduct site induction on infection control within a few weeks of employment. 38. Conduct annual review of staff training. **Staff Development** 52. Maintenance staff team briefings and appraisal schemes in infection control.	**Staff Development** 61. Equal access, and improve working lives for staff.
Customers Satisfaction	**Customer Satisfaction Requirements**			29. Measure the number of completed maintenance jobs that fail to meet the required standard in infection control. 31. System to review and analyse complaints against maintenance services, and recommend improvement.	38. Measure the speed of response to maintenance requests.	60. Measure the number of maintenance products that do not conform to the request. 61. Ensure visual display of response to complaints. 62. Make available complaint boxes/leaflets to enable people to raise issues related to quality of maintenance services.

7.4.1 Liaison and Communication with ICT

As shown in Table 7-14, establishing close collaboration with the ICT is probably one of the most important CSFs in HM in IC. The results of the literature review indicated that advice from the ICT is important in IC in HM. A similar conclusion is also reached in this research study. In addition to advice, early consultation with the ICT is also identified as an important performance measure in reducing the incidence of maintenance-associated HAIs. Liaising and communicating with the IC department is probably one of the most important CSFs in HM in IC. In fact, the HMU needs to consult the ICT on all maintenance activities (refurbishment, alteration, maintenance of premises/equipment, etc) with implications for IC. The consultation process must sufficiently early enough to give the ICT time to respond to IC issues. Basing their judgment on sound evidence, the ICT may either recommend that certain measures be put in place before the commencement of the maintenance project, decide to set up a special committee to assess and monitor the impact of any maintenance project from start to completion. In the worst-case scenario, the ICT should be allowed to delay or not approve a maintenance project on IC grounds.

Once a maintenance project has been approved, it is good practice for the maintenance team to liaise and communicate directly with person(s) in charge of the work area. The reasons are that the person in charge (usually clinical personnel) will keep an eye on the quality of maintenance work done and provide feedback to maintenance officials on ways to improve performance in infection control. In addition, the person in charge - i.e. a staff nurse or sister - could ensure that maintenance and cleaning staff work together to ensure that an area is cleaned after maintenance work. It might also be the case that certain susceptible patients in the wards have to be moved from maintenance work areas.

Despite the benefits of the HMU working close with ICT, the two groups appear to function as separate entities, with the HMU requesting help from the IC department on an ad hoc basis. A survey conducted by the NAO (2004) found that 17% of NHS Trusts did not always consult the ICT on issues regarding theatre ventilation or air conditioning/air pressure control systems. A further 22% did not consult the ICT when reviewing plans for alterations and additions to clinical buildings. In this research study, HM managers disagreed with IC members on obtaining infection control permits before the start of maintenance work which posed a risk of HAIs. HMUs that fail to liaise and establish clear lines of communication with the ICT are more likely to perform poorly in IC. Communication between the ICM and maintenance staff (in-house and contracted) is central to good infection control practices.

7.4.2 Infection Control Practices

Many in the NHS view IC as something that is the sole responsibility of clinicians alone. As this research study has demonstrated, infection control practices are equally important in the way maintenance is carried out. One of the most important performance measures under infection control practices relates to the prevention of airborne dust from spreading in the healthcare built environment. Dust contamination in hospital wards (especially in high risks wards) has been an important factor in the transmission of HAIs in hospitals. Those particularly at risk include immune-suppressed patients in the organ transplant, chemotherapy and burn units (Kidd *et al*, 2007). Despite the risk associated with dust contamination, it appears the issue has failed to attract the attention of the IC members. Although reference is often made to ICRA (Infection Control Risk Assessment), its application in NHS Trusts is patchy. Already, in the USA, there is an accreditation scheme for construction-related works in hospitals.

Hand hygiene is also identified in this research as an important performance measure to reduce maintenance-associated HAIs. In order to reduce the incidence of HAIs in high-risk patient areas in hospitals, HM staff must adhere to hand hygiene. The hands of healthcare workers remain one of the main routes for the transmission of HAIs in healthcare settings (Billy, 2000). According to the DH, poor hand hygiene practices have been linked to infection rates in hospitals (NAO, 2009). Where advised, maintenance staff should protect themselves by using personal protective equipment (i.e. overalls and facemasks). They should also report injuries, especially those related to sharps, and take measures to cover wounds or sores. In the event of symptoms of an infection, i.e. diarrhoea or vomiting maintenance staff should report it to or seek the advice of the ICT. New recruits in the HMU working in close proximity to patients should undergo pre-employment health checks, and be immunized according to the same standards applied to clinical staff.

HM managers should have an administrative procedure whereby individuals or nurses in charge of certain areas are notified of impending maintenance work. This is likely to reduce the amount of time maintenance staff spend waiting for areas to be cleared. After the completion of maintenance work, especially in patient areas, maintenance staff should also notify the charge nurse or person in charge. This gives the charge nurse the opportunity to raise any issues about the thoroughness of the work done. Depending on the issues raised, the maintenance staff might only need to explain or redress some ‘minor’ issues relating to the work. In some instances, the charge nurse might be in a better position to coordinate the cleaning exercise.

Any waste generated through maintenance work must be carefully handled, especially around susceptible patients. It is important for the HMU to develop procedures for the safe transportation of maintenance waste around hospitals. The poor handling of maintenance waste might contaminate the healthcare built environment, and therefore put patients at risk of contracting HAIs. Depending on the type of maintenance project under consideration, it might be the necessary to use signage to re-direct healthcare users from high-risk maintenance areas.

7.4.3 Service Level Agreements

In the literature, not much attention is given to the external providers of HM services and HAIs. As shown in Table 5-4, few clinical documents have examined the role of the external providers of HM services in IC. Many attribute the poor performance of the NHS in IC to the contracting-out of HM services. According to Unison (2005), the problem lies with the way NHS Trusts formulate service level agreements. Given the current economic climate faced by many NHS Trusts, the raison d’être of the SLA has been to look for cost savings rather than improve service quality, e.g. the prevention of HAIs.

It is necessary to stipulate in SLAs that contractors have responsibility for any unsafe equipment or practice that jeopardise or put healthcare users at risk of acquiring HAIs. In addition, it necessary for NHS Trusts to select the external providers of the HM services on the grounds of strong technical, resource, managerial, and communication capabilities. Contractors must also understand and agree to comply with policies and procedures aimed at minimizing the risk of HAIs. Where necessary, contractors must also have arrangements for staff to undergo mandatory induction and training on IC.

In recent years, the government has cut the budget allocated to NHS Trusts. Thus, faced with a dwindling maintenance budget, and the pressure of further cuts, most maintenance managers do not pay sufficient attention to IC issues when entering into contracts with contractors. Given the rigidity of service level agreements (SLAs), it is often not possible for contractors to act spontaneously in response to emergencies. Contractors are more likely to stick to the terms of the contract outlined in the SLA. Most often, NHS Trusts find it difficult to impose sanctions on underperforming maintenance contractors. Because of the costs of litigation, most NHS Trusts adopt the strategy of waiting until the very end of the contract. This of course may be putting the life of healthcare users, especially those with weakened immune systems, at risk of contracting HAIs.

7.4.4 Maintenance Strategies

In order to minimise the risk of HAIs, the failure of critical assets, equipment, and components must be reduced substantially. An important step in this direction is the development of a water safety plan to identify, manage, and control the risk of HAIs. A review of the literature suggests that many NHS Trusts do not have such a plan. The timely execution of all planned maintenance work with a likely impact on HAIs is also important. The reliability of equipment could also be further improved through safe record keeping. Categorising equipment into significant and non-significant items is not considered a key performance measure. Despite the possibility of reducing HAI, it appears that cost is the overarching factor in the application of maintenance strategies in NHS Trusts. Instead of just focusing on reducing maintenance costs, the maintenance unit should also focus on the prevention of maintenance-associated HAIs in the NHS.

7.4.5 Risk Assessment

The prevalence of maintenance-associated HAIs necessitates the need for managers to consider risk assessment in healthcare maintenance. The first step is for all the stakeholders (i.e. designated coordinators, infection control team, facilities, and contractors) of the HM in IC to participate in a meeting to identify the risk, and to respond to maintenance-associated infections. Risk assessment in HM will minimise the potential transmission of HAIs, and prevent the disruption of clinical activity, the issue of legal enforcement notices, and corporate manslaughter (NHS Shetland, 2011). Based on the recommendations of the risk assessment committee, the HMU should decide on a case-by-case basis the sort of preventative measures to adopt. The success of any preventative measures in HAI depends on the level of awareness and education of maintenance staff in risk identification and management. It is important for the HMU to establish clear roles and responsibilities for maintenance staff in IC. In addition, managers should have a channel for reporting, managing and analysing complaints and incidences against the HMU in IC. Putting such measures in place helps the HMU improve on risk identification and management about HAIs. Although many do not consider the ICRA important in IC, is still an effective tool for identifying and minimizing the risk of airborne contamination associated with maintenance work.

7.4.6 Maintenance Resource Availability

The nature of business of the NHS is different from that of other organisations, which focus primarily on profit maximization. As a public organisation, the primary focus of the NHS is providing safe patient care. It is therefore the role of HM managers to secure adequate resources for the mandatory and operational compliance of HM services in IC. This is not straightforward business, as the NHS Trust also has other priorities. HM managers must present a case for the allocation of extra resources to the HMU. According to NAO (2000), there appear to be a clear mismatch between what is expected of ICT and the level resources allocated to them (NAO, 2000). The HMM could use evidence gathered from reviewing the condition of the hospital building services and infrastructure. In this way, top management will identify the contribution of the HMU in IC. With the provision of adequate maintenance resources, the HMU will for example be able to hire competent staff, purchase quality products, or conduct risk assessments in relation to HAIs, etc. HMUs with adequate resources are in a better position to implement and coordinate maintenance strategies in IC. HMUs with limited or inadequate resources might just be meeting statutory requirements.

7.4.7 Staff Education

The education (staff training and staff development) of HM staff in IC was rated as one of the least important performance measures in HM in IC. However, some of the performance measures in this area were identified important in IC. For example, HM staff need adequate information and technical guidance on IC. This same performance measure is also identified in the literature as important in IC. The nature of maintenance requires that skilled and competent staff are employed to undertake a range of complex activities. Representation of the HMU on the IC risk/governance committee could also enhance the participation and co-operation of HM staff with the ICT.

Presently, HM staff lack the required knowledge and skills to prevent the spread of HAIs in the NHS. The results of the pilot case study conducted in this research attest to this fact (see Table 4-4). This problem is not restricted to HM services alone. According to figures released by the NAO (2000), about 10% of NHS Trusts did not provide induction training for nurses and healthcare assistants. Although all directly employed NHS staff undergo induction in IC, mandatory training and education is often restricted to clinical staff. Worst affected are the temporary staff employed by agencies, who sometimes may also work closely with susceptible patients. In some cases, i.e. in maintenance services, the NHS provides guidelines regarding the ventilation requirements of wards, but leaves it for contracted staff to achieve the required standards (NAO, 2000).

According to the NAO (2000), the education and training of NHS staff on infection control issues helps to reduce the risk of HAIs in the NHS. Education and training enhances the skills and competence of maintenance staff in the provision of safe and efficient maintenance operations in infection control. However, it appears that top NHS officials are not taking the issue seriously. According to the NAO (2000), only 49% of NHS Trusts even bother to audit the effectiveness of programs to educate and/or train NHS staff in IC.

7.4.8 Customer Satisfaction

One of the least developed performance measures in HM in IC is customer satisfaction. The word ‘customer’ here refers to anyone (patients, doctors, nurses, etc) using a healthcare establishment. As in most public organisations, the issue of customer satisfaction has not been addressed sufficiently in the NHS. The business agenda of most privately owned firms is different from that of publicly funded organisations. While private firms strive to make profit, publicly funded organisations do not. In order to satisfy the customers of the HMU in IC, the HMU will have to measure the number of completed maintenance jobs that do not meet the required standard in IC. In addition, the HMU needs to put in place a system for measuring speed in response to maintenance requests, and for reviewing and analysing complaints against the HMU in IC. With such a system in place, the HMU will be able to raise performance in HM in IC.

7.5 THE APPLICATION OF THE HM – BSC MATRIX

The categorisation of the CSFs and performance measures into levels of importance will enable HM managers and IC members to select pertinent CSFs and performance measures that drive performance in HM in IC. The research allows managers to compare the level of importance of a performance measure with those under the same or different CSFs. Performance measurement does not stop with the identification of the CSFs and performance measures. HM managers need to have a thorough understanding of the strategy of NHS Trusts in IC (see section 5.6). This is to ensure that all the departments and units in an NHS Trust are pursuing the same agenda in IC. Once HM managers are confident and understand where the NHS Trust is heading in IC, they will be able to state the mission statement of the HMU in IC. The mission statement is a platform for the HMU to say how they support the NHS in its effort to reduce the incidence of HAIs. After the selection of relevant and pertinent CSFs and performance measures from the list provided in Table 7-15), HM managers will have to formulate goals, and set objectives and targets, as well as measure performance. By measuring performance, HM managers will be able to ascertain whether they are attaining or failing to meet performance targets in IC. Since performance measurement is an on-going process, HM managers will have to put measures in place for the selection of CSFs and performance measures from the list or to set new target in IC.

As shown in Table 7-16, a simple performance measurement system (PMS) has been devised in this research to enable HM managers to quantify performance in IC. The PMS should enable HM managers to establish the level of performance against individual performance measures, as well as a group of performance measures in a mean zone. Where there is more than one mean zone, the performance tool allows HM managers to measure and compare performance of all mean zones at the same time. Finally, through the application of the PMS, HM managers will be able state the level of performance of the HMU in IC. The performance tool has to be used in conjunction with the HM-BSC matrix (Table 7-15). The PMS applies the same mean zones as those used in the HM-BSC Matrix. Thus it is a requirement that HM managers select performance measures from the HM-BSC Matrix. The selected performance measures are to be categorised according to the same mean zones as those used in HM-BSC Matrix. HM managers should work closely with the ICT to select the most pertinent performance measures to help the HM unit drive performance in IC.

For every performance measure selected from the HM-BSC matrix, HM managers must rate the level of importance on a scale of 1 – 5. In doing so, HM managers must take into account the interpretation given to the rating scale. A shown in Table 7-17, the rating scale ranges from very poor to excellent. Since the performance measures have varying levels of importance in IC, the weightings are also taken into consideration. Therefore, the weighted mean for each performance measure is calculated by multiplying the level of performance (L) against the weight (W). This is however not needed when calculating the performance of individual performance measures. As shown in Table 7-16, the performance of a performance measures is calculated by simply dividing its level of performance (L) by five. Since the results are presented in percentages, the result is then multiplied by a hundred. The formula used to score individual performance measures (S) is given as:

$$\frac{(L)}{(5)} \times 100$$

Where:
L – Level of performance
W – Weight

The formula provided above informs the HM manager whether poor results are coming from the most important or least important performance measures. In Table 7-16, a small number of performance measures have been applied to demonstrate the application of the PMS in HM in IC. Since the formula allows HM managers to gather information about individual performance measures, resources and effort could easily be prioritised. The BSC principle requires that managers select CSFs and performance measures from the internal business processes, financial, innovation and learning and customer satisfaction perspectives. The PMS that has been developed in the research study allows managers to select the most prudent CSFs and performance measures from all the four BSC perspectives.

Table 7-16: Performance Tool for the Application of the HM - BSC Matrix (An Exemplar)

Mean Zones	**Selected Performance Measures (P)**	**Performance Level Rating (L)**					**Weighting (W)**	**Weighted Score (L×W)**	**Performance Score 1- for each Performance Measure** $\frac{(L)}{(5)} \times 100$	**Performance Score 2- for each Individual Mean Zone (T)**	**Performance Score 3 – Considering all Mean Zones (U)**	**Overall Performance of the HMU in HAI**
		1	**2**	**3**	**4**	**5**						
WS_A ≤ 3.82 to ≥ 4	1. Early consultation & authorization from the Infection Control Team before commencement of any maintenance work posing a risk of HAIs.				4		4	16 (WS_1)	80%	$\frac{(WS_1 + WS_2 + WS_3)}{N(P_A) X (LXW)} \times 100$ $\frac{16 + 12 + 12}{3 (20)} \times 100$ **= 66.6%**	$\frac{\Sigma (WS_A)}{\Sigma (WS_A + WS_B + WS_C + WS_D)} \times 100$ $\frac{(16 + 12 + 12)}{60 + 30 + 30 + 10} \times 100$ $\frac{4000}{130}$ **= 30.77 %**	$\frac{\Sigma (WS_A + WS_B + WS_x)}{[N(P_A) \times 20] + [N (P_B) \times 15] \ldots} X 100$ $\frac{40 + 21 + 20 + 4}{3 (20) + 2 (15) + 3 (10) + 2 (5)} \times 100$ $\frac{85 \times 100}{130}$ **= 65.38%** **Performance Status: GOOD**
	2. Provide active means to prevent airborne dust from dispersing into high-risk patient areas.			3			4	12 (WS_2)	60%			
	3. The development of a water safety plan (reviewed annually) by maintenance and infection control teams to identify, manage and control risks of waterborne infections associated with maintenance activities.			3			4	12 (WS_3)	60%			
WS_B ≤ 3.64 to >3.82	4. Ensure in–house staff and contractors work to same clear guidelines.				4		3	12 (WS_4)	80%	$\frac{(12 + 9)}{2 (15)} \times 100$ **= 70%**	$\frac{(12 + 9)}{130} \times 100$ **= 16.15 %**	
	5. Contracted workers must attend all mandatory induction and training in infection control.			3			3	9 (WS_5)	60%			
WS_C ≤ 3.46 to >3.64	6. Put a system in place for maintenance staff to liaise with domestic staff regarding cleaning during and on completion of work.	1					2	2 (WS_6)	20%	$\frac{(2 + 10 + 8)}{3 (10)} \times 100$ **= 66.66 %**	$\frac{(2 + 10 + 8)}{130} \times 100$ **= 15.38 %**	
	7. System to review and analyse complaints against maintenance services, and recommend improvement.					5	2	10 (WS_7)	100%			
	8. Employ skilled and competent staff to ensure safe and efficient maintenance operations.				4		2	8 (WS_8)	80%			
WS_D ≤ 3.28 to >3.46	9. Regularly meet with Infection Control and Clinical representatives to ensure maintenance processes complement clinical care.	1					1	1 (WS_9)	20%	$\frac{(1 + 3)}{2 (5)} \times 100$ **= 40 %**	$\frac{(1 + 3)}{130} \times 100$ **= 3.08 %**	
	10. Conduct site induction on infection control within a few weeks of employment.			3			1	3 (WS_{10})	30%			

The PMS can also be applied to calculate the level of performance of performance measures in a mean zone. As shown in Table 7-16, the four mean zones of the PMS are depicted by WS_A, WS_B, WS_C and WS_D and assigned weights of 4,3,2,1 respectively. The calculations presented in column (T) take into account only the performance measures in one mean zone. This is more appropriate where all the performance measures are selected from a single mean zone. As shown in Table 7-16, the performance of WS_A is 66.6%. According to the classification presented in Figure 7-1, the level of performance is considered good. However, this suggests scope for further improvement in the performance of the HM in IC. The formula for calculating performance in a mean zone is given as:

$$\frac{(WS_1 + WS_2 + WS_3)}{N(P^A) \times (L \times W)} \times 100$$

Where:
WS_1, WS_2, WS_3 – Weighted score for individual performance measures
W – Weight
L – Level of performance
$N(P_A)$ – Number of performance measures in the mean zone
(L×W) – Maximum weighted score for a performance measure

Where there is more than one mean zone, the performance of a mean zone is calculated by taking into account all the performance measures of the other mean zones. This allows the HM managers to compare performance across different mean zones. It also informs HM managers about where to direct resources and effort. As shown in Table 7-16, when the mean zones are aggregated, the level of performance of the mean zones falls. This is because the weights of the different performance measures are factored into the calculations. The PMS also allows the HM manager to estimate the overall performance of the HMU in IC. The first step to calculate 'performance score 3' (refer to Table 7-16) will be to add the score of performance measures in the mean zone (i.e. (WS_1 +WS_2 +WS_3). This is then divided by the total number of performance measures in the mean zones, multiplied by their respective maximum weighted scores. The final score is also multiplied by 100. In the example provided above, the performance of mean zones WS_A, WS_B, WS_C, WS_D are 30.77%, 16.15%, 15.38%, and 3.08% respectively. To improve on the result of the mean zones, managers have to improve in the performance of individual performance measures in the mean zone. Assuming that the three performance measures in WS_A achieved 100%, the performance of WS_A will be estimated at 46.1%. Similarly, those for WS_B, WS_C and WS_D are estimated to be

23.1%, 23.07% and 7.7% respectively. Therefore, the overall performance of the PMS is calculated by simply adding the percentage scores of the four mean zones. In the example provided, the performance of the HM is estimated at 65.38%. Relying on the scale provided in Figure 7-1, the performance of the HMU in IC is interpreted as good. The formula for considering performance in more than one mean zone is provides as:

$$\frac{\Sigma (WS_A)}{\Sigma (WS_A + WS_B + WS_C + WS_D)} \times 100$$

Where:
Σ – Sum
WS_A – Weighted score of mean zone 'A'

The formula for establishing performance for entire PMS is provided as:

$$\frac{\Sigma (WS_A + WS_B + WS_x)}{[N (P_A) \times 20] + [N (P_B) \times 15) + [N (P_C) \times 10] + [N (P_D) \times 5)]} \text{ X } 100$$

Where:

N (P) – Number of performance measures in a mean zone

Table 7-17: PMS Rating Scale

1	**Very Poor**
2	**Poor**
3	**Average**
4	**Good**
5	**Excellent**

1%	25 %	50%	75%	100%
Poor	**Average**	**Good**	**Excellent**	
≥1% - <25%	≥25% - <50%	≥50% - <75%	≥7.5 - ≤ 10	

Figure 7-1: Scale for Interpreting the Result of the PMS

CHAPTER 8 : CONCLUSIONS

8.1 INTRODUCTION

The first section of this chapter summarizes the research process that is adopted throughout this research study. This is followed by an examination of the implications of the findings of this research study. A section is also provided on the limitations of the study. In the final section, suggestions and recommendations are provided on the way forward in this research area.

8.2 SUMMARY OF THE RESEARCH PROCESS ADOPTED

Although there is strong epidemiological evidence linking HM with HAIs, it has not been given enough attention by healthcare officials. Top management officials continue to view IC as a clinical issue, needing the attention of clinicians alone. With no real product of its own, HM is seen by many as a drain on scarce resources. Because HMUs grapple with limited resources, they tend to focus their attention on cutting cost. As a result, HM units in the NHS do not take the issue of IC seriously. HM units in the NHS are not adopting CSFs and performance measures in infection control.

Given the aforementioned research issues, the aim of this research study was to develop a PMS, and identify the CSFs and key performance measures in HM in IC. The research aims of this study were guided by six research objectives. The first section of the research was conducted mainly through the application of an in-depth literature review. This was mainly to enhance understanding of the different research areas surrounding the research topic. It was through the literature review process that the research gaps were identified and the aims and objectives of this research study were formulated. The historical link between non-clinical services and HAIs in IC was also established through the in-depth literature review. Thereafter, content analysis was applied to establish epidemiological evidence of the link between healthcare facilities management (HFM) and HAIs. Also in this section, the causes of and measures to reduce HAIs in HFM were examined.

The results obtained from the literature review, as well as the content analysis processes helped in the selection of key research documents for establishing the CSFs and performance measures in HM in IC. Overall, a thorough scrutiny of various sources of research material led to the selection of 27 key documents. These documents were inputted into qualitative software called QRS NVivo[7], and grounded theory analysis was undertaken (open, axial and selective coding). It was during this phase of the research project that the research and interview questions were further developed. The research and interview questions applied in the pilot study. The main research method in the pilot study was an exploratory case study. The result obtained from the pilot study revealed that HM managers did not have the required knowledge of IC to participate in this study. Thus, in order to address this problem, the decision was taken to apply the Delphi approach. In the Delphi approach, participants are selected on the basis of the level of knowledge they possess on the subject area under investigation. Therefore the decision was taken to apply the Delphi approach in order to identify the CSFs and key performance measures in HM in IC.

8.3 CONCLUSIONS OF THE RESEARCH STUDY

The main conclusions of this research study are presented under the following headings:

8.3.1 The Significance of the Role of Non-Clinical Services in IC

Although non-clinical services are not given the same level of attention as clinical services, they nonetheless play a significant role in IC. In this research study, historical evidence is used to show how HFM services could be applied to reduce rates of HAIs in hospitals. In the immediate years before the bacteriological era, the prevalence of HAIs in hospitals was mainly attributed to non-clinical services i.e. 'inanimate human contagions' and 'inanimate non-human miasmata'. Thus, to reduce the prevalence of HAIs, healthcare authorities relied on non-clinical measures. Some of these non-clinical measures were championed by people like Pringles, Lind, Semmelweiss and Nightingale. At the time, the implementation of some of these measures was hailed for bringing down rates of infections, i.e. puerperal fever in hospitals. Pioneer such as Florence Nightingale even gained international renown for rendering hospitals safe for patient care.

It is important for healthcare authorities to pay more attention to tackling the non-clinical causes of HAIs in the NHS. The role of non-clinical services in IC should not be considered as something which is irrelevant in today's world, or downgraded in an attempt to cut costs through outsourcing. As this research has shown, the risk factors of acquiring HAIs are not limited to clinical services alone. There are two risk factors of HAIs associated with healthcare facilities management (HFM) services. These are environmental and behavioural risk factors. Environmental risk factors are often associated with the poor performance of FM services like cleaning, maintenance, waste management, laundry and catering. Behavioural risk factors are associated with poor hand-washing compliance and unhygienic staff practices, etc. Failure to minimise some of these risk factors could expose healthcare users to the risk of acquiring HAIs. In addition to tackling the clinical risk factors of HAIs (i.e. therapeutic risk factors), healthcare authorities must also pay sufficient attention to non-clinical risk factors of HAIs.

8.3.2 The Causes and Measures to Reduce HAIs in HFM

Evidence of the link between HFM and HAIs comes not only from history. In this research study, epidemiological evidence is collated to demonstrate the link between HFM services and HAIs. Although all HFM services contribute to patient care, those directly linked to HAIs include the planning and design of hospitals, cleaning, maintenance, waste management, laundry and catering services. In the NHS, these services are organised under the healthcare facilities management (HFM) division. These services obviously occur alongside the provision of clinical services in hospitals.

Although HFM officials are involved in the day-to-day running of hospitals, they are often not invited to participate in the planning and design of new hospitals or projects. Some newly completed hospitals (i.e. PFI hospitals) in the UK have been criticised for their lack of utility rooms and sluices. The involvement of HFM officials in the planning and design of hospitals may positively influence the performance of new hospital buildings at the building occupancy stages. For example, HFM could contribute information about the specification and number of hand-washing facilities. This of course may increase the observance of hand hygiene, and thus reduce the incidence of HAIs.

Other HFM services like cleaning, maintenance, waste management, laundry and catering also play an important role in IC. As this research study has shown, poor performance in any of these HFM services could result in the incident of HAIs. The only time HFM services get the attention of healthcare officials is when there is an outbreak of infection. This attitude costs the NHS extra money in terms of drug acquisition, litigation and closures. With one of the worst rates of HAIs in Europe, the NHS must endeavour to adopt a holistic approach to tackling the root causes of HAIs. At the moment, HFM workers, especially contractors, are not being given the right level of training and education in IC. A standard should set for the training of all HFM workers in IC. Presently, wide variations exist in the training and education of HFM workers in IC. By engaging the HFM division in IC, the NHS will raise overall performance across the NHS in IC. For its part, the HFM division will be able to demonstrate to its stakeholders its contribution in the core business objectives of the NHS – *patient wellbeing*.

8.3.3 Identifying the CSFs and Performance Measures in HM in IC

Of the aforementioned HFM services linked with HAIs, healthcare maintenance (HM) is probably one of the most important. Evidence gathered in this research study indicates a strong epidemiological link between HM and HAIs. However, healthcare authorities in the UK have not adequately addressed the issues of maintenance-associated HAIs in the NHS. HM continues to be treated as though it has real no connection with HAIs. As this research has shown, many HMUs in the NHS do not measure their performance in IC. Many still do not have CSFs, performance measures or a performance measurement system in IC.

The in-depth literature review identified 27 key IC documents. Analysis of these documents led to the identification of eight CSFs and 67 performance measures in HM in IC. In contrast to the usual treatment of this topic elsewhere, this study categorised the CSFs and performance measures under the four principles of the BSC. The four principles of the BSC have been commended by many for driving overall performance in an organisation. In addition, the BSC allows managers pay attention to the financial and non-performance measures. The results of the pilot study clearly indicate that the focus of the HM unit is on financial measures. In an industry with a history of conducting performance measurement in an ad hoc fashion, the identification of the

CSFs and performance measures in IC are invaluable. Although the CSFs and performance measures identified in this research study relate to HM, there is scope for modification and adoption in other HFM services in the NHS.

8.3.4 The Importance of CSFs and Performance Measures in IC

This research study did not stop with the identification of the CSFs and performance measures in HM in IC. One of the major challenges facing managers is selecting the right set of CSFs and performance measures to drive performance. In this research study, therefore, the Delphi approach was applied to arrive at a consensus on important performance measures in HM in IC. The CSFs and key performance measures were identified by HM managers and IC members. In total, they identified 53 important performance measures in HM in IC. This list does not tell managers concisely which CSF and performance measure is more important than another. Therefore, steps were taken to classify the CSFs and performance measures into varying levels of importance in IC. Once this was achieved, it became clear that 'liaison and communication with members of the ICT' is one of the most important CSFs in HM in IC. Others include CSFs like 'maintenance resource availability' and 'infection control practices (cleaning and administrative requirements)'. Some of the CSFs like 'staff training and development', 'risk assessment' and 'customer satisfaction' have a slightly lower level of importance in HM in IC. The fact that one CSF is more important than another does not mean that all of its performance measures are very important too. The HM-BSC Matrix that is developed in this research study makes it easy for HM managers to compare and select performance measures according to their level of importance in IC.

8.3.5 The Development of the Performance Measurement System (PMS)

In order to derive the full benefit of the performance measurement system, HM managers need to have a thorough understanding of the strategy of NHS trusts in IC (see section 5.6). They need to develop a mission statement that is aligned to the vision of the NHS Trust and Facilities in IC. To give it credence, the mission statement of the HMU in IC should be signed and approved by top management. The mission statement is a platform for the HM to tell NHS staff and the public that it is part of the NHS. Thereafter, the HM unit could select its CSFs and performance measures from the ones developed in this research. After the selection of the CSFs and performance measures, the HM unit has to set itself goals, objectives and targets in IC. By setting itself ambitious targets in IC, the HMU will be able to verify whether it is contributing to the aims and objectives of the NHS Trust in IC. As performance measurement is an on-going process, corrective action should be the mantra of the HM in IC.

This research study did not stop with the identification of the CSFs and performance measures in HM in IC. It developed a performance measurement system (PMS) that can be used by HM in IC. At the moment, most HFM services do not really bother to measure performance in IC. The results of the pilot case study show that many HM managers do not even know the vision and strategy of their NHS Trust in IC. Thus, the development of a performance measurement system will go some way to meeting some of these challenges.

The PMS that is developed in this research study could be used by HM managers to measure performance of the HM unit at four different levels. At the first performance level, results are provided about single performance measures. At the second performance level, results are provided only about the performance measures in a mean zone. This is useful in a situation in which the HM manager selects all the performance measures from a single mean zone. At the third performance level, results are provided about all the performance measures in a mean zone, taking into account the performance measures in the other mean zones. The results gathered at the third performance level allow the HM manager to compare performance across all mean zones. At the final performance level, results are provided for the entire PMS.

The PMS that is developed in this research study is like a dashboard for HM managers. It is designed in a way which enables HM managers to direct resources and effort to the most critical areas of performance in IC. This is achieved at the level of single performance measures or performance measures grouped into mean zones. Since HM managers are able from time to time to check the first, second and third levels of performance, they are in a better position to achieve the targets of the HM unit in IC. New performance measures could easily be added or old ones discarded from the PMS.

8.4 THE LIMITATIONS OF THIS STUDY

This research study, like many others, has its own limitations and drawbacks. The findings of this research study may not reflect in entirety what is happening across NHS hospitals. This is because of the different arrangements involved in the provision of HM services in the NHS. Currently there are four ways of providing HM services in the NHS: in-house, outsourced, mixed (outsourced and in-house), and PFI (private finance initiatives). Thus it is possible that these different approaches used in the provision of HM services have varying levels of performance.

The number of Delphi participants was not as many as the researcher would have expected. Again, as in most research of this nature, the researcher could not verify whether the supposed Delphi participants were actually the ones completing the Delphi exercises. Given the variation in the level of HM services in the NHS, there was always the possibility that some of the Delphi participants did not have the required level of expertise on some of the performance issues covered in this research study.

8.5 RECOMMENDATIONS AND FUTURE RESEARCH

This research study covered a number of important issues concerning the performance of HM in IC. The following recommendations are suggested to healthcare authorities and members of academia.

8.5.1 Recommendations for Healthcare Authorities

- Presently, it appears that much attention is focused on tackling the clinical causes of HAIs in the NHS. However, as this research study has shown, there is strong evidence linking HFM services with the prevalence of HAIs in the NHS. In order to reduce the huge socio-economic and health burden of HAIs, the NHS should adopt a holistic approach to tackling the root causes of HAIs in the NHS. Although progress has been achieved over the last couple of years, the UK is still lagging behind other western countries in rates of HAIs. Healthcare authorities, especially those working for the NHS, have to increase the level of communication and integration between HFM units and IC departments. Presently, the two are working as separate entities. On a number of key performance measures, there are significant differences between HM managers and IC members. HM managers disagreed strongly about obtaining IC permits from the IC department. Such minor differences expose healthcare users to the risk of acquiring HAIs.
- In the NHS, the main aim of maintenance strategies is to reduce cost. In this research study, an integrated HM strategy is developed to minimise the risk of HAIs

in hospitals. The integrated HM strategy mixes corrective, preventive, and condition-based maintenance strategies, which are already being used in the NHS to cut cost. In this research study, however, these maintenance strategies have been integrated to reduce the occurrence of failures that might expose healthcare users to the risk of HAIs. Now healthcare authorities need to invest money to investigate the practical application of some of the suggestions inherent in such an integrated HM strategy in IC.

- Although dust prevention was considered by the Delphi participants to be one of the most important performance measures in IC, there is only limited adoption of the Infection Control Risk Assessment (ICRA) in NHS Trust. In the US the ICRA is accredited for construction companies working in hospitals. Embedded in the ICRA is a comprehensive risk assessment framework for minimising dust contamination in hospitals. Even if healthcare authorities are not considering making the ICRA a requirement in the NHS, they should consider providing training and education on its voluntary application across the NHS.
- Although government guidelines clearly state that IC is everyone's business, HFM is being left out. Many of the government guidelines and policies reviewed in this research study do not even mention the contribution of HFM in IC. In order to focus everyone's attention on the subject of HAIs, government guidelines and policies, both at the national and local levels, must include HM. A review of HM policies across NHS Trusts in the Northwest revealed wide variations in the content and quality of IC material. There is a need for healthcare authorities to formulate clear policies and guidelines on HM in IC.

8.5.2 Recommendations for Future Researchers

- The CSFs and performance measures that have been developed in this research study needs to be integrated into an HM-BSC framework in IC. As discussed earlier, the HM-BSC framework should be linked to the strategy of the NHS Trust in IC. It should include key issues like the vision, mission statement, goals, objectives and targets of the HM in IC. Until these key issues are identified with input from experts, it will be difficult to show the contribution of the HM unit in the overall strategy of the NHS in IC.

- There is a need to investigate whether the CSFs and performance measures that are developed in this research study apply to all the FM approaches in the NHS. Therefore, more research is needed to ascertain whether variations exist in the application of the CSFs and performance under the following FM approaches: in-house, outsourced, mixed, and PFI.
- The PMS that is developed in this research study has not yet been tested. In order for the PMS to gain the prominence it deserves, it needs to be tested with a number of Acute NHS Trust in England.
- Researchers need to investigate the most appropriate method for applying the PMS. It is recommended that researchers also investigate the suitability of software in applying this PMS.

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LIST OF APPENDICES

Appendix 1: Invitation Cover Letter

The Grenfell-Baines School of Architecture,
Construction and Environment
UNIVERSITY OF CENTRAL LANCASHIRE

Date:
«Title» «First_Name» «Last_Name_»
«Department»
«Hospital»
«Street»
«Town»
«Post_Code»

Dear «First_Name»

My name is **Stanley Njuangang**, PhD Candidate at the University of Central Lancashire. Our research team is currently conducting a study **on identifying key performance measures in healthcare maintenance in the control of hospital-acquired infections (HAIs).** HAIs are a major socio-economic and health burden for the National Health Service (NHS).

Therefore, because of your profound knowledge, we are nominating you to participate in a Delphi study to identify these issues. As you well know, the application of Delphi in this study is to elicit, refine, and draw upon the collective opinion and expertise of a panel of experts. A core component of Delphi is anonymity. The Ethics Committee of the University of Central Lancashire has approved this research. Some of these issues will be addressed in subsequent correspondence.

As part of the Delphi exercise, you will be expected to respond to three rounds of questionnaires. Each Delphi round last for about two weeks, and the questionnaires only take thirty – forty minutes to complete. At the end of the Delphi exercise (expected in November 2013), you will receive a summary of the Delphi results.

To ensure that the information gathered meets the required standard, we kindly ask you to complete sections 1 and 2 of the attached form. Please state your level of experience by ticking one of the boxes. **If you tick yes** to any of the boxes, then you have been nominated to take part in this study. **As this study will be conducted online, we kindly ask you to provide us with your email address**. Use the self-addressed stamped envelope to return the completed form. Address any issues to **snjuangang@uclan.ac.uk** or phone: 07828822747/01772893221.
Please nominate a colleague for this study.

Yours Sincerely

Appendix 2: Delphi Participant Selection Criteria

The Grenfell-Baines School of Architecture,
Construction and Environment
UNIVERSITY OF CENTRAL LANCASHIRE

Section 1

Profession	Level of Experience		
Individual with Responsibility for Infection Control and Prevention (i.e. Microbiologist, Infection Control Doctor, Infection Control Nurse, etc)	5 years and over	Yes ☐	No ☐
Manager NHS Estates and Facilities	5 years and over	Yes ☐	No ☐
Head of maintenance/operations	5 years and over	Yes ☐	No ☐

Section 2

Email Address	

Appendix 3: Delphi Round One Instructions

"Identifying Performance Goals and Measures in Healthcare Maintenance in the Control of Hospital-Acquired Infections (HAIs)"

Delphi –ROUND One

A. Useful Definitions

1. **Delphi: "…***long-range forecasting technique, that elicits, refines, and draws upon the collective opinion and expertise of a panel of experts*" (Gupta and Clarke, 1996).
2. **Hospital-acquired infections:** "are *infections that were neither present nor incubating when a patient***,** *visitor or hospital staff enters the hospita*l" (National Audit Office, 2000).
3. **Healthcare maintenance: "***work undertaken to keep or restore hospital premises to acceptable standards of safety and efficiency having due regard to the needs of patients and staff within the immediate environment, the requirements of the NHS and the resources available"* (Woodbine Report, 1970).
4. **Critical Success Factors:** "*key areas of performance that are essential for the organisation to accomplish its mission* [goals, objectives, or projects]" (Caralli *et al*., 2004: 2).
5. **Performance measures:** "*specific standards which allow the calibration of performance for each critical success factor, goal, or objective*" (Bullen and Rockart, 1981).

B. Instruction to fill the attached questionnaire

1. Please fill in Section 1.
2. In Section 2 of the questionnaire:
   a. Please read carefully Columns A (**Critical Success Factors**) and B (**Performance Measures**).
   b. Use the blank spaces in Column C to **identify new performance measures**, if any.
3. In Section 3, please **fill in new performance goals and their respective measures**, if any.
4. In Section 4, please use the blank spaces to **comment** on the Delphi exercise.

Please send the filled in questionnaire on or before **November 14, 2013** to Mr. Stanley Njuangang at snjuangang@uclan.ac.uk.

Appendix 4: Delphi Round One Instrument

1	Respondent Personal Information	
1. Position of Responsibility:		
2. Years of Experience:	1.	
3. State your area(s) of research/interest:	2.	
	3.	

2	Performance Issues	
Critical Success factors (A)	**Performance measures (B)**	**Identify New Performance Measures (C)**
Resources Resources	1. Regularly review the condition of hospital building services & infrastructure, and feed into investment program.	4.
	2. Adequate resources for mandatory and operational compliance in infection control.	5.
	3. The purchase of quality maintenance materials and products from reliable suppliers	6.
	4. Conduct monthly review of expenditure against budget in IC.	7.
Maintenance Strategies	1. Conduct daily check of all critical maintenance systems posing the risk of HAIs.	6.
	2. Categorize hospital assets, and maintenance equipments into significant and non significant items in infection control	7.
	3. Ensure the timely execution of all planned maintenance work posing risk of infection.	8.
	4. The use of a computer-based maintenance system to coordinate planned, defect/failure maintenance work	9.
	5. Keep account of the effectiveness of all critical maintenance equipment/assets that may cause HAI	10.
Risk Assessment	1. Use a recognised risk assessment tool to match the level of risk associated with maintenance work.	5.
	6. Educate staff and set clear lines of individual responsibility in managing the risk of maintenance-related infections.	6.
	3. Involve all stakeholders in risks identification and response (i.e. the ICT).	7.
	4. Process for reporting, managing, and analyzing complains and incidences in infection control.	8.
Infection control practices	***Cleaning Requirements***	
	1. Maintenance work should ease the cleaning of hospitals.	9.
	2. Provide active means to prevent airborne dust from dispersing into atmosphere.	10.
	3. Adherence, compliance and use of personal protective equipment where necessary	11.
	4. Wash equipments after use.	12.
	5. Compliance with hand hygiene whilst working in clinical areas	13.
	6. Provide adequate or temporal hand washing facilities for maintenance staff.	14.

	7. Report injury especially if 'sharp' related, cover wounds or sores.	15.
	8. Maintenance staff must not work in clinical areas if any symptoms of infection exist i.e. diarrhoea or vomiting (seek advice from the ICT).	16.
	Transportation Requirements	
	1. Transport clean and sterile equipments to storage areas via route that minimises contamination.	5.
	2. Redirect pedestrian traffic from work area.	6.
	3. Contain construction waste before transport in tightly covered containers.	7.
	4. Appropriate signage warning healthcare users of the risk of maintenance-associated HAI.	8.
	Administrative Requirements	
	1. Maintain and review infection control policies and procedures.	6.
	2. Pre-employment health check and immunization program for all in-house and contracted maintenance staff.	7.
	3. Ensure relevant and appropriate safe systems of work.	8.
	4. Obtain infection control permit, and assess patients for risk of fungal infection before commencement of work.	9.
	5. Inform Charge Nurse before commencement of maintenance work.	10
Liaison and Communication with the Infection Control Team	1. Establish formal communication between maintenance staff and contractor's employees.	7.
	2. Seek the advice of the Infection Control Team (ICT) on such matters concerning infections.	8.
	3. Early consultation & authorization from the Infection Control Team before commencement of any maintenance work posing the risk of HAIs.	9.
	4. Liaising with person in charge of area where maintenance is to be carried.	10.
	5. Liaise with hotel/domestic services regarding cleaning during and on completion of work.	11.
	6. Set up an organisational structure for healthcare maintenance with clear lines of responsibility in infection control.	12.
Service Level Agreement (SLA)	***Contract Requirements***	
	1. Select contractors based on strong technical, resource, managerial, and communication capabilities.	4.
	2. Take into account changes in assets and legislation when renewing contracts.	5.
	3. Customer satisfaction surveys should be part of Service Level Agreement with contractors.	6.
	Contractor Requirements	
	1. Put in place arrangement to response to emergency calls.	4.
	2. Procedure to supervise maintenance	5.

	work and variables i.e. spares etc.	
	3. Contractor should have safe record keeping, and adhere to mandatory code of conduct in infection control.	6.
	Contracted Staff Requirement	
	1. Attend all mandatory training (induction)/immunization programs in infection control.	3.
	2. Take responsibility for unsafe equipment, or practice posing risk of infection.	4.
Staff Education	***Staff Training***	
	1. Conduct annual review of staff training.	5.
	2 Provide all maintenance staff with information on statutory and technical guidance on infection control.	6.
	3 Induct all maintenance staff on the control of HAIs in the NHS.	7.
	4 Ensure the employment of skilled and competent staff.	8.
	Staff Development	
	1. Representation of the maintenance unit in the infection prevention and control, risk/governance committees.	5.
	2. Staff team briefings and appraisal schemes in infection control.	6.
	3. Personal development plans for staff in infection control.	7.
	4. Equal access, and improve working lives for staff.	8.
Customer Satisfaction Requirements	1. Measure the number of defect maintenance products	5.
	2. System to review, and analyse complains against the performance of the maintenance unit in infection control.	6.
	3. Measure maintenance response times (speed).	7.
	4. Make available complain boxes/ leaflets to enable people raise issues related to quality of maintenance services.	8.
2A	**New Critical Success Factors (A)**	**New Performance Measures (B)**
1.		1.
		2.
2.		3.
		4.
3	**Comments**	
–		

Thanks for completing round one of the Delphi study.
SAVE AND EMAIL to:
snjuangang@uclan.ac.uk

Appendix 5: Delphi Round Two Instructions

"Identifying Performance Measures in Healthcare Maintenance in the Control of Hospital-Acquired Infections (HAIs)"

This phase of the Delphi exercise is very crucial as it concerns the identification of key performance measures in healthcare maintenance in the control of hospital-acquired infections (HAIs) in the National Health Service (NHS).

A. INSTRUCTIONS

1. Read carefully each Delphi question (where necessary, refer to the Instruction Note in 'Delphi – Round 1', as it defines key terms used in this Delphi questionnaire).

2. **Use the rating scale provide in table one to rate the** performance measures (column C) in healthcare maintenance in the control of hospital-acquired infections (HAIs) in the NHS. Check only one box for a performance measure.
3. Please **save a copy** of the completed Delphi questionnaire for future reference.
4. Before the **26th of November 2013**, email the completed response sheet to Mr. Stanley Njuangang at snjuangang@uclan.ac.uk

Table 1: Rating Scale for Level of Importance

1	**Very important**
2	**Important**
3	**Unimportant**
4	**Very unimportant**

Proceed to the assignment sheet in the next page.

Appendix 6: Delphi Round Two Instrument

Critical success factors (A)	Performance measures in healthcare maintenance in the control of hospital-acquired infections (HAIs) (B)	1 Very important 2 Important 3 Unimportant 4 Very unimportant			
Resources	1. Review of the condition of hospital building services & infrastructure to feed into investment program.	1 ☒	2 ☐	3 ☐	4 ☐
	2. Secure adequate resources for mandatory and operational compliance of the healthcare maintenance unit in infection control.	1 ☒	2 ☐	3 ☒	4 ☐
	3. Purchase quality maintenance materials and products from reliable suppliers.	1 ☒	2 ☐	3 ☐	4 ☐
	4. Develop processes to control the introduction of new equipment/fabric that can be maintained efficiently and reduce the risk of HAIs (cheap capital purchase may be more expensive to maintain in the long term and pose risk of HAIs).	1 ☒	2 ☐	3 ☐	4 ☐
	5. Conduct monthly review of expenditure against budget in IC.	1 ☐	2 ☒	3 ☐	4 ☐
Maintenance Strategies	6. Daily check of all critical maintenance systems posing the risk of HAIs	1 ☒	2 ☐	3 ☐	4 ☐
	7. Categorize hospital assets, and maintenance equipments into significant and non significant items in infection control	1 ☐	2 ☒	3 ☐	4 ☐
	8. Ensure the timely execution of all planned maintenance work posing risk of infection.	1 ☒	2 ☐	3 ☐	4 ☐
	9. Use a computer-based maintenance system (i.e. reliability-centred maintenance) to coordinate all maintenance work.	1 ☒	2 ☐	3 ☐	4 ☐
	10. Prioritize and respond to building defects in time critical period to minimise the risk of HAIs.	1 ☒	2 ☐	3 ☐	4 ☐
	11. Keep account of the effectiveness of all critical maintenance equipment/assets that may cause HAI.	1 ☐	2 ☒	3 ☐	4 ☐
	12. Computer system that promotes mobility and allows maintenance staff to carry all the information they require, and communicate back to coordinators when job cannot be completed first time (so that parts / people can be planned in swiftly for revisit).	1 ☒	2 ☐	3 ☐	4 ☐
Infection control practices	***Cleaning Requirements***				
	13. Conduct maintenance work in a manner that eases cleaning.	1 ☒	2 ☐	3 ☐	4 ☐
	14. Provide active means to prevent airborne dust from dispersing into high risk patient areas.	1 ☒	2 ☐	3 ☐	4 ☐
	15. Compliance with the use of personal protective equipment as required.	1 ☒	2 ☐	3 ☐	4 ☐
	16. Wash and sanitize drainage equipment after use.	1 ☒	2 ☐	3 ☐	4 ☐
	17. Compliance with hand hygiene whilst working in clinical areas	1 ☒	2 ☐	3 ☐	4 ☐
	18. Provide temporal hand washing facilities for maintenance staff working in high risk patient areas.	1 ☒	2 ☐	3 ☐	4 ☐
	19. Report any injury especially if 'sharp' related, cover wounds or sores.	1 ☒	2 ☐	3 ☐	4 ☐
	20. Maintenance staff must not work in clinical areas if any symptoms of infection exist i.e. diarrhoea or vomiting (seek advice from the ICT).	1 ☒	2 ☐	3 ☐	4 ☐
	Transportation Requirements				
	21. Transport clean and sterile equipments to storage areas via route that minimises contamination.	1 ☐	2 ☒	3 ☐	4 ☐

		1	2	3	4
	22. Redirect pedestrian traffic from work area.	1 ☐	2 ☒	3 ☐	4 ☐
	23. Contain construction waste before transport in tightly covered containers.	1 ☐	2 ☒	3 ☐	4 ☐
	24. Health & safety signage used	1 ☒	2 ☐	3 ☐	4 ☐
	Administrative Requirements				
	25. Maintain and review infection control policies and procedures.	1 ☒	2 ☐	3 ☐	4 ☐
	26. Pre-employment health check and immunization program for all in-house and contracted maintenance staff.	1 ☐	2 ☒	3 ☐	4 ☐
	27. Put in place safe working system for maintenance staff in infection prevention.	1 ☒	2 ☐	3 ☐	4 ☐
	28. Before commencement of maintenance work, obtain infection control permit, and assess patients for risk of maintenance-associated HAIs.	1 ☒	2 ☐	3 ☐	4 ☐
	29. Inform Charge Nurse before commencement of maintenance work.	1 ☒	2 ☐	3 ☐	4 ☐
	30. Ensure in –house and contractors work to same clear guidelines	1 ☒	2 ☐	3 ☐	4 ☐
Risk Assessment	31. Use a recognised risk assessment tool (i.e. infection control risk assessment – ICRA) to match the level of risk associated with maintenance work.	1 ☐	2 ☒	3 ☐	4 ☐
	32. Educate staff and set clear lines of individual responsibility in managing the risk of maintenance-related infections.	1 ☐	2 ☒	3 ☐	4 ☐
	33. Involve all stakeholders in risks identification and response (i.e. the ICT).	1 ☒	2 ☐	3 ☐	4 ☐
	34. Process for reporting, managing, and analyzing complains and incidences in infection control.	1 ☐	2 ☒	3 ☐	4 ☐
Liaison and Communication with the Infection Control Team	35. Set communication channel between maintenance staff and contracted staff.	1 ☒	2 ☐	3 ☐	4 ☐
	36. Seek the advice of the Infection Control Team (ICT) on such matters concerning infections.	1 ☐	2 ☒	3 ☐	4 ☐
	37. Early consultation & authorization from the Infection Control Team before commencement of any maintenance work posing the risk of HAIs.	1 ☒	2 ☐	3 ☐	4 ☐
	38. Liaise with person in charge of area where maintenance is to be carried.	1 ☒	2 ☐	3 ☐	4 ☐
	39. A system for maintenance staff to liaise with domestic staff regarding cleaning during and on completion of work.	1 ☒	2 ☐	3 ☐	4 ☐
	40. Regularly meet with infection Control and Clinical representatives to ensure maintenance processes complement clinical care.	1 ☐	2 ☒	3 ☐	4 ☐
Service Level Agreement with contractors	***Contract Requirements with external providers***				
	41. Select contractors on their strong technical, resource, managerial, and communication capabilities.	1 ☒	2 ☐	3 ☐	4 ☐
	42. Take into account changes in assets and legislation when renewing contracts.	1 ☒	2 ☐	3 ☐	4 ☐
	43. Customer satisfaction surveys should be part of Service Level Agreement with contractors.	1 ☐	2 ☒	3 ☐	4 ☐
	44. Contractor should have arrangement to response to emergency calls.	1 ☒	2 ☐	3 ☐	4 ☐
	45. Contractor should have procedure to supervise maintenance work and variables i.e. spares etc.	1 ☐	2 ☒	3 ☐	4 ☐
	46. Contractor should have safe record keeping, and adhere to mandatory code of conduct in infection control.	1 ☒	2 ☐	3 ☐	4 ☐
	Contracted Staff Requirement				
	47. Contracted workers must attend all mandatory induction and training in infection control.	1 ☒	2 ☐	3 ☐	4 ☐
	48. Contractors have to take responsibility for any unsafe equipment, or practice posing risk of infection.	1 ☒	2 ☐	3 ☐	4 ☐

		1	2	3	4
Staff Education	**Staff Training**				
	49. Conduct annual review of staff training.	☐	☒	☐	☐
	50. Employ skilled and competent staff to ensure safe and efficient maintenance operations.	☒	☐	☐	☐
	51. Provide all maintenance staff with information on statutory and technical guidance on infection control.	☒	☐	☐	☐
	52. Conduct site induction on infection control within few weeks of employment.	☒	☐	☐	☐
	Staff Development				
	53. The maintenance department should be represented in infection prevention & control, risk/governance committees.	☒	☐	☐	☐
	54. Maintenance staff team briefings and appraisal schemes in infection control.	☒	☐	☐	☐
	55. Educate of maintenance staff on the assessment and management of risk in maintenance-associated hospital-acquired infections (HAIs).	☒	☐	☐	☐
	56. Equal access, and improve working lives for staff.	☐	☒	☐	☐
Customer Satisfaction Requirements	57. Measure the number of maintenance product that do not conform to the request.	☐	☒	☐	☐
	58. System to review, analyse complains against maintenance services, and recommend improvement.	☒	☐	☐	☐
	59. Measure the speed to response to maintenance request.	☒	☐	☐	☐
	60. Ensure visual display of response to complaints.	☒	☐	☐	☐
	61. Measure the number of completed maintenance jobs that failed to meet the required standard in infection control.	☒	☐	☐	☐
	62. Make available complain boxes/ leaflets to enable people raise issues related to quality of maintenance services.	☐	☒	☐	☐

Thanks for completing round one of the Delphi study.

SAVE AND EMAIL to:

snjuangang@uclan.ac.uk

Appendix 7: Delphi Round Three Instructions

"Identifying Performance Measures in Healthcare Maintenance in the Control of Hospital-Acquired Infections (HAIs)"

Dear X,

Once again, thanks very much for taking the time to complete the Delphi rounds. This is the third and final round of the Delphi exercise. Out of the six-three performance measures considered in round two, forty-three achieved consensus. Those that did not achieve consensus, in addition to four new performance measures identified in round one, have been included in this Delphi instrument. The round three Delphi instrument also includes your response and the participant group's percentage score (maintenance managers and infection control personnel) in round two. As part of the iteration process to achieve consensus, you can either m**aintain your response in round two or re-rate** each performance measure.

INSTRUCTIONS

1. Read carefully each Delphi question (where necessary, refer to the Instruction Note in 'Delphi – Round 1', as it defines key terms used in this Delphi questionnaire).
2. **In column D, maintain your response in round two or re-rate** each performance measure. **Table 1** clearly shows the rating scale to use. Check a box for every performance measure.
3. Please **save a copy** of the completed Delphi questionnaire for future reference.
4. Before the 20th of December 2013, email the completed response sheet to Stanley: snjuangang@uclan.ac.uk

Rating Scale for Level of Importance

1	**Very important**
2	**Important**
3	**Unimportant**
4	**Very unimportant**

Proceed to the assignment sheet in the next page.

Appendix 8: Delphi Round Three Instrument

Critical Success Factors **(A)**	**Performance measures in healthcare maintenance in the control of hospital-acquired infections (HAIs)** **(B)**	**Your response and total scores (%) from the Second Round Delphi exercise** **(C)**				**Please Rate Here** 1 Very important 2 Important 3 Unimportant 4 Very unimportant **(D)**			
Resources	1. Conduct monthly review of expenditure against budget in IC.	**1** ☐ 0%	**2** ☒ 60%	**3** ☐ 40%	**4** ☐ 0%	**1** ☐	**2** ☒	**3** ☐	**4** ☐
	2. Use risk assessment in maintenance-associated HAIs to direct maintenance resources to highest risk activities.	**1** ☐	**2** ☐	**3** ☐	**4** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐
	3. Involve the HMU and IC department in the purchase of maintenance materials and products.	**1** ☐	**2** ☐	**3** ☐	**4** ☐	**1** ☒	**2** ☐	**3** ☐	**4** ☐
Maintenance Strategies	4. Daily check of all critical maintenance systems posing the risk of HAIs	**1** ☒ 33.3%	**2** ☐ 60%	**3** ☐ 6.7%	**4** ☐ 0%	**1** ☒	**2** ☐	**3** ☐	**4** ☐
	5. Categorize hospital assets, and maintenance equipments into significant and non significant items in infection control	**1** ☐ 20%	**2** ☐ 53.3%	**3** ☒ 26.7 %	**4** ☐ 0%	**1** ☐	**2** ☒	**3** ☐	**4** ☐
	6. Use a computer-based maintenance system (i.e. reliability-centred maintenance) to coordinate all maintenance work.	**1** ☐ 26.7%	**2** ☒ 73.3%	**3** ☐ 0%	**4** ☐ 0%	**1** ☐	**2** ☒	**3** ☐	**4** ☐
	7. Keep account of the effectiveness of all critical maintenance equipment/assets that may cause HAI.	**1** ☐ 28.6%	**2** ☒ 73%	**3** ☐ 0%	**4** ☐ 0%	**1** ☐	**2** ☒	**3** ☐	**4** ☐
	8. The development of a water safety plan (reviewed annually) by maintenance and infection control teams, to identify, manage and control risks of waterborne infections associated with maintenance activities.	**1** ☐	**2** ☐	**3** ☐	**4** ☐	**1** ☒	**2** ☐	**3** ☐	**4** ☐
Infection Control Practices	***Cleaning Requirements***								
	9. Wash and sanitize drainage equipment after use.	**1** ☒ 40%	**2** ☐ 40%	**3** ☐ 6.7%	**4** ☐ 6.7%	**1** ☒	**2** ☐	**3** ☐	**4** ☐
	10. Provide temporal hand washing facilities for maintenance staff working in high risk patient areas.	**1** ☐ 26.7%	**2** ☐ 46.7%	**3** ☒ 26.7%	**4** ☐ 0%	**1** ☐	**2** ☐	**3** ☒	**4** ☐
	Transportation Requirements								
	11. Redirect pedestrian traffic from work area.	**1** ☐ 13.3%	**2** ☒ 66.7 %	**3** ☐ 13.3%	**4** ☐ 6.7%	**1** ☐	**2** ☒	**3** ☐	**4** ☐
	Administrative Requirements								
	12. Pre-employment health check and immunization program for all in-house and contracted maintenance staff.	**1** ☐ 40%	**2** ☒ 46.7%	**3** ☐ 13.3%	**4** ☐ 0%	**1** ☐	**2** ☒	**3** ☐	**4** ☐
	13. Have an agreed construction HAI plan to control all contract works on site. Reviewed plan annually to see level of compliance and provide annual improvement action plan based on previous years findings.	**1** ☐	**2** ☐	**3** ☐	**4** ☐	**1** ☒	**2** ☐	**3** ☐	**4** ☐
	14. Develop work culture that supports prioritization of maintenance work in infection control.	**1** ☐	**2** ☐	**3** ☐	**4** ☐	**1** ☒	**2** ☐	**3** ☐	**4** ☐

Risk Assessment	15. Use a recognised risk assessment tool (i.e. infection control risk assessment – ICRA) to match the level of risk associated with maintenance work.	**1** ☐ 26.7%	**2** ☒ 66.7%	**3** ☐ 6.7%	**4** ☐ 0%	**1** ☐	**2** ☒	**3** ☐	**4** ☐
Liaison and Communication with the Infection Control Team	16. Regularly meet with infection Control and Clinical representatives to ensure maintenance processes complement clinical care.	**1** ☐ 33.3%	**2** ☒ 53.3	**3** ☐ 13.3	**4** ☐ 0%	**1** ☐	**2** ☒	**3** ☐	**4** ☐
Service Level Agreement with contractors	***Contract Requirements with external providers***								
	17. Take into account changes in assets and legislation when renewing contracts.	**1** ☐ 26.6%	**2** ☒ 60%	**3** ☐ 13.3%	**4** ☐ 0%	**1** ☐	**2** ☒	**3** ☐	**4** ☐
	18. Customer satisfaction surveys should be part of Service Level Agreement with contractors.	**1** ☐ 13.3%	**2** ☒ 60%	**3** ☐ 26.7%	**4** ☐ 0%	**1** ☐	**2** ☒	**3** ☐	**4** ☐
	Contracted Staff Requirement								
	19. Contracted workers must attend all mandatory induction and training in infection control.	**1** ☐ 46.7%	**2** ☒ 26.7%	**3** ☐ 13.3%	**4** ☐ 6.7%	**1** ☒	**2** ☐	**3** ☐	**4** ☐
Staff Education	***Staff Training***								
	20. Conduct annual review of staff training.	**1** ☐ 33.3%	**2** ☒ 60%	**3** ☐ 6.7%	**4** ☐ 0%	**1** ☐	**2** ☒	**3** ☐	**4** ☐
	Staff Development								
	21. Maintenance staff team briefings and appraisal schemes in infection control.	**1** ☐ 33.3%	**2** ☒ 46.7%	**3** ☐ 13.3%	**4** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐
	22. Equal access, and improve working lives for staff.	**1** ☐ 26.7%	**2** ☐ 46.7%	**3** ☒ 26.%	**4** ☐ 0%	**1** ☐	**2** ☐	**3** ☒	**4** ☐
Customer Satisfaction Requirements	23. Measure the number of maintenance product that do not conform to the request.	**1** ☐ 20%	**2** ☒ 66.7%	**3** ☐ 13.3%	**4** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐
	24. Ensure visual display of response to complaints.	**1** ☐ 20%	**2** ☒ 60%	**3** ☐ 20%	**4** ☐ 0%	**1** ☐	**2** ☒	**3** ☐	**4** ☐
	25. Make available complain boxes/ leaflets to enable people raise issues related to quality of maintenance services.	**1** ☐ 13.3%	2 ☒ 60%	3 ☐ 20%	4 ☐ 6.7%	1 ☐	2 ☒	3 ☐	4 ☐

Thanks for completing round three of the Delphi study.

SAVE AND EMAIL:

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Appendix 9: Conference Publications

<u>Papers published in refereed conference proceedings:</u>

1. Njuangang, S., Liyanage, C.L. and Akintoye, A. (2013). *A Methodological Approach to Identify Key Performance Indicators and Measures in Maintenance Services in Infection Control*. In: AEI 2013: Building Solutions for Architectural Engineering. American Society of Civil engineers (ASCE), PP. 702-714. ISBN 978-07844-1290-9.

2. Njuangang, S., and Liyanage, C.L. (2010). A Critical Review of the Implication of Outsourcing in the National Health Services (UK): a Facilities Management Perspective, *COBRA (The Human Dimension Session), Paris,* September 2010. http://www.rics.org/site/download_feed.aspx?fileID=8092&fileExtension=PDF

3. Njuangang, S. and Liyanage, C. (2011), **"**Raising the Profile of Facilities Management in Healthcare – Through Better Management of Infection Control", *in Property and Project Management proceedings of the 10th International Postgraduate Research Conference* in Salford, University of Salford 2011, pp. 323-336.

4. Njuangang, S. and Liyanage, C. (2011), "Key Considerations in the Strategic positioning of Maintenance Service in the Core Business Agenda of an Organisation – Healthcare Infection Control", *in the International Conference on Infrastructure Development in Africa,* Kwame Nkrumah University of Science and Technology, Ghana.

5. Njuangang, S. Douglas, C.H. and Liyanage, C.L. 2010. Corporate Decision Making in the Implementation of EMSs: Key Drivers and Barriers, *CIB World Congress (TG 65 Session)*, Salford, 10th-13th of May 2010.