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Developing an evidence-based understanding of hospital space planning efficiency

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Abstract: Over the last two decades there has been a steady increase in the demand for healthcare services and a commensurate rise in the global expenditure in health (WHO, 2014). Given the significance of the financial investment in capital works programmes required to meet growing healthcare needs and the expanding environmental impact of the healthcare industry, it is important to gain a detailed understanding of how healthcare infrastructure assets currently perform, the strategic drivers impacting on hospital space use efficiency, and the complex interrelationship of factors that impact on the healthcare environment.

This paper outlines a research project that was conducted by the University of Melbourne in conjunction with a local architectural practice partner, to examine space planning efficiency and emerging trends in hospital space planning requirements. To assist in developing a greater understanding of the space planning efficiency of healthcare infrastructure, and changing trends in hospital space planning, this study examined a range of measures across 31 hospitals against regional and international benchmarks. This paper outlines a novel multi-modal research methodology established to examine the complex range of interconnecting planning measures impacting space planning efficiency, and some of the difficulties in assessing hospital space planning efficiency.

Keywords: Healthcare design, space planning efficiency, evidence-based design.

1. INTRODUCTION

Over the last two decades there has been a steady increase in the demand for healthcare services and a commensurate rise in the global expenditure in health (WHO, 2014). In 2014-15, in Australia alone, approximately $161.6 billion was spent on health care (Malik, Lenzen, McAlister, & McGain, 2018). Healthcare provision is a highly energy intensive industry, and it is estimated that the healthcare industry accounts for 7% of the total CO_2 emissions in Australia, 10% in the USA (up from 8% in 2008), and 4% in the UK (Malik et al., 2018). Furthermore, it is estimated that hospitals are responsible for approximately 44% of the total healthcare CO_2 output. Given the significance of the financial investment in capital works programmes required to meet growing healthcare needs and the expanding environmental impact of the healthcare industry, it is important to gain a detailed understanding of how healthcare infrastructure assets currently perform, the strategic drivers impacting on hospital space use efficiency, and the complex interrelationship of factors that impact on the healthcare environment.

Planning efficiency ratios and departmental grossing factors, informed by other space planning metrics, healthcare guidelines, models of care, and healthcare delivery statistics, are crucial in the planning and delivery of healthcare facilities (Allison & Hamilton, 2008; Ampt, Harris, & Maxwell, 2008; Itoh, Nakayama, Liu, & Kawaguchi, 1993). Such measures provide a rich resource to support the evidence-based design and delivery of efficient, cost effective, functional and high-quality healthcare facilities. Whilst there are standard international area and efficiency measures such as Net Operational Floor Area (NOFA), Construction Floor Area (CFA), Planning Efficiency Ratio (PER), and Circulation, there are often region-specific metrics, variations in the measurement methodology due to local differences in regulatory compliance, and planning and procurement processes (Allison & Hamilton, 2008).

This paper outlines a research project that was conducted by the University of Melbourne in conjunction with a local architectural practice partner, to examine space planning efficiency and emerging trends in hospital space planning requirements. To assist in developing a greater understanding of the space planning efficiency of healthcare infrastructure, and changing trends in hospital space planning, this study examined the department grossing factors and planning efficiency ratios measured across 31 hospitals against regional departmental averages, target Departmental Conversion Factors, and international benchmarks. This paper outlines a novel multi-modal research methodology established to examine the complex range of interconnecting planning measures impacting on space planning efficiency, and some of the difficulties in assessing hospital space planning efficiency across a range of facilities and differing healthcare systems.

2. METHODOLOGY

2.1 Rationale

In the design and delivery of healthcare infrastructure, it is important to have a comprehensive understanding of the space requirements needed to support the complex range of clinical care needs (Devine et al., 2015; DHHS, 2016; Hicks, McGovern, Prior, & Smith, 2015; Krugman, Sanders, & Kinney, 2015; Latimer, Gutknecht, & Hardesty, 2008). Given the need to accommodate technological advances and future proof against changing healthcare and infrastructure requirements, an evidence-based understanding of current hospital space planning efficiency and performance can help inform an assessment of ways in which to reduce the carbon footprint associated with healthcare delivery, and the extent to which assets can respond to rearrangements of services, modified health care models, and changing healthcare needs (Latimer et al., 2008; Sprow, 2012; Wilson-Stronks, Lee, Cordero, Kopp, & Galvez, 2008; Zeisel, 2013).

One of the continuing trends in health care delivery has been to promote the provision of healthcare services close to where people live (Joseph & Phillips, 1984). Aligning the geographical distribution of healthcare facilities and services with needs is an important aspect of providing an accessible healthcare system that meets national health care needs (DoH, 2011; HealthcareUK, 2016).

The study enabled the examination of space planning efficiencies at a department-by-department granularity, floor by floor, and at the whole of hospital scale, for both individual hospitals, and across the range and geographical distribution of hospitals included within the study. Such large benchmarking studies are rare in the hospital space planning sector and provide an insight into healthcare infrastructure and an important evidence base by which to help assess:

- Current space planning use and efficiency;
- Differences in hospital space planning use and efficiency between regions and between different hospital types, hospitals with different service provision foci, and models of care;
- Track changes in the space requirements needed to support changing health care requirements and infrastructure needs;
- The potential for improvements in space planning efficiency;
- Ways in which to reduce CO_2 emissions through:
    - The potential for reductions in the building footprint (CFA)
    - Reduced embodied energy associated with physical healthcare infrastructure
    - The potential for improved operational energy efficiency of the built infrastructure
    - Reduced heating, cooling and lighting needs.

2.2 Efficiency Metrics

Carried out in four phases, the study incorporates both quantitative measurement and analysis of select space planning efficiency measures across the 31 hospitals included within the study, as well as a systematic literature review to obtain an in-depth understanding of existing healthcare space planning efficiency research and metrics, and develop a qualitative understanding of key space planning issues, emerging trends, and the resulting spatial implications for healthcare design and delivery. The protocols utilised for the systematic literature review were developed utilising the PRIMSA checklist and guidelines.

In line with common international practice, the principal approach to this study focused on a comparison of departmental measures in conjunction with an analysis of the overall hospital planning efficiency (see Figures 1 & 2) through an examination of floor-by-floor and 'whole of hospital' planning efficiency ratios (AHIA, 2016; Allison & Hamilton, 2008; Itoh, Nakayama, Liu, & Kawaguchi, 1993). The efficiency metrics and departmental measures and assessment parameters utilised within this study reflect standard international area and efficiency measures, as well as select metrics specific to the regions examined, so as to facilitate the analysis and comparison both internally between hospitals in each region, and across the full range of hospitals examined.

Key elements of the study included the measurement and analysis of departmental grossing factors, planning efficiency ratios, research on international efficiency metrics, development of an appropriate research methodology, and the development of measurement processes and standards for the various area classifications (such as Net Operational Floor Area, Net Floor Area, etc. – see figures 2 & 3). Key steps in the consultancy included measuring, retrieving and studying all relevant information within building plans; compiling standardised schedules of areas for each hospital; compiling the schedules of departmental grossing factors and planning efficiency ratios; and, summarising the planning efficiency of selected hospitals.

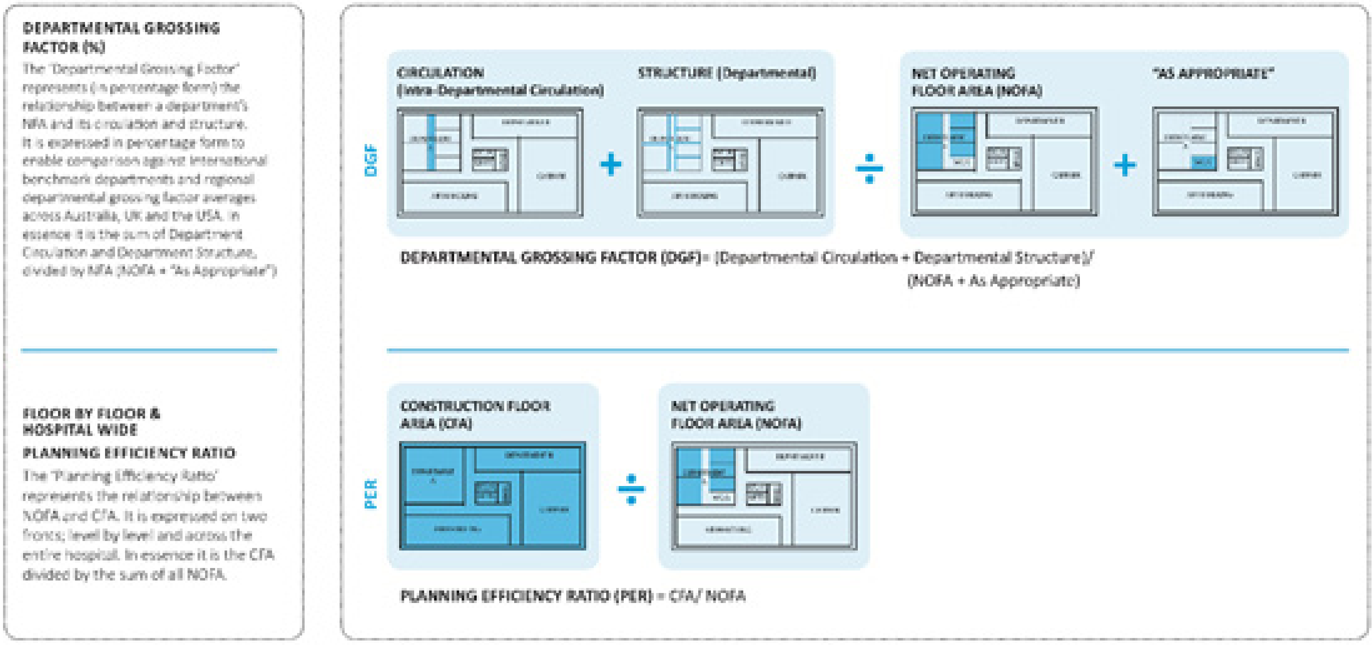

Figure 1: Planning efficiency measures.

It should be noted that the focus of this research is on select space planning efficiency measures, with a particular focus on planning efficiency ratios (PER) and Departmental Grossing Factors (DGF). The research does not examine the broader complexity of factors that impact on hospital planning efficiency such as models of care, patient and work flow, patient numbers etc.

2.3 Data mining process

The study included the collection of a total 25,884 measurements and data points across 31 hospitals to enable a comprehensive examination and comparison of select space planning efficiency measures across the hospitals included within the study.

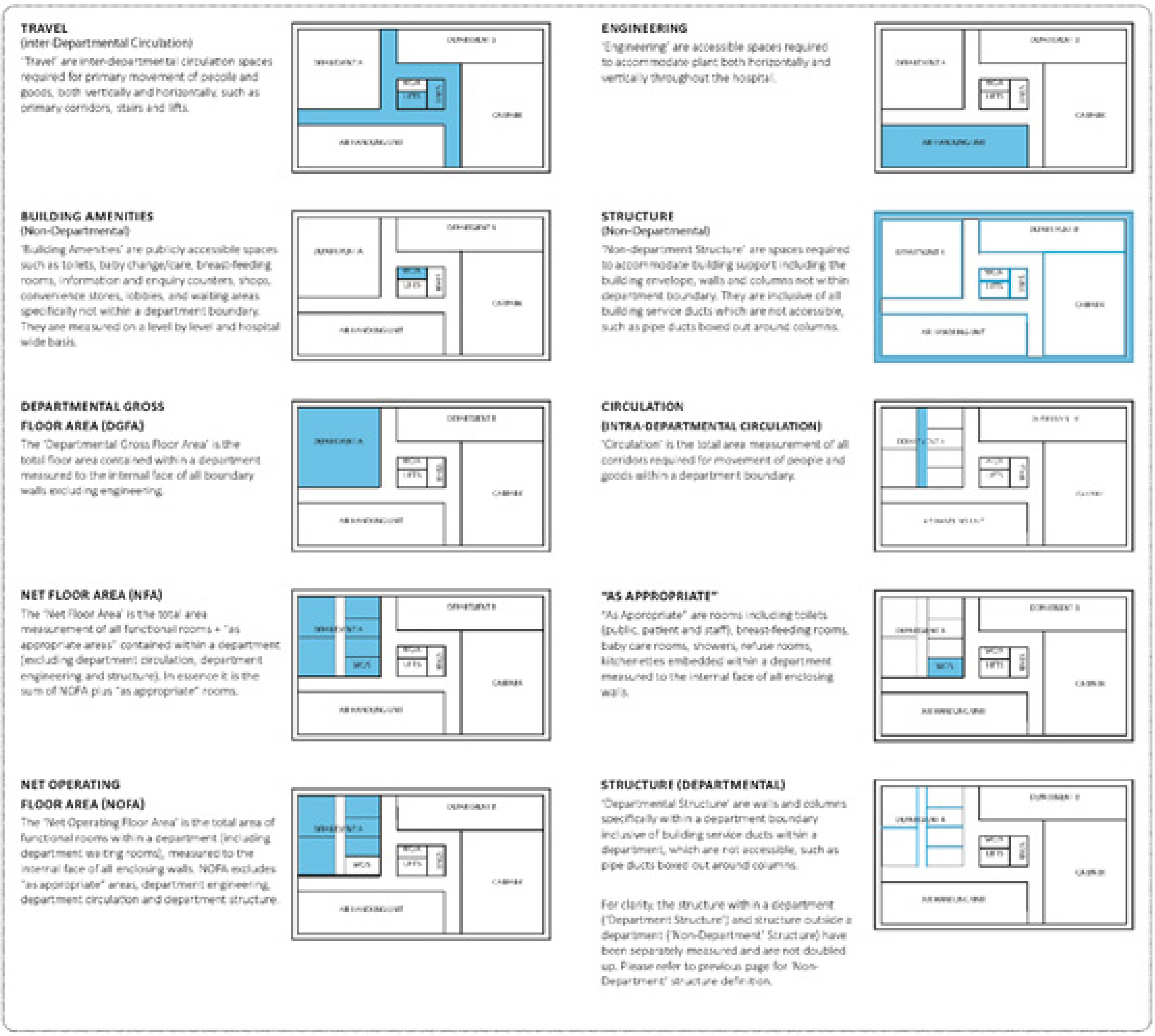

Figure 2: Area measurement definitions.

The area measurement and data mining process were conducted in phases so as to enable the testing and piloting of the research methodology (see Figures 2 & 3 for area measurement definitions and inclusions and exclusions). Once collated and verified, the raw data from the data mining process was then entered in to a custom designed data base so as to enable comparative analysis and cross tabulation across the 25,884 data points collected. The bespoke database was designed to be agile and enable a comprehensive analysis of the interrelationship between the area measures and the space planning efficiency metrics examined within this study.

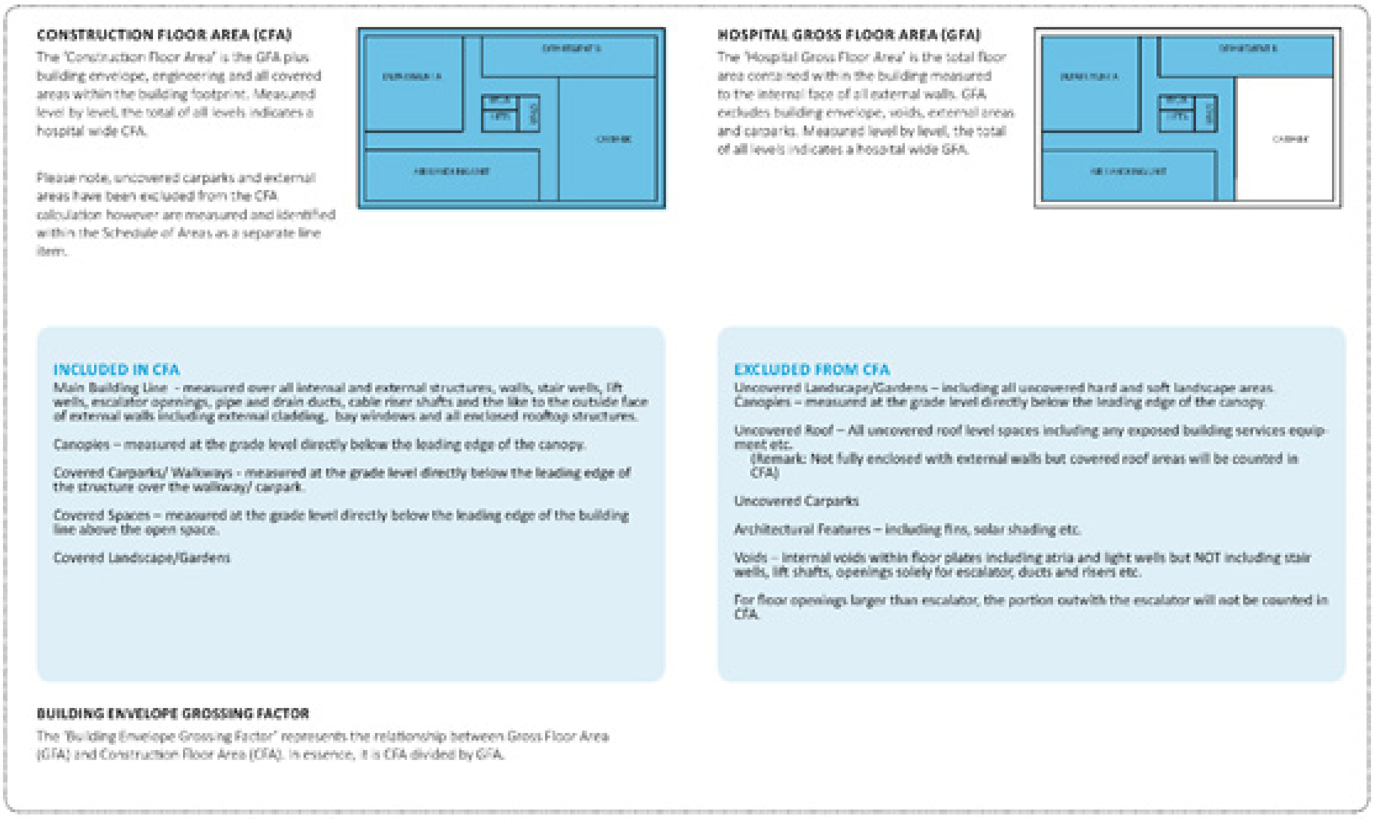

Figure 3: Area definitions and inclusions.

2.3.1 *Area measurement and data extraction*

- Electronic computer aided design (CAD) files and/ or hard copy print drawings for each of the Region 1[1] public and private hospitals (n=21) were obtained from relevant government authorities.
- The hard copy drawings and AutoCAD CAD files received were evaluated and re-drafted as three-dimensional building information model (BIM) Revit files, compensating for any errors, anomalies and omissions in the data sets.
- Departmental boundaries and floor-by-floor space allocations created were then reviewed for accuracy.
- “Raw” area data was extracted from the finalised BIM model files to create schedules of accommodation (SoA) for each hospital.
- A bespoke computational algorithm was created by the research team to automate the process for converting the raw files into standardised and ordered summary schedules. The algorithm was created to reduce manual error and translational data errors within the end data outputs.
- Each output schedule was evaluated and reviewed against the drawn data and any apparent anomalies were then reviewed and rectified where required.
- Appropriate international comparator hospitals were selected by the research team (n=10). The international hospitals were selected so as to reflect a representative sample in terms of facility scale, service mix and geographic distribution.
- In the case of the International Benchmark facilities, the process of drawing production involved the use of existing level-by-level hospital plans based upon existing drawing records or design drawings available to the research team through project sources and/ or internal records.
- The schedules of accommodation for the International Benchmark facilities were taken from previously prepared project documents for each facility. For the international comparator hospitals, the drawings were utilized as reference material to enable a better understanding of the functionality of each of the hospitals.

1 Please note that hospitals utilised within the study, and the geographic regions from which case study hospitals were selected, have been anonymised in accordance with our research agreement.

2.4 Data extraction and accuracy

Creation of reference schedules for the case study hospitals was automated using a bespoke computer algorithm created by the research team for the purposes of this study. This algorithm took “raw” room by room data from the Revit model outputs and organized it into a standardised format for import into the data base. The resultant schedules included the outcomes of measurement methods (i.e. Construction Floor Area over Nett Operational Floor Area as the measure for the Efficiency Ratio and reference to “As Appropriate” areas being excluded from the Nett Operational Floor Area figures).

It should be noted, that whilst the capacity to use the research data in a more long-term longitudinal tracking capacity was inbuilt into the research database, that the study is a “a point in time study” and reflects information as provided at the time of the study. Furthermore, data accuracy is impacted on by the accuracy of the source drawings and information available to the research team at the time of the study. Without accurate and up to date ‘as-built’ BIM models, there may be slight variations between the hospitals as drawn and the current in-use layout.

2.5 Data alignment

The original source material from which the Revit drawings and summary schedules were derived was formulated by different sources and at different points in time. As a result, between hospitals there were slight variations in the terminology utilised and in the naming of different departments and units. The health planning unit area figures listed in each hospital summary schedule reflect the health planning unit terminology listed on the original plans as provided to the research team. In order to facilitate benchmarking and a comparison between hospitals and health planning units, a process of ‘terminology alignment’ was carried out across all facilities included within the study to ensure data alignment between hospitals and facilitate a comparison of ‘like with like’.

For the sake of uniformity across all of the data, the health planning unit terminology and unit definitions as set out in the Australasian Health Facility Guidelines (AusHFG) (AHIA, 2016) were adopted across all case study hospitals (see Figure 4). Terminology from the original source material was aligned with the corresponding terminology utilized within the Australian Health Facility Guidelines to ensure concordance across all data sets, and area measures and room data within the database was then provided with an additional revised ‘aligned unit’ tag.

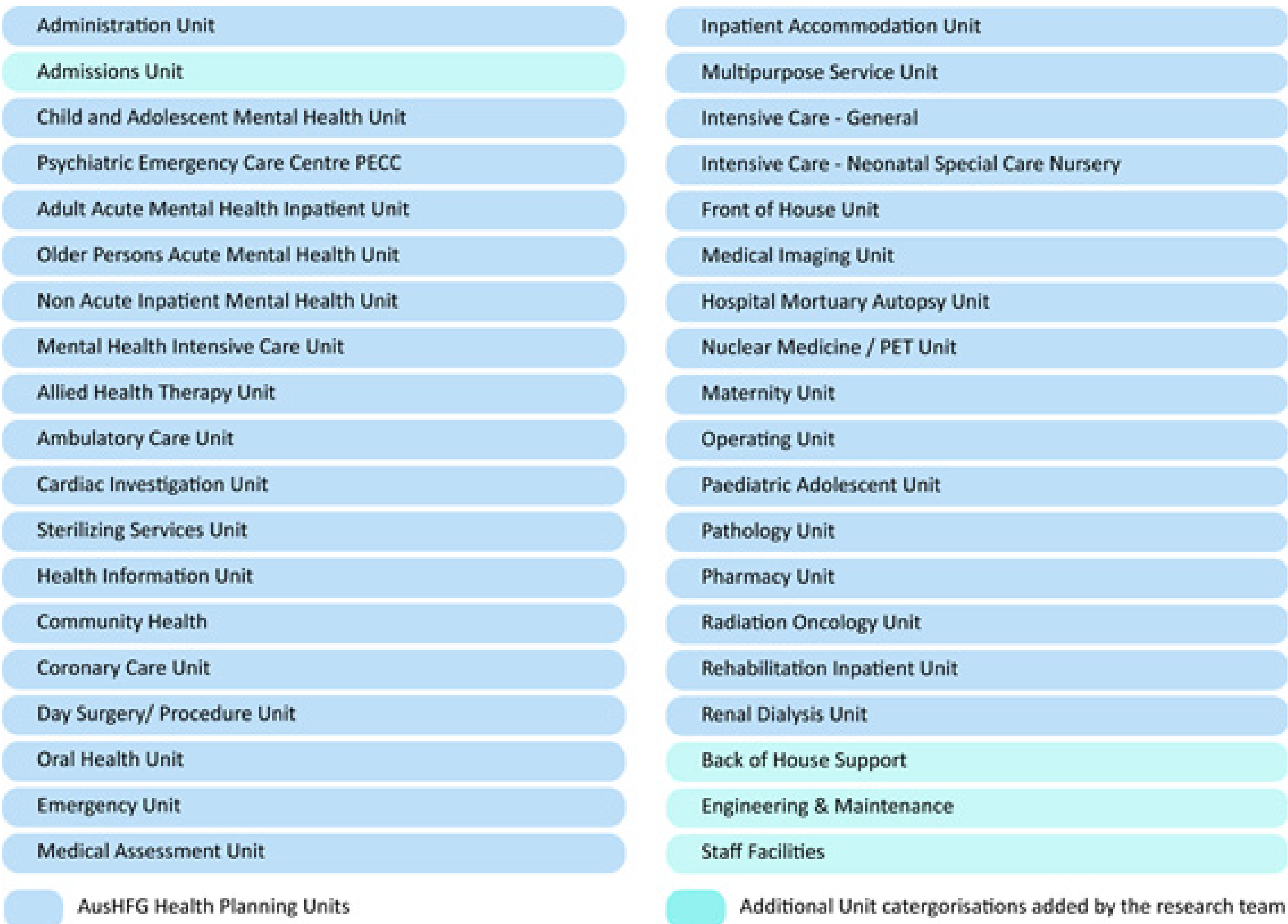

Figure 4: Terminology realignment: unit categories.

Due to differences in models of care between hospitals and service mix, terminology alignment was not always a straight forward process. Due to the slight overlap between some health planning units, in some cases further clarification was sought by the research team from local governing health authorities as to the clinical nature of the unit, and an informed judgement was then made about how best to classify the individual health planning unit. Furthermore, four additional units that were not represented within the AusHFG, but deemed necessary by the research team, were added to the revised unit terminology list (see Figure 4). The terminology alignment process went through rigorous in-house review by the research team to insure accuracy in the revised area terminology assignment and consistency in classifications, before then being assigned revised departmental tags in the research data base.

2.6 Statistical treatment

Whilst this is the largest study of its kind known to the research team (n=31 hospitals), the broader study sample is comprised of 3 smaller sample clusters (Region 1 public hospitals (n=11), Region 1 private hospitals (n=10), and international hospitals (n=10)). For statistical and comparative purposes, each sample pool is considered as a discrete sample.

The sample size of the hospitals and comparatives is relatively small within this study, and as such there is a reduced statistical confidence in results than if the sample sizes were larger. Within this study we have controlled for this reduced confidence by increasing the margin for error (confidence interval) around our measurements. Our primary statistical tests used to compare measures amongst sample and comparator hospitals were Pearson Correlations. It is important to bear in mind however that statistical inference tests describe how a variable, or set of variables (independent variables), affect the value of a particular measurement of interest (dependent variable). There are many different forms of inference tests, and each test has its own set of conditions (parametric assumptions) which need to be satisfied before its results can be relied upon. Some tests rely on more assumptions than others, and these parametric assumptions are more prone to error when sample sizes are smaller. With smaller sample sizes we do not have as clear a picture of what the underlying population data looks like, and as such, it is more difficult to know what assumptions to make. To mitigate this error, within this study we controlled for these effects by ensuring that the sample taken was representative of the broader population, and by undertaking a number of statistical checks on the sample data to determine whether these assumptions are reasonably expected to hold for the underlying (unknown) population. It should be noted that statistical inference tests association and not causation, and there may be unobserved variables that are the root cause of variations in efficiency measures.

3. KEY FINDINGS

The systematic review undertaken as part of this research project revealed a significant gap in the literature in relation to hospital space planning efficiency. To date, there have been very few studies that examine hospital space planning efficiency, and no publicly available research was found that utilised comprehensive area measurements across entire hospitals and against international benchmark data. Whilst the findings of this research are currently in commercial confidence, the research methodology adapted for this project proved a robust mechanism through which to compare a range of planning and efficiency measures:

- between departments in a single hospital;
- between floors in a single hospital; and,
- as a 'whole of hospital' planning efficiency overview of individual hospitals (PER).

Furthermore, it provided the ability to benchmark and assess individual departmental planning efficiency and whole of hospital planning efficiency values against other hospitals, regional aggregate values and international comparator data.

The structuring of the database, to enable a comprehensive exploratory examination of a large range of variables enabled the research team to obtain an in-depth understanding of the space planning efficiency of the hospitals examined within this study, and to identify departments and hospitals that were atypical in relation to others within the data set. Furthermore, it allowed the team to set suitable region specific space planning targets for future healthcare infrastructure projects.

Applied to a larger data set and expanded efficiency metrics, the methodology and database established for this research project could help fill some of the gaps in our existing evidence-base, and significantly improve our understanding of hospital space planning efficiency and design.

4. POTENTIAL FUTURE RESEARCH AVENUES

Whilst the focus of the research was on select space planning efficiency measures (PERs and DGFs), the data base that was created has been established so as to be able to expand over time and incorporate additional data. It is hoped that through an expansion of the database and further allied research projects, that the research team can track trends in hospital space planning and departmental area allocation over time, conduct comparative analyses and benchmarking of the carbon footprint of hospitals, assess variations in energy efficiency and use associated with different hospital space planning, and examine the broader complexity of factors that impact on hospital planning efficiency such as models of care, patient and work flow, patient attendance figures etc. Through a better understanding of the space planning efficiency and the space requirements needed to support complex clinical care needs, we are better able to meet changing healthcare needs, whilst reducing the carbon footprint of our healthcare systems.

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