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REVIEW ARTICLE

NAVIGATING COMPUTING DEVICE REQUIREMENTS: A SYSTEMATIC REVIEW AND GUIDE FOR HEALTHCARE ADMINISTRATORS

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ABSTRACT

BACKGROUND:

The transition from paper-based to electronic-based processes is an ongoing issue in all health systems with varying levels of maturity and progress throughout the world. Hospitals are increasingly transitioning to digital medical records and paperless workflows. As medical administrators tackle the challenge of ensuring computer systems and hardware meet the needs of the staff hospital environment, it is essential to adopt a systematic and well-informed approach to allocate different wards with computing devices based on staffing numbers, patient occupancy, and patient flow requirements.

GOAL:

To review existing literature and develop a framework for determining the necessary computing resources for a hospital ward to operate effectively.

METHODS:

A systematic review was conducted using the PRISMA process and relevant publications were identified, covering data from 1946 to January 2022. Only articles in English were included, and any articles relating to software development and digital medical records were excluded. The quality of the studies included was assessed using the Johanna Briggs Institute (JBI) Checklist for Qualitative Research. A search of grey literature was also conducted due to the paucity of search results, for a total of 14 included studies. Additionally, we mapped the workflow in clinical wards. Drawing insights from a multivariate analysis based on this mapping and literature review, we formulated and validated a framework for hospitals to strategically plan computer usage and optimise ward workflows.

PRINCIPAL FINDINGS:

We propose a framework based on the number and skills of a mix of staff, patient turnover and the extent of computerised tasks. Whilst individual hospitals will differ in computing and technology utilisation, our proposed framework can be adapted to suit unique needs.

PRACTICAL APPLICATIONS:

A similar framework can be used to implement computers across various health services. It can also be adapted for sporting organisations, where multiple health professionals need computers to manage athletes' health and performance.

KEYWORDS
computing devices; computing device requirements; medical administration; computer integration; computing device allocation; clinical ward workflow; framework; computer usage; technology utilisation

INTRODUCTION

Medical administrators play a pivotal role in enhancing patient safety, improving clinical outcomes, and achieving cost savings within healthcare organisations. In an era of increasing adoption of online medical record-keeping and the transition towards paperless workflows within hospitals, a key consideration for hospital management is to ensure that staff are provided with adequate computing devices. It is widely accepted that in the current technological era within healthcare settings, having access to computing devices can help staff make informed decisions, reduce errors, enhance communication, and improve overall operational efficiency by streamlining workflows [1,2]. Consequently, this not only enhances patient safety and optimises clinical outcomes but also improves financial efficiency. Moreover, it enables more effective utilisation of human resources, a crucial aspect given the current context of medical staff shortages.

Device requirements needed in a hospital ward depend on factors such as staff composition, staff count, length of patient stay, workload, workplace design and technology utilisation. A one-size-fits-all approach to developing a technology profile for a hospital ward and deploying devices is impractical. Holistically considering these factors allows for a more precise assessment and allocation of computers in a hospital setting. Consequently, there arises a compelling requirement for a standardised framework that hospitals can customise to determine information technology resources needed on a hospital ward. Such a framework would help hospitals meet the needs of the ward staff, streamline patient flow and save costs. This review aims to analyse existing literature and create a suitable framework that can determine the number of computer resources needed to operate a ward efficiently. Within hospital wards, a myriad of technical devices are employed to enhance healthcare delivery. However, this publication specifically focuses on desktops, workstations on wheels, tablets, and handheld devices. It deliberately excludes the consideration of printers, fax machines, barcode scanners, and patient monitoring devices to maintain a concentrated scope on the core computing infrastructure.

METHODS

CRITERIA FOR CONSIDERING STUDIES

The methodology for this review was established before its commencement, encompassing the formulation of review questions, the development of a search strategy, the establishment of inclusion/exclusion criteria, and the assessment of risk of bias. In addition to a literature review, due to a lack of available literature, a ward workflow analysis of computer utilisation and mapping of tasks needing technological devices was also performed.

The PICO question guiding this review was: 'In hospital wards, what are the optimum computing devices to facilitate job efficiency?'. Publications reporting the number and makeup of computing devices were identified from Medline, Embase, Emcare and Web of Science. A grey literature search was conducted using a web-based search engine. The database coverage was from 1946 to January 2022. Refer to Supplementary 1 for a detailed breakdown of the search strategy. The authors, in collaboration with a staff member from a local hospital library, conducted the initial literature search. Subsequently, two distinct library staff members conducted independent peer reviews of the initial search. The quality of included studies was assessed using the Johanna Brigg's Institute (JBI) Checklist for Qualitative Research. The review was registered in the Open Science Framework (OSF) - (DOI 10.17605/OSF.IO/7Q4UB).

SEARCH METHODS FOR IDENTIFICATION OF STUDIES

Identified studies were exported to an end note library. Keyword search was performed by two authors on EndNote title fields. Publications relating to software development and digital medical records were excluded based on the title field. Local hospital library staff obtained full text of each of the selected publications from different national databases.

DATA COLLECTION AND ANALYSIS

For eligible studies, information including the author, publication year, publication country, and a summary of findings was extracted and recorded in a Microsoft Excel spreadsheet. For ward workflow analysis, responses were

recorded in structured spreadsheets, categorizing key variables such as user requirements, frequency of use, and operational preferences. Data analysis functions in Excel, such as logical operators and statistical tools, were utilised to identify patterns and derive a formula for determining the number of computers needed.

The *PRISMA 2020 Checklist* was used to ensure that the systematic review was completed appropriately.

ETHICS APPROVAL

No ethics approval was sought for this research study as it involves a comprehensive literature search and analysis. All data utilised in this research is publicly available through published sources and no interventions or interactions with patients were conducted.

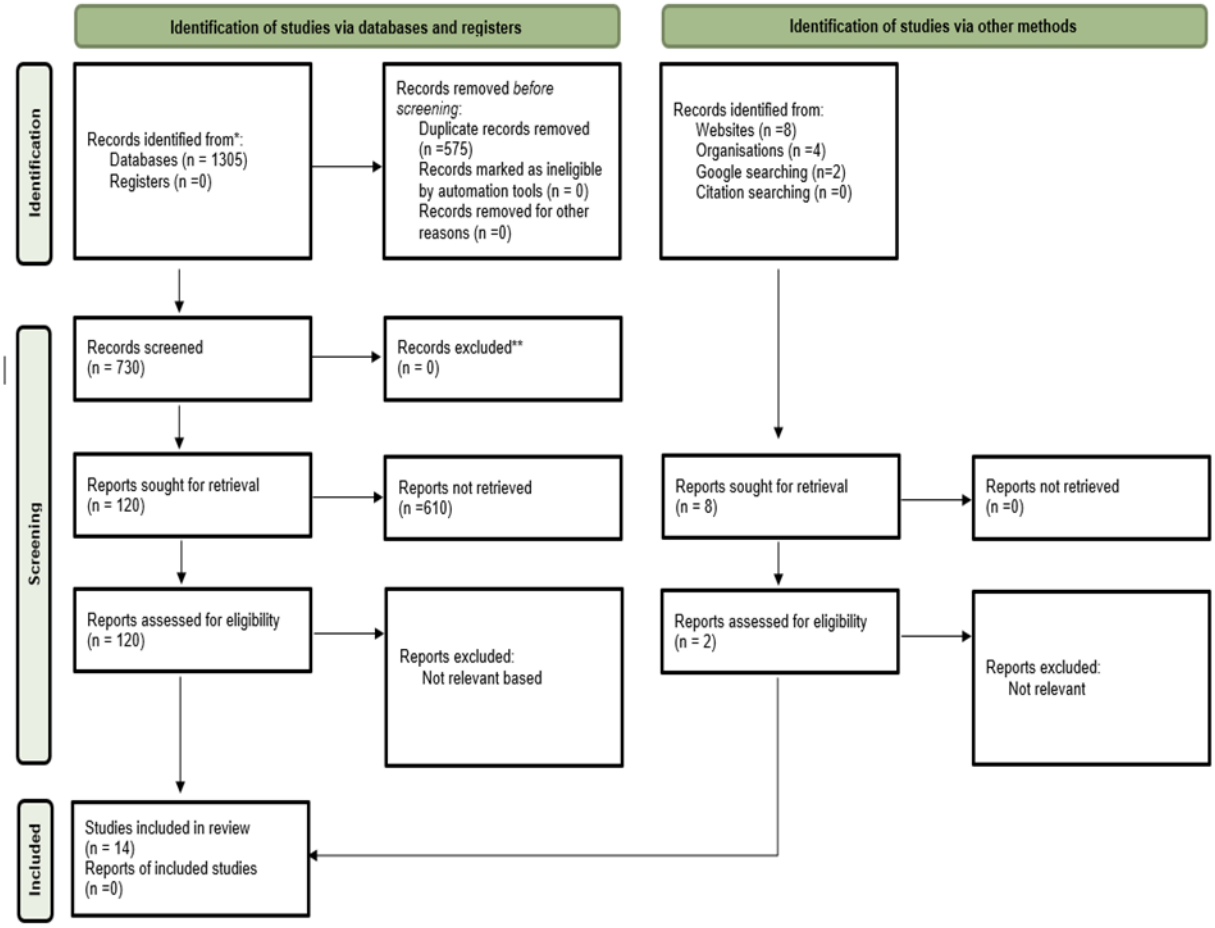
The local hospital ethics committee cleared the research as it involved no direct interaction with human subjects or collection of personal data. All sources were accessed according to their terms of use, and ethical approval was not required. Following recommendations, we adhered to ethical research principles, respecting intellectual property and properly citing all sources.

RESULTS

STUDIES IDENTIFIED

After the identification and screening process, the review ultimately incorporated a total of 14 studies. The PRISMA flow diagram of search results is presented below (Figure 1).

FIGURE 1: PRISMA FLOW DIAGRAM



QUALITY APPRAISAL

Overall, the studies included in this publication were of high quality. All 14 studies included in the review met 8 out of 10 criteria in the JBI Checklist for Qualitative Research. 5 studies met all 10 criteria. Figure 2 below displays a more detailed quality appraisal.

FIGURE 2 - SUMMARY OF QUALITY ASSESSMENT

Author, Study Title	Summary of key findings	Quality (JBI Qual Checklist)
Ammenwerth, E. et al (2000). "Mobile information and communication tools in the hospital."	Diverse requirements of different professional groups cannot be fulfilled by a single multifunctional device and propose, therefore, a 'multi-device mobile computer architecture' i.e. hospital wards/consultation environments require a layout of multiple mobile devices to fulfill staff requirements.	9/10 Lacking ethics section
Andersen, P. et al (2009). "Mobile and fixed computer use by doctors and nurses on hospital wards: multi-method study on the relationships between clinician role, clinical task, and device choice."	Selecting the right device depends on the role of the user, the nature of the clinical task and the amount of mobility required for the task. Nurses and doctors on ward rounds preferred to use highly mobile devices i.e. COWS, while very minimal work was performed using tablets or at the bedside	10/10
Archibald, D. et al (2014). "Residents' and preceptors' perceptions of the use of the iPad for clinical teaching in a family medicine residency program."	The use of tablet devices requires smooth interface configuration, computer literacy workshops and ultimately more evidence from pilot studies to integrate the needs of medical teachers and learners.	10/10
Archibald, D. et al (2014). "Residents' and preceptors' perceptions of the use of the iPad for clinical teaching in a family medicine residency program."	Online information systems may assist in the automation of calculating the Pneumonia Severity Index and therefore optimise pneumonia patients' care	9/10 Participant voices not adequately represented
Block, L. et al (2013). "In the wake of the 2003 and 2011 duty hours regulations, how do internal medicine interns spend their time?"	Interns today spend less time with patients due to increasing volumes of patient data, documentation and communication with other providers.	10/10
Fortmeyer, R (2007). "The new age of high-tech hospitals."	Future hospital designs will require consideration of digital infrastructure and space planning before being built, not after.	9/10 Ethics not applicable
Gregory, D. et al (2012). "Healthcare design and IT solutions."	Important to also include clinical perspectives and clinical workflow early in the design process to improve productivity and patient outcomes.	8/10 Lacking participant's voice, and ethics not applicable

Halpern, N. A (2014). "Innovative designs for the smart ICU : Part 1: From initial thoughts to occupancy."	Implementing technology in an ICU requires multiple mock-ups, simulations for advanced technologies and standardised technological platforms.	9/10 Ethics not applicable
Hedge, A. et al (2011). "Ergonomics concerns and the impact of healthcare information technology."	Ergonomic design principles must be taken into account when designing and implementing information technology in healthcare settings to avoid increased risk of work-related musculoskeletal disorders.	9/10 Ethics not applicable
McCoy, S. (2005). "Planning for mobile devices: a systems approach. Continually assess devices by unit, type, and user function."	Forward planning regarding the use of computing devices in clinical workspaces is needed for the efficient running of that workspace.	9/10 Ethics not applicable
Patel, V. et al (2015). "Prescription Tablets in the Digital Age: A Cross-Sectional Study Exploring Patient and Physician Attitudes Toward the Use of Tablets for Clinic-Based Personalized Health Care Information Exchange."	Patients and providers are open to implementing tablets in clinical care. Such use may be beneficial to improve patient health literacy and patient-provider communication, but more research is needed. Concerns about privacy and security of patient information were raised.	10/10
Reynolds, T. L. et al (2019). "Evaluating a handheld decision support device in pediatric intensive care settings."	Use of a handheld mobile decision support device in reducing the cognitive load of nurses at the bedside	9/10 Ethics lacking
Sasaki, N. et al (2016). "Hospital information technology infrastructure affects quality of care [Conference Abstract]."	Hospitals with adequate IT infrastructure i.e. access to wireless internet, medical evidence databases and medical libraries allow staff to access evidence-based medicine and clinical practice guidelines, therefore arguably providing higher quality care.	9/10 Ethics lacking
Zborowsky, T. et al (2010). "Centralized vs decentralized nursing stations: effects on nurses functional use of space and work environment."	A "hybrid" model in which staff can access a centralised meeting room can balance computer duties as well as direct patient communication and care.	10/10

RESULTS

The reviewed studies highlight the importance of considering appropriate device type, workflow, usage patterns, software requirements, and layout when determining computer needs in a hospital. Eight studies discussed device type considerations, while four addressed ward layout and existing software. Three studies focused on clinical workflow mapping, another four considered ward

type, and one study discussed staff role considerations. Refer to Supplementary 2 for a summary of the studies.

The studies primarily targeted project managers. Individual studies did not focus on integrating their findings into a broader, cohesive strategy that addresses the practical needs and decision-making processes of medical administrators. The lack of a comprehensive approach diminishes the usability of the studies for medical administrators, highlighting the need for a unified framework.

DISCUSSION

A recent study underscored the shift in focus for junior medical officers (JMOs) towards tasks like documenting information, and inputting patient data in differing software and other computer-based activities [3]. This highlights the crucial role of computer availability in achieving optimal workflow performance. The lack of adequate computing devices negatively impacts the promptness of care delivery, patient flow, and the overall experience of Junior Medical Officers. This underscores the necessity for the provision of sufficient devices and efficient space planning [4,5,6]. This also aligns with the authors' investigation into ward workflows, revealing that Junior Medical Officers (JMOs) dedicate a minimum of 20 minutes daily on each ward searching for technological devices to complete their tasks.

FACTORS AND DEVICE TYPES TO CONSIDER

Different computer devices can be deployed for specific technological and clinical requirements [7] as summarised below (Table 1).

Ward workflow analysis (Supplementary 3) and literature show that key factors deciding the optimal type of device and device ratios are:

- Ward Type – wards with high patient turnover (high flow wards) e.g., acute medical and surgical units that have increased activities such as admissions, documentation of handover, medical reconciliation, and discharges [8]
- Number of staff for different clinical roles at a given time [9,10] - Most hospitals have peak activity between 8 am and 1 pm and computing devices need to meet requirements during this time
- Type of tasks – tasks requiring extensive typing like documenting notes in electronic medical records vs. "Clickable actions" such as ordering pathology or viewing static information like imaging on screen [10,11,12]
- Software requirements and compatibility with different device types. Additionally, the efficiency of software usage can impact the device type. For example, software that relies heavily on text inputs may be more cumbersome to use on devices with smaller screens. Similarly, automatic processing features of the software may require sufficient processing power and memory, influencing the choice of device [13].
- Staff familiarity and preferences [14,15]
- Ward design [16,17]

Administrators must also decide between enterprise-wide clinical information systems or diverse vendors. The literature favours single vendor integrated systems for cost-effectiveness, universal access, and reduced strain on hospital infrastructure [18]. Considerations for ergonomic design of computing design are also important to prevent work-related musculoskeletal disorders [19].

PROPOSED FRAMEWORK

Based on the above literature review and ward workflow analysis following is the proposed framework (Figure 3). This framework has been validated in wards at two hospitals, differing in size yet sharing a comparable technology profile, particularly in terms of software utilized and workflows requiring computer support.

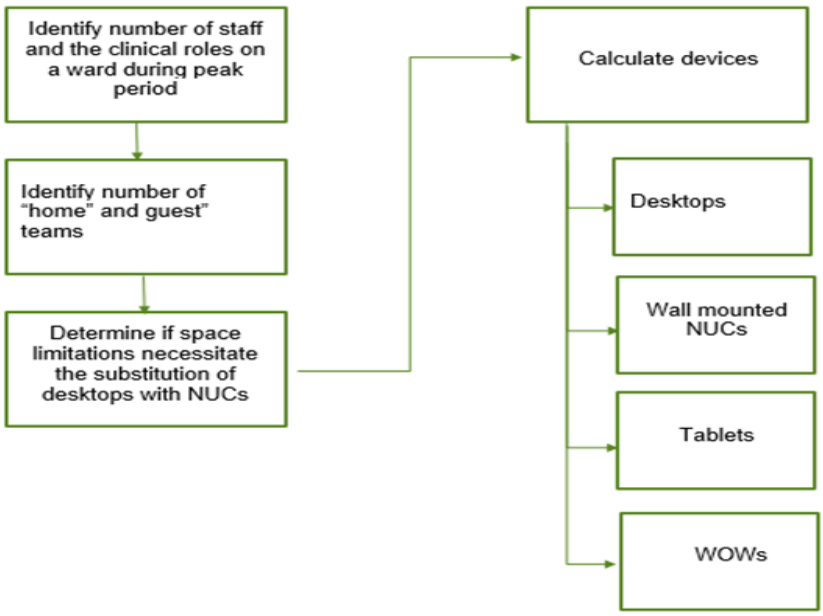
❖ Step 1: Identify the number of staff and their clinical roles during peak activity periods. Calculate the number of devices based on Table 2 (Refer to Table 2)

❖ Step 2: Identify the number of home teams on the ward. Each team is allocated one Workstation on Wheel.

❖ Step 3: If space constraints prevent desktop provision or if the ward has a sizeable area, consider replacing a desktop with Next Unit of Computing (NUC's)

❖ Step 4: Provide each team doing ward rounds with a tablet if radiology and pathology applications are compatible

FIGURE 3: PROPOSED FRAMEWORK FOR DETERMINING REQUIRED DEVICES



A comprehensive workflow analysis was undertaken, involving interviews with staff members and monitoring of their computing device utilisation across eight distinct wards at various times. Additionally, we recorded data on the time required to complete medical notes and the time lost due to inadequate access to computing devices. A multivariable longitudinal regression analysis was conducted, using the ward staff and staff role as independent variables with the number of workstations required per ward as the outcome variable. Subsequently, these ratios were validated across more than 5 wards in different hospitals.

We suggest the following ratio of computing devices for high-flow and normal-flow ward settings to be used in conjunction with the above framework. "High flow" wards are characterised by increased patient turnover, with a higher volume of patient admissions and discharges each day. In contrast, "normal flow" wards experience decreased patient turnover, with a lower volume of daily admissions and discharges.

TABLE 2: PROPOSED RATIO OF COMPUTING DEVICES FOR A CLINICAL ROLE (E.G. FOR EVERY 3 NURSES ON A GENERAL FLOW WARD, THERE SHOULD BE 1 COMPUTING DEVICE)

Clinical role	Computing device ratio	
	High flow ward	General ward
Nurse	1:2	1:3
Nurse management	1:1	1:1
Shift coordinator (SC)	1:1	1:1
Flow Coordinator	1:1	1:1
Staff Development Nurse (SDN)	1:2	1:2
Doctor	2:3	3:5
Pharmacy Support	1:2	1:2
Pharmacy	1:1	1:1
Allied Health	1:2	1:3

Supplementary 4 estimates the required number of computing devices for a standard general medicine ward using the ratios outlined in the article.

LIMITATIONS

Our framework provides solid foundation for determining the optimal number of computing devices needed in a ward to support efficient workflows. However, further research and data on direct and indirect costs, as well as effectiveness metrics, are necessary to validate claims of improved efficiency. Grouping wards or workflows with similar characteristics can reveal variations in device needs, allowing for more targeted recommendations. Advanced models like (Autoregressive integrated moving average) ARIMA can also identify trends and seasonal patterns, offering insights into how device requirements change over the year.

CONCLUSIONS

We have developed a stepwise framework to calculate the number of computer devices needed for a ward and validated it in two hospitals with similar workflows and technology utilisation. It can be customised by other hospitals to determine the ideal number of computing devices needed in their healthcare settings.

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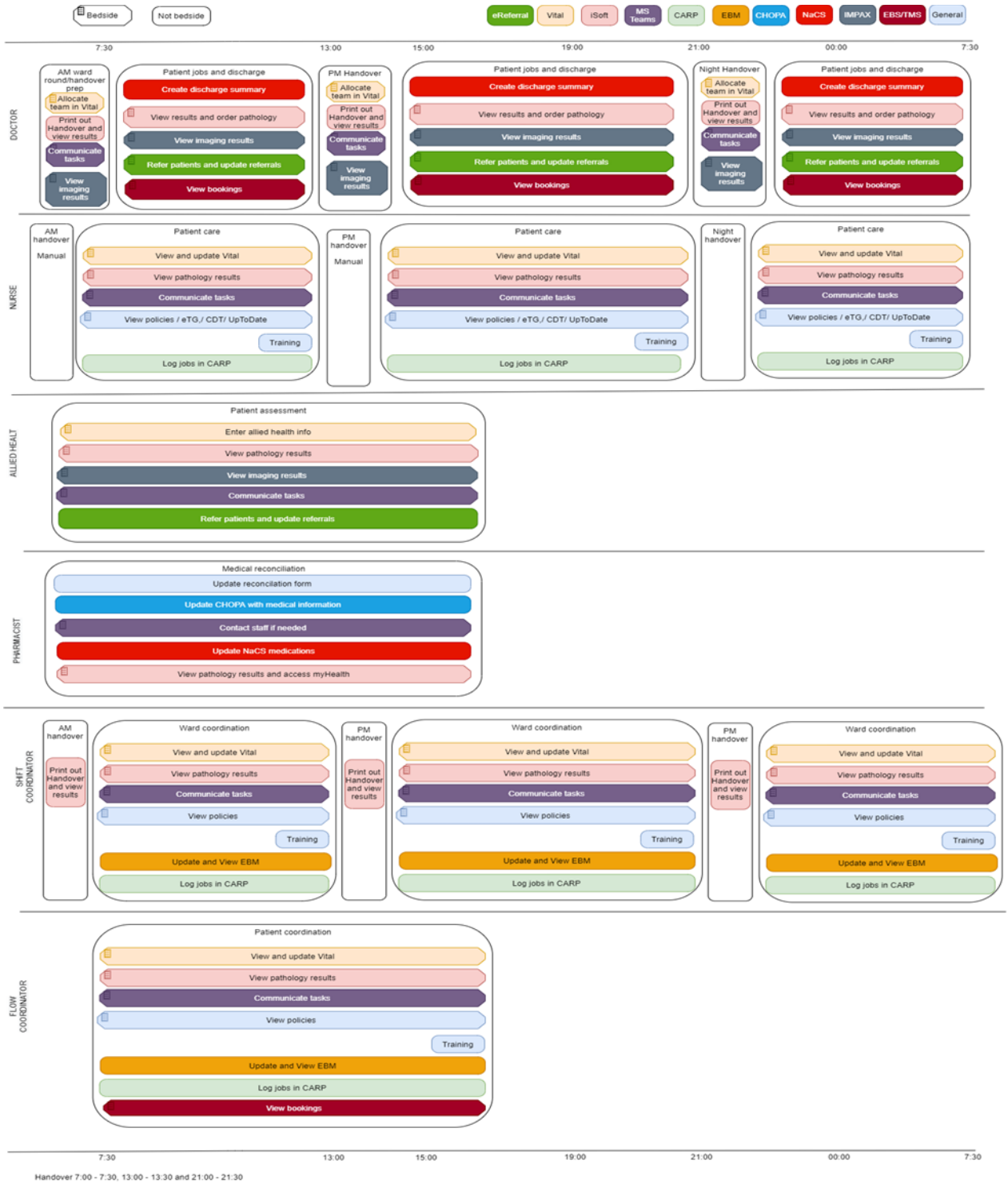
APPENDIX I: SUPPLEMENTARY 1 – DATABASES COVERED

Database and platform	Database coverage	Date of final search
Medline All (Ovid)	1946 to April 19, 2022	20-Apr-22
Embase (Ovid)	1974 to March 11, 2022	20-Apr-22
Emcare (Ovid)	1995 to 2022 Week 15	20-Apr-22
Web of Science	1997-present	20-Apr-22
Grey literature/ Google		19-Jul-22

APPENDIX II: SUPPLEMENTARY 2 - WARD WORKFLOW MAPPING



APPENDIX III: SUPPLEMENTARY 3 THE PROPOSED RATIO OF COMPUTING DEVICES FOR CLINICAL ROLE. (E.G. FOR EVERY 3 NURSES ON A GENERAL FLOW WARD, THERE SHOULD BE 1 COMPUTING DEVICE).

Clinical role	Computing device ratio		Recommended Desktops
	General	Max Staff	
Nurse	1:3	7	7 / 3 ≈ 2.5
Nurse management	1:1	1	1
Shift coordinator (SC)	1:1	1	1
Flow Coordinator	1:1		
Staff Development Nurse (SDN)	1:2	2	2 / 2 = 1
Doctor	3:5	8	8 / 3/5 ≈ 5
Pharmacy Support	1:2		
Pharmacy	1:1	2	2
Allied Health	1:3	7	7 / 3 ≈ 2.5
Total			15

TABLE 1 ADVANTAGES OF DISADVANTAGES OF DEVICES

Device	Advantage	Disadvantages
Traditional desktops *Preferred device for tasks that require more than one screen, a large screen, or lots of typing*	Wide software compatibility Cheap	Space constraints in hospitals making it hard to deploy desktops
Wall mounted Next Unit of Computing (NUC) *Preferred device for nurses to access information such as guidelines when NUC is close to patient rooms*	Can be accommodated in hallways, optimising space utilisation Can be strategically placed in locations where staff have convenient access	Standing workstations - Not suitable for lengthy tasks
Tablets	Optimal for bedside usage where typing requirements are minimal (Andersen et al., 2009) Improves patient-provider bedside communication (Patel and Hale et al., 2015)	Non-web-based applications are often not compatible (Archibald, Macdonald et al., 2014; Reynolds and Delucia et al., 2019) User resistance if unfamiliar with tablet interface (Ammenworth et al., 2000)

	Cheap	Risk of infection transmission Can be misplaced
Mobile phone using hospital wifi	Staff using personal mobile and hospital Wi-Fi can save costs (McCoy, 2005)	Needs Wi-Fi Limited battery Monitoring non-work usage
Workstation on Wheels *Good forward and medication rounds*	Mobile and allows for point-of-care documentation (Ammenworth et al., 2000)	Space and manoeuvrability on the crowded ward (Ammenworth et al, 2000) Expensive