THE CENTER FOR HEALTH DESIGN®

Health Environments Research & Design Journal
1-17

DOI: 10.1177/1937586715577370
herd.sagepub.com
SAGE

Field Research and Parametric Analysis in a Medical–Surgical Unit

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Abstract

Objective: To study the workplace in a medical–surgical (med-surg) unit and to identify suboptimal environmental conditions that can be improved in the current unit and avoided in future design, through rapidly deployed field research and timely simulation. **Background:** Literature emphasizes the importance of the healthcare workplace and the effect on patient outcomes. What is lacking are studies conducted on-site and used for immediate application in design to assess and improve workplace conditions. **Methods:** A rapidly deployed field research and simulation study was conducted in a 40-bed med-surg unit of a large healthcare system as part of the process of designing a new medical tower. Online surveys, systematic behavioral observations, semi-structured interviews, sound studies, and advanced spatial analysis through parametric modeling were conducted. **Results:** The following created challenges for patient monitoring, care coordination, and management: (1) waste and variability in walking, (2) limited point-of-use access to supplies, (3) large distances traveled for minor tasks, and (4) low visibility and connectivity. The corridor is used as a workspace/communication hub. There is a distinct difference in beginning of day and night shift patterns and between walking "distance" and walking "sequence." There is a tendency for nurses to multitask, but a simulation exercise shows that for key tasks like medication delivery, multitasking may not always reduce walking distances. **Conclusion:** Co-location of medications, supplies, and nourishment; accommodation for work on wheels; and spatial and technological connectivity between care team and patients should be considered while designing a med-surg unit. Understanding the key activity sequences helps determine the proximity of spaces in relationship to patient rooms and each other.

Keywords

nurse walking distance, nurse activity, nurse activity sequence, med-surg units, parametric modeling

Introduction and Literature Review

The nurse's workplace has generated much interest in the past decade for healthcare designers and facility managements alike. This interest, to a large extent, can be attributed to the 2004 Institute of Medicine's report titled "Keeping Patients Safe: Transforming the Work Environment of Nurses" (Page, 2004). The design of the workplace

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is critical to a patient's well-being and safety, as found by Battisto, Pak, Vander Wood, and Pilcher (2009) who posit that operational efficiency, staff satisfaction, and more importantly, medical errors can be linked to workplace design.

Nurse walking is a key component of the workplace experience that has been discussed at length in the literature. Studies show that nurses can walk as much as 6 miles during a shift (Pati, Harvey, & Thurston, 2012), prompting researchers to examine how much this walking is relevant and of value and how much time is being wasted in nonessential walking that can be directed toward patient care and nurse well-being. In a previous study by Hendrich, Chow, Skierczynski, and Lu (2008), researchers found that nurses walked an average of 2.4–3.4 miles in the day shift; while for the night shift nurse, the average walking distance varied between 1.3 and 3.3 miles. Walking distances have been a key argument in the centralized versus noncentralized nurse station (NS) debate. Pati, Harvey, and Thurston (2012) examined nursing support spaces and the impact the different unit configurations had on the nurse's walking distances. The study compared centralized, decentralized, and room/bedside models. In the centralized model, all support spaces were located in one central location in the support core, whereas in the decentralized model, support spaces were distributed in more than one places in the support core area. In room/bedside model, some of the support spaces were provided at the bedside or room-side alcoves. The authors found that the mean walking distance for nurses in the centralized models was 6.43 miles. This walking distance reduced by 26.8% in the decentralized model and by 67.9% in the bedside model. Also (in the centralized model) the nurse walked the most for documentation/to documentation center. The second most frequent walking pertained to medications.

Hendrich et al. (2008) in their influential 36-hospital time and motion study reported that nurses in medical–surgical units spent over 36% of their time in the NS and nearly 31% of their time in the patient room (PR), over 77% in nursing practice, over 35% in documentation, over 20% in care coordination, over 19% in patient care, and over 7% on patient assessment. In a pre–Electronic Health Record implementation era, documentation was an activity that took up the largest proportion of nursing time, and the NS was the hub for all documentation and care coordination.

Battisto and colleagues (2009) conducted a task analysis to describe nurse activities in acute care facilities. The authors reveal that documentation was the most frequent activity performed by nurses. This was followed by patient assessment and medication administration. Although nursing activities took place all over the unit, the most common locations were the PR (bedside and bathroom) and the NS. The computer was the most frequently used equipment. The authors observed that of the problems nurses encountered during the performance of their activities, physical- or environment-related problems were the second most frequent at 39%. Examples of environmental problems were observed as nurse stepping over cords, moving around the clutter to assess the patient, and not having adequate space for medication preparation.

With an objective to quantify nurse work flow, Cornell and colleagues (2010) studied the activities of 27 nurses in a medical–surgical (med-surg) unit. They report that the five most frequent activities included assessment/treatment (18.5%), communication (12%), electronic charting (11.4%), personal time (10.1%), and walking (8.1%). The authors also found that most activities lasted between 10 s and 2 min, indicating that nurses "shift" their activities continuously, and that interruptions kept their activities from being completed. Work flow patterns of the nurses depicted that nurses frequently switched activities, that they used the computer after documenting requirements had accrued, that interactions with peers were unplanned and of short duration, and that nurses spent the longest time with their patients.

Another key component of the workplace that has been discussed in the literature is visibility. Visibility is very important in patient care—both for the caregiver and for the patient. A nurse is required to be constantly aware of the assigned patient's condition, especially in acute care. But patient assignment that may not be in adjacent rooms and/or of consistent acuity makes the task of "being aware" a challenge. Having a line of

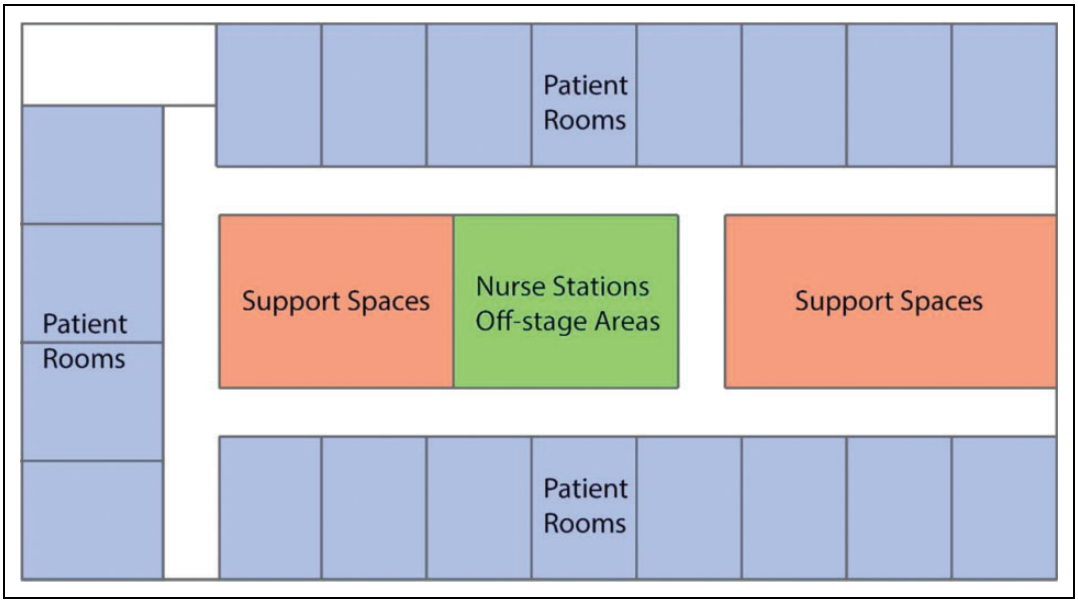

Figure 1. Conceptual layout for each unit wing.

sight or visibility of the patient or PR allows the nurse to maintain contact with the patient, consequently establishing reassurance for the patient (Lu, 2010; Lu & Zimring, 2012). Studies show a relationship between improved visibility and reduced walking for nurses (Hendrich, Fay, & Sorrells, 2002; Lu, 2010; Lu & Zimring, 2012), which translates into more time at the patient bedside and in patient care (Lu & Zimring, 2012). With the patient being directly visible by the caregiver, it ensures a faster response by the latter when there is a change in patient condition (Lu & Zimring, 2012) and as such making visibility a critical variable in reduced patient falls and increased patient safety (Hendrich et al., 2002; Pati, Harvey, & Cason, 2008). Peer-to-peer visibility is also considered key to effective teamwork in high-stress environments like inpatient units and emergency departments (Pati, Harvey, & Pati, 2014; Pati et al., 2008). Lack of peer visibility results in feelings of "working alone," leading to a sense of insecurity especially during stressful periods and, consequently, adverse/negative impacts (Pati et al., 2008).

Case Study Context

Although a strong body of research exists on nurse activity and walking distances as well as patient and peer-to-peer visibilities, it is evident that there is a certain degree of variability between different delivery models and sites. It is important, given the relevance of the issue of work flow and the impact of workplace, that we carefully examine working conditions on-site prior to making design decisions.

It is this evidence-based, context-specific approach that was taken by a large 400-bed hospital looking to create a new patient tower. The leadership identified the need to carefully study conditions in the current med-surg and intensive care units to inform design decisions in the new tower. The main purpose of the study was to understand the current state and how the existing unit responded to the existing work flow. This study was intended to inform the new design. The existing med-surg unit was designed more than a decade ago. The unit has 2 wings, 4 nursing stations, 20 rooms in each wing, 2 medications and clean supplies rooms, 1 nourishment room (NR; shared by both wings), 2 soiled linen, 2 equipment rooms, and 4 linen closets (see Figure 1).

The staffing and ratio to number of PR is as follows: 8 registered nurses (RNs) (1:5), 4 nursing assistants (1:10), 2 patient care supervisors (1:20), and 2 unit clerks (1:20). A nursing director oversees the unit. Additional

staff on the unit include physicians, respiratory therapist/occupational therapists (RT/OTs), care navigators, social workers, dietary services, transport, and maintenance. The presence of ancillary staff varies during the day. The unit studied was a first to fill unit, therefore, at full occupancy at most times. Patient assignment was by block although this could be changed if high-acuity patient percentage increased on a given day.

The core work area on each unit is the central NS. The NS is divided into the following four areas: two open NSs with visibility into the corridor (these open NSs also seat the telemetry units) and two offstage areas that hold administrative supplies such as printers, extra computers, seating, and the pneumatic tube. In the current unit, the offstage areas are not visible from the corridors. All nurses have work on wheels (WoWs) for computers. Most nursing assistants have WoWs as well. Visitors to the unit, such as the RT/OT, have assigned WoWs which they use when they visit and leave the unit.

Aim

To study the workplace in a med-surg unit and to identify suboptimal environmental conditions (that impact patient care and overall efficiency) that can be improved in the current unit and avoided in future design.

Method

The research method in this study was a combination of field research (for observed and reported data on human behavior and perception) and off-site spatial analysis (for spatial data that provides the context for human behavior; see Figure 2). The field research method involves a triangulation approach including photo-essay, sound recordings, interviews, on-site observation, and online surveys. The off-site spatial analysis provides visibility, proximity, and walking distance analyses using a parametric modeling tool. The model (field research + spatial analysis) was developed as a rapidly deployable model that could be replicated during the course of the project. As shown in Figure 2, the research method is designed to be executed in 14 days, which includes 2.5 days of on-site data collection for interviews, shadowing, behavioral mapping, and online surveys.

Prior to starting the study, a detailed photo-essay was undertaken—this entailed a tour of the facility with annotations on a to-scale map and systematic photo-documentation. A 16-question survey that included open-ended questions was conducted with the unit staff. The survey was sent online by the nursing director who reviewed the survey questions. Demographic questions about years of experience, patient load, and current role were asked. Identifiers such as age and gender were not asked. Respondents were asked to rate the importance of key locations to the PR and central documentation center. The list of key spaces was determined from previous literature and the expert review of the medical planning team. These included PR, caregiver documentation outside room, medication room, nurse server, conference/education room, supplies, equipment room, locker/break room, nourishment (meals), nourishment (ice/water), toilet, waiting room, service elevator, patient transfer elevator, linen, and soiled utilities. Survey responses were analyzed with a one-sample *t*-test. Questions were also asked about the importance of visibility to patients, peers, and across the unit. Open-ended questions were asked about the frequency of visiting different locations and about the general challenges in working and providing patient care. This survey instrument was reviewed by two researchers not involved in the study and three members of the project's medical planning team.

The online survey was sent to 33 staff members, and a total of 29 of them (response rate = 89%) responded to the 16-question survey. Forty-five percent of the respondents had been at the hospital for 1–5 years, whereas 21% had been at the hospital for more than 15 years. The respondents included leadership/management, provider (medical staff), clinical staff–bedside nurse, nurse manager, and others. Thirty-eight percent of the respondents (11 total) were bedside nurses. The questions were focused around proximity, walking, visibility, and overall efficiency.

Following the online survey, a field research protocol was developed based on discussions with the nursing director, facility director, and

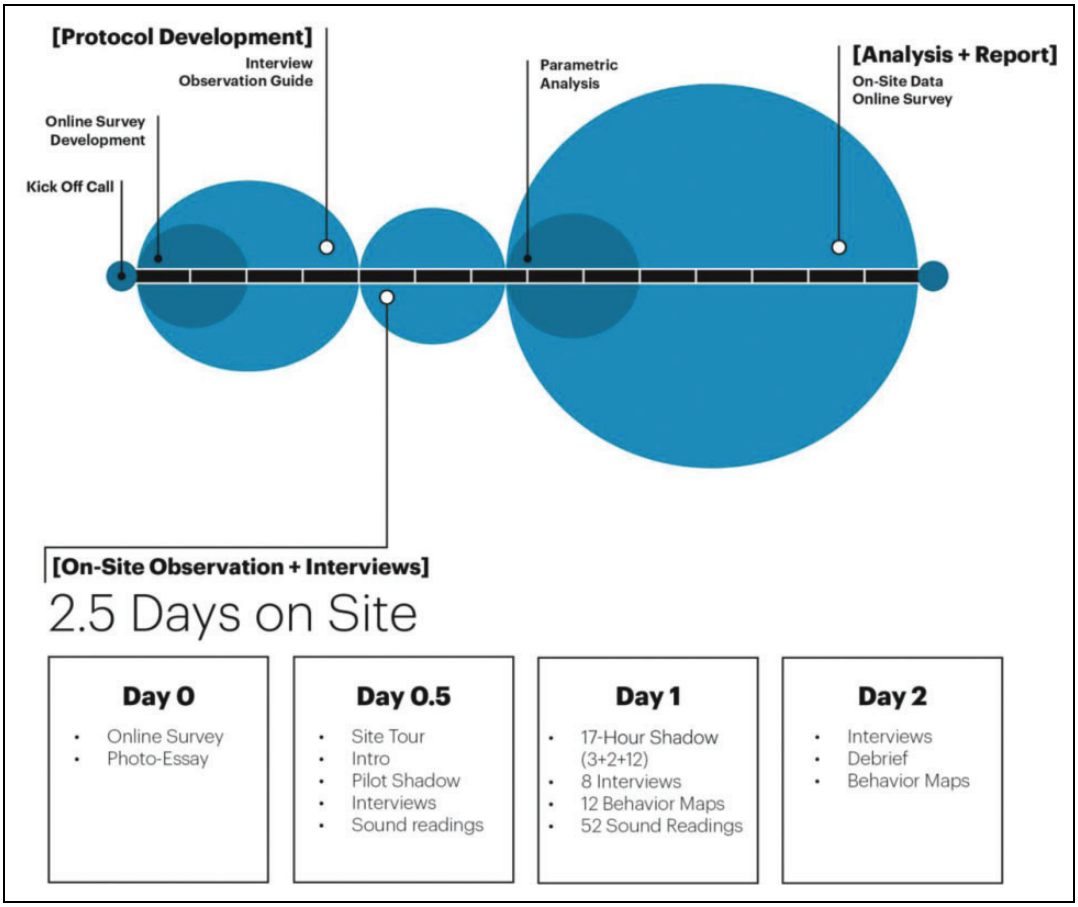

Figure 2. Timeline to conduct field research and spatial analysis.

chief nursing officer. The field research involved extensive shadowing, unit-wide observations, calculating walking distances, collecting sound levels from predetermined locations, and interviews with key staff (see Table 1). During shadowing sessions, walking steps from one task to another were counted and recorded; however, the steps that nurse took within a space such as NSs, medications/supply rooms, and PRs were not counted because the researcher walked with the nurse up to the door/threshold for each of these rooms/areas. These "step" data were compared with the data collected with the help of a pedometer app, and a 20% error was seen. The study was designed to be completed in a period of 2 days—the module developed was a "repeatable" module for field research that can be rapidly deployed for just in time studies.

Table 1. Field Research + Parametric Analysis Model Based on 2.5 Days On-Site.

Reported Data	Observed Data	Spatial Data
16 Interviews (6 RN, 3 PCS, 3 leadership, 2 NA, 1 UC, and 1 care navigator)	**17 hr of RN shadowing (day + night)**	Travel distance from point-to-point (all patient rooms to all support spaces)
Surveys (31 responses)	**Behavior maps (6) + sound readings (10)**	Sight lines/isovist analysis from nurse–patient and peer to peer

Note. Site work shown in boldface. RN = registered nurse; PCS = patient care supervisor; NA = nursing assistant; UC = unit clerk.

Table 2. Categories of Nursing Activity.

Activity	Description
Communication 1 (care coordination)	Activities involving care coordination of a patient, team meetings and huddles, work-related conversations with coworkers, educating and mentoring
Communication 2 (social interaction)	Communications with coworkers but not pertaining to patient care or work, socializing
Documentation	Charting, scanning, documenting, and printing
Med 1 (med preparation)	This activity pertained to the preparation of medications
Med 2 (med administration)	This pertained to the delivery and administration of medication to the patient
Patient Care 1	This pertained to any clinical activity involving patient interface
Patient Care 2	This pertained to any nonclinical activity involving patient interface
Miscellaneous	This pertained to other noncare activity not involving patient interface
Break	This included the nurse's breaks for lunch, coffee, toilet, and so on

Note. med = medication.

Table 3. Comparison of Activity Data With Existing Evidence.

	Activities From Shadow Data		Hendrich et al. (2008)	Williams et al. (2009)	Pati et al. (2012)
	n	%	%	%	%
Patient care (patient assessment + call response)	71	20	21	35	—
Med delivery	44	13	13	11	14
Nourishment delivery	12	3.5	—	5.5	6
Supply delivery	15	4	—	—	16
Break	11	3	—	19	1.5
Working at NS	195	56	43	25	33

Note. med = medication; NS = nurse station.

The data obtained from shadowing the nurses on their shifts were manually documented in observation sheets by research personnel. Twelve hours of day shift data (beginning of shift to end of shift for one RN) and 4 hr of night shift data (two RNs for 2 hr each) were documented. The researchers made a note of the time, the location to which the nurse went, steps taken to that location, and the nurse's activities at the location. This information was transferred verbatim into excel spreadsheets. Nurse activities were coded and categorized based on the categories and subcategories of nursing activity outlined by Hendrich et al. (2008). Table 2 presents these categories of activities. Data were also compared with three main studies related to this topic (Hendrich, Chow, Skierczynski, & Lu, 2008; Pati et al., 2012; Williams, Harris, & Turner-Stokes, 2009), in order to evaluate how representative the data were of findings from previous and more extensive studies. This is discussed and illustrated further in Table 3.

After the activities were coded into the previous categories, these data were sorted. On sorting the data, some key patterns of movement emerged. For instance, it was seen for delivering medications to the PR, most of the time, the nurse started from the assigned NS went to the clean supplies and medications room, delivered medications to the PR, and returned to the NS. A variation in this sequence was also observed when the nurse went back to the assigned NS from the clean supplies and medications room to chart or do care coordination before delivering the medication to the patient.

Traditionally, walking distances have been assessed based on point-to-point proximity

between patient and key support areas (Hendrich et al., 2008; Pati et al., 2012; Shepley & Davies, 2003). Point-to-point proximity approach doesn't take into account situations where nurses make multiple stops in order to complete one sequence of activity. These activity sequences could impact work flow and need to be investigated further. Point-to-point movement of the nurse was observed and cross-checked with her path drawn on the unit layout on the observation sheet to determine an activity sequence and this was color coded. Distinct activity sequences emerged, which were categorized into the following six key activity areas consistent with Hendrich's work.

1. Patient care:
   a. Individual assessment
   b. Round assessment (at the start of and toward end of shift)
2. Medication delivery
3. Call response
4. Nourishment delivery
5. Supply delivery
6. Break

In addition to field research (focused on human behavior and perception), a detailed analysis of the space was conducted using parametric modeling tools. A rhino/grasshopper model was developed to assess the walking distance from every PR to the closest support space (proximity calculator). Proximity assessment was exported to a heat map, and margins for low (under 60 feet), reasonable (60–120 feet), and extensive (more than 120 feet) walking were defined to color code the data. Reasonable distances were determined taking the room size as a reference. One nurse was assigned to five rooms in a block assignment and the door-to-door distance between Room 1 and Room 5 is 60 feet. Less than this distance was considered as low, double this distance was considered as reasonable, and more than double this distance was considered as extensive. The heat map color codes the distances in a gradation toward these limits. This was a broad classification made based on conditions in this site, given the lack of benchmark information in the industry around "ideal" walking distances. Also this classification does not take into account the frequency information (number of trips made to each space). The low, reasonable, and extensive margins as a function of type of space is an ongoing research initiative that these findings will inform. In this case, a more subjective determination was made by the clinical and design team, for example, excessive distance larger than 120 feet was acceptable for a break room but not for a medication room.

Additionally, a sequence mapper was developed to map the walking distances for key sequences and to calculate total walking based on key sequences and their frequencies (this will be discussed in detail in an upcoming article). The proximity calculator and sequence mapper were developed as models that can be used to assess the design solutions following the research phase of the study. In addition, the rhino/grasshopper model (isovist) was used to analyze the sight lines to evaluate the visibility of patients or PRs from central nursing stations.

Approval for conducting the study was sought and received from the hospital's institutional review board before start of data collection. This study was considered exempt since there was no interaction with patients, staff information was deidentified, and patient information was not collected.

Results

Walking Distance and Proximity

Existing issues with walking distance and adjacencies, and determination of desired proximities, were a focus of the study. The shadow data revealed that nurses walked 1.8 miles from the time they were debriefed in the conference room to the time that they did their hand offs to the next nurse. This was the walking "on the floor" and did not take into account distances from parking lot to unit, any walking off the unit (such as to the cafeteria during the break), or walking inside the spaces (PRs, NSs, etc.). In the interview, many nurses, who wear pedometers/use fitness apps, reported to the research team that they walk an average of 2.5–3 miles a day in the course of their work. The reported walking is consistent with the studies by Hendrich et al. (2008) and Shepley and Davies (2003), though significantly lower than Pati et al. (2012). Also, it seems consistent with

the reported data. Taking into consideration the 20% error observed when compared with the pedometer app data, it brings the walking distance to 2.1 miles. The distance was also calculated by tracing recorded steps on an AutoCAD (Version 2013) drawing showing total 1.93 miles of walking. Thus, the 20% error thumb rule is valid.

In interviews, long walking distances were also reported by the nurse managers and director as a challenge for care coordination and overall management. The location of patient care supervisors on one end of the unit and the nursing director on the other end posed a challenge both for the management to connect and in terms of direct visibility to their staff.

Bedside nurses were particularly frustrated by the long walking distance to locations such as the NR to get a small item such as apple sauce/juice for a patient. This comment came up repeatedly in face-to-face interviews and survey of open-ended comments. Yet, the shadow data revealed only eight instances—during the day shift (and twice during the night shift)—of going to the NR. An analysis of the flow and distances on the plan revealed that the frustration may be about more than just the point-to-point walking distance, that is, it could be linked to (a) the sequence of activities related to NR visits, (b) the variability in the walking distance to the NR, and (c) the high frequency of visits for minor tasks or getting small items.

For a high-acuity patient, the nurse may have to go to the medications room, get medication, document, go to the PR to administer the medication at the bedside, then walk all the way to the NR to get some jell-O to have the medications with, return to the PR, and administer the medication. If the patient throws up, the nurse would then go back to the clean supplies room, get supplies, cleanup the patient, pick up new linen, change the patient, drop-off soiled linen, and then return to the NS for charting. Sometimes she may have to go again to the NR for ice and water to give to the patient. In this instance, for this single medication event with a patient the nurse would have walked the following path:

NS – PR – Medications – PR – NR – PR – Ice – PR – Supplies – PR – Linen – PR – Soiled – NS.

For a room on one end of the unit—the total walking would be 84 + 103 + 103 + 15 + 15 + 76 + 76 + 103 + 103 + 67 + 67 + 68 + 79 feet; that's a total of 959 feet (426 steps). This is for a single sequence of events that was described by a nurse to have occurred during the medication administration of a patient with high acuity.

To understand walking distances and variability, based on insights from the reported and observed data, parametric modeling tools were used to conduct a detailed spatial analysis. The proximity calculator generated distances from each PR to closest support spaces. A pivot table was created from point-to-point distances, and it was converted into a heat map (see Figure 3) with color coding from the shortest (under 40 feet) to longest (greater than 120 feet) distance. The map revealed that the distance to break room, nourishment, and conference room was moderately high (on average more than 100 feet). The heat map also revealed that depending on the PR, the location to the closest support space could vary greatly (due to the centralized model). To understand the variability, the walking distances for nurses were calculated based on their room assignment. The maximum variability in walking distance (based on analyzing the plan) was found for break room, equipment room, soiled utility, and nourishment. In fact, for nourishment depending on which room the nurse was going to, the walking could range from 13 to 138 feet. In other words, because staffing and room assignments changed every day, a nurse could be walking 13 feet for apple sauce on 1 day and 138 feet for apple sauce on the next.

In the survey, when asked about the importance of proximity of support spaces from the PR, the responses were consistent and statistically significant. Table 4 shows the four most important proximities for staff from the PR and the central documentation center. Table 3 compares the activity data from this study with three main studies on this topic (Hendrich et al., 2008; Pati et al., 2012; Williams et al., 2009), in order to evaluate how representative our data is for generating key optimal sequences and their frequencies. Table 5 displays the number of times nurses went to different locations on the unit during the day and night shifts. As shown in this table, the locations frequented most by the nurses in both shifts were

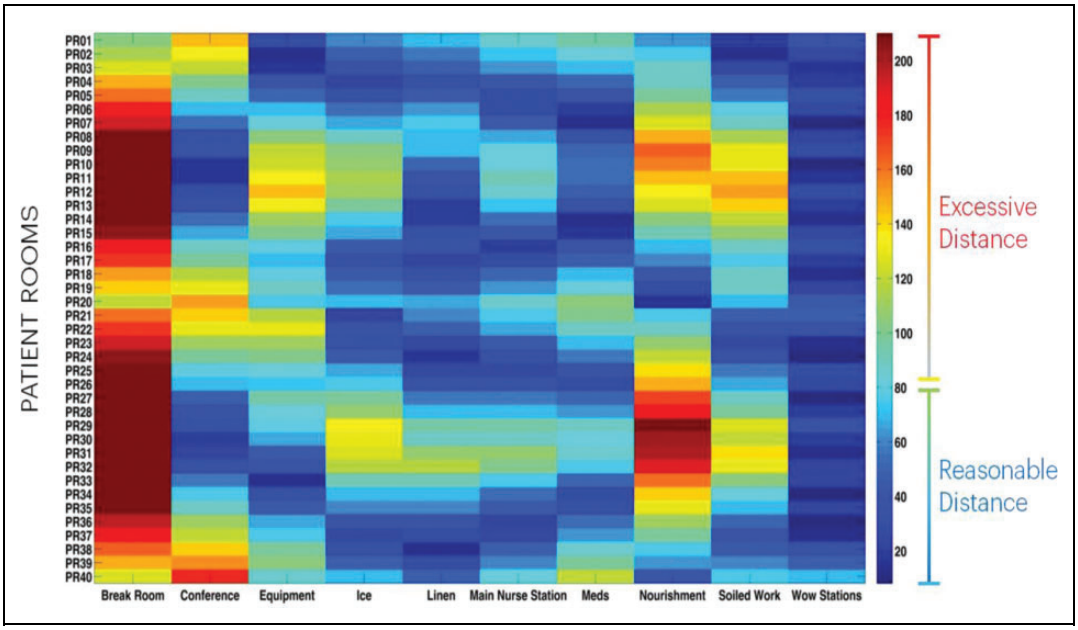

Figure 3. Heat map showing distances between patient rooms and support spaces in the unit.

Table 4. Important Proximities for Staff From the Patient Room and the Central Documentation Center.

Proximity to Patient Room (All Staff)	Proximity to Patient Room (Bedside Nurse)	Proximity to Central Documentation Center
Supplies	Medication	Patient room
Medications	Supplies	Medication/supplies
Nourishment	Equipment	Equipment
Documentation	Nourishment	

Note. This proximity priority was consistent with the observation and interview data.

the PRs, the assigned NS, the clean supplies and medication room, and the corridor (which, it may be noted, doubled as a workspace in addition to serving the function it was designed for).

Since the medications and supplies were co-located in this unit, nurses frequently got medications and supplies together for a patient. In the interviews, all staff talked about the need for more point-of-use supplies, however, the co-location of medications and supplies was perceived as a plus. The staff discussed the need for basic supplies such as intravenous (IV) pumps, at the patient bedside and ensuring that these supplies were stocked. Staff also

Table 5. Frequency of Visiting Each Location.

Location	Total Number of Times in 16 hr	Total Number of Times in Day Shift (12 hr)	Total Number of Times in Night Shift (4 hr)
Patient room	99	74	25
Assigned nurse station	71	61	10
Clean supplies/ medications room	38	25	13
Corridor	26	19	7
Other nurse station	23	19	4
Nourishment room—water/ ice	9	7	2
Nourishment room—snack	1	1	0
Offstage	10	4	6
Supervisor's office	2	2	0
Kitchen—soiled holding	1	1	0
Clean supplies/ medications room (West)	1	1	0
Conference room	1	0	1
Soiled holding	1	0	1
Linen	1	0	1

Table 6. Overlaps Between Key Sequences.

	Patient Assessment	Med Delivery	Call Response	Nourish. Delivery	Supply Delivery	Break
Patient assessment	X	6		2	1	1
Med delivery	6	3[a]	3	2		
Call response		3	X	1		
Nourishment delivery	2	2	1	X		
Supply delivery	1				X	
Break	1					X

Note. The "X" indicates that there is no overlap between two similar key sequences. med = medication.
[a]Med delivery sequences had overlapped 3 times when medications were delivered to more than one patient.

preferred the double loaded corridor (W) compared to the single entry from the staff area (E).

Multitasking and Impact on Walking

The sequence analysis for shadow data also revealed that nurses frequently multitask arguably to increase productivity and efficiency. Table 6 shows the instances of overlap between the different key sequences.

Analysis for shadow data to find key sequences and their variations shows that there was an effort to multitask while administrating medications to patients. Sometimes (3 of the 14 times) the nurse prepared and took medications for several patients at once and delivered them one after another. Medication delivery for some patients and patient assessment for others is frequently combined. Multitasking also took place when there was a need to get and deliver nourishments during medication delivery or patient assessments.

Literature suggests that multitasking can be a potential source of errors (Flanders & Clark, 2010; Kalisch & Aebersold, 2010). To understand if multitasking reduces time on task, optimal walking distances were calculated (no multitasking). Actual and optimized walking were compared. Actual walking was calculated using recorded steps and drawing shadowed paths using AutoCAD software.

Using AutoCAD software, all the paths from shadow data were drawn and color coded in order to calculate more accurate actual walking, by considering nurse walking into the spaces such as NSs and PRs. Optimized walking was calculated using a parametric model by using key sequences and their frequencies. Frequency of visits to the key locations was calculated and then developed as independent sequences where medication delivery was not combined with other medication delivery or tasks. Comparison of actual (multitasking) versus optimal task (no multitasking) pathways shows that multitasking did not decrease travel distance. The findings indicate that although nurses try to incorporate multitasking in order to decrease their walking and increase their efficiency, it may, in fact, have the opposite effect. The research team is getting information from other data sets to validate this pilot finding. Table 7 shows the comparison between actual and optimized walking distances for major tasks such as patient assessment, medication administration, and break.

The proximity calculators and the sequence mapper were then used to develop future state models for ideal proximities and sequences that reflect these priorities. These details will be shared in an upcoming publication on actual versus ideal caregiver paths and how they can be planned and assessed during the design process.

Activity Analysis of the First 2 hr of the Shift

Much has been written about the activities on a med-surg floor, especially around bedside nurses. The beginning of the shift is always critical due to the change-of-shift procedures for patient hand overs. The shadow data sought to understand how the shift change and how the beginning of the shift varied for the day and night shift. The

Table 7. Comparison Between Actual and Optimized Walking Distances.[a]

Major Sequences	Optimized Walking From Rhino/Grasshopper	Actual Walking From Recorded Steps	Actual Walking From AutoCAD Drawing
Patient assessment	1,981	2,018	2,231
Med administration[b]	5,737	5,114	6,263
Break	935	1,051	1,067
Total walking[c]	1.64 miles	1.78 miles	1.93 miles

Note. med = medication.
[a]Except total walking, all other distances are reported in feet. [b]Med administration includes all activities related to call responses and med/nourish/supply deliveries. [c]Total walking is the entire distance the nurse walked during a 12-hr shift. This includes the distances associated with major sequences mentioned in this table.

shadow data from the day shift (one nurse for 12 hr) and night shift (two nurses for 2 hr each) were extremely revealing in terms of "actual" pathways (how nurses behaved/walked) vis-à-vis planned pathways (how architects may visualize this path based on key tasks and ideal pathways). Due to the small sample, in terms of comparing day and night shift, we focused on analyzing activity for the bedside nurse in the first 2 hr of the shift.

The most common places that the two nurses went to on each of their shifts in the first 2 hr included the PRs, their assigned NSs, the clean supplies and medications room, and the corridor. The above-mentioned observations conform to the findings of Hendrich et al. (2008), in which the authors found that the nurses spend over two thirds of their time in PRs and NS, and to the study findings of Pati et al. (2012) who found that spaces designated for clean supplies and medications and for charting and telephones (the NS) were the most frequented locations on the unit. Although the number of times the nurses went to the PR was comparable in the first 2 hr of the day and night shift, overall the nurse spent more time in the PR during the night shift. Additionally, the night shift nurse spent more time in the clean supplies and medications room than the day shift nurse in the beginning of the shift. Since the sample size is small (shadow data from one nurse in each shift), this cannot be considered conclusive, however, based on follow-up conversation with clinical staff, it is likely that the trend (more time in PR and in clean supplies and medications) is because the nurses were getting the patients ready and comfortable for the night and preparing the unit for the day shift, which tends to be busier.

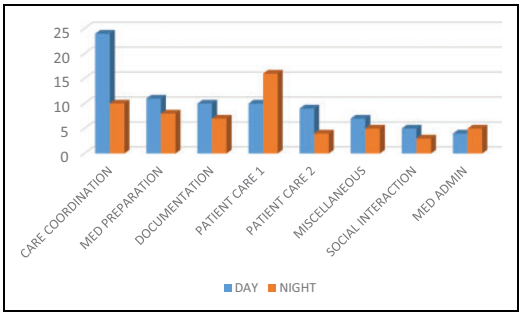

Figure 4. Activities in first 2 hr of shift.

In fact, in assessing the type of activity in the first 2 hr of the shift, it was found that day shift nurses spend more time in care coordination communication, while night shift nurses spend more time in direct patient care and at patient bedside, in the first 2 hr (refer to Figures 4 and 5). This is consistent with the findings from Miller (2001) who found that day shift nurses collaborate more with physicians than night shift nurses. Figure 4 shows the day and night shift activities and the utilization of key locations.

Communication was a key component of the first 2 hr in both shifts, but communication related to care coordination was much higher in the day shift. A complete breakup of the types of communication is shown in Figure 6.

Interestingly enough, as indicated in Figure 7 and Table 8, in the day shift more care coordination took place in the NSs and the corridor as compared to the night shift, where a majority of the care coordination was at the patient bedside. Both day shift

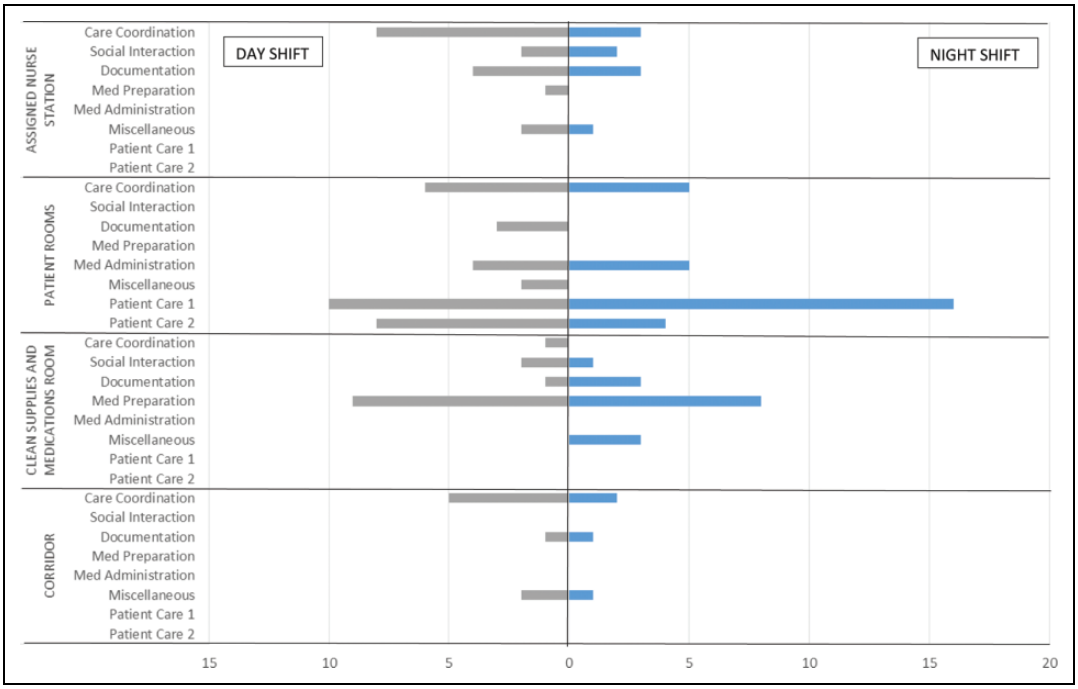

Figure 5. Activities at top four locations during the first 2 hr of day and night shifts.

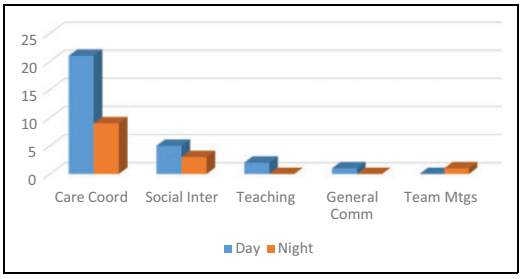

Figure 6. Frequency of different communication types in first 2 hr of shift.

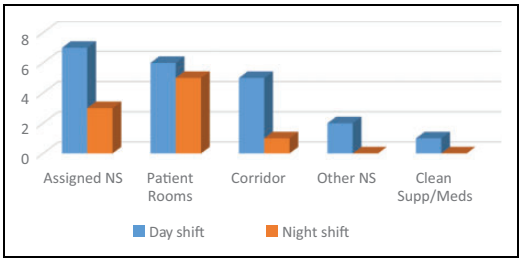

Figure 7. Care coordination locations.

and night shift nurses used WoWs, but night shift nurses may be more sensitive to the need for being quiet, thus avoiding conversations in the corridor. Overall care coordination happened more in the day shift than in the night shift. Care coordination (where caregivers communicate, coordinate, and discuss patient care) was observed between the nurse and the several care providers (physicians, nurses, nurse assistants [NAs], and nurse supervisors) and between the nurse and the other support staff (unit clerk, therapist, dietician, patient transport, administration, and others).

Visibility and Connectivity

Survey data and on-site observations also revealed that care coordination could be an issue due to poor visibility/connectivity.

Patient–nurse visibility. In this unit, PRs have no windows into the corridor. The long corridor makes visibility a challenge even with doors partially open. The analysis of sight lines (isovist) shows that at max, only 25% of the patient doors are visible from the central nursing unit. Currently nurse

Table 8. Frequency of Activities at Different Locations on the Unit.

	Activities							
Locations	Care Coordination	Social Interaction	Patient Care 1	Patient Care 2	Documentation	Med Preparation	Med Administration	Miscellaneous[a]
Assigned nurse station	58	11	5	4	44	2	0	11
Patient room	16	0	42	21	7	0	17	7
Corridor	15	0	1	0	4	0	0	1
Other nurse station	12	1	0	0	8	0	0	1
Offstage	6	3	0	0	0	0	0	0
Clean supplies and meds	3	5	0	2	1	25	0	4

Note. med = medication.
[a]Miscellaneous activities refers to picking up supplies, water, snacks, and activities involving infection control.

management attempts to assign the high-acuity/confused patients to the visible rooms, but this can be a challenge in a unit that is first to fill, so often at full occupancy. Nurses have slightly more visibility by parking WoWs on the corridor, unlike the patients who have no visibility into the staff areas if their doors are closed and minimum visibility if doors are open. Interview data revealed that occasionally a nurse or unit clerk does not realize when a patient has been taken for a procedure.

Nurse–physician visibility. Interview data show that nurses often miss the physicians when they come on their rounds because they may go straight to PRs or to the offstage work areas to chart (the low visibility into these spaces makes it easy to miss seeing someone in them). Physicians, in turn, also have trouble finding the nurses because of the large size of the unit and low visibility of the offstage spaces. This affects care coordination and, in the long term, patient recovery. Additionally, if the nurse is in the medications/supply room, which have opaque doors, they can be easily missed.

Nurse–nurse/NA visibility. Nurses and NAs sometimes have difficulty finding other nurses for help or witnessing a medication. The lack of a reliable technology compounds this problem.

Unit clerk–nurse visibility. The unit clerk is the conduit for call responses—paging the nurses/NAs/patient care supervisors in response to a call light. Technology frequently fails or a nurse may have left the walkie-talkie in the station. In such an eventuality, the low visibility the unit clerk has of the unit hinders her ability to locate nurses.

Leadership–staff visibility. The lack of visibility also impacts the leadership (nursing director and patient care supervisors) as it becomes a challenge to round up the staff, motivate them, and put new protocols in place without knowing where the staff is on the unit. With the staff being equipped with WoWs, their availability is no longer limited to the core NS.

The unit also has issues with ''auditory visibility''/ability to hear relevant sounds related to patient care, combined with visual cues. For example, when a bed alarm goes off, the sound is very distinct and a light comes up on the PR door. The nurse can quickly scan the room and know the problem. However, in the case of an IV alarm, there is no visual cue and nurses were found putting their ears to each PR door to assess where the sound was coming from. The constant beeping in the unit could also potentially contribute to alarm fatigue. Observations suggested a certain level of alarm fatigue—tuning out alarm sounds unless there was a critical alarm sound. This could relate to delay in care and patient perception of getting care on time, however, this needs to be investigated further.

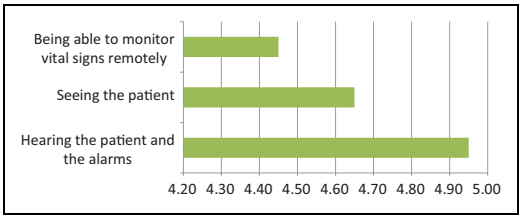

Figure 8. Importance of patient monitoring.

"Virtual Visibility"—or visibility via technology is another challenge on this unit due to the use of outdated walkie-talkies/phones. The call response system is dependent on the unit clerk calling the nurse/NA/supervisor and the nurse/NA responding to the call. If the nurse has left the phone behind or has her hands full with patient care, she cannot respond to the call/message. There is no virtual system that centralizes where help is needed and what kind of help is needed to ensure timely help is provided. It was very important for nurses to be able to monitor their patients by clearly hearing them as well as hearing the alarm system (see nurse response to survey question [5-point Likert-type scale—1 = *being not at all important* and 5 = *being very important*] in Figure 8).

Unaccommodated WoWs

One of the most critical insights for the research team was the extensive use of the WoWs and the change in the work culture based on the WoWs. The WoWs are the first thing that nurses lay claim to as they start their day. The WoW is a constant companion for the nurse—it is taken into the PR, meds/supply room, and NS when it's time to chart or take a break. Unfortunately the unit was never designed for WoWs. This means WoWs are constantly in the corridor, or cluttering the main NS rendering the entire unit, other than the PRs, a work area. Table 9 summarizes the pro and cons of WoWs on the unit.

Interruptions and Distractions

According to the Merriam-Webster online dictionary, to interrupt (n.d.) means "to cause (something) to not be even or continuous: to change or stop the sameness or smoothness of (something)" and a distraction (n.d.) is "something that makes it difficult to think or pay attention." Literature shows that interruptions during the performance of a task or an activity are linked with the occurrence of medical errors (Flynn et al., 1999; Westbrook et al., 2010). The shadow data of this study reveals that the nurse was interrupted 10 times as she prepared medications, documented, or coordinated care with peers.

Table 9. Effects of WoWs.

Positive WoW Effect	Negative WoW Effect
On the go charting	Corridors are now work spaces
No log-in, log-out issues	Patient mobility deterrent
Flexibility	Increased sound levels
Mobile storage for nurses	Potential HIPAA violations
Corridor parking	Units in the room are unused
Bedside charting	Infection risk

Note. WoW = work on wheel; HIPAA = Health Insurance Portability and Accountability Act.

Literature also says that distractions can create the potential for errors while performing tasks, like medication delivery (Hohenhaus & Powell, 2008). According to the shadow data, the nurse was distracted 10 times while preparing medications, coordinating care, and documenting. The previous interruptions and distractions occurred only during the day shift. There were no interruptions or distractions observed during the 4 hr of shadowing the nurse on the night shift.

In the medication delivery sequence which took place 17 times during the day shift, interruptions and distractions happened during the medication preparation time in the clean supplies and medications room. There were two interruptions and four distractions as the nurse prepared medications. The nurse was also interrupted when she was in the corridor putting on the isolation gown prior to entering a high-acuity isolated patient's room and she was distracted while engaged in coordinating care on her walkie-talkie in the NS, by the conversation of the other nurses.

High Noise Levels

Noise levels on the unit were found to be in excess of the World Health Organization guidelines of 35

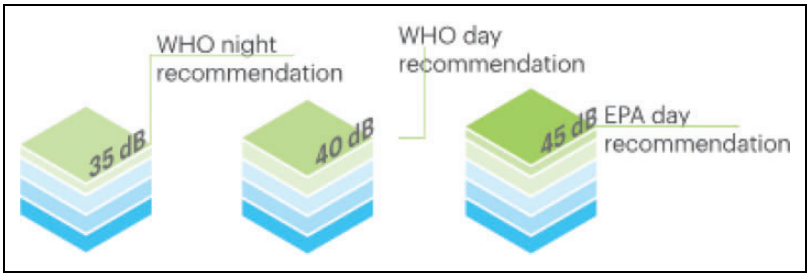

Figure 9. WHO and EPA recommendations for noise levels. Adapted from Berglund, Lindvall, Schwelaand, and Goh (1999) and United States Environmental Protection Agency (1974).

dB for night time and 40–45 dB for day time (refer Figure 9). Current average noise level in the unit is around 50 dBs at night and between 60 and 65 dBs at daytime. Peaks can be as high as 102 dB due to "sharp" noises such as door closing or drawers slamming. Key sources of noise were alarms beeping (including constant beep of the telemetry unit), nurses talking, and the ice machine.

Conclusions

There is considerable waste and variability in walking, in part due to multi-stop sequences in the completion of single activities. Nurses reported that the limited point-of-use access to supplies, the walk to getting small items—such as apple sauce—as a source of great frustration even though the need may arise only a few times a day. There is currently low visibility and connectivity across the unit, which creates challenges for patient monitoring, care coordination, and management. Spaces that are not on key pathways are unused. The corridor is used as a workspace/communication hub due to the extensive usage of WoWs. There is a distinct difference in beginning of shift patterns for day and night shift and between walking "distance" and walking "sequence." There is a tendency for nurses to multitask, but a simulation exercise shows that for key tasks like medication delivery, multitasking may not always reduce walking distances.

Walking, visibility, and connectivity are issues that have been investigated extensively in med-surg units. However, each health system, each delivery system, and each organizational culture is unique and there is a need to do on-site field research, and a deeper analysis of the spatial context, to address solutions.

For this study, a key takeaway from the research was the need to co-locate nourishment with medications and supplies, accommodate WoWs, and provide spatial and technological connectivity between the care team and the patients. Care coordination challenges and challenges of fragmented time on task plus multitasking were identified and strategies to address these need to be discussed. Methodologically, a 2.5-day field study module combining field research with space analytics is of value since it allows a triangulation between observed, reported, and spatial data that can be invaluable for rapidly deployed research which can be timely in informing design, rather than being a postrationalization argument for decisions already made.

Implications for Practice

- Design the workplace and the core of the med-surg unit based on key sequences of activities, not just point-to-point distance between key locations.
- Locate nourishment area close to the medications and supplies. Co-location of medications and supplies works well, but design carefully to avoid interruptions during medication preparation.
- Streamline the layout of spaces, and point-of-care supplies, so nurses are enabled for focused tasks rather than multitasking during high-risk error prone tasks such as medication delivery.

- Combine field research and spatial parametric analysis tools so behavior and spatial data can be layered in a thorough analysis of the current work environment before designing a new one.

Acknowledgment

The authors would like to thank ProMedica Toledo Hospital, Toledo, Ohio.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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