MAXIMIZING FACILITY EFFICIENCY: A STUDY OF NURSE WORK PATTERNS IN A NEONATAL INTENSIVE CARE UNIT

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Margaret Taylor
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ABSTRACT

This study observed nurse transit times and activity patterns in an open bay neonatal intensive care unit (NICU) to understand opportunities for improving efficiency by redesigning the NICU layout, and to use these data to estimate the impact of an alternative pod room NICU layout under consideration. The transit times and activity patterns of 4 nurses were observed while working in the open bay NICU in a hospital. Nurses were observed for a combined total of 48 hours, and times and activity patterns were recorded using a customized template for electronic software running on a smart phone. These times and activity patterns were then projected onto a proposed pod room layout for the same NICU to estimate the impact of this redesign prior to actual construction.

Results showed that the nurses spent 89% of their work time in the NICU and when in the NICU they spent 44.8% of their time charting neonate information, 40.1% on direct patient care at the incubator, 6.8% of their time in transit between NICU location, 5.4% of the time on washing or sanitizing their hands and 2.9% of the time searching for supplies. Based on this information and the spatial layout of the existing and proposed NICUs it was found that each layout has its own unique layout deficiencies, and the proposed layout does not necessarily improve efficiency. The proposed layout lowers transit times for movements from the incubator to the computer, the incubator to the medical supply cart, and the computer to the medical supply cart however the open bay layout lowers transit times for movements from the incubator to the sink. All other movement transit times depend on the specific pod unit within the pod layout where care is taking place.

BIOGRAPHICAL SKETCH

Meg Taylor is a graduate student at Cornell University in Design and Environmental Analysis, majoring in Facilities Planning and Management with a minor in Healthcare Administration. She also completed her undergraduate degree in Design and Environmental Analysis, majoring in Facilities Planning and Management.

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CHAPTER ONE: INTRODUCTION

Neonatal Intensive Care Units (NICUs) are critical in maintaining the health and wellbeing of newborns in a hospital. NICUs are focused specifically on providing care for critically ill and medically unstable newborns who require constant nursing throughout the day and night, complicated surgical procedures, continual respiratory support, and/or other intensive interventions (White, 2007). In addition to the NICU, spaces that support the newborns in a hospital include delivery rooms and nurseries where high-risk newborns are monitored and provided both extensive and intermediate care. Varying levels of care are needed in all spaces, as each newborn requires a different level of support based on their condition. On the obstetrics unit as a whole, NICUs provide support spaces where the most critical care for newborns occurs.

Since the first NICU opened in 1965 at Yale-New Haven Hospital in Connecticut, more than 800 NICUs have been built in the United States. Furthermore, recently the number of hospitals reporting NICU beds has increased, along with the total number of NICU beds in each hospital. From 2001 to 2004, hospitals in the United States reporting NICU beds increased by 6.6% and hospitals reported an increase of 14.1% in the total number of beds in each NICU. (Gupta, Martin, & McCormick, 2006) According to Shepley (2002), there are two likely causes for the growth in the number of NICUs across the country: advances in medical science and an increase in the number of ill newborns because of modern illnesses such as drug dependence. As a result of this growth, the design of many NICU units is a new process. (Shepley, 2002)

There are three defined levels of NICUs in hospitals. A level 1 NICU supports pre-term newborns born 37 weeks or more after conception. In a level 1 NICU, basic care is provided to relatively healthy newborns that were brought almost to, or through to, full term. A level 2 NICU

supports pre term newborns born 32 weeks or more after conception. In a level 2 NICU, more specialty care and support is provided to the newborns that are delivered well before full term. These newborns tend to have moderately severe problems that can be expected to resolve quickly. A level 3 NICU supports pre term newborns born 23 weeks or more after conception. In a level 3 NICU, subspecialty care is provided to critically ill newborns that are delivered significantly before full term and require high acuity and comprehensive care. (Hardy, 2005)

NICU Nurses

According to Braithwaite (2008), the NICU is a highly specialized environment where nurses must care for critically ill neonates with complex medical issues. Quality nurse care in the NICU requires a precise level of attention to detail and as a result, nurses in the NICU experience psychological and physical stress, both of which can lead to high levels of absenteeism, low morale, mental fatigue, and exhaustion. Neonatal care can suffer and because of this, job satisfaction, emotional support, and self-care are all highly important in providing a supportive staff environment that prevents burnout. Preventing burnout not only leads to higher quality care, it can also lead to decreased costs for an organization. The cost of a nurse turnover is up to 150% of the nurse's annual compensation, which has a large effect on the efficiency of operations in a hospital. (Braithwaite, 2008)

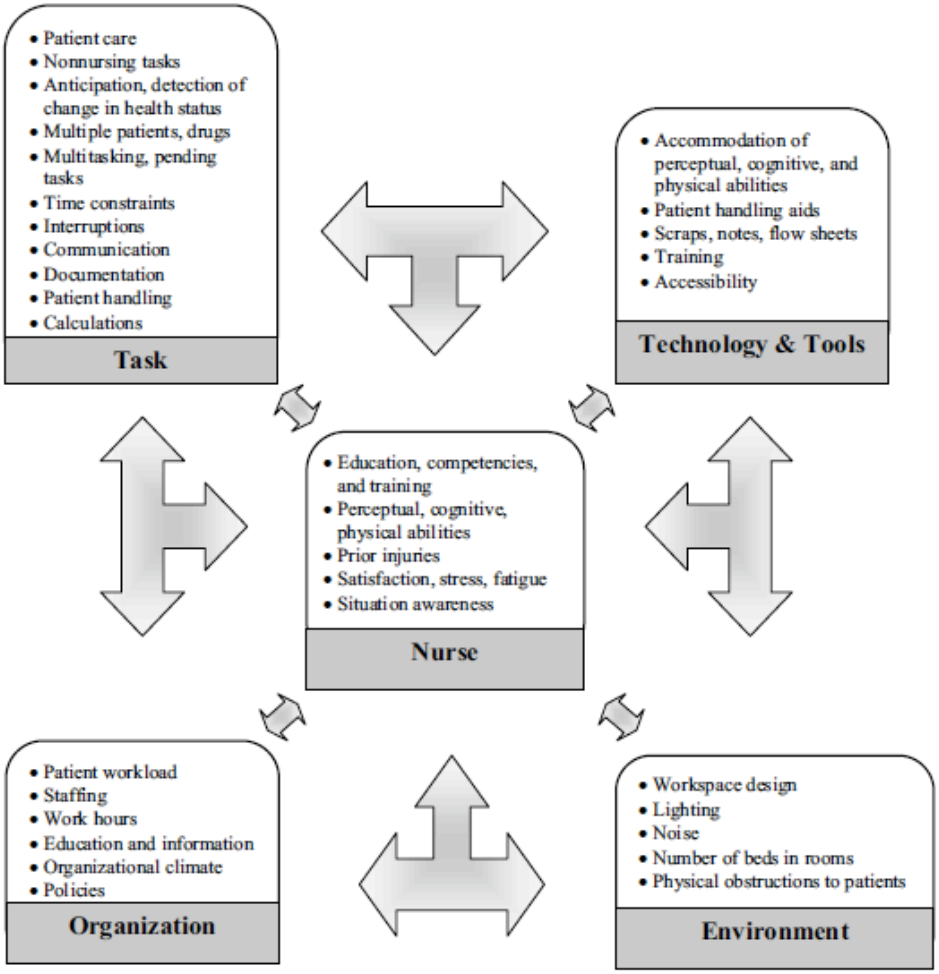
Overall, lower rates of burnout can lead to better retention rates, better recruitment rates, and safer delivery of care for neonates. Specifically, stressors in the work environment can lead to high rates of burnout. Specialized care areas of nursing, such as oncology, hospice, and intensive care, are ridden with abundant stressors and include high noise levels, constantly shifting patients and technology environments, lack of materials required to complete tasks, and

ethical dilemmas surrounding life saving care. Higher job satisfaction is the key to lower burnout rates, and fatigue is an important element in job satisfaction. Fatigue can be lowered by providing nurses with supportive environments to work in, thus improving their ability to care for neonates who rely solely on nurse care. (Braithwaite, 2008)

The Balance Model

It is important to understand the mechanisms underneath a nurse's stress load, or the stress load of any other worker, in a given environment. The balance model can also be used to explain the interaction between parts of a nurses' system in the hospital. According to the balance model, there are five components that combine to contribute to a worker's stress load. These five components include individual, task, technology, organization, and the environment. Within these components, positive and negative elements should be balanced in order to maximize employee comfort. (Smith, & Sainfort, 1989) Figure 1 shows the balance model as it is adapted to nursing. Within the component of the environment is workspace design, lighting, noise, number of beds in rooms, and physical obstructions to patients. (DeLucia, Ott, & Palmieri, 2009)

Figure 1. The Balance Model Applied to Nursing



Nurse Walking Patterns and Times

According to the American Nurses Association, there are 3.1 million licensed registered nurses (RNs) in the United States, and of the total number of licensed RNs in the United States who are employed as nurses, 62.2 percent are employed RNs working in hospitals. In addition, it is projected that there will be a total of 581,500 new jobs in nursing between 2008 and 2018, equaling a 22 percent projected growth in nursing employment. (American Nurses Association,

2011) With nurses at the forefront of healthcare in hospitals in the United States, nurse productivity on the job is key in creating a more efficient care process.

While a majority of research in the healthcare environment is aimed at patients, there is increasing evidence that suggests improving design for positive staff outcomes is equally as important (Ulrich, Quan, Zimring, & Joseph, 2004). Nurses spend the most time with patients out of any care provider in a hospital, and the quality of care that nurses provide directly impacts patient outcomes. As a result, improving nurse performance can improve patient safety simultaneously. Nurses are overloaded with stimuli on a regular basis because current nurse work systems often do not take into account human cognitive, perceptual, and physical limits and capacities. (DeLucia et al., 2009)

There are three categories of tasks that nurses perform: direct patient care, indirect patient care, and nonnursing tasks (Hobgood, Villani, & Quattlebaum, 2005). Nonnursing tasks include searching for medical supplies and equipment during a work shift and walking from one location to another. According to Hendrich & Chow (2008), the elements of a hospital work environment, such as inefficient work processes and designs, cause stress for nurses and limit the time they can spend in direct patient care. In addition, according to the American Association of Critical-Care Nurses (2004), critical care nurses such as those in the NICU, spend more of their time on indirect patient care tasks than they do on direct patient care tasks. As a result, one of the metrics for evaluating the delivery of high quality care is based on the optimal use of a nurses' time. (American Association of Critical-Care Nurses, 2004)

Walking to retrieve materials and complete necessary tasks involved in patient care can make up a significant amount of time in a nurse's day. According to a survey of hospital nurses,

85% of nurses spend 60 minutes per shift searching and waiting for supplies and equipment (Dare, 2009). These nurse work activities of hunting and gathering are directly tied to nurse walking times, which are an integral part of the daily working life of a nurse. Burgio, Engel, Hawkins, McCorick, & Scheve (1990) found that nurses spent 28.9% of their time walking during one shift, and that out of all of the activities during the day, walking from one location to another was the second most frequent activity. Another study found that nurses spent 17% of their time during a work shift walking (Jydstrup & Gross, 1966).

In addition, the distances that nurses walk are another dimension of nurse activity. Studies have found that the average distance walked by a nurse during a 12-hour shift ranged from 4.1 miles (Welton, Decker, Adam, & Zone-Smith, 2006), to 5.6 miles (Hollingsworth, Chrisholm, Giles, Cordell, & Nelson, 1998). Another study found that the average distance walked by a nurse during a 10-hour shift ranged from 2.4 to 3.4 miles (Hendrick & Chow, 2008).

In high acuity level departments and divisions of a hospital such as the NICU, fatigue can have immense implications on the extent to which quality care is provided to newborns (Braithwaite, 2008). It is important that nurses in the NICU are not stressed by their physical environment, therefore the space should support nurse activities, not block or impede them (Shepley, 2002). In a study by Cochrane, Nishimura, Spencer, & Taylor (2012), it was found that physical features of inpatient care centers and other facilities can impede efficient nurse work and decrease time spent on direct patient care, and as a result decrease patient safety. Within the NICU, time management is one of the most critical factors for providing quality care to newborns, and the layout and placement of supplies in the NICU is crucial in setting the stage for the time that it will take nurses to provide care for the newborns in the unit.

Layouts of NICUs

According to Rashid and Zimrig (2008), physical variables can be grouped into the category of indoor environmental variables and the category of interior design variables. Indoor environmental variables include variables in a setting such as noise, lighting, ambient temperature, and air quality. Interior design variables on the other hand include variables in a setting such as the use of space, furniture, fixtures and equipment, finishing materials, color, artwork, natural views, and environmental graphics. (Rashid & Zimrig, 2008)

One of the major physical features that can impede efficient nurse care is a poorly laid out unit. Spatial layout is a dimension with direct ties to the function of the obstetrics unit as a whole. White (2007), suggests that the width of aisles in patient rooms and nurseries be wide enough to allow for the movement of large medical equipment such as infant respiratory devices, electrical and gas units be located in an easily accessible area, and all equipment should permit flexibility in where and how it can be moved. For the NICU specifically, White (2007) makes the following recommendations for space requirements:

"Each infant space shall contain a minimum of 120 square feet (11.2 square meters) of clear floor space, excluding handwashing stations, columns, and aisles…There shall be an aisle adjacent to each infant space with a minimum width of 4 feet (1.2 meters) in multiple bed rooms. When single infant rooms or fixed cubicle partitions are utilized in the design, there shall be an adjacent aisle of not less than 8 feet (2.4 meters) in clear and unobstructed width to permit passage of equipment and personnel. Multiple bed rooms shall have a minimum of 8 feet (2.4 meters) between infant beds. There shall be provision for visual privacy for each bed, and the design shall support speech privacy at distance of 12 feet (3.6 meters)… Where a single infant room concept is used, a hands-free handwashing station shall be provided within each infant room. In a multiple bed room, every infant bed shall be within 20 feet (6 meters) of a hands-free handwashing station. Handwashing stations shall be no closer than 3 feet (0.9 meter) from an infant bed or clean supply storage. Handwashing sinks shall be large enough to control splashing and designed to avoid standing or retained water. Minimum dimensions for a handwashing sink are 24 inches wide x 16 inches front to back x 10 inches deep (61 cm x 41 cm x 25 cm) from the bottom of the sink to the top of its rim. Space for pictorial handwashing instructions shall be provided above all sinks. There shall be no aerator on the faucet. Walls adjacent to handwashing sinks shall be constructed of non-porous material. Space shall also be provided for soap and

towel dispensers and for appropriate trash receptacles. Towel dispensers shall operate so that only the towel itself need be touched in the process of dispensing, and constructed in such a fashion as to be consistent with Standard 23. Handwashing facilities located at a level where they can be used by people in wheelchairs shall be available in the NICU…Charting/Staff Work Areas: Provision for charting space at each bedside shall be provided. An additional separate area or desk for tasks such as compiling more detailed records, completing requisitions, and telephone communication shall be provided in an area acoustically separated from the infant and family areas. Dedicated space shall be allocated as necessary for electronic medical record keeping within infant care areas." (12-16)

Supportive unit layouts and designs can positively impact nurse work experience and are directly related to goals of improving quality and reducing waste. In the NICU specifically, because infants are usually in critical care and require a great deal of support and constant nurse attention, nurse work patterns are an integral part of the care provided for neonates in a hospital.

Layouts and Searching and Gathering

According to Shepley (2002), an efficient NICU unit allows nurses to spend more of their time on patient care instead of moving between locations and searching for supplies and other staff members. By reducing the time that nurses take to search for and gather supplies, nurses will have more time to care for patients and will have reduced stress levels (Shepley, 2005). In order to reduce searching and gathering and walking time, the layout of activity spaces and supplies in the NICU physical environment should be addressed. In a time and motion study of two medical surgical units, traditional and decentralized nursing station layouts were evaluated according to excess nurse motion, inefficiencies, amount of direct patient care time, amount of medicine dispensing time, and amount of documenting chart time. The inpatient unit with decentralized work stations led to a decrease in nurse walking time and trips to collect supplies, and an increase in nursing availability and direct patient care time compared to a unit with a centralized station. (Cochran et al., 2012)

Layouts and Task Interruption

The layout of the NICU can also affect the number of interruptions a nurse experiences. Here, interruptions are used to explain distractions to or interferences with tasks that are due to the NICU layout and the organization of equipment and supplies within it. Interruptions, whether they are predicted or unpredicted, force individuals to switch tasks and in turn switch their attention, increasing the mental resources required from the individual. When handling multiple tasks, disruptions in workflow from interruptions can be reduced by cues from the environment. (Trafton, & Monk, 2007) In the NICU, frequent short interruptions affect nurse workflow. Poor equipment and supply placement can disrupt the natural workflow of a nurse who is moving through the space trying to complete a task. For example, when the computer system required for charting information is across the room from the incubator, the nurse is forced to travel across the room unnecessarily to complete a task, thus disrupting the workflow. Reducing frequent unnecessary interruptions because of an unsupportive environment is equally as important as lowering the actual time nurses spend on walking and searching and gathering.

Types of NICU Layouts

There are several types of NICU layouts found in hospitals. The traditional model of NICUs consists of a multiple bed, single room, open bay NICU where newborns are provided care in the same large environment in order to allow for easy nurse visibility and access. In this model, there are no walls or boundaries between one infant and another, and incubators are arranged near one another with medical supplies and materials located in one location for the entire unit. The majority of NICUs today are designed according to this open bay environment,

even though adult patient rooms have progressed towards mainly private rooms (Brown & Taquino, 2001).

Another model of NICUs is the single patient, single incubator room unit, where newborns are given a private room. Each private room houses all of the equipment needed to take care of the newborn. According to White (2010), the single patient room NICU unit provides privacy for the newborn and the family, while also maximizing space for medical care. Single patient rooms have space for the incubator and necessary medical equipment and staff supplies, and have space for visitors, such as family members, to stay in the room if desired. Single patient rooms allow for a greater degree of patient privacy, significantly reduce the rate of infection, and improve clinical outcomes. In a study by Domancio, Davis, Coleman, & Davis (2010), single patient rooms were found to have a 5% lower rate of nosocomial infection rates than the rates in an open bay environment. In addition, staff and family members perceive a higher degree of personal safety in single patient rooms compared to open bay environments (Bartley & Streifel, 2010), and the average length of stay for patients in single patient rooms is shorter than the length of stay in open bay environments (Domancio et al., 2010). Brown & Taquino (2001) found similar results; the single patient rooms allow for increased privacy and confidentiality, while decreasing stress levels of family, staff and patients. In addition, single patient NICU rooms enhance family centered care by providing spaces for the newborn's family to stay and help the healing process. Parents are able to provide more continuous support, while simultaneously allowing for participation in decisions about the newborn's care (Beck, Weis, Greisen, Anderson, & Zoffmann, 2009). Likewise, single patient rooms aid in reducing stress levels among staff members and contribute to their overall satisfaction (Shepley, Harris, & White, 2008).

A study by Carlson, Walsh, Wergin, Schwarzkopf, & Ecklund (2006) found that while the private room NICU has emerged as an alternative to large open bay units, radical design changes in locations where this switch occurs causes difficulties in implementation because it is not always a financially or spatially feasible model. Private rooms require a great deal of resources in terms of space, material supplies and number of employees, and caregivers can often feel further isolated from other support staff and have fewer opportunities for experiential learning (Domancio et al., 2010). Especially in the construction phase, private rooms result in higher costs due to an increase in square footage (Moon, 2005). It has also been found that while physician and nurse practitioner staff members of a NICU unit prefer a single patient room layout, nurses prefer an open bay layout because they perceive the open bay as being better for staff communication, coworker access, and mutually supportive interactions among parents (Domancio et al., 2010). Smith, Schoenbeck, and Clayton (2007), similarly found that the rankings of patient care team interaction quality significantly declined after a switch from an open bay NICU to a single patient room NICU, possibly because the NICU operational management was not modified upon the move to the private room model and as so staff members were not able to adjust.

More recently, there has been a push towards a different layout of NICUs – the pod room NICU. The development of a pod room NICU came about as a means to address the issues with both open bay and private patient room NICUs. In a pod room NICU, incubators are all placed in one room, but physical divisions exist between the incubators, such as half walls, sliding walls, or curtains, and materials are placed in multiple locations in the room based on the location of each incubator. Between two to six newborns share a space similar to the open bay layout, but with pods of space occupying one large space. (Naval Medical Center San Diego, 2009)

This layout allows for more privacy, and takes design elements from both the open bay and single patient room units in order to create one functional space. The concepts of nurse visibility and convenience in care are addressed along with concepts of privacy and individual space for visitors (Laing, Ducker, Lead, & Newmarch, 2004). In addition, a new model of nursing team microsystems has developed in order to address this development of small units inside of one larger space. The microsystems of nurses provide care to newborns by geographically grouping support spaces and teams (Goldschmidt & Gordin, 2006). This is a striking illustration of how the development of care in the NICU is becoming more segmented with small spaces inside one large unit.

One last NICU layout consists of a less integrated combination of the open bay and private patient rooms. According to Shepley et al. (2008), some NICU units have an open bay environment and a small set of private rooms in an attempt to combine the two most common models. Unfortunately, some newborns receive care in the private rooms, and some are placed in the open bay environment, leading to differences in care and more privacy for only a few of the newborns and their family members.

Nurse Walking Times and NICU Layout

Walking distance and patient contact are two of the most important issues for nurses in hospitals (Seelye, 1982). In a case study by Shepley (2002), nurse walking times in an open bay NICU were compared to a closed private room NICU by collecting information regarding a nurse's location, their activity, and arrival and departure times. The study found that there were no significant differences in nurse walking times as measured by pedometers for three-hour segments when comparing the two types of NICU layouts. In addition, a study by Shepley et al.

(2008) found that there were no significant differences in distances traveled by nurses in the two different NICU layouts. Contradicting findings indicate that nurses in private room NICUs walk half of a mile more each shift compared to nurses working in open bay NICUs after the same staff and work processes on the unit shifted to a private room model. (Stevens, Helseth, Khan, Munson, & Smith, 2010). Despite these different discrepancies, walking times for nurses remains an important factor in determining the amount and quality of care in a NICU. Careful thought must be put into unit and space configuration decisions to minimize activities, such as searching for supplies, and maximize activities such as nurse engagement with patients and families (Shepley, 2004).

Lean Processing

With the rising costs of patient care, hospitals across the United States have struggled with lowering costs while maximizing patient care at the same time. Now, hospitals are turning to practices that help them eliminate inefficiencies and increase quality of care. Lean processing is one method that hospitals can utilize to help eliminate inefficiencies in health care delivery. The philosophies and management tools upon which Lean processing is based originated with Toyota Motor Corporation's Lean methodology, which was used to streamline the manufacturing process for Toyota's vehicles. Toyota's initial goal was to use Lean processing to improve efficiency and quality in its production process, and now, these same goals are present in the healthcare environment where there is a strong push for efficiency and quality. (Kim, Spahlinger, Kin, & Billi, 2006) At the core of Lean processing in healthcare is the concept of improving quality of care for patients by reducing errors and waiting times (Graban, 2009). In order to do so, non-value added processes in the original system must be identified. This process is known as identifying "Muda", which translates to waste in English. Muda is broken down into waste in

activities of overproduction, waiting, transportation, processing, inventory, movement, and defective products. In identifying and evaluating where waste, such as repeated steps, rework, and unnecessary motion, exist in a process in a hospital, waste can be converted into value added activities (Fine, Golden, Hannam, & Morra 2009).

Although Lean health care is a relatively novel concept, the operation and quality improvement brought forth from Lean processing and methodology has immense implications for not just one part of a system in a hospital, but for the entire system as well (Kim et al., 2006). The ultimate goal in lean processing is to create value and eliminate waste. Efficiency in care is critical is in the high intensity and acute environment in the NICU. Eliminating waste in the NICU affects both the staff and the patients, and allows for better quality of care. More specifically, reducing the unnecessary and excess nurse movements in the NICU can help create a more efficient environment.

In order to implement lean methodologies, data collection processes must take place to assess the current operations in a facility (Patton, 2011). "Genchi genbutsu" is the Japanese term for gathering important information on the functioning of a system through observation. It is used to describe the collection of data instead of the use of perceived knowledge about the functioning of an environment. (Liker, 2004) Tools derived from concepts such as Genchi genbutsu are used in data collection processes today in order to help understand different systems. The tools below were used in this study of the NICU to collect this information via direct observations.

Behavioral Observation Methods

Behavioral observation methods were used for recording nurse activity patterns in the hospital in this study of the NICU. Observation is defined as "the action or process of observing something or someone carefully or in order to gain information" (Oxford University Press, 2013). Qualitative observational research "is an inquiry process of understanding based on distinct methodological traditions of inquiry that explore a social or human problem" (Creswell, 1998, pp. 15). More specifically, Creswell explains that participant observation is a technique for gathering information in a setting. The researcher can be fully immersed in observing the activities of the setting, and may conduct one-on-one interviews with research participants if desired. (Creswell, 1998)

Time Motion Study

One common form of behavioral observation that is used to improve operations in many healthcare environments is known as a time motion study. Time motion studies are a common tool used to collect information to support lean processing (Patten, 2011). The concept of time studies came about fully in the 1910s and 1920s with Frederick W. Taylor's use of a time study where a researcher would determine any elements of a job, and record how long each element took (Nadworny, 1957). The concept of a motion study however was developed by the Gilbreths as a way to improve methods of work. Leading into the 1940s, the time studies and the motion studies were separate, but were merged to create a single form of observation, the time and motion study (Barnes, 1940).

Within a time motion study, activities are traditionally broken down into five main categories: transportation, operation, inspection, delay, and storage (Meyers, & Stewart, 2001).

Melgar, Schubiner, Burack, Aranha, & Musial (2000) observed attending physician's activities in a residency-based community clinic and divided activities into four main categories: direct contact with residents, clinic operations, personal and/or professional activities, and miscellaneous time. Each of these categories had a series of subcategories. The times for each activity were recorded and totaled in order to assess the time distribution among the four categories. Between 1 and 3 attending physicians were observed at a time for an average of three hours and 33 minutes. Out of a total 6,389 minutes of observation, direct contact with residents accounted for 43.1% of the time, clinic operations accounted for 33.7% of the time, personal and/or professional activities accounted for 18% of the time, and miscellaneous time accounted for 5.2% of the time. Statistically there was no significant difference among the individual faculty members for direct contact with resident time or personal and/or professional activities time, but there was there was a significant difference for clinic operations time. (Melgar et al., 2000)

Similarly, both Lurie, Rank, Parenti, Woolley, & Snoke (1989) and Pizziferri, Kittler, Volk, Honour, Gupta, Wang S., Wang T., Lippincott, Li, & Bates (2005) used time motion studies to collect data in healthcare settings. Lurie et al. (1989) evaluated how house officers spend their time by observing officers for 35 hours in three different teaching hospitals. House officer's activities were broken down into main categories including performing procedures, direct patient evaluation, documenting new patient evaluations, and sleep time. It was found that the house officers spent considerable time charting but much less time was spent on direct patient evaluation. (Lurie et al.,1989) Pizziferri et al. (2005) conducted continuous time motion observations of 16 physicians in five different clinics before and after implementation of an electronic health record system After pilot observations, individual physician tasks were

categorized as follows, each with their own sub categories: direct patient care, indirect patient care - write, indirect patient care - read, indirect patient care - other, administrative, and miscellaneous. The total time spent on each activity was recorded and evaluated. It was found that the average time spent per patient on computer-based indirect patient care increased post implantation, while paper and phone based care time decreased. In addition, there were post implementation decreases in walking inside time per patient and personal time per patient. (Pizziferri et al., 2005)

A time motion study was also used to study nurses' cognitive work in a general acute medicine unit and a neuromedicine unit. Researchers recorded the physical activities of nurses through direct observation, and documented the location and duration of each activity. A task analysis was performed that broke down the job and specific activities into task duration, frequency, environmental conditions, and other factors required for activities. Nurse care activities and percent of time spent on a given activity were calculated following the observations. Out of 43 hours, 25% of the time was spent on patient contact, 26% of the time on consultation, 23% of the time on documentation, 16% of the time on medication preparation and administration, 5% of the time on searching, and 5% of the time on break time. Additionally, nurses walked from one location to another an average of 13 times per hour. (Potter, Wolf, Boxerman, Grayson, Sledge, Dunagan, & Evanoff, 2005)

Unfortunately, according to Patten (2011), there are two major challenges that researchers must face when conducting time motion studies in healthcare environments. The first is that frequent interactions with patients cause the need for very highly controlled cleanliness in the environment, and researchers must take precautions to ensure they do not spread germs from themselves to patients or from their equipment to patients. The second major challenge that

researchers face is patient confidentiality. All observations must take into consideration keeping patient information confidential (Patten, 2011).

There is limited research that measures transit times and activity patterns in open bay NICUs compared to pod room NICUs. The goal of this study is to measure nurse transit times and activity patterns in an open bay, multiple bed NICU, in order to discover opportunities for improving the efficiency of the NICU layout, and in order to compare a pod room NICU to the open bay NICU. Similarly to the strategies used by the time motion researchers above, a time motion strategy was used in the NICU and is discussed in Chapter 2.

Study Objectives

There were two purposes of this study. The first purpose was to determine the activity patterns and times associated with nurses working in a NICU in order to increase a database of knowledge and understanding of the activity patterns of NICU nurses in a hospital setting. The second purpose was to compare the transit times of nurses in an open bay NICU to the transit times of nurses in a pod room NICU in order to asses which of the two layouts is associated with shorter nurse transit times. Both of these combine to form a deeper understanding of how critical care nurse activities can be affected by the built environment, in this case the layout specifically. The following describes the methods and tools used to evaluate both the activity patterns and times of NICU nurses, and to compare the transit times of nurses in an open bay NICU with the transit times in a pod room NICU.

CHAPTER 2: METHODS

Study Population

Setting

Research was conducted in a level 2 NICU at a community hospital in the United States. The level 2 NICU is an open bay, multiple bed NICU that is scheduled to relocate to a new pod room multiple bed NICU. It houses a maximum of four neonates at one time, has one desk station with a computer, phone and filing system, and has a single storage location for each set of supplies and materials in the room, including a single medical supply cart holding acute supplies. There is one sink in the space, and one hand sanitizing unit next to the sink. In addition, there are two large windows on the westward facing wall of the room, and there is one door to enter the space. All major locations in the NICU, including the cabinets, the computer and filing station, the sink, the medical supply cart, and the incubator where the neonates were located for the duration the study's observations, were abbreviated and coded (Figure 2). Each of the coded locations were then labeled on the current floor plan of the NICU (Figure 3).

Figure 2. Coded Locations in Open Bay and Pod Room NICU

C/F - Computer/Filing

I - Incubator

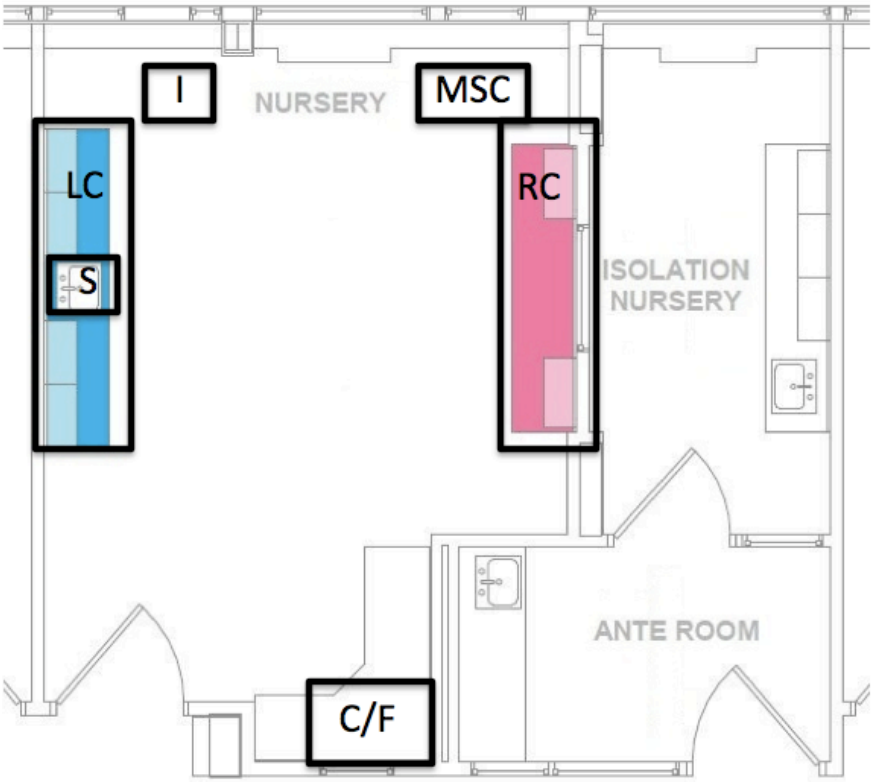
LC - Left Cabinets - Non-Acute Supplies

MSC - Medical Supply Cart

RC - Right Cabinets - Acute Supplies

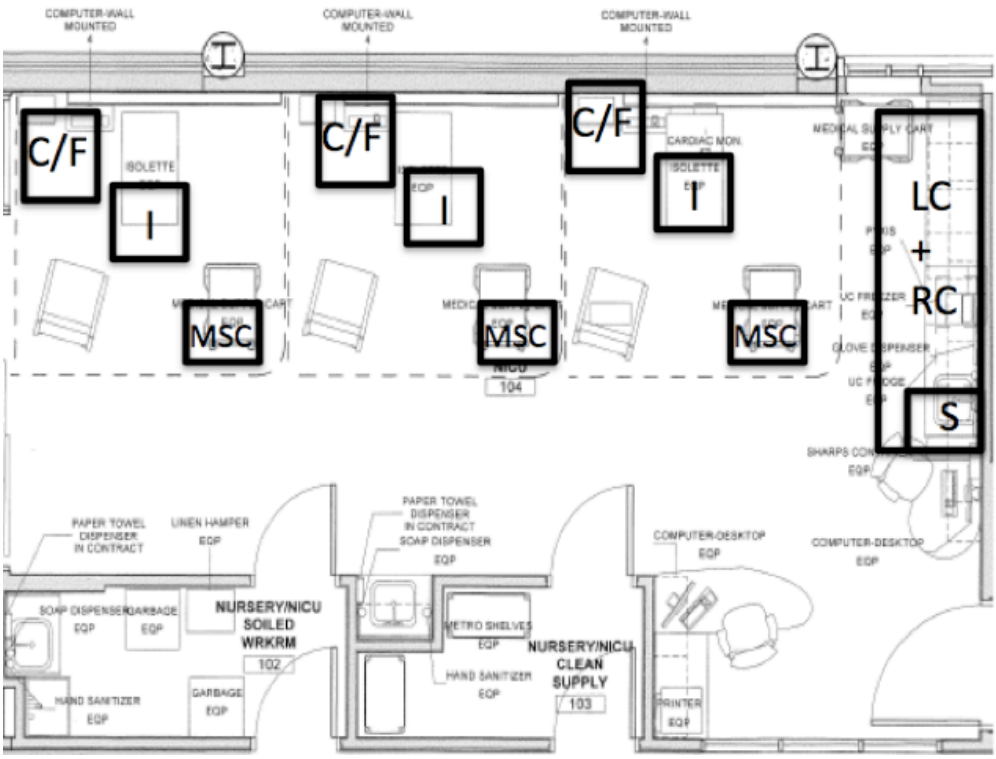
S – Sink

Figure 3. Open Bay NICU Layout with Coded Locations



The level 2 NICU will relocate to a unit with a pod room multiple bed NICU layout. The pod room NICU will house a maximum of three neonates and it will have three wall mounted computer stations. There will be a medical supply cart next to each of the three neonate incubators, and all other materials and equipment, including the sink, will be placed in a single location in the room. The pod room NICU will have three large windows, and three doors to enter the space. Each of the coded locations above were also labeled on the proposed layout (Figure 4).

Figure 4. Pod Room NICU Layout with Coded Locations



Participants

Information on nurse transit times and activity patterns was observed in the current NICU. Four nurses were observed one at a time in the NICU for a total of 12 hours each, 48 hours all together, over different days during the day time shift, when the majority of patient care and nurse activity occurs. The NICU nurses are all female, and range in age from approximately 25 to 60. They have at least five years of experience working in the NICU, have all received at minimum their Bachelors of Nursing, and are all registered nurses at the hospital. The four nurses selected were the four nurses in the community hospital's obstetrics unit who worked in the NICU. The Director of Nursing identified the four nurses that work in the NICU due to experience and training prior to the beginning of observations. Each nurse has the same job

description according to the unit's description for nurses given permission to work in the NICU; this includes working in labor and delivery on the unit. In addition, the unit recommends that there be one nurse caring for one neonate at a time over the course of a given shift. This is done to increase the consistency of care provided.

Observation Measures

Information on nurse transit times and activity patterns was measured via direct observations by the researcher. Each of the four nurses was observed for a total of 12 hours, six hours one day, and six hours another. The day that the nurse was observed on depended on the presence of a neonate. This led to observations of nurses on different days of the week and non consecutive days. All nurses were observed between 12pm and 6pm. During each observation period, nurse activity patterns were operationalized as the time spent at each location and the number of times and activity occurred, and nurse transit times were operationalized as the time for movement between locations. Transit time includes any time that passed while a nurse moved between locations including the time that a nurse took to start getting out of their chair and then walk, or to walk and reach the incubator but to subsequently walk to an appropriate place around or behind the incubator, or to walk to one set of cabinets and find the correct drawer before opening it. Because of this, the term transit is used instead of walking, so that the entire movement time is included. All observations were collected on a smart phone (Apple iPhone 4S) using an application (Mangold International Obansys v1.1) and a customized behavioral checklist template.

Research Instruments

Information on nurse transit times and activity patterns was measured via direct observations by the researcher. Each of the four nurses was observed for a total of 12 hours, six hours one day, and six hours another. The day that the nurse was observed on depended on the presence of a neonate. This led to observations of nurses on different days of the week and non consecutive days. All nurses were observed between 12pm and 6pm. During each observation period, nurse activity patterns were operationalized as the time spent at each location and the number of times an activity occurred, and nurse transit times were operationalized as the time for movement between locations. Transit time includes any time that passed while a nurse moved between locations including the time that a nurse took to start getting out of their chair and then walk, or to walk and reach the incubator but to subsequently walk to an appropriate place around or behind the incubator, or to walk to one set of cabinets and find the correct drawer before opening it. Because of this, the term transit is used instead of walking, so that the entire movement time is included. All observations were collected on a smart phone (Apple iPhone 4S) using the an application (Mangold International Obansys v1.1) and a customized behavioral checklist template.

Figure 5. Obansys Home Screen

Figure 6. Obansys NICU Coding Description

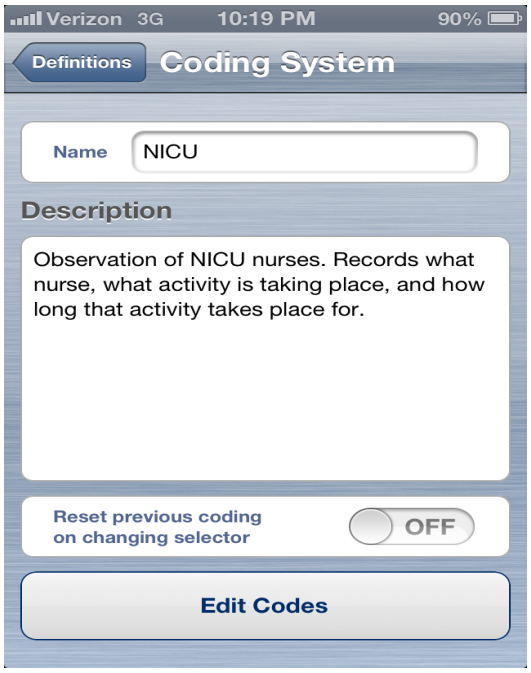


Figure 7. Example of Obansys Logging Set-Up Screen

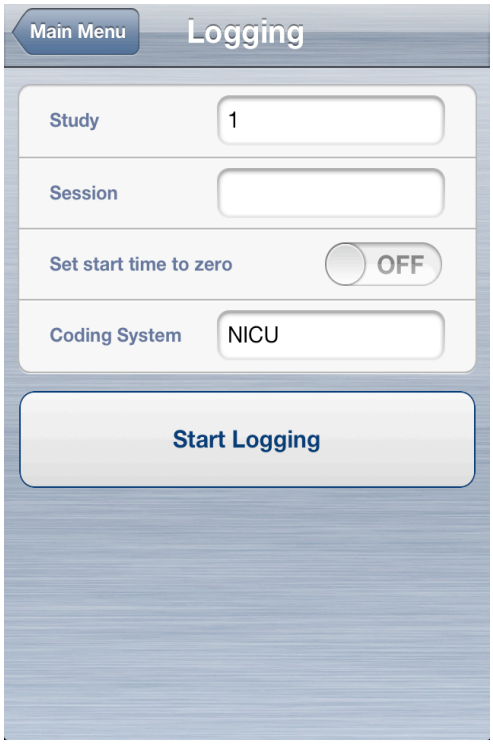
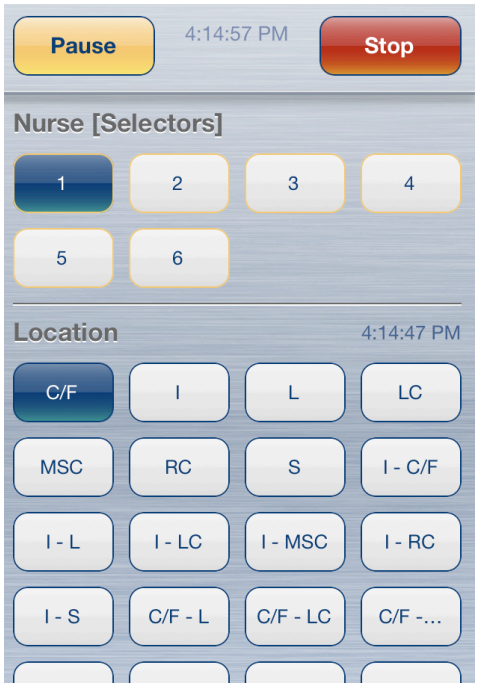


Figure 8. Example of Obansys Logging Screen



Prior to beginning observations the researcher conducted pre-study pilot observation sessions in order to create a final coding system that allowed for quick and comprehensive data recording and streamlined the observation process. Using the final coding system, the researcher observed one nurse at a time in the NICU. The date, time of day, and location of the newborn that the individual nurse was taking care of was recorded upon the researchers' arrival to the unit. The pre-study pilot observation sessions were also conducted in order to assess nurse activities and divide them into categories. The nurse activities in the NICU consist of time spent at the incubator caring for the neonate, time spent at the computer and filing station charting data for the neonate, time spent at the cabinets and medicine supply cart searching for supplies for caretaking, time spent at the sink or the hand sanitizers cleaning hands, and time spent in transit from one location to another.

These nurse activities were divided into three main categories, as used by Hobgood, Villani, & Quattlebaum (2005): direct patient care, indirect patient care, and nonnursing tasks. In the category of direct patient care is time nurses spend at the incubator. In the category of indirect patient care is time spent washing or sanitizing hands or time spent charting information. In the category of nonnursing tasks is time spent in transit from one location to another and time spent searching for and gathering supplies. More specifically, searching for and gathering supplies was coded as the time spent at either the left cabinets (non acute supplies), right cabinets (acute supplies), or medical supply cart (acute supplies).

Data Analysis

After each of the observation periods, the information was exported from the Obansys application to Microsoft Excel. In order to protect the privacy of each of the four nurses observed nurse names and personal information were removed from each data set. The total time spent for each movement was calculated, along with the total time spent on each activity for each observation period. For example, the total time a nurse spent in transit from the computer to the incubator was calculated, along with the total time the nurse spent in transit, regardless of the specific activity. The percentage of each activity time out of the total observation time was also calculated. In addition, the number of times that an event occurred was recorded in Obansys and totaled at the end of each observation period. Similarly to the time spent on each movement and activity, the number of times that a movement occurred was calculated along with the total number of times that an activity occurred for each observation period. For example, the number of times that a nurse moved from the computer to the incubator was calculated (movement), along with the total number of times that a nurse was in transit from one location to another (activity). The percentage of each activity count out of the total activity count was also calculated.

Differences in nurse activity times and counts were also evaluated. Nurse activity times were broken down into average activity time for each nurse, the standard deviation and the minimum and maximum activity times along with the nurse associated with those times. This information was also calculated for activity counts and average time per activity count.

Assumptions

There are several assumptions made in this study about the work environment of the NICU. First, the major assumption is that all nurse activity patterns and transit times will remain the same after the relocation to the pod room NICU as they were observed in the current open bay NICU. Within this assumption, it is assumed that there will be no changes in organizational policies such as care routine or staffing requirements, as any changes would most likely affect the work patterns of the nurses. There is also the assumption that there will be no changes in each individual nurses' activities, whether those changes be affected by the larger organizational structure or personal reason. These assumptions along with other limitations will be discussed further in the study limitations section.

CHAPTER 3: RESULTS

Based on the results below, a comparison was made between the current open bay NICU and the projected pod room NICU in order to determine the transition times per activity associated with each layout. Adjacency recommendations were then made according to two major goals: reduce the amount of time that nurses spend on any transitions from one location to another and reduce the number of times (counts) that nurses are required to transition from one location to another. These recommendations will be discussed following the results.

Compilation of Activity Durations and Counts

First, because nurse activities that occurred outside the NICU were not recorded, such as trips to the restroom and breaks, it is important to note that out of 2,880 minutes, nurses spent 2563 minutes and 46 seconds in the NICU. This indicates that on average, 89% of every six hour observation time was spent in the NICU.

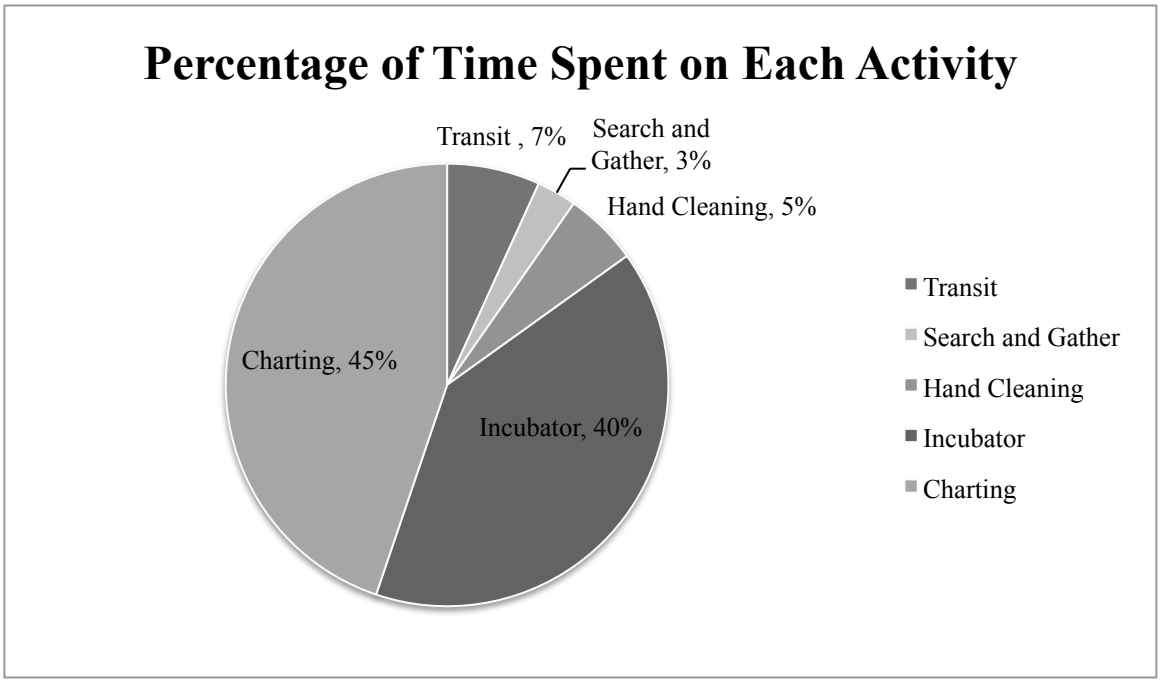
Figure 9 shows the duration in minutes and seconds of each movement and each activity (transit time, charting time, hand cleaning time, incubator time, search and gather time), the percentage of total time each movement and activity represents, the number of times each movement and activity occurred, and the percentage of total counts each movement and activity represents.

Figure 9. Compilation of Data from Observations

Location	Duration (minutes/seconds)	Percentage of Total Time	Count	Percentage of Total Count
C/F	1149.31	44.8344	203	16.0856
C/F - RC	0.58	0.0326	5	0.3962
RC	28.40	1.1179	20	1.5848
I-RC	10.17	0.3967	18	1.4263
I	1027.15	40.0689	313	24.8019
I- LC	23.51	0.9371	87	6.8938
LC	26.40	1.0499	50	3.962
I - S	42.55	1.6599	126	9.9842
S	138.31	5.3955	66	5.2298
I- CF	80.51	3.1607	292	23.1379
C/F - S	2.09	0.0915	12	0.9509
C/F - LC	2.15	0.0939	8	0.6339
C/F - MSC	4.37	0.1905	13	1.0301
MSC	17.53	0.6938	24	1.9017
I - MSC	5.16	0.2113	17	1.347
MSC - RC	1.07	0.0517	8	0.6339
Total	**2563.46**	**99.9900**	**1262**	**100**
Total transit time	174.16	6.7939	586	46.4342
Total charting time	1149.31	44.8344	203	16.0856
Total hand cleaning time	138.31	5.3955	66	5.2298
Total incubator time	1027.15	40.0689	313	24.8019
Total search/gather time	74.13	2.8919	94	7.4485
Total time	**2563.46**	**99.9900**	**1262**	**100**

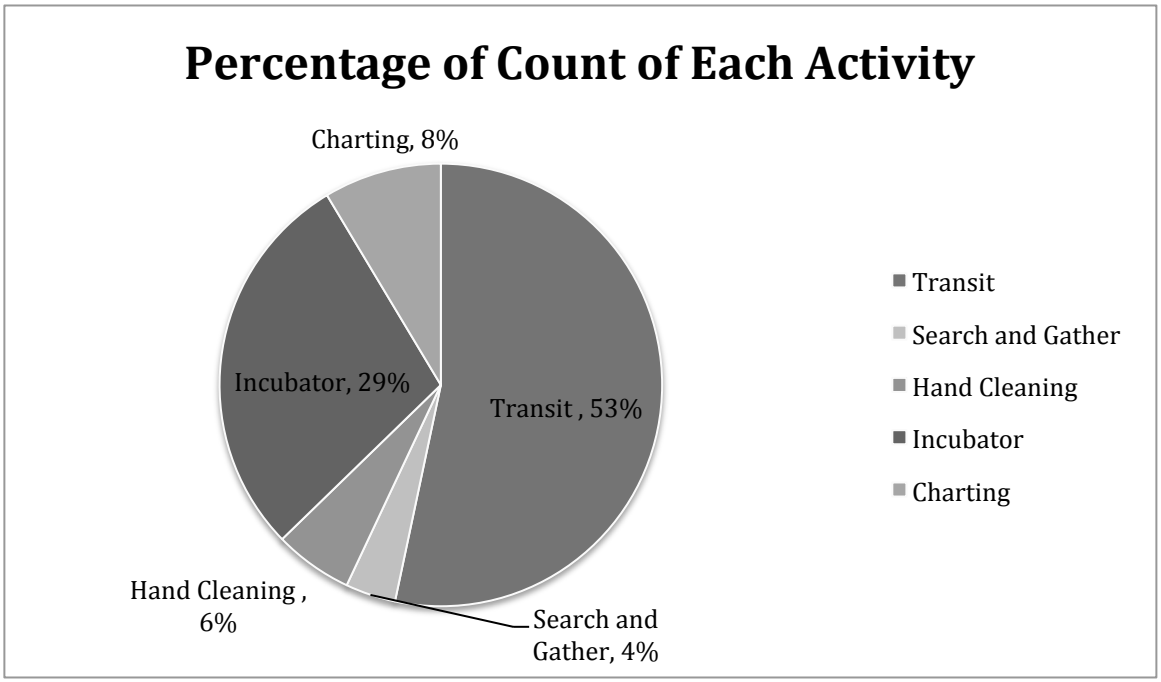
Out of a total of 48 hours of observation, nurses spent approximately 174 minutes in transit, 1149 minutes charting patient information, 138 minutes hand washing or hand sanitizing, 1027 minutes at the incubator caring for the neonate, and 74 minutes searching and gathering materials. Nurses spent 6.8% of the that total time in transit, 44.8% charting neonate information, 5.4% hand washing or hand sanitizing, 40.1% at the incubator caring for the neonate, and 2.9% searching and gathering supplies (Figure 10). This indicates that nurses spent 40.1% of the time on direct nursing tasks, 50.2% of the time on indirect nursing tasks, and 9.7% of the time on nonnursing tasks. Of the time spent in transit, transit between the incubator and the computer and filing accounted for the most time. Time spent in transit between the incubator and the computer and filing made up 3.2% of the total time of all movements, indicating that nurses traveled between the incubator and the computer and filing most often compared to all other transit movements.

Figure 10. Breakdown of Time of Nurse Activities



During the total 48 hours of observation, nurses were in transit between locations 586 times, were at the computer filing station charting neonate information 203 times, were at the sink and hand sanitizer 66 times, were at the incubator caring for the neonate 313 times, and were searching and gathering supplies 94 times. Approximately 46% of the activity counts were transit, 16% charting neonate information, 5% hand washing or hand sanitizing, 25% caring for the neonate at the incubator, and 8% searching and gathering supplies (Figure 11). This indicates that nurses traveled between locations because equipment and supplies were not located near one another based on task requirements, causing nurses to leave what they were doing at one location to transition to another location, and only allowing them to do one activity at a time with transit in between. Movements between the incubator and the computer and filing accounted for approximately 23% of the total counts of movement. Movements between the incubator and the sink accounted for approximately 10% of the total counts of movement.

Figure 11. Breakdown of Count of Nurse Activities



Comparison Between Nurses Observed

In addition, variations in time and counts spent on the five major activities (transit, search and gather, hand cleaning, patient care at the incubator, and charting) were calculated for each of the four nurses observed in the time motion study (Figure 12). Out of 720 minutes of observation for each nurse, Nurse 1 spent 613 minutes and 15 seconds in the NICU, Nurse 2 spent 681 minutes and 10 seconds in the NICU, Nurse 3 spent 637 minutes and 53 seconds in the NICU, and Nurse 4 spent 626 minutes and 49 seconds in the NICU.

Figure 12. Compilation of Individual Nurse Data

	Activity	Time (minutes/seconds)	Count	Time per Activity (minutes/seconds)
Nurse 1	Transit time	27.42	124	0.22
	Data Entry time	169.29	41	4.13
	Hand Cleaning time	65.09	15	4.34
	Incubator time	343.34	59	6.22
	Search/Gather time	7.31	9	1.2
Nurse 2	Transit time	53.33	144	0.37
	Data Entry time	310.31	46	7.15
	Hand Cleaning time	23.53	15	1.57
	Incubator time	267.53	81	3.3
	Search/Gather time	25.2	22	1.15
Nurse 3	Transit time	40.32	161	0.25
	Data Entry time	352.11	59	6.37
	Hand Cleaning time	26.17	19	1.36
	Incubator time	200.16	83	2.41
	Search/Gather time	19.07	32	1
Nurse 4	Transit time	45.06	157	0.29
	Data Entry time	318.3	57	5.58
	Hand Cleaning time	23.48	17	1.38
	Incubator time	215.32	90	2.39
	Search/Gather time	23.53	27	1.27

Each of the following comparisons are based on observations of each nurse for 12 hours. Figure 13 shows the breakdown of average time spent per activity, the standard deviation, and the minimum and maximum times for each activity along with the nurse associated with those times. This is further illustrated in Figure 16 below. Figure 14 shows the breakdown of average count per activity, the standard deviation, and the minimum and maximum counts for each activity along with the nurse associated with those counts. This is further illustrated in Figure 17 below. Figure 15 shows the breakdown of average time spent per movement, the standard deviation, and the minimum and maximum time per movement along with the nurse associated with those times. This is further illustrated in Figure 18 below.

For every 12 hours, nurses spent an average of 41 minutes and 53 seconds in transit (standard deviation = 11:23), an average of 287 minutes and 50 seconds entering data (standard deviation = 81:16), an average of 34 minutes and 57 seconds cleaning their hands (standard deviation 20:39), an average of 256 minutes and 59 seconds at the incubator caring for the neonate (standard deviation 65:03), and an average of 19 minutes and 18 seconds searching and gathering materials (standard deviation 8:07). (Figure 13)

Figure 13. Individual Nurse Time Data

Activity	Average Time Spent Per Activity (minutes:seconds)	Standard Deviation (minutes:seconds)	Minimum Time (minutes:seconds)	Maximum Time (minutes:seconds)
Transit	41:53	11:23	27:42 (Nurse 1)	53:33 (Nurse 2)
Data Entry	287:50	81:16	169:29 (Nurse 1)	352:11 (Nurse 3)
Hand Cleaning	34:57	20:39	23:48 (Nurse 4)	65:09 (Nurse 1)
Incubator	256:59	65:03	200:16 (Nurse 3)	343:34 (Nurse 1)
Search and gather	19:18	8:07	7:31 (Nurse 1)	25.20 (Nurse 2)

For every 12 hours, nurses spent an average of 146.50 times in transit (standard deviation = 16.66), an average of 50.75 times entering data (standard deviation = 8.66), an average of 16.60 times cleaning their hands (standard deviation = 1.92), an average of 78.25 times at the incubator caring for the neonate (standard deviation = 13.40), and an average of 22.50 times searching and gathering materials (standard deviation 9.88). (Figure 14)

Figure 14. Individual Nurse Count Data

Activity	Average Count	Standard Deviation	Minimum Count	Maximum Count
Transit	146.50	16.66	124 (Nurse 1)	161 (Nurse 3)
Data Entry	50.75	8.66	41 (Nurse 1)	59 (Nurse 3)
Hand Cleaning	16.50	1.92	15 (Nurse 1 and 2)	19 (Nurse 3)
Incubator	78.25	13.40	59 (Nurse 1)	90 (Nurse 4)
Search and gather	22.50	9.88	9 (Nurse 1)	32 (Nurse 3)

For every 12 hours, nurses spent an average of 28 seconds per transit count (standard deviation = 0:07, an average of 6 minutes and 21 seconds per data entry count (standard deviation = 1:29), an average of 2 minutes and 16 seconds per hand cleaning (standard deviation = 1:46), an average of 3 minutes and 58 seconds per incubator count (standard deviation = 2:21), and an average of 1 minute and 15 seconds per search and gather (standard deviation = 0:12). Both the average transit time per count and the average search and gather time per count had the lowest standard deviations, indicating higher consistency between nurses compared to other activities. This is of importance because transit time and search and gather time are the two activities within the category of nonnursing tasks, and therefore non-value added tasks. (Figure 15)

Figure 15. Individual Nurse Time Per Count Data

Activity	Average Time Per Count (minutes: seconds)	Standard Deviation (minutes:seconds)	Minimum Time Per Movement (minutes:seconds)	Maximum Time Per Count (minutes:seconds)
Transit	0:28	0:07	0:22 (Nurse 1)	0:37 (Nurse 2)
Data Entry	6:21	1:29	4:13 (Nurse 1)	7:15 (Nurse 2)
Hand Cleaning	2:16	1:46	1:36 (Nurse 3)	4:34 (Nurse 1)
Incubator	3:58	2:21	2:39 (Nurse 3)	6:22 (Nurse 1)
Search and gather	1:15	0:12	1:00 (Nurse 3)	1:27 (Nurse 4)

Figure 16 shows the comparison between activity times for nurses and provides a more in depth explanation of differences between activity times of the nurses. The most amount of time that a nurse spent in transit was 53 minutes and 33 seconds (Nurse 2), and the least amount of time was 27 minutes and 42 seconds (Nurse 1). The most amount of time that a nurse spent on searching and gathering supplies was 25 minutes and 20 seconds (Nurse 2), and the least amount of time was 7 minutes and 31 seconds (Nurse 1). The most amount of time that a nurse spent on hand cleaning was 65 minutes and 9 seconds (Nurse 1), and the least amount of time was 23 minutes and 48 seconds (Nurse 4). The most amount of time that a nurse spent on patient care at the incubator was 343 minutes and 34 seconds (Nurse 1), and the least amount of time was 200 minutes and 16 seconds (Nurse 3). Finally, the most amount of time a nurse spent on charting was 53 minutes and 33 seconds (Nurse 2), and the least amount of time was 27 minutes and 42 seconds (Nurse 1). These results indicate that Nurse 1 is the most different from the other three nurses. While the time at the incubator for the other three nurses ranged from 200 minutes and 16 seconds to 267 minutes and 53 seconds, Nurse 1 spent 343 minutes and 34 seconds at the

incubator. This pattern, where Nurse 1 is an outlier in terms of activity times, can be noted for the other activities as well. While the time spent hand cleaning for the other three nurses ranged from 23 minutes and 48 seconds to 26 minutes and 17 seconds, Nurse 1 spent 65 minutes and 9 seconds cleaning her hands. While the time entering data for the other three nurses ranged from 310 minutes and 31 seconds to 352 minutes and 11 seconds, Nurse 1 spent only 169 minutes and 29 seconds entering data. While the time searching and gathering materials for the other three nurses ranged from 19 minutes and 7 seconds to 25 minutes and 20 seconds, Nurse 1 only spent 7 minutes and 31 seconds searching and gathering materials. While the time in transit for the other three nurses ranged from 40 minutes and 32 seconds to 53 minutes and 33 seconds, Nurse 1 only spent 27 minutes and 42 seconds in transit. In summary, Nurse 1 spent less time entering data, searching and gathering supplies, and in transit, and more time cleaning her hands and caretaking at the incubator. In addition, Nurse 1 spent the least amount of time total in the NICU overall.

Figure 16. Variations in Time Spent on Activities Among the Four Nurses Observed

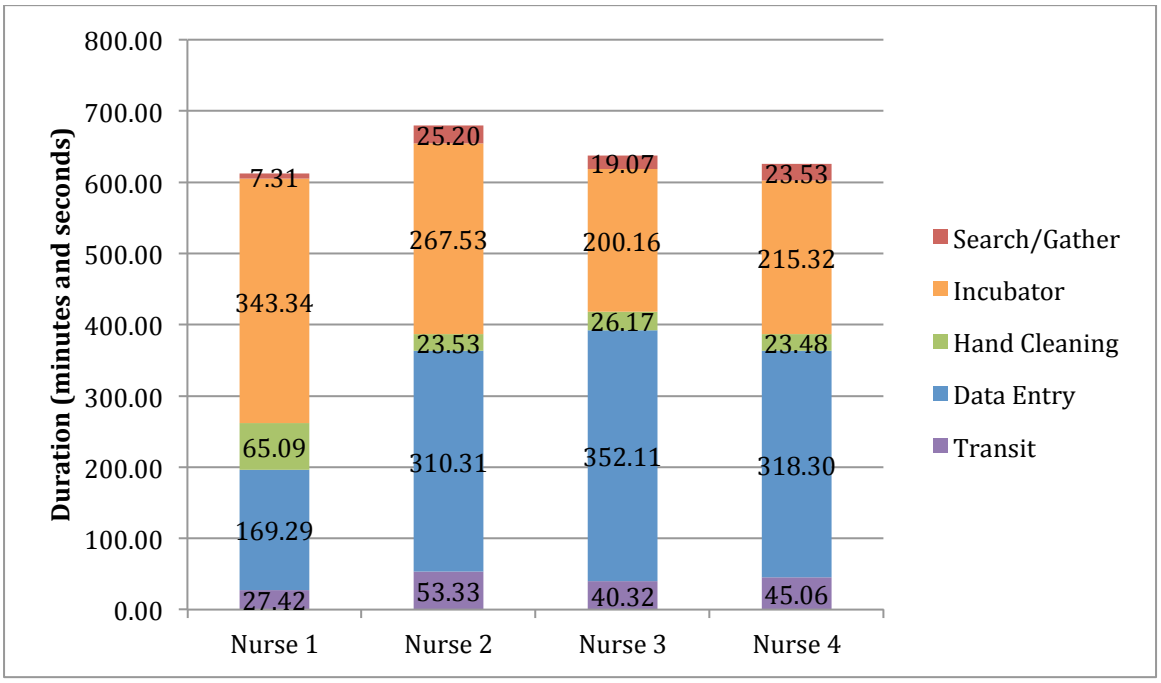
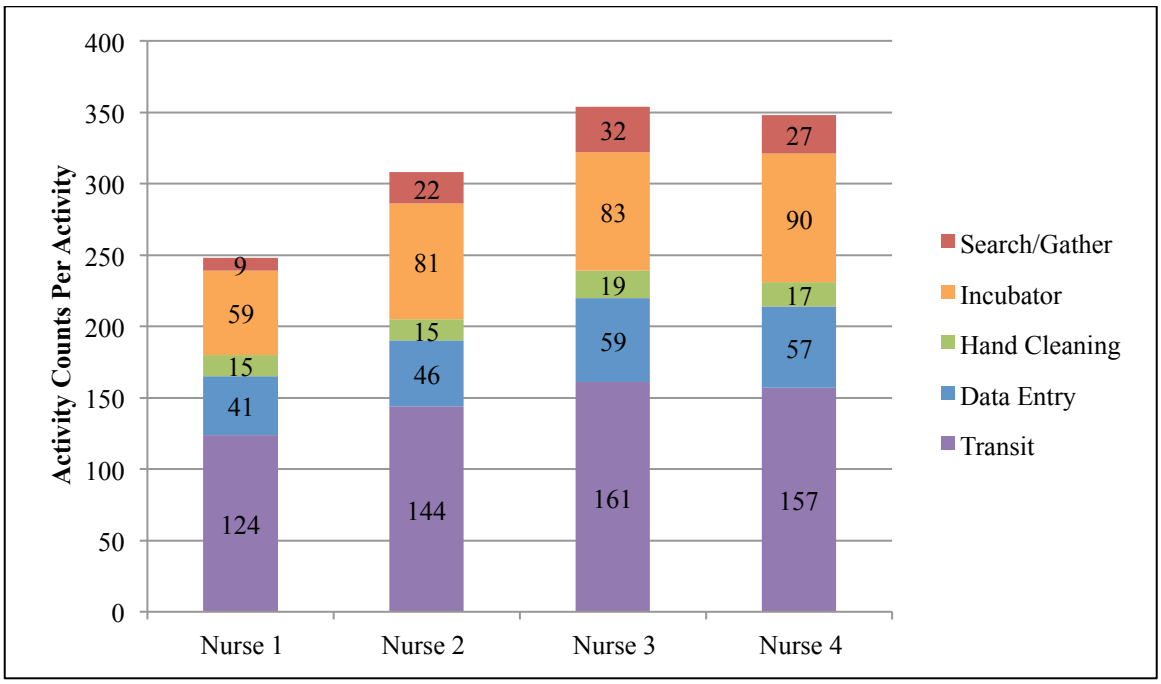


Figure 17 shows the comparison between activity counts for nurses and provides a more in depth explanation of differences between activity counts of the nurses. The most number of times that a nurse was in transit from one location to another was 161 (Nurse 3), and the least amount was 124 (Nurse 1). The most number of times that a nurse searched and gathered supplies was 32 (Nurse 3), and the least amount was 9 (Nurse 1). The most number of times that a nurse cleaned their hands was 19 (Nurse 3) and the least amount was 15 (Nurse 1 and Nurse 2). The most number of times that a nurse was at the incubator was 90 (Nurse 4), and the least amount was 59 (Nurse 1). Finally, the most number of times that a nurse charted information was 59 (Nurse 3), and the least was 41 (Nurse 1). This pattern, where Nurse 1 is an outlier in terms of activity counts can be noted for searching and gathering materials, caretaking at the incubator, charting, and in transit from one location to another. While the number of times the other three nurses searched and gathered materials ranged from 22 to 32 times, Nurse 1 only searched and

gathered 9 times. While the number of times the other three nurses went to the incubator to care for the neonate ranged from 81 to 90 times, Nurse 1 only went to the incubator 59 times. While the number of times the other three nurses went to the computer to chart ranged from 46 to 59, Nurse 1 only went to the computer 41 times. And finally, while the number of times the other three nurses were in transit from one place to another ranged from 144 to 161 times, Nurse 1 was only in transit 124 times. These results may be the effect of Nurse 1 spending less time in the NICU compared to the other three nurses, leading to fewer activity counts total.

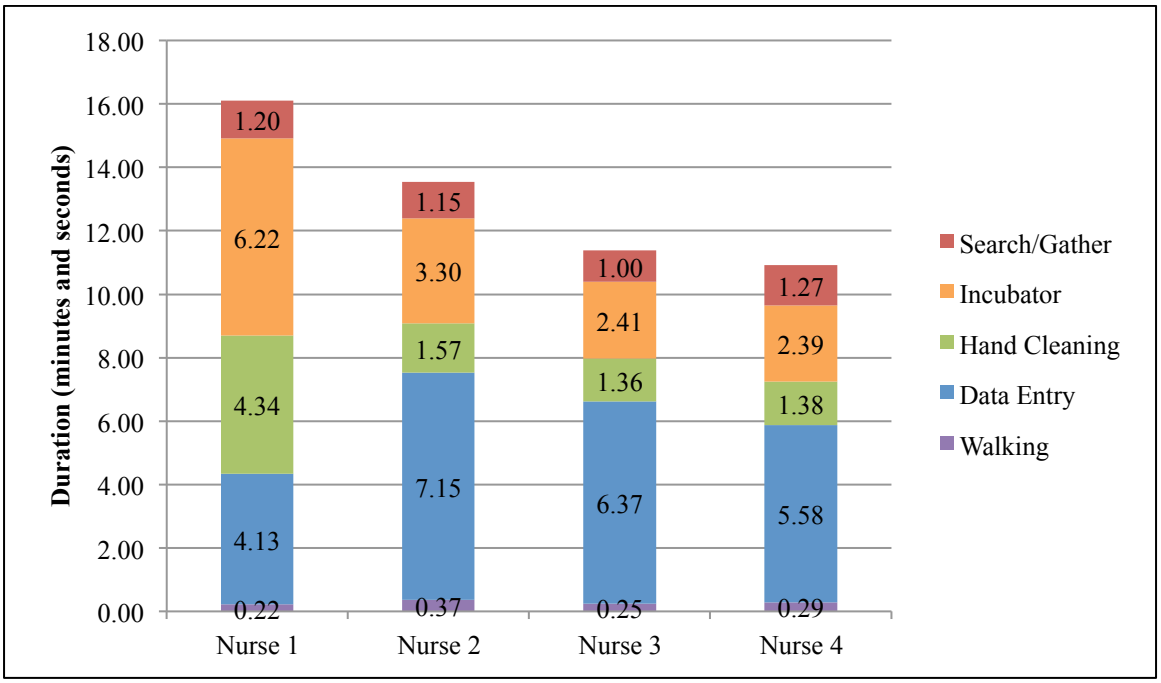
Figure 17. Variations in Counts of Activities Among the Four Nurses Observed



Combining the data above, Figure 18 shows the average amount of time each nurse spent on one given activity in the NICU and a more in depth explanation of the differences between activity times per count of the nurses. Nurse activity count was divided by nurse time for that activity in order to reach the time per activity for a given activity. For example, Nurse 1 spent 27 minutes and 42 seconds time total in transit, and was in transit to and from locations 124 times,

resulting in an average time for each transition of 22 seconds. There are a few notable patterns that stand out from this analysis. All of the four nurses spent approximately the same amount of time per search and gather and per transition. Nurse 1 spent less time per data entry (4 minutes and 13 seconds) than the other three nurses (5 minutes and 58 seconds to 7 minutes and 15 seconds). In contrast, Nurse 1 spent more time per hand cleaning (4 minutes and 34 seconds) than the other three nurses (1 minutes and 36 seconds to 1 minutes and 57 seconds), and more time per incubator time (6 minutes and 22 seconds) than the other three nurses (2 minute and 39 seconds to 3 minutes and 30 seconds).

Figure 18. Average Time Spent on a Single Activity Among the Four Nurses Observed



Comparison Between Open Bay NICU Transit Times and Counts and Pod Room NICU Transit Times and Counts

The observed movements from one location to another, and the nurse transit times and average transit speeds in the open bay layout were projected on to the proposed pod room layout based on knowledge of activity patterns and spatial information in the proposed pod room layout. The spatial information included information about the size of the space, distance between equipment, and the location of equipment.

The average length of transit time spent on each specific activity, such as moving from the incubator to the computer, was compared for the current and proposed layouts based on distance in feet between the incubator to the computer in one unit and the distance in feet between them in another. This information on transit times in the current space and transit times in the proposed space allowed the investigator to determine, given the same nurse activities, which NICU layout is associated with shorter transit times, and where deficiencies may exist in each layout.

In Figure 16, the "Time in Current Open Bay Layout" is defined as the average time that one given transition takes in the NICU and was calculated as the total transit time for each transition divided by the number of times that transition occurred (count). Taking the time for each transition in the current open bay layout, the average foot per second was calculated by dividing the distance between the two locations by the time for that transition. (Figure 17)

Keeping in mind the transit time accounts for activities such as movement around equipment, picking the correct drawer to go to, or getting out of the chair at the computer filing station, the average feet per second is different for each activity, even if the distance is the same.

Additionally, while there is only one location for each piece of equipment in the open bay layout, the pod room layout has multiples of some pieces of equipment, including 3 incubators, 3 medical supply carts, and 3 wall mounted computer stations. The result of having three different pod stations within one large room is that the distance between the equipment in the pod station and the sink and the left and right cabinets (which are located in only one location in the room) changes depending on the specific pod station where care is taking place. In order to account for the effects of this situation on transit times, a minimum time for a transit path and a maximum time for a transit path was projected for necessary movements. The "Minimum Time in Proposed Pod Room Layout" and the "Maximum Time in the Proposed Pod Room Layout" was calculated with the knowledge of the minimum and maximum distance in feet between one location and another and the average feet per second. The minimum refers to the distances between the pod that is closest to the single sink and wall of cabinets, and the maximum refers to the distances between the pod that is furthest from the sink and cabinets. If there were no minimum or maximum times due to the layout of certain pieces of equipment, the minimum and maximum times were kept the same. (Figure 19 and 20)

The analysis indicates that the adjacencies in the pod room layout address lowering transit time for transitions from the incubator to the computer (28 seconds versus 5 seconds), the incubator to the medical supply cart (30 seconds versus 12 seconds), and the computer to the medical supply cart (33 seconds versus 7 seconds), regardless of the pod where care takes place. Conversely, the analysis indicates that the adjacencies in the open bay layout address lowering transit time for transitions from the incubator to the sink (34 seconds versus between 42 seconds and 1 minutes and 57 seconds). (Figure 19 and 20)

The pod where the care takes place has immense implications for which layout offers lower transit times. For all other transitions the open bay layout allowed for approximately the same time or more as the minimums for the pod room layout, but less than the maximums in the pod room layout. For the transition between the incubator and the right cabinet in the open bay the average time is 57 seconds, but for the pod room layout the average time ranges from 39 seconds to 2 minutes and 17 seconds, depending on the pod where care takes place. For the transition between the incubator and the left cabinet in the open bay the time is 27 seconds, but for the pod room layout the time ranges from 27 seconds to 1 minute and 40 seconds. For the transition between the computer and filing and the sink in the open bay the time is 17 seconds, but for the pod room layout the time ranges from 17 seconds to 39 seconds. For the transition between the computer filing and the left cabinet in the open bay the time is 26 seconds, but for the pod room layout the time ranges from 22 seconds to 59 seconds. For the transition between the computer filing and the right cabinet in the open bay the time is 12 seconds, but for the pod room layout the time ranges from 10 seconds to 28 seconds. Finally, for the transition between the right cabinet and the medical supply cart in the open bay the time is 13 seconds, but for the pod room layout the time ranges from 13 seconds to 57 seconds. Each of the results above indicate that adjustments could be made in both the open bay and the pod room in order to lower nurse transit time to as low of a time as possible. (Figure 19 and 20)

Figure 19. Average Time Each Transition Takes For Open Bay and Pod Room Layouts

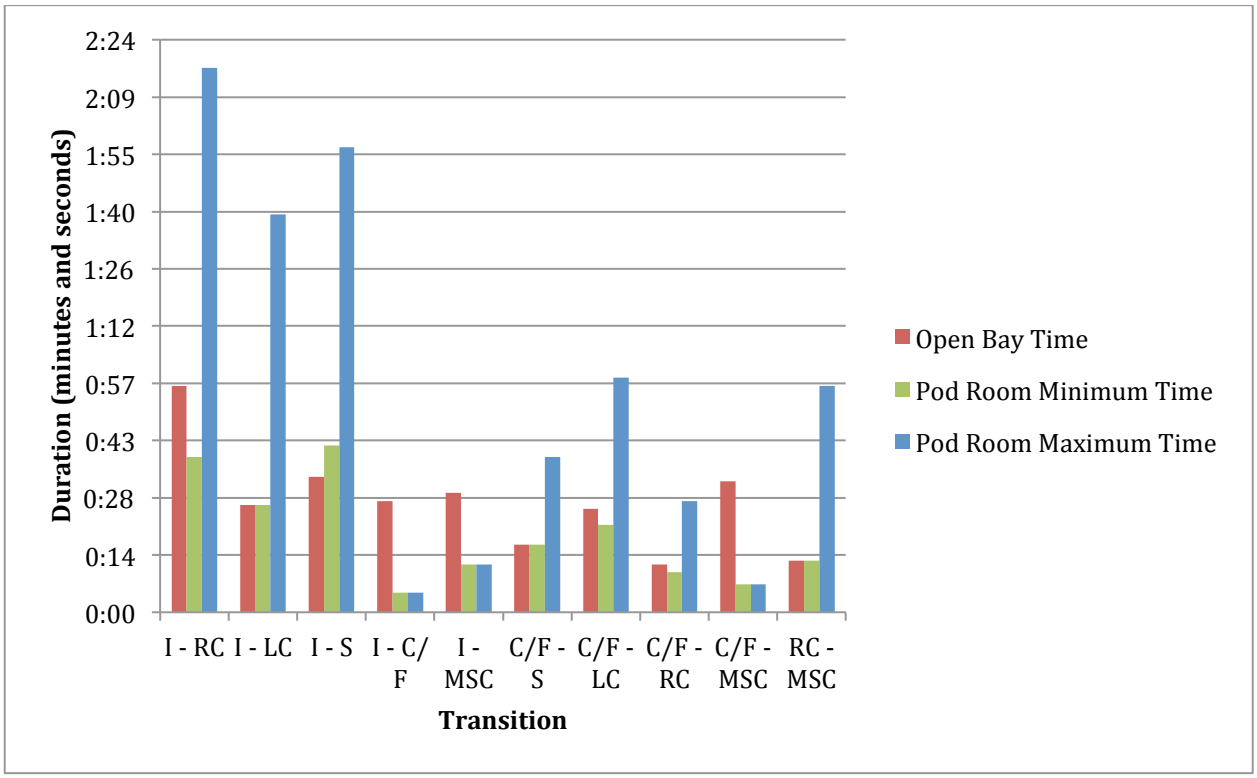


Figure 20. Average Time Each Transition Takes For Open Bay and Pod Room Layouts and Average Feet Per Second Traveled for Each Transition

Transition	Average Time in Current Open Bay Layout (minutes:seconds)	Average Feet Per Second	Minimum Time in Proposed Pod Room Layout Depending on Pod Used (minutes:seconds)	Maximum Time in Proposed Pod Room Layout Depending on Pod Used (minutes:seconds)
I - RC	0:57	.11	0:39	2:17
I - LC	0:27	.15	0:27	1:40
I - S	0:34	.12	0:42	1:57
I – C/F	0:28	.39	0:05	0:05
I - MSC	0:30	.17	0:12	0:12
C/F - S	0:17	.41	0:17	0:39
C/F - LC	0:26	.27	0:22	0:59
C/F - RC	0:12	.58	0:10	0:28
C/F - MSC	0:33	.30	0:07	0:07
RC - MSC	0:13	.23	0:13	0:57

Adjacency Recommendations

From observations and data analysis, it is clear that the adjacencies between different pieces of equipment and supplies in the open bay NICU are not ideal. The adjacency recommendations below are based on the observed nurse transit times and activity patterns and aim to address two major goals:

1. Reduce the time that nurses spend on any transitions from one location to another.

2. Reduce the number of times (counts) that nurses are required to transition from one location to another, thereby decreasing interruptions in care.

In order to maximize nurse time and energy, the recommendations address issues with adjacency that were uncovered during the time motion study. Each of the recommendations could be made

to an open bay NICU, or could be addressed in a pod room NICU layout or single patient room NICU layout, depending on the monetary and physical space resources of the unit and of the hospital as a whole. Each of the following recommendations would help achieve minimum transit times in the NICU, and address the goal of completely eliminating significant transit counts by combining critical tools together to create a zone of care.

It is important to note that there may be activities that require movements outside of the basic zone of care recommended above, including, for example, movements required to transport the neonate in and out of the NICU if needed, or movements required to leave the NICU to go to the restroom or cafeteria.

1. **One computer and filing system should be placed on a movable cart next to each incubator or on a wall mounted unit next to each incubator.**

   The results of the study indicate that nurse transition between the computer and filing system and the incubator accounted for a total of approximately 3.2% of the total shift time and approximately 23.1% of the total shift counts. In the open bay layout, the computer and filing system and the incubator are not located close to one another (See Figure 3). In the pod room layout however, the computer and filing system is located right to the left of the incubator (See Figure 4). As a result of this, the time motion study concluded that the average time for each transition between the computer filing and the incubator was 28 seconds. The projections for the pod room, which was based on square footages, concluded that the average time for each transition between the computer filing and the incubator was 5 seconds, dramatically lower that the open bay. In summary, locating a computer and filing system adjacent to each of the incubators in a NICU,

whether it be an open bay NICU or a pod room NICU, would both reduce the time that it takes to transition between the two activities and would reduce the number of transitions between the two if transition time could be eliminated entirely.

2. **One sink should be placed on one of the walls next to each incubator.**

   The results of the study indicate that nurse transition to and from the sink from any of the locations in the NICU accounted for a total of approximately 1.8% of the total shift time and approximately 10% of the total shift counts. In order to eliminate these times and counts completely, a sink could be placed on one of the walls next to each incubator in either the open bay or pod room NICU. Careful consideration would have to take place in order to eliminate contamination of the neonate or supplies during nurse hand washing. In the open bay layout, the sink is placed in one location in the room along a wall of cabinets (See Figure 3). The same can be found in the pod room NICU, where the sink is placed on the right most wall in the space between cabinets (See Figure 4). Locating a sink adjacent to the incubator would decrease and ideally eliminate transit time and counts associated with transitioning two and from the sink for hand washing activities.

3. **One supply cart equipped with at most two multiples of all acute supplies, non acute supplies, and medical supply cart supplies should be placed next to each incubator on the floor.**

   The results of the study indicate that nurses transition to and from the acute supplies, to and from the non acute supplies, and two and from the medical supply cart approximately 1.9% of the total shift time and approximately 12.4% of the total shift counts. In the open bay NICU, the acute supplies are located in a set of cabinets along the right wall, the non

acute supplies are located in a set of cabinets along the left wall, and the medical supply cart is located in a corner of the room adjacent to the acute supply cabinets (See Figure 3). In the pod room NICU, the acute supplies and non acute supplies are located in a set of cabinets along the right side of the space, and the medical supply carts are located adjacent to each of the incubators (See Figure 4). For the pod room NICU, the number of medical supply carts has multiplied from one cart to three. It is recommended that the medical supply carts stay where they are located in the pod room NICU, but that they be expanded in order to increase the storage capacity. Along with additional storage capacity, the medical supply cart should be reorganized to only hold a small number of each supply. Currently, the medical supply cart holds a large number of each supply because it supplies the equipment for the entire open bay. Increased storage space in the medical supply cart would allow for the addition of acute and non acute supplies in the cart and create a single storage unit for all of the supplies. In turn, the zone of care surrounding the incubator would be more complete and eliminate transit time and counts to and from the acute supplies, to and from the non acute supplies, and to and from the medical supply cart, decreasing unnecessary interruptions in care. Unfortunately, each supply cart would have to be stocked on a regular basis so that all supplies are available for the nurses when needed, posing problems with the possibility of additional staffing needed for the equipment and supply departments within a hospital.

Chapter 5: DISCUSSION

The results showed that NICU nurses spent 89% of their work time in the NICU, and when in the NICU they spent 44.8% of the time on charting neonate information, 40.1% of the time on direct patient care at the incubator, 6.8% of the time in transit between NICU location, 5.4% of the time on washing or sanitizing their hands, and 2.9% of the time searching for supplies. This indicates that 40.1 % of the time was spent on direct patient care, 50.2% of the time was spent on indirect patient care, and 9.7% of the time was spent on nonnursing tasks, including time in transit and time searching for supplies.

In comparing the transit times in the open bay NICU layout and the pod room NICU layout, it was found that each layout has it's own unique layout deficiencies, and the proposed pod room layout will not necessarily improve efficiency. The proposed layout lowers transit times for movements from the incubator to the computer, the incubator to the medical supply cart, and the computer to the medical supply cart. However, the open bay layout lowers transit times for movements from the incubator to the sink. All other transit times depend on the specific pod unit within the pod layout where care is taking place.

These findings are important because they give a more complete picture of the activity time and counts of nurses in the NICU. First, the breakdown of time and count information indicates that nurses spend a significant amount of time on indirect patient care. While less time was spent on nonnursing tasks than direct and indirect patient care, it is important to note that approximately 10% of the time was spent on nonnursing tasks. Ideally, the nonnursing task time would be as minimal as possible, leading to the importance of the layout of the NICU in determining transit and searching and gathering times for nurses. Second, the comparison

between the open bay NICU and pod room NICU indicates that the pod room NICU is not always associated with shorter nurse transit times as it was predicted. If more than one neonate is present in the proposed pod room NICU, the transit times for nurses increase drastically across all but three movements, as nurses will be forced to travel longer distances because they are caring for a neonate in a pod further from the main cabinets and sink in the space. As a result, without any changes made to the pod room layout, the results suggest that the open bay NICU is associated with shorter transit times if there is more than one neonate at a time in the NICU. However, if the pod room layout is adjusted slightly to incorporate more equipment and supplies within each pod, the pod room layout would be associated with shorter transit times. These adjustments include the addition a washing station and a movable cart with all both acute, non acute, and medical cart supplies to each pod. As fiscally conscious trends in the healthcare industry continue, future NICUs may stray from the private room layout and instead provide a pod room layout with similar amenities with fewer construction and operational costs than the private room model.

Up to this point, there has been a limited amount of research conducted that measures the nurse transit times in an open bay NICU layout as they pertain to the layout of the NICU and the physical location of materials and equipment as they compare to a pod room NICU layout. There is a large body of research analyzing the differences in nurse walking times and work patterns in open bay NICU layouts and in private patient room NICU layouts, but none regarding pod room NICU layouts. Despite this, the findings of the study are parallel to literature in the healthcare field outside of the NICU. In a study of hospital residents, Melgar, et al. (2000), found that direct patient contact with residents accounted for 43.1% of the resident's time. This is similar to direct nurse contact with neonates in the NICU from this study, which accounted for 40.1% of the time.

In addition, Lurie et al. (1989), found that house officers spent more time charting than on direct patient evaluation, similar to our findings that NICU nurses spent more time charting (44.8%) than on direct patient care (40.1%). In terms of searching and gathering times, Potter et al. (2005) found that nurses spend 5% of their shift searching for supplies, and walked from one location to another an average of 13 times per hour. Similarly, nurses in the NICU spent approximately 3% of their time searching for supplies and walked from one location to another an average of 12 times an hour.

Contrasting evidence from literature also exposed itself during analysis. Burgio et al. (1990) found that nurses spent 28.9% of their time walking during one shift, and that out of all of the activities during the day, walking from one location to another was the second most frequent activity. In addition, Jydstrup & Gross (1966) found that nurses spent 17% of their time walking during a work shift. However, our results found that nurses only spent 6.8% of their time in transit during one shift.

Research in the NICU specifically will contribute to broadening the knowledge that exists on nurse walking times in different units of the hospital. As nurse walking time and distances increase, so do the physical and work related demands on nurses (Hendrich, 2008). Physical features of hospital facilities can impede efficient nurse work and decrease time spent on direct patient care, resulting in a decrease patient safety (Cochrane et al., 2012). It is crucial to build on information from research on layouts within a hospital or healthcare facility as well as research on nurse walking times in order to understanding the interaction between the two.

Research on NICU nurses is also of importance because there is a nursing shortage in the United States, partially due to the large number of nursing professionals who are retiring as a

result of aging and burnout from stress on the job (Jennings, 2008). As Braithwaite (2008) explains, the NICU environment is highly specialized and as a result quality in nurse care requires a precise level of attention and detail. NICU nurses experience psychological and physical stress leading to absenteeism, low morale, and mental fatigue and exhaustion. (Braithwaite, 2008) Creating a more supportive working environment that reduces physical and mental fatigue might help reduce burnout on the job, and extend the average age of retirement for nurses. Waste in the environment that contributes to less supportive working environments can be identified by using lean processing (Fine et al, 2009). In the case of the NICU layout, waste of unnecessary motion was of focus of the study. The time spent searching for supplies and time in transit are examples of wasted time in the NICU.

It is important to note that in the acute care setting of the NICU, externalities for productivity exist with the decrease of nurse transit time. Frequent short interruptions in task are dangerous in acute care environments (Trafton & Monk, 2007) where care, though often provided intermittently, must occur in a timely, focused manner. Decreasing trips around the NICU that are needed to provide immediate care also decreases the frequent short interruptions in task caused by transit. In addition, decreasing the time and frequency of these trips increases the time that can be spent on other tasks. Other tasks or activities are not just directly related to patient care at the bedside, but can also be related to care tasks including for example, nurse communication with staff and physicians. Becker (2007) suggests that communication is an important aspect of providing high quality care in healthcare and that face-to-face communication with colleagues in necessary. Thus, increasing the time available for communication could improve quality of care.

The larger purpose of this study is to help develop a database of information on creating more efficient hospital environments. While the majority of healthcare environment research is focused on patient outcomes, there is a growing need for research focused on staff outcomes as well. As stated above, as nurse walking times increase in a given work shift, nurse comfort and productivity decrease (Hendrich, 2008). The more time that nurses spend in transit, the less time they have available for any other tasks related directly or indirectly to patient care. In addition, the more that nurses transition between spaces and activities, the more time patient care is interrupted. Layout therefore has immense implications for improving patient care in the hospital setting. In developing information on efficient layouts in the NICU, the database of information on the effects of the hospital environment on staff working patterns and efficiency will expand. Such information could then be used to inform future design decisions made by hospital administrators and healthcare architects, designers, and policy makers.

Study Limitations

One limitation of the study is the variability of activity patterns among nurses. There were slight differences in time spent performing different activities between the four nurses observed, resulting in data that is the average between all of the nurses. These differences may have been a result of variations in training. Each nurse received their training at a different university, in separate NICUs, possibly leading to disparities in the length of time a nurse spends charting data or the length of time that a nurse spends at the incubator. In addition, although the nurse's job descriptions are the same, nurse age and number of years working in a NICU may have also lead to the differences observed.

Another limitation of the study is the small sample size of nurses that were observed. Though the nurses were representative of a large range of experience levels and ages, there were a small number of nurses observed and there may be certain characteristics of these nurses that influenced the time and activity patterns recorded. Because the NICU is a highly regulated environment where caretaking for the neonates is organized and on a very specific time sequence, there is little room for nurse discrepancies in care, but there may be differences that exist despite the controlled care setting.

Additionally, nurses were originally going to be interviewed by the Principle Investigator following the completion of 12 hours of observation time, however, the interviews could not be completed because of large scheduling difficulties. While working a 12 hour shift, nurses have patients to care to the entire time, especially in acute care settings such as the NICU where neonates must be monitored at all times. Also, nurses often only take very short breaks and are too tired once their shift is completed to stay at the hospital longer. Interviews may have offered insight into perceptions of activity patterns compared to actual activity patterns, or insight into major layout issues as seen through the eyes of the nurse, but they were not able to be completed. Questionnaires are recommended for further research as they are faster and require less of a time commitment and less coordination from the nurse.

Finally, it is important to note that one of the assumptions of the study is also inherently a limitation of the study. The study assumes that nurse work and activity patterns will remain the same in the proposed pod room layout as they are in the current open bay layout. In conjunction with this, it is assumed that there will be no major changes in care provided and no major changes in organizational structure in the NICU, as that would cause changes in any observed

work and activity patterns in the new space. An example of an organizational change that would affect nurse transit times would be a new requirement that increases the staffing requirements for the NICU despite having the same number of neonates. In the current NICU, one nurse is assigned to one neonate, but if the total number of nurses per neonate were to increase the total nursing time to run the pod unit would increase as well.

Another aspect of unchanged work and activity patterns is the assumption that changes in the built environment that will occur as a result of the move to a new unit will not affect nurses. Beyond the layout, there are a number of factors in the environment that may have an effect on nurse activity patterns. These include elements of the ambient environment such as lighting and noise levels. Different types of lighting or different lighting levels may not change the activity patterns, but may affect transit times, causing differences between the original nurse work and activity times and the future nurse work and activity times.

Conclusion

These findings indicate that the layout of a hospital setting can affect the length and number of times that employees spend performing activities directly or indirectly related to patient care. Nurses in the NICU spend a significant amount of time on direct patient care and charting, but there is also time is taken away from these activities and others for axillary tasks such as walking and searching and gathering materials. The open bay NICU layout and the pod room NICU layout provide different transit times given the same nurse work and activity patterns. In the pod room NICU these times vary drastically depending on the number of neonates in the NICU at one time. In conclusion, demanding healthcare settings such as the acute care setting of the NICU should have environments that provide support to caregivers and do not

hinder care. Creating a more complete zone of care in the physical environment may help to reduce unnecessary interruptions in patient care and lower non value added time for nurse care.

APPENDIX

Appendix 1. Nurse Consent Form

I am asking you to participate in a research study. This form is designed to give you information about this study. I will describe this study to you and answer any of your questions.

Project Title: Nurse Work Patterns – Maximizing Efficiency in the Neonatal Intensive Care Unit (NICU)

Principal Investigator: Meg Taylor,
Department of Design and Environmental Analysis, Cornell University
Email: met84@cornell.edu
Phone: (607) 229-4623

Faculty Advisor: Alan Hedge,
Department of Design and Environmental Analysis, Cornell University.
Email: ah29@cornell.edu
Phone: (607) 255-1957

What the study is about
The purpose of this research is to determine the nurse walking times and activity patterns for the current layout of the NICU, and for the proposed layout of the NICU (which begins construction in December of 2012). Through observations, nurse walking times and activities will be recorded in hopes of finding which layout is associated with less nurse walking time. The overall goal is to increase efficiency and nurse comfort in the NICU.

What we will ask you to do
I will ask you to allow me to observe you during a maximum of twelve hours in the NICU. I will record the time that it takes you to walk from one place to another and the activity you do that requires the walk. You will not be asked to do anything outside of performing your regular duties during a shift. The time commitment for observation will be a maximum of twelve hours.

Risks and discomforts
I do not anticipate any risks from participating in this research.

Benefits
The direct benefit of participation in the research is the understanding, after data analysis, of what the transition from the current NICU to the proposed NICU will mean in terms of your daily walking times and activity patterns.

The expected benefits to society include the development of a larger database of information on creating more efficient hospitals. While the majority of healthcare design research is focused on patient outcomes, there is a need for a focus on nurse outcomes as well. As nurse walking times increase, nurse comfort decreases, therefore the goal of this study is to determine which layout might reduce nurse walking times. Information from this study may benefit people who design and implement new or renovated NICUs now and in the future.

Payment for participation
There is no payment for taking part in the study.

Privacy/Confidentiality
Your privacy will be protected throughout the course of this study. You will be associated with a number, so your name will not be recorded during the observations, interviews, or analysis and write-up. This is ensured in order to provide you with confidentiality. In addition, I will not ask you to provide any personal information, such as your age or the number of years you have been working.

Taking part is voluntary
Commitment to a maximum of twelve hours of observation is required for participation. However, your involvement and commitment to this observation period and interview is voluntary and you may refuse to participate before the study begins**.**

If you have questions
The main researcher conducting this study is Meg Taylor, a graduate student at Cornell University. Please ask any questions you have now. If you have questions later, you may contact Meg Taylor at met84@cornell.edu or at (607) 229-4623. If you have any questions or concerns regarding your rights as a subject in this study, you may contact the Institutional Review Board (IRB) for Human Participants at 607-255-5138 or access their website at http://www.irb.cornell.edu. You may also report your concerns or complaints anonymously through Ethicspoint online at www.hotline.cornell.edu or by calling toll free at 1-866-293-3077. Ethicspoint is an independent organization that serves as a liaison between the University and the person bringing the complaint so that anonymity can be ensured.

You will be given a copy of this form to keep for your records.

Statement of Consent
I have read the above information, and have received answers to any questions I asked. I consent to take part in the study.

Your Signature_____ Date_____

Your Name (printed)_____

Signature of person obtaining consent_____ Date_____

Printed name of person obtaining consent_____

This consent form will be kept by the researcher for at least five years beyond the end of the study.

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