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Modeling the workflow of one primary care physician-nurse team.

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MODELING THE WORKFLOW OF ONE PRIMARY CARE PHYSICIAN – NURSE TEAM

By

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ABSTRACT

Primary care has been identified as a vital part of the healthcare system in the U.S., and one that operates in a challenging, unique environment. Primary care sees a wide variety of patients and is undergoing a series of major transformations simultaneously. As a result, primary care would greatly benefit from a systemic approach to the analysis of its workflows. Discrete-event simulation has been identified as a good tool to evaluate complex healthcare systems. The existing primary care DES models focus on the physician. Also, those models are limited in (a) their usefulness to produce generic models that can easily and quickly be customized and (b) the analysis of the specific tasks performed to treat a patient. Hence, a research idea was developed to address these limitations, which led to a progressive multi-part study developing the necessary components to model a primary clinic. The study was constructed to allow each progressive study to build on the previous.

The first part of the study developed a new approach to address those limitations: modeling a primary care clinic from the viewpoint that the physician is the entity that moves through the system. This approach was implemented based on observational data and a standardized primary care physician task list using ARENA© simulation software. The completed model is evidence-based, with the simulation producing predictions and

analysis associated with a given patient visit that has not happened by mimicking reality. The benefits of this type of flexible model are that it allows for analysis of any type of "cost" that can be quantified, and it can then be utilized for predicting and potentially subsequently reducing procedural errors and variation in order to increase operational efficiency.

The second part of the study was to develop a standardized primary care nurse task list, which is needed given the current transformation of primary care from a doctor-based model to a team-based model. A comprehensive, validated list of tasks occurring during clinic visits was complied from a secondary data analysis. For this, primary care clinics in Wisconsin were selected from a pre-existing study based on 100% participation of the physician-nurse teams. The final task list had 18 major tasks and 174 second-level subtasks, with 103 additional third-level tasks. This task list, combined with the primary care physician task list, provides a tool set that facilitates clinics' analysis of the workflow associated with a complete patient encounter.

Finally, the third part of the study used observational data, the standardized primary care nurse task list, and a similar modeling methodology to the first part to develop a simulation model of the primary care nurse. The model was implemented using ARENA© simulation software. This model is flexible, resulting in an easily-customizable model, and robust in that it allows the analysis of any type of "cost" that can be quantified, such as time, physical or mental resources, money, et cetera. This can potentially be used to predict, and reduce, procedural errors and variation in response to changes to the workflows or environment; hence, the operational efficiency and medical accuracy can be more accurately evaluated.

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I. INTRODUCTION

Primary care is a key part of the U. S. healthcare system. In fact, it has been called a "critical," component (Bates, Ebell, Gotlieb, Zapp & Mullins, 2003). Primary care is the frontline of healthcare, as 66.5% of healthcare in the U. S. is performed in primary care clinics (Agency for Healthcare Research and Quality, 2008). As the frontline, primary care is a vital part of healthcare, "promoting health, preventing debilitating disease and reducing disability" (Lionis, et al, 2009, p. 2). Also as the frontline, primary care sees the largest variety of patients, introducing a large amount of uncertainty and variability into the primary care system; hence, it is not surprising that it has been said, "primary care more than any other specialty is characterized by uncertainty" (Delaney, Fitzmaurize, & Hobbs, 1999, p.1).

In addition to operating in a very uncertain environment, primary care faces a variety of other challenges. First, primary care clinics operate in an environment of intense competition and rapidly changing guidelines (Alexopoulos et al., 2001). Second, primary care's patients are conditioned to expect very fast, high quality service (Swisher, Jacobson, Jun, Balci, 2001). Finally, a major challenge is the number of transformations primary care is currently undergoing. There are three major transformations occurring:

- The shift from paper-based records to electronic medical records (EMRs)
- The shift from a physician-based model of care to a team-based model of care
- The shift from the traditional, patient-as-a-target care model towards patient-centered care model

Considering how important primary care is and the number of challenges it is facing, it becomes obvious that primary care is a system in need of attention. It has actually been said that "primary care, the backbone of the nation's health care system, is at grave risk of collapse" (Institute of Medicine, 2000). Further, in 2000, the Institute of Medicine suggested that systemic issues are at the root of the problems plaguing healthcare. The recommendations of how to begin addressing these problems include understanding the workflows in healthcare (Malhotra, Jordan, Shortliffe, & Patel, 2007). Industrial engineering provides a wealth of tools to understand workflows, as well as identify and recommend improvements. Discrete-event simulation (DES) in particular is very appropriate, as there are many variables present, which leads to a large number of connections, effects, and interactions (Taylor & Lane, 1998). DES has been used as far back as the 1960s to examine healthcare systems (Brailsford, Sykes, & Harper, 2006). DES can be used to analyze a system's processes, resources, and facility requirements, in turn allowing the prediction of the best clinical practices (Fone, et al, 2003).

DES models can be extremely complex, since they are representative of the complexity of the organizations modeled and the fact that people are not only users and resources in the system, but also the end product (Brailsford, 2007). Despite the complexity level, several successful DES models have been produced, leading to improvements in a variety of healthcare systems; Fone, et al. (2003) and Jun, Jacobson, and Swisher (1999) performed reviews of literature, identifying over 180 papers using simulation to examine healthcare. However, most of these examples focus on topics and areas outside of primary care clinics. The general lack of models focusing on primary care is a problem. This problem is intensified because those that do exist are based on expert opinion, are not flexible enough to quickly customize the model to another clinic, and are at such a high level that detailed workflows cannot be examined. Therefore, the aim of this study is to develop a general DES model of a primary care clinic that can be customized to different clinics, is based on observational data, and is detailed enough to examine clinic task-level workflows.

A. Research Objectives

This research was approached from the standpoint of developing several smaller research objectives, which combine to develop the model previously described. The end-goal of the model is to use it to it to evaluate the impact of EMRs on clinic workflow, with a special focus on errors and re-work caused by the new record system. Hence, five unique, smaller sub-studies were identified.

- Model the physician's workflow based on observational data and a previously developed primary care physician task list (Wetterneck, et al, 2011).
- Develop a primary care nurse task analysis list.
- Model the nurse based on observational data and the primary care nurse task list.
- Combine the physician and nurse simulation models to form a complete team model, including interruptions and communication between entities.
- Expand the team model to the clinic level, including multiple teams serving multiple patient rooms simultaneously.

It is acknowledged that it is not possible to complete all of these research objectives in the scope of this thesis. Therefore, the scope of this study was limited to the first three sub-studies, and these three objectives will be discussed in detail.

The first objective, the physician model, involves using a previously developed primary care physician task list and previously collected, de-identified data to identify the sequencing of tasks occurring during a patient encounter. These sequences must account for tasks that were previously completed in the appointment, the current point in the appointment timeline, what must be completed during the appointment, and the variations seen in different patients. While expert opinion has used in the past, there are limitations induced by this approach (Hoffman, Crandall, & Shadbolt, 1998). Hence, observational data is used to address those limitations. Additionally, the task list is used because the model needs to be detailed enough to investigate detailed, task-specific workflows if it is to allow for the evaluation of the impact of EMRs on the physician's workflow.

The second objective is necessary for the development of a task-level nurse simulation model. The observational data used to develop the primary care physician task list, which will be used in the first objective, was collected using tandem observations (Wetterneck & Holman, 2011). Hence, the set of nurse observations will be used in the development of a similarly organized primary care nurse task analysis list using a secondary task analysis. Therefore, the tasks are not required to be known a priori. A preliminary list development and a literature review will be conducted simultaneously, followed by list refinement.

The third objective is the development of the nurse simulation model. Again, observational data will be used in conjunction with the task list developed in the second objective to identify task sequences occurring in the observed nursing encounters. Those sequences will account for the same things as in the physician simulation model. The use of observational data allows for the prevention of limitations induced by expert opinion.

The model will also be developed to be to the same level of detail as the physician model, permitting the evaluation of detailed workflows. In turn, this facilitates the evaluation of the impact of EMRs on the nursing workflows.

B. Research Significance

The scope of this thesis, and the two remaining proposed research objectives, have the potential to significantly impact the application of Industrial Engineering techniques in healthcare, as well as the potential for extension to other research areas. Specifically, this represents a rather unique combination of qualitative techniques based in human factors with discrete-event simulation. Previously, the quantitative techniques combined with qualitative techniques have not included operations research tools. This combination could open the door to more robust studies in a variety of application areas outside of healthcare. The direct potential benefits of this research, including the objectives not falling within the scope of this thesis, include providing a basis for the more effective implementation of EMRs, allowing for the realization of the full benefits of health information systems. The direct potential benefits of the research conducted in this thesis include developing a basis for the evaluation of a variety of areas in addition to the implementation of EMRs, such as physician-nurse trust issues, errors and re-work, and quantifying a variety of resources required to treat patients.

C. Thesis Organization

This thesis is organized following the manuscript format, with the manuscripts forming the body of the thesis. Chapters I and V are the traditional introduction and conclusion, respectively. Chapters II, III, and IV are stand-alone article manuscripts reporting the results and conclusions of this study. Chapter II describes the development of the primary care physician simulation model. Chapter III develops the primary care nurse task analysis list. Chapter IV uses a similar modeling methodology as in Chapter II, combined with the task list developed in Chapter III, to develop a simulation model of the primary care nurse.

II. NEED FOR ALTERNATIVE SIMULATION METHODS FOR MODELING A PRIMARY CARE PHYSICIAN

A. Introduction

Primary care clinics are the most common healthcare facility found in the world today and the most utilized. In the U. S., it is estimated that 66.5% of all healthcare is performed in primary care clinics (Agency for Healthcare Research and Quality, 2008). Hence this is the frontline of healthcare. Primary care clinics operate in an environment of "aggressive pricing, tough competition, and rapidly changing guidelines" (Alexopoulos et al., 2001, p. 1386), which places a heavy burden on organizations providing care. Additionally, healthcare consumers are conditioned to expect a high quality and efficient service, causing organizations to carefully design their care system to meet this expectation (Swisher, Jacobson, Jun, Balci, 2001). However, healthcare is also characterized by uncertainty, making the planning and design of these systems for the present and the future difficult. According to Delaney, Fitzmaurice, and Hobbs:

> "Primary care more than any other specialty is characterized by uncertainty. This is not only because it is the first point of contact and the recipient of undifferentiated problems, but also because primary care has the role of monitoring and providing optimal continuing care for many common chronic conditions" (1999, p. 1).

Further, aggressive and/or inflated pricing by vendors within healthcare combined with the limited resources of patient to pay the final bill has resulted in increased pressure on caregiving organizations to control the overall costs, while still providing quality care. Hence, Alvarez and Centeno (1999) found that this pressure, combined with heightened competition, has “prompted health care managers to look for tools to effectively and efficiently operate their institutions” (p. 1685). As a result, medical decision makers are now working alongside operations research analysts, seeking to manage and improve their operations and the patient experience (Swisher et al., 2001, p. 124).

1. Benefits of Simulation in Healthcare

For years, healthcare professionals have recognized the benefits of mathematical models and simulation in addressing the high levels of uncertainty and variability when treating a patient because of their power and flexibility. According to Brailsford, Sykes, and Harper (2006), operations research models have been used in healthcare “to assist clinical decision-making, facility location and planning, resource allocation, evaluation of treatments, and organizational redesign,” as far back as the 1960’s (p. 466). Additionally, Gibson (2007) found that discrete event simulation (DES) can be used to analyze a working system’s processes, resources, and facility requirements to predict the best clinical practice, which is a strength of DES (Fone, et al., 2003). However, these models are not easily created due to the complexity of the organizations involved (Brailsford, 2007) and the fact that healthy people are not only the users but also the product. Hence, simulations require true collaborations with communication and interaction between organizations, end-users, and modelers to succeed.

2. Previous Simulation Models

Fone, et al. (2003) performed an extensive review of previously published work using simulation in healthcare. This review of 182 papers found 94 papers that focus on hospital scheduling and organization with only a few examining outpatient and walk-up clinics. The largest groupings of papers focused on modeling infection and communicable disease, cost and economic evaluation, and screening. The remaining 20 miscellaneous papers covered disparate topics (Fone, et al., 2003). In addition, papers of note showed DES was found to be viable for modeling emergency departments; these include Kirtland, Lockwood, Poisker, Stamp, and Wolfe (1995), Komashie and Mousavi (2005), Wang, Guinet, Belaidi, and Besombes (2009), Avarez and Centeno (1999), Connelly and Bair (2004), and Ceglowski, Churilov, and Wasserthiel (2007).

Jun, Jacobson, and Swisher (1999) conducted a survey of DES in health care clinics from the past twenty years. These simulations focus on patient flow (scheduling and admissions), patient routing and flow scheme, scheduling and the availability of resources, the allocation of resources, bed sizing and planning, room sizing and planning, and staff sizing and planning. Despite the variety of applications, only a few articles report using DES to study complex, multi-facility systems, likely due to the extensive data requirements and the prohibitive cost of obtaining such data (Jun, et al., 1999)

A further review of published literature yielded only a few examples of primary care or outpatient clinic models. In 2002, Swisher and Jacobson published an example of a model focusing on a primary care clinic. The goal of the simulation was to determine the staffing and facility size of a two-physician clinic. The key performance measures were clinic profit and patient and staff satisfaction. The primary statistics considered in the simulation were staff and facility utilization, patient throughput, staffing costs, patient revenues, and patient time in system.

In 1999, Côté's outpatient clinic model focused on patient flow and resource utilization. It was noted that there were issues collecting clinic observational data to simulate. Hence, homogenous physician treatment patterns of patients were assumed to build the model. Weng and Houshmand (1999) also created an outpatient clinic model with the goal to maximize patient throughput and reduce total time in the system. While the authors had access to sparse observational data, expert opinion was used to fit distributions to processing times. In 2001, Swisher, et al. noted that the focus of studies modeling outpatient clinics was on patient scheduling. Further, the reliability of these types of models and methods were brought into question due to assumptions required to fill voids in observational data, highlighting the need for more data-based modeling. However, the authors stated that these models would be too costly and time consuming to create based on the data required.

3. Limitations of Current Primary Care Clinic Models

As noted in the exploration of previous work, there is a general lack of primary care clinic simulation models. This can perhaps be explained by "management's reluctance to reduce complex processes to a model representation" (Alvarez and Centeno, 1999, p. 1685). As noted by Weng and Houshmand (1999), the data collection required to build robust, data-based model has been deemed too costly. However, healthcare professionals argue that the complexity seen in a clinic system, while a function of the individual's medical training preferences for care decisions and the organization, is also a function of patient variation. Variation incurred as a result of an individual patient's preferences for care combined with the mix of patient conditions, health, and disease states in a given physician's practice, dictating what the next step in the process will be. Hence, this leads modelers to the use of expert opinion to estimate process parameters associated with situational patient care, which, while an accepted practice, is less desirable than a model based on actual observational data.

Another issue associated with current healthcare simulations is that they are not generic, lacking the ability to be tailored to clinics other than the one it was based on. The result is a simulation that has limited utility, being built for a single purpose based on a single scenario, organization, and facility. Therefore, this type of simulation does not address the need for modifiable tools to address larger multi-organizational healthcare problems related to clinic management (Young, Eatock, Jahangirian, Naseer, and Lilford, 2009).

Approaches to modeling systems typically start by modeling at a high level such as an entire clinic or hospital or healthcare network (Weng & Hoshmand, 1999; Swisher & Jacobson, 2002). Hence, delays such as patient wait times become primary variables with high correlation to overall system efficiency. In these models, physicians and nurses become resources that are evaluated based on overall utility, but what is lost are the details of how each procedure is performed. The result is a model which represents the system but never evaluates the variation in tasks performed; this variation has been considered a primary contributor to medical errors which has been an emphasis of the IOM since the release of To Error is Human: Building a Safer Health System (2000).

The relative rarity of primary care clinic models, combined with the lack of availability of foundation models that can quickly be customized to a specific clinic, puts organizations at a disadvantage when attempting to address issues associated with primary care clinics. Additionally, the specific focus of the current models leaves many areas unexamined. Furthermore, the current models cannot be extended to examine those areas in the future. As Eldabi (2009) notes, these problems are almost all "wicked" problems, that is, problems that are almost impossible to solve. Most people attempt to solve these problems using the "tame" approaches that science has developed, but these are destined to fail. In order to address the above limitations, a new, and in its own way, wicked modeling approach must be developed and utilized.

B. Research Objective

The objective of the initial research was to develop a simulation model based on observational data of a physician–patient encounter at a primary care clinic. The key to the model would be that it represents the actual events that occurred, not textbook, theoretical or expert consensus/opinion of best practices. Hence, it was decided that the model should be based on the movements and actions of the physician, not the patient. For this, a standardized primary care physician task list was utilized as a fundamental structure (Wetterneck et al, 2011). This will facilitate the model being flexible and easily customized to different physicians, as, in reality, each physician has a unique patient population and organizational context but, in general, similar tasks and goals of care. From a temporal standpoint, it was determined the model should represent the time for which the patient is present in the clinic exam room. The model begins when the physician enters the patient's clinic exam room for the first time, and ends when the physician leaves for the final time, ending the face-to-face clinic exam room time.

C. Methods

1. Model Concept Development

Given the goal and requirements of the model, the decision to model the patient encounter based on the physician's perspective was not only reasonable but also unique from a simulation standpoint. This implies that the physician, not the patient, will be the entity that moves through the model with the patient being the resource.

The significance of this change to modeling a patient as a resource rather than an entity can best be understood by looking at how entities have been previously defined in simulation. Schriber and Brunner (2005) use the term entity as the object that instigates and responds to events. Banks (1999) more simply defines an entity as "an object that requires explicit definition." (p. 9) Both Schriber and Brunner (2005) and Banks (1999) define a resource as an element that provides service to an entity. Brailsford (2007) perfectly describes the typical interpretation of entities and resources in health care:

> "DES, in which entities flow around a network of queues for service, appears to be tailor-made for hospital systems in which patients join waiting lists for appointments, investigations, and treatments. In DES, entities have characteristics which determine their pathway through the network, in exactly the same way as patients have individual characteristics which determine their pathway through the hospital system."

As this is the typical approach used in simulation of health care systems, the authors recognize that modeling the physician as the entity, instead of a resource, is a radically different way to analyze the system.

However, this is not the first case made for the alternative approach when simulating healthcare systems. Hay, Valentin, and Bijlsma (2006) made the argument that the patient should not come first in simulating emergency care. This is counter to traditional modeling approaches, which "sees the hospital as a factory variant through which the patient passes, claiming whatever resources are required;" the viewpoint in which the medical resource is the driver instead of the patient is proposed (Hay, et al., 2006, p. 439). Hence, this viewpoint is now extended to primary care clinics; the alternate viewpoint allows easier customization of a generic model to a specific system, while addressing the limitations of previously published simulation models. Specifically, the failure of traditional models is that they do not address individual patient variation and the variability in the actual treatment that occurs as a result. Modeling the patient as the resource allows the inclusion of this variability, as well as the potential to capture tasks occurring between patient encounters and in clinic downtime. Additionally, this new approach better represents the sequence of actions that occur during a patient visit, being it is structured to work the way primary care physicians are trained to treat patients. Hence, the new model will more accurately reflect the reality of the decisions required for a physician to treat an individual patient.

2. Conceptual Framework

The combination of requirements to incorporate treatment variation based on the goal of a customizable, evidence-based model yields a unique framework for the non–traditional model, Figure 1. The framework utilizes the triage and treatment technique of **S**ubjective information, **O**bjective information, **A**ssess and **P**lan (SOAP) utilized to further the goal of patient care. In premise, the model allows for the primary care physician to choose how to proceed after every individual task is performed by choosing first the part of the SOAP, either Subjective, Objective, Assess, or Plan, needed to further the patient visit. Next, the specific task to complete within that area is selected and performed. After the task is complete, the whole process repeats until the primary care physician decides the appointment is complete.

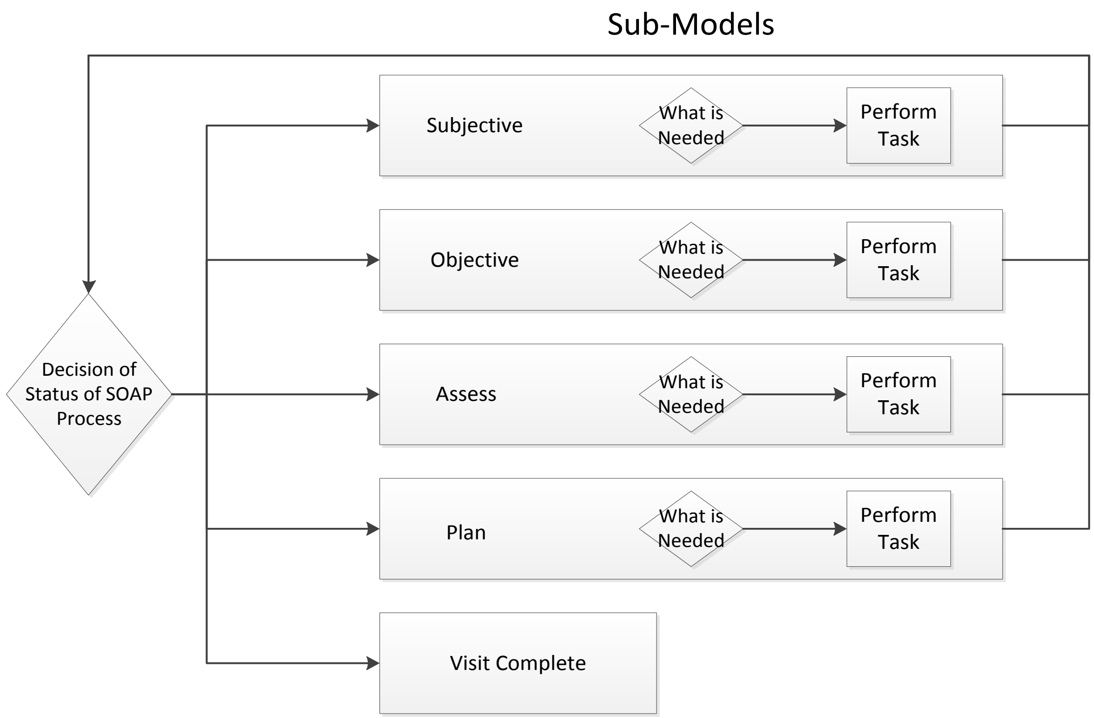

FIGURE 1-Global Methodology Framework for Physician Model

3. Data Analysis

A secondary data analysis was performed utilizing de-identified observation data from a recent study of clinician work at multiple primary care clinics in Wisconsin (Grant: Agency for Healthcare Research and Quality (AHRQ) K08 HS17014, PI: Wetterneck). The study was approved by the University of Wisconsin institutional review board for the data collection (IRB: IMD11-0389). The University of Louisville institutional review board approved the secondary analysis of the data (IRB: 12.0085).

The data were originally collected by two researchers performing tandem observations of nurse/physician pairs (Wetterneck and Holman, 2011). Additionally, more information was provided to allow for development of a more representative, complete model through discussions of scenarios, where insights were shared regarding healthcare experiences and/or context of how the data was collected. A single clinic's data was selected for use based on several criteria:

- 100% participation of physicians and nursing staff
- Urban-based
- Electronic Medical Records (EMRs)
- Post EMR implementation, 2+ years

Basic information regarding the clinic data were:

- 6 physicians composed of 4 MDs and 2 Physicians Assistants
- 8 nurses
- Physician-Nurse team concept present
- Minimum of one half-day continuous observation of each physician
- Approximately 24 total hours of physician observation performed
- 53 patients encounters observed and included in the data set

Only adult patient visits were included in the dataset; pediatric and obstetric visits were excluded based on these being specialized patient visits. Data was obtained as a time-stamped transcript of events in the form of a Word file.

The first step of the data analysis was to code the observational data based on the physician task list. For this, the qualitative analysis software NVIVO© (QSR International) was used. For the purpose of identifying basic simulation events and structure, the physician task list was modified to consolidate the tasks related to patient medications into one task and by adding a travel task. The modified primary care physician task list is shown in Appendix I. Two researchers independently coded observations. The inter-rater reliability was acceptable at 82% comparing independent coding of two observations (Boyatzis, 1998).

After the coding was completed, a statistical analysis was performed to determine the probabilities of each task for creation of Markov probability distribution tables. The following aspects were incorporated into the calculations:

- Task sequence position mean and standard deviation
- Application of normal distribution to task sequences
- Independent versus dependent tasks
- Tasks that occurred more than once

Note that an underlying distribution of task sequence position was expected. Therefore, the parametric normal distribution was applied to smooth the task sequence positions to include variation due to both the patient and physician.

4. Model Flexibility, Validity, and Reliability

The decision to orient the model around decision making results in the model not only showing the physical resources needed to treat a patient, but the mental resources as well, i.e. the number of decisions required to be made. In addition, it results in a model that is easy to customize to a different physician-all that is needed is to change the probabilities in the model to those based on that specific physician. To ensure real world validity of the model, a series of checks were inserted to ensure that no particular task was performed more than observed in reality. The model was constructed using ARENA© simulation software (Rockwell Automations).

D. Results

Figure 2 shows a high-level view of the completed model. This demonstrates the different layout of the model with the alternative perspective. Since it is a decision-based model, note the number of decision branches. This is also seen within each main task's submodel. The number of individual main tasks is representative of the physician task list's primary tasks, e.g., enter room, gather information, etc.

To understand the model, it is best to walk through it step by step. First, the physician entity arrives, and then the following Read/Write modules read in the probabilities of each task from an accompanying spreadsheet. This process is shown in-depth in Figure 3.

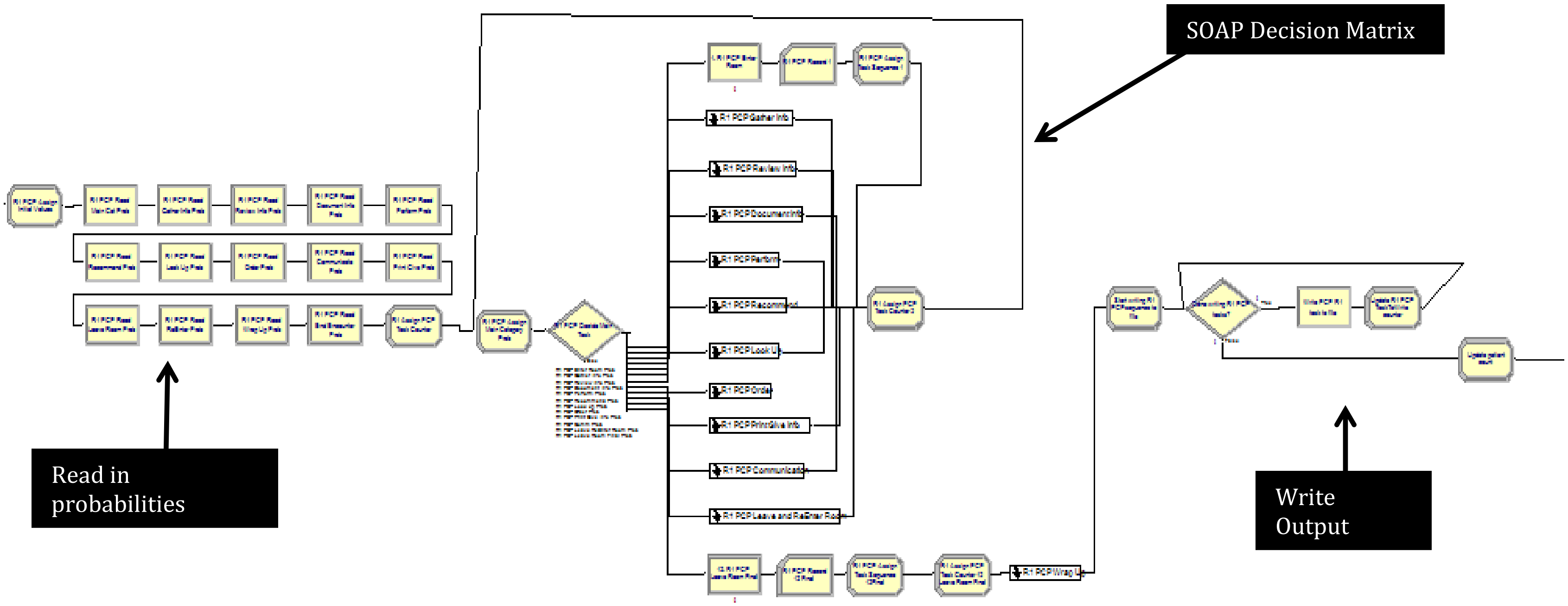

FIGURE 2-High Level View of Physician Model

Then, the physician entity enters a decision matrix that is used to make the decision about what task should be done next. The first Decide module decides which main task the physician should consider next (the main headings shown in Appendix I). This decision is based on probabilities that take into account both what has happened preceding the current task and what point the physician is at in the appointment. This is best seen in Figure 2. That decision routes the physician into a submodel for that specific task. An example of a submodel is shown in Figure 4. First, the physician reaches another Decide module, which again uses probabilities based on previous tasks and the current point in the appointment to determine the specific task that should occur next. The physician is then routed through a series of modules that include the process of completing that task, and updating counters and variables to reflect the task that just occurred.

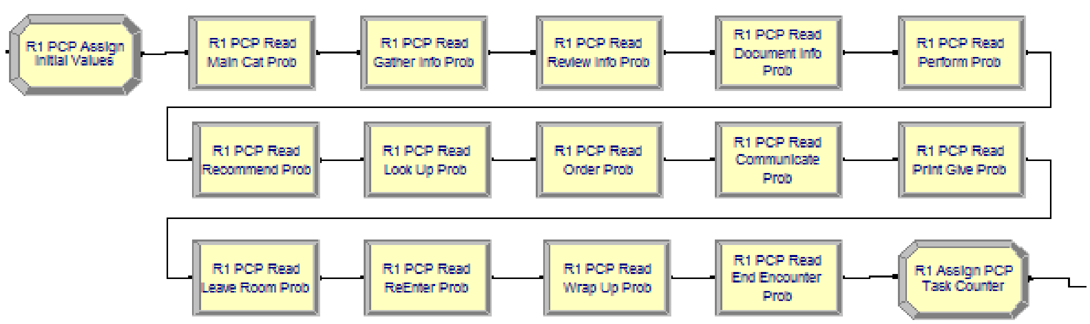

FIGURE 3-Beginning of Physician Model

The physician then exits the submodel, and the probability tables are updated for the next loop through the decision matrix. The physician entity returns to the first Decide module, and the process repeats until the entity is routed to the final exit of the room at the end of the appointment. The entity then exits the decision loop, and goes through a series of modules that write the task sequence that the entity followed to file for later examination. Figure 5 shows this process.

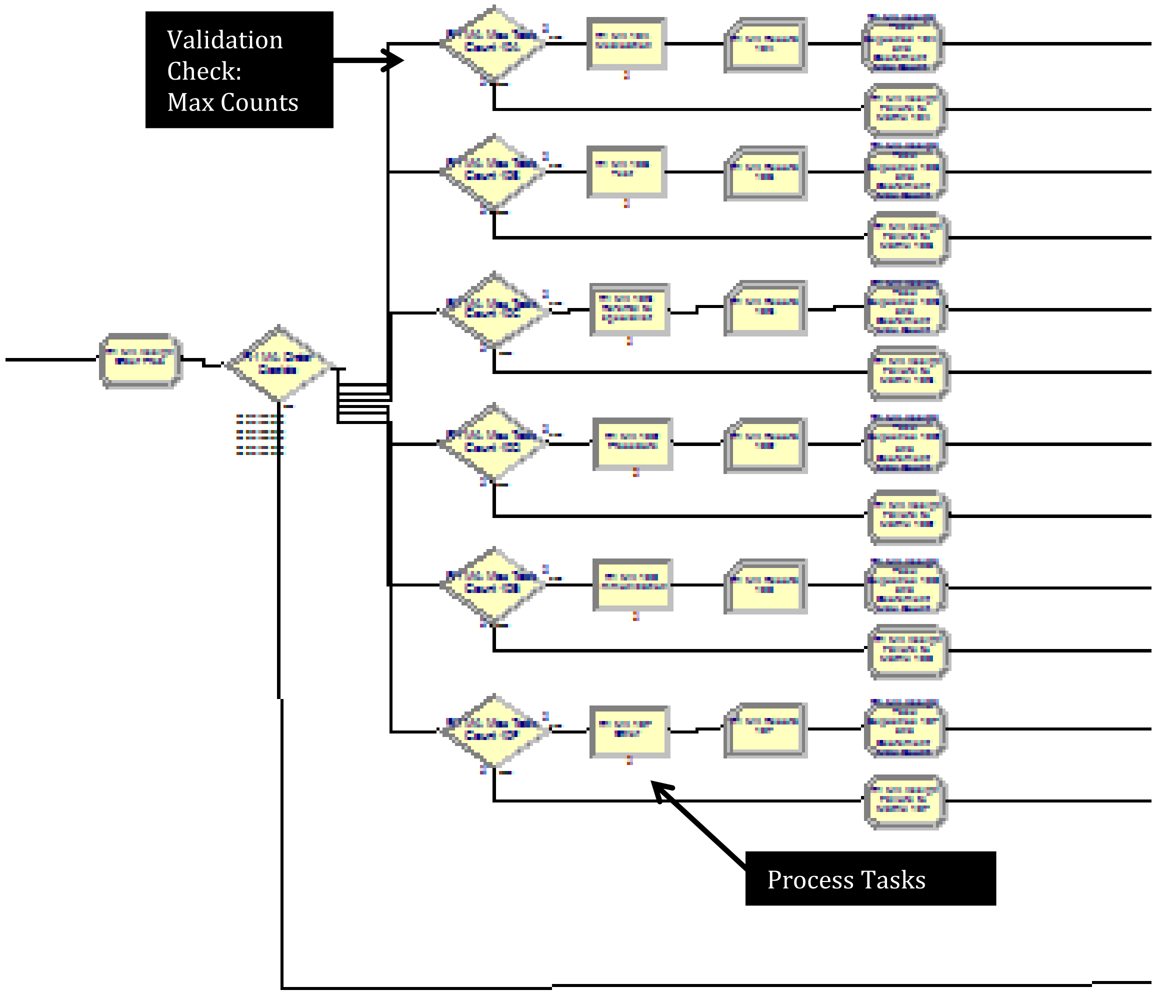

FIGURE 4-Task Submodel for Physician's Order Task

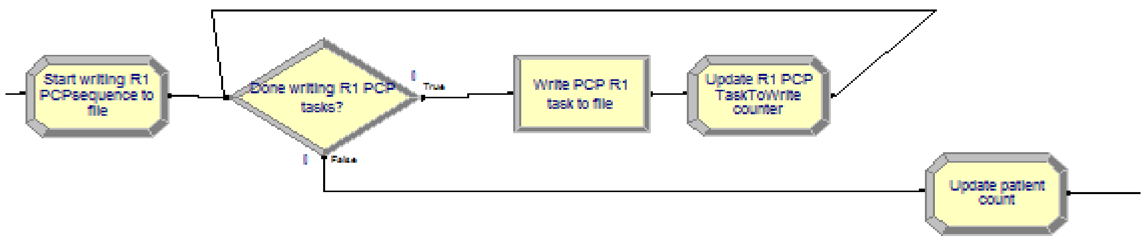

FIGURE 5-End of Physician Model.

In order to convey the size of the model, the basic model statistics are reported. In the model of a single physician there were 11 submodels, which contain 199 Decide modules, 419 variables, 15 Read/Write modules, 185 Process modules, and 209 Assign modules. An example of the outputs produced by the simulation model is shown in the following tables. Table I shows is the task sequence output from one patient encounter; this task sequence is the predicted task sequence generated by the simulation for a hypothetical patient encounter. Table II shows the failure output from the patient encounter, including the task number the failure occurred on and the attempted task code that failed. In this output, a failure represents an occasion in the model where the selected task was not allowed because it had already been completed the maximum number of times allowed.

TABLE I

PHYSICIAN SIMULATION TASK SEQUENCE OUTPUT

Task Number	**Task Code**
1	1
2	2W10
3	3V
4	12
5	11B9Leave
6	1ReEnter
7	3R
8	3X
9	3W
10	3R
11	2K
12	2C
13	2W4
14	3W
15	3C
16	3K
17	5C
18	2G
19	3C
20	12
21	2C
22	2K
23	4O
24	2C
25	6A
26	2R
27	2G
28	2Z
29	2B
30	12Final

TABLE II

PHYSICIAN SIMULATION TASK FAILURE OUTPUT

Failure Number	**Task Number**	**Task Code**
1	21	11B9
2	27	4O

1. Simulation Output

The task sequence and failure output is shown in Table I and II, respectively. The task sequences can be used in a variety of ways to improve primary care clinic operation. In order to demonstrate the usefulness of this model, a brief case study was developed, based on a series of assumptions. The first assumption was that the number of observations included in the development of the probability tables is sufficient to make predictions. The second assumption centered on the time required to complete each task. Eventually, the time-stamped observations will be used to develop the process times required; however, currently there are not enough observations to develop valid processing time distributions. Hence, a triangular distribution with a minimum of 0.5 minutes, maximum of 1.5 minutes, and an average of one minute was used to estimate the processing time required for each individual task for demonstration purposes. Figure 6 shows this distribution.

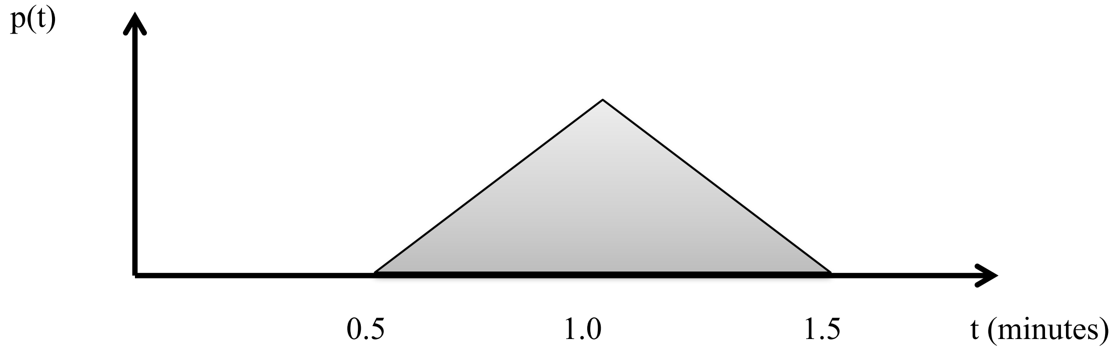

FIGURE 6-Triangular Distribution of Each Physician Task's Process Time

Two potential applications include the use of simulated patient encounters to impact the scheduling of appointments and to make material ordering more accurate. As an example of the first application, a day's worth of appointments, which is approximately fifteen encounters, were simulated. The number of tasks was counted for each appointment, as well as the simulated time of each appointment. Additionally, the expected range of time needed for the appointment, based on the number of tasks and the triangular distribution of each task's process time, was calculated. The number of tasks, expected range of appointment time, and simulated time are shown in Table III. This shows that the average patient should be scheduled for between 18.4 and 55.1 minutes, with the simulation showing an expected appointment length of 36.7 minutes. The scheduled appointment length should depend on the individual clinic's desired patient satisfaction. Assuming the clinic wanted to satisfy 80% of the patients, that is that 80% of the appointments are expected to be less than or equal to the scheduled appointment length, the patient's physician encounter should be scheduled for 43.5 minutes. Now, the task times used to simulate this were not accurate, but the potential is evident when one considers clinics schedule appointments for twenty, thirty, forty-five, or sixty minutes. The output from this simulation could be used to make appointment scheduling more accurate. Further, it could be used to estimate encounter lengths of the overall clinic patient population or a specific population, such as patients with diabetes.

TABLE III

SIMULATION OUTPUT TO IMPACT PHYSICIAN APPOINTMENT SCHEDULING

Patient	Number of Tasks	Possible Range of Time to Complete			Model's Estimated Time to Complete (minutes)
		Minimum Time (minutes)	Average Time (minutes)	Maximum Time (minutes)	
1	47	23.5	47	70.5	48.2
2	54	27	54	81	55.5
3	30	15	30	45	28.3
4	37	18.5	37	55.5	36.5
5	47	23.5	47	70.5	48.2
6	42	21	42	63	42.7
7	27	13.5	27	40.5	26.2
8	29	14.5	29	43.5	28.0
9	26	13	26	39	25.5
10	38	19	38	57	36.2
11	45	22.5	45	67.5	44.2
12	24	12	24	36	24.3
13	29	14.5	29	43.5	30.1
14	38	19	38	57	37.8
15	38	19	38	57	38.2
Average Patient	36.7	18.4	36.7	55.1	36.7

The second application that will be explored is the use of the simulation output to improve the materials order. For this purpose, the simulation model was used to generate one month's worth of patient encounters; that is, sixteen days, assuming the physician worked four days a week for four weeks with fifteen patient encounters on each day, were simulated. Then, the task sequences were analyzed to generate frequency counts, which are shown in Table IV. For this portion of the analysis, it is assumed that the same type and amount of supplies are used each time a task is completed in all appointments. It is assumed that clinics would be aware of the amount and kind of materials needed to complete each task. Using this information combined with the projected task frequencies, the materials order can be refined to be less wasteful.

TABLE IV

PHYSICIAN TASK FREQUENCY COUNTS

Task	Day																Total Count
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
2C. Patient's current medications	58	55	48	52	68	61	51	42	58	57	63	50	54	61	55	49	882
6A. Medication	30	36	28	43	35	28	33	36	32	32	39	41	35	29	29	41	547
3C. Patient's current medications	30	39	29	35	31	26	25	21	24	38	31	32	28	32	32	35	488
2K. Vitals/weight	24	28	26	29	26	30	25	31	24	21	23	32	26	33	28	34	440
8A. Order-Medication	30	27	35	19	19	26	29	21	20	31	32	20	19	25	17	33	403
12. Leave room	21	24	17	26	17	22	24	31	22	20	37	29	29	28	24	30	401
2B. Problem information	26	21	27	38	29	26	27	17	30	21	19	33	18	14	19	19	384
6M. Other	22	25	25	32	25	19	23	22	20	25	17	31	24	18	20	22	370
6B. Diet/exercise	14	31	17	29	21	15	25	18	27	28	27	23	24	22	19	26	366
2J. Exercise/diet	25	14	25	34	16	26	25	25	21	24	25	19	23	18	29	15	364
2R. Test results	19	21	21	14	19	16	18	16	16	18	19	20	26	16	18	11	288
5C. Perform-Physical exam	16	13	14	23	14	18	22	18	9	23	20	15	21	18	13	29	286
3K. Vitals/weight	19	16	11	18	19	21	17	14	12	19	16	18	16	10	15	18	259
1. Enter room	15	15	15	16	15	15	15	15	15	15	15	15	15	15	15	15	241
12. Leave room-Final	15	15	15	16	15	15	15	15	15	15	15	15	15	15	15	15	241
2G. Allergies and adverse reactions	17	12	18	18	17	19	12	19	17	12	8	14	16	12	14	15	240
3R. Test results	19	15	20	9	8	7	14	10	11	11	17	14	11	18	9	14	207
2Z. Other	11	10	9	12	15	14	10	8	13	12	16	14	16	7	16	12	195

1. Re-Enter room	9	9	8	7	6	6	13	11	14	11	17	13	13	10	9	11	167
11B(9). Other	9	11	6	8	9	9	8	11	12	9	12	9	11	12	13	10	159
2A. Chief complaint	5	7	8	6	10	12	8	8	8	13	5	7	8	10	6	3	124
3V. Previous appointments with same MD	8	7	7	5	9	9	8	4	8	7	10	9	7	7	6	7	118
2W(10). Psychiatric	6	3	9	7	8	11	4	9	5	9	7	8	11	5	6	9	117
2T. Diagnosis	5	6	7	4	7	9	7	8	3	9	10	7	8	11	7	5	113
11B(1). Office	6	5	6	7	4	7	7	7	7	6	9	8	9	4	4	9	105
7C. Look up-Drug information	5	4	2	6	7	4	7	10	3	11	6	6	8	10	5	6	100
5J. Perform-Login to computer/EHR -2	9	9	6	7	6	5	4	11	6	6	3	5	5	7	4	6	99
3O. Family history	2	5	5	4	4	5	6	3	6	6	7	7	9	7	2	10	88
3G. Allergies and adverse reactions	5	5	9	5	7	8	1	7	4	7	2	6	6	5	4	5	86
3X. Past medical/surgical history/problem list	6	5	5	3	6	6	2	6	5	6	6	5	5	2	4	6	78
3W. Nursing notes/clinic note	5	0	4	5	6	7	3	3	1	4	3	4	6	6	10	4	71
2L. Daily life activities	3	2	6	8	4	1	3	4	4	6	8	3	2	3	2	8	67
6F. Referral to specialist	6	7	4	3	3	3	3	8	1	4	4	2	8	3	1	4	64
4C. Patient's current medications	4	1	4	2	2	5	2	1	3	9	4	4	4	2	1	4	52
2X. Social contact	2	0	3	4	4	3	1	4	2	3	5	6	4	3	5	2	51
5A. Perform-Procedure	5	3	2	4	2	2	2	3	3	3	2	7	2	3	2	6	51
2O. Family history	3	4	1	3	1	3	3	4	2	2	6	2	3	3	1	3	44
2U. Secondary patient	5	3	2	0	0	4	1	1	3	5	4	4	4	2	0	4	42
4O. Family history	3	4	1	1	5	3	3	3	2	1	1	4	4	1	0	6	42
4T. Diagnosis	0	2	4	1	1	4	1	2	2	4	3	4	3	5	2	2	40
2W(8). Respiratory	4	1	5	3	3	1	4	3	1	3	3	1	2	1	2	2	39

4X. Past medical/surgical history/problem list	1	1	3	2	1	2	1	4	5	1	3	3	2	3	1	6	39
2Y. "Anything else" question	1	2	3	3	0	5	1	5	1	4	1	4	2	1	1	3	37
6E. Follow-up appointment	1	3	3	2	1	1	2	3	2	4	4	3	2	1	0	5	37
2W(7). Cardiovascular	3	0	2	3	2	2	3	2	1	1	3	3	3	0	3	4	35
2E. Patient pharmacy	3	1	2	2	2	3	1	1	1	3	4	0	3	4	1	3	34
2W(4). Constitutional (fever, weight loss, etc.)	1	0	2	4	3	3	2	4	1	1	3	3	1	1	1	4	34
5J. Perform-Login to computer/EHR	2	3	3	2	1	3	3	0	1	0	4	3	3	4	1	1	34
6D. Procedure	5	2	2	4	1	3	1	2	6	2	0	0	0	0	3	0	31
3E. Patient pharmacy	1	2	1	2	3	4	3	1	1	1	1	3	1	3	1	1	29
3H. Drug/alcohol use	1	0	2	2	6	1	1	1	1	2	3	1	1	1	1	3	27
6K. Home monitoring	2	0	3	1	2	2	2	0	1	4	0	4	1	1	0	3	26
3A. Chief complaint	0	0	0	0	4	3	0	2	0	2	2	2	1	3	2	2	23
2H. Drug/alcohol use	1	2	0	2	0	4	1	1	0	1	1	3	3	0	2	0	21
2W(2). Neurological	1	2	1	1	0	0	0	1	0	2	2	2	4	0	1	0	17
3BB. Other	0	1	2	0	1	0	1	1	2	2	0	2	1	0	1	0	14
2Q. Preventative screening	1	2	2	0	0	0	1	0	0	0	0	1	3	1	0	0	11
2F. Cost/access/insurance	1	0	0	0	1	1	0	1	0	1	1	1	0	0	1	0	8
5D. Perform-Hand sanitization	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1

E. Discussion

The model presented here is a new twist on modeling a healthcare event. Essentially, the approach was to change the perspective of the model. The resulting model views the physician as the entity that moves through the healthcare system. This has many advantages over the traditional modeling approach, including the following.

- The model mimics the physician's procedure in a patient encounter, in that they can move backwards and forwards through the SOAP model as need be.
- The model is generic and easily customizable to any physician or practice.
- Any type of cost that can be quantified can be considered, including time, money, mental or physical resources et cetera.
- The model can examine a variety of populations; it can consider an entire practice, only one physician, a specific patient population to understand the changes specific to that particular population.
- The model is based on real-world data and will change with the clinic as the data is updated.
- The model is expandable to consider multiple team and room effects simultaneously.

Finally, this approach to modeling a primary care clinic is unconventional but effective. The basis of this model is observational data, but it has been stated previously that this type of data collection is too costly and time consuming by other authors, the assumption being that the cost is not worth the benefits. However, the potential benefits of the model presented in this paper range from reducing procedural errors and variation, to increasing operational efficiency, and to allowing physicians to be more thorough. Hence, this type of modeling shows real potential for addressing many of the current problems seen in healthcare today.

1. Model Limitations

As in any study, there are limitations to this model. One issue is that the model does not currently capture the patient's waiting times. However, after the inclusion of the nurse, the model will be able to capture patient waiting time based on the arrival of the patient to check-in, as well as the wait period once the nurse has roomed the patient and they are waiting on the physician. Once complete, the model of the full patient encounter will no longer have this limitation.

Another issue stems from the size of the model. A high level of complexity is required to develop a task-level model, thus resulting in a very large model. Traditional modeling methodologies may be able to capture some similar information with a smaller, and faster, model at this point in the analysis. However, it is questionable whether future steps in the analysis could be completed using traditional methodologies.

2. Future Work

As the model of the primary care physician has been completed, the application of the nurse is at the forefront. Hence, a standardized nurse task list must be developed, and then a similar analysis to the primary care physician should be performed to build that simulation model for integration. The two models will be combined in order to model the entire patient encounter, from the time the nurse is notified of the patient arrival to the time the physician ends the appointment. This model will then need to be validated and verified. After, application of the model to the clinic as a whole will be examined to determine if organizational level operations can be simulated with these types of models.

During the next stage of future work, benefits will be examined regarding both the positive and negative impacts of EMRs on primary care. One example is the capacity to quantify the mental resources required to treat a patient facilitates evaluating the mental workload of both physicians and nurses. Other possible avenues for expansion include evaluating errors, re-work, and physician-nurse trust issues in the primary care clinic.

F. Conclusion

The goal of this research was to propose and implement a new viewpoint of simulation modeling that considers the physician, not the patient, as the entity that moves through the simulation model. The review of literature revealed that models of primary care clinics are scarce, and a case study examining emergency medicine had previously proposed not using the patient as the simulation model entity. This idea was extended to primary care clinics, and implemented using observational data and a standardized physician task list. The result is a unique model that is based on decisions made during a physician-patient encounter. This results in the model capturing both the mental and physical resources used to treat a patient. Work is planned to extend the model to include a nurse. The possibility of modeling the entire primary care clinic was described. This will then set the stage for future work exploring topics like the impact of EMRs on primary care, the mental workload of both physicians and nurses, and errors, re-work, and physician-nurse trust issues in the primary care clinic.

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III. DEVELOPMENT OF A PRIMARY CARE NURSE TASK LIST TO EVALUATE CLINIC WORKFLOW

A. Introduction

Primary care clinics shoulder the majority of the burden on the health care system today, with 66.5% of all health care in the U. S. performed in primary care clinics (Agency for Healthcare Research and Quality, 2008). Additionally, primary clinics operate in an environment of "aggressive pricing, tough competition, and rapidly changing guidelines," (Alexopoulos et al., 2001, p. 1386), which further exacerbates the burden placed on organizations providing primary care. While operating in these sub-optimal conditions, primary health care providers must serve consumers who are conditioned to expect high quality and efficient service. Therefore, organizations must carefully design their systems to meet this expectation while taking into account the conditions they operate in (Swisher, Jacobson, Jun, Balci, 2001). Furthermore, the design of healthcare systems is complicated by the fact that health care is characterized by uncertainty; this makes the design of health care systems for the present and future difficult. Primary care clinics face more uncertainty than any other healthcare specialty, as they are the first point of contact and are not specialized. Hence, primary care receives a myriad of problems, including monitoring and providing treatment for chronic conditions (Delaney, Fitzmaurice, Hobbs, 1999). As a result, tools are needed to analyze and evaluate primary care clinics. Wetterneck, et al. (2011) demonstrated the need for and usefulness of a standardized primary care physician task list to assist with the design of primary care clinics, as well as developing said list.

However, primary care is currently undergoing a series of transformations. One of these transformations is moving towards a patient-centered clinic; as a part of this transformation, primary care clinics are moving from a doctor-based model to a team-based model, with teams composed of primary care physicians and nurses/medical assistants, in order to provide patient care (Bodenheimer, 2011). Furthermore, Bodenheimer and Laing note that "during the 15-minute visit, primary care physicians cannot provide acute, chronic, and preventive care while building meaningful relationships with their patients and managing multiple diagnoses…the 15-minute physician visit must be eliminated as the central institution of primary care" (2007, p. 457). Bodenheimer and Laing go on to suggest that the physician visit be replaced with the team model (2007). Richards, Carley, Jenkins-Clarke, and Richards also noted increased advocation for multidisciplinary teams composed of doctors and nurses (2000).

The support for a team-based model is summarized by Grumbach and Bodenheimer in 2004: "medical settings in which physicians and nonphysician professionals work together as teams can demonstrate improved patient outcomes," (p. 1246) and "a well-functioning team with a clear division of labor might relieve physicians of some of their workload." (p. 1251). The caveat of the team model is briefly mentioned here, and is also mentioned by Richards, et al. (2000) with the statement that there must be an increased understanding between doctors and nurses about their roles for the team model to work. Both Grumbach and Bodenheimer (2004) and Bodenheimer and Laing (2007) also make this important point: each team member must clearly understand their roles in the system, and their roles must be documented in protocols for the team model to be effective. In order to understand each team-member's role, the tasks performed must be understood and documented. Wetterneck, et al. (2011) has already developed a standardized primary care physician task list to this end. Therefore, a primary care nurse task list is needed in order to analyze the entire primary care team and to understand and document the nurse's tasks.

1. Existing Nurse Task Lists

Battisto, Vander Wood, Pak, and Pilcher note that there is clearly a gap in the current literature in that there is "little objective information that describes what nurses do" (2009, p. 538). However, some nursing task lists do already exist. For example, the National Council of State Boards of Nursing (2007) created a task list to survey nurses about tasks they performed; this task list was created based on expert opinion and feedback about the task list was not solicited from participants. Another example of an author-developed task list, presumably based on expert opinion, was found in Evans, et al. (2007) and was used to study two pain modalities in various hospital units. Keohane, et al. (2008) developed a task list based on expert opinion to support a time motion study to measure the proportion of time nurses spend on various activities in an inpatient tertiary academic medical center. Fullerton, Johnson, and Oshio developed another task list focusing on nurse-midwives in 1999; this task list was based on expert opinion, but did incorporate feedback from participants in the pilot study. Two other examples of expert-opinion based task lists are found in Paquay, et al. (2007), which focuses on tasks performed in nursing homes, and Brixey, Robinson, Turley, and Zhang (2010), which uses a task list to examine interruptions in the emergency department. There are two important characteristics to be noted here:

1. None of the task lists focus on primary care environments.
2. These lists were developed based on expert opinion.

The first characteristic is an issue because it has already been shown that primary care is an area of health care that needs all possible tools available to assist with the design of workflows in order to meet patient needs in the operating environment. The second characteristic is problematic because there is a lack of empirical evidence supporting the validity and reliability of information collected from experts; additionally, the process of knowledge elicitation may induce bias (Hoffman, Crandall, & Shadbolt, 1998). Therefore, a generic, easily modifiable tool that is based on observational data to analyze the nurse portion of a physician/nurse team needs to be developed.

Before the development of such a tool is started, it is important to fully consider the entire healthcare system. To this end, the Systems Engineering Initiative for Patient Safety (SEIPS), developed by Carayon, et al. (2006), was utilized to examine the primary care system. There are five components of the SEIPS model, listed below. Before taking any action to develop the task list, all five components were considered and identified in the system.

- Person: the individual of focus in the system in this case is the nurse, but the patient is also considered, as they are involved in their care.
- Organization: the culture and constraints due to the specific clinic's organization, including communication, relationships, and teamwork between nurses and others in the clinic.

- Technologies and tools: paper and computer forms used in the clinic, medical equipment, and the electronic medical record system that is utilized.
- Tasks: all tasks performed during the time the patient is physically present in the clinic. These will be identified through the development of the task list.
- Environment: the physical layout of the clinic, patient room and workstation design, and the noise and lighting in the clinic.

The consideration of these system elements further points out the necessity of identifying the tasks performed by the nurse. The list will facilitate the evaluation of the primary care system described above, and also allow the evaluation of the entire patient encounter given the recent shift to a team-based model of care in primary care clinics. It is important to note that the proposed list will be developed to focus specifically on nursing tasks in primary care clinics that occur while the patient is physically present in the clinic. This means that the tasks that occur outside the face-to-face time with the patient are not currently captured.

B. Methods

1. Settings and Participants

This study uses data from one U. S. observational study of primary care clinics, shown in Table V. This study involved one clinic in Wisconsin where 100% of the nurses chose to participate. A total of eight nurses participated, with six partnered with a physician to form a team. Participating primary care clinics were recruited using the Wisconsin Research and Education Network (WREN), the research-based primary care network in Wisconsin. The study was approved by the University of Wisconsin institutional review board (IRB: IMD11-0389). The University of Louisville institutional review board approved the secondary analysis of the data (IRB: 12.0085).

TABLE V

STUDY CLINIC AND PARTICIPANT CHARACTERISTICS

Characteristics	Study
Primary care clinics	1
Clinic location	Urban
Observation dates	September 2008-March 2009
Number observations of adult, non-pregnant patients	53
Electronic Medical Records	Present
Number participating nurses	8

2. Data Collection

The observations performed in this study were conducted between September 2008 and March 2009. Two researchers, a human factors engineer and a human factors trained physician, collected the data. These researchers performed tandem observations of physician/nurse pairs (Wetterneck and Holman, 2011). The observers were trained in the collection of observational data, and followed a protocol based on the Systems Engineering Initiative for Patient Safety model to determine what to record from the observations. The observers, who also collected data in one of the studies used by

Wetterneck, et al. (2011), collected the same information about the nurse as the physician. This information included:

- The tasks performed by the nurse.
- The care delivery environment.
- How the patient and the nurse interacted, and any other people present during or involved in the encounter.
- The technology and tools used in the appointment.
- Details about the organization.

The observers took notes free hand and then transcribed the notes as soon as possible after the observation. For the purposes of this study, an observation began when the nurse was notified of patient arrival, or began tasks preparing for a specific patient visit, and ended after the nurse had completed all tasks associated with the patient visit.

3. Development of the Task Analysis List

The observational data set consisted of fifty-three patient encounters, which were taken over six months of observation, from one primary care clinic in Wisconsin. A secondary task analysis was performed on the observational data in order to understand nurse workflow. As observers recorded everything as it occurred, and the observations were analyzed later, it was not required to know all possible tasks a priori. This, as in Wetterneck et al. (2011), is a particular strength of this study.

There were three steps associated with the development of the nurse task list; these steps were the same as those used by Wetterneck et al. to develop the primary care physician task list. The three steps were:

1. Preliminary list development-using data from the first two of observations, a preliminary task list was developed. This included tasks before and after direct patient contact. The original tasks were organized by topic.
2. A review of literature-a literature search using peer-reviewed journals was conducted, and this step was conducted at the same time as the preliminary task list development. Few articles were found that examined nurse tasks, while there were none found that focused on nursing tasks in primary care.
3. List refinement-the transcripts from the observations were examined, and findings from the transcripts of the observations, literature review, and a pilot data analysis were incorporated to refine the original task lists. This included the addition of new tasks, combination of some tasks, and re-organization as needed.

The final list that resulted was the same format as the list developed in Wetterneck, et al (2011), with the major tasks generally characterized by a verb, and the subtasks composed of subjects and details that clarify the major tasks. This facilitates the combined use of the lists to analyze the entire primary care team.

The task list was entered in Microsoft Excel 2010 and the major tasks were organized in the order they might occur in during a patient encounter, and then assigned a number 0 through 17. The number 0 was used to represent tasks that occur before patient contact, as the number 1 indicated the initiation of patient contact in the physician task list. Each subtask under a major task was assigned the same number as the major task as well as a letter, for example '3D. Medication' for when the nurse gathers medicine information from a patient. Any third-level task was assigned an additional number, for example ‘3D(1). Side effects’ to define the task at the lowest level identified in observations. This is the same numbering system used in Wetterneck, et al. (2011).

In order to verify the task list, a pilot data coding was conducted on two observations by two independent researchers. Each observation was coded using NVIVO© software. The output of the coding was a list of tasks performed and the sequence in which they were performed. The coding results were reviewed and discussed by the research team. Iteratively, any adjustments to the task list that were needed were made until consensus on the final list was achieved. Using the final task list, an acceptable inter-rater reliability score of 87.9%were achieved using one observation (Boyatzis, 1998).

C. Results

The final task list had 18 major tasks, 17 of them defined by action verbs and one that included all tasks that occurred before calling the patient from the waiting room, and 174 subtasks clarifying the major task for a total of 192 possible tasks. Table VI shows the first-level and second-level tasks on the list. These tasks were arranged in a linear sequence order that represents the order that the tasks might be performed in during a patient encounter. The complete task list is available in Appendix II. Twelve of the major tasks were completed with the patient during the encounter. Two of the other tasks were performed before the encounter, one including preliminary work and the other calling the patient from the waiting room. One of the remaining four tasks outside the room was included to document the nurse escorting the patient or others present during the appointment, another noted when the nurse left the room for the final time, the third included the tasks performed by the nurse after they had left the room for the final time, and the fourth and final task outside the room indicated the nurse traveling outside the room.

TABLE VI

ABBREVIATED PRIMARY CARE NURSE TASK LIST

0. Preliminary Work Prior to PT Contact	
	0A. Alerted that patient arrived and is in waiting room
	0B. Preparation for PT visit (specific to that PT)
1. Call patient from waiting room	
2. Enter room	
3. Gather information from patient	
	3A. Complaint(s) (chief, new, confirmation of reason for visit, list of, "told to come in")
	3B. Problem information (pre-existing, new, questions, concerns, etc.)
	3C. Patient's current medications (verbal, list, notes, bottles, etc.)
	3D. Medications
	3E. Patient pharmacy
	3F. Cost/access/insurance
	3G. Allergies and adverse reactions
	3H. Drug/alcohol use
	3I. Tobacco use
	3J. Exercise/diet

	3K. Vitals/weight/vision
	3L. Daily life activities
	3M. Support network, living situation, or help in emergency situation
	3N. Advanced medical directive/end of life
	3O. Family history
	3P. Patient home monitoring information
	3Q. Preventative screening
	3R. Test results
	3S. Physical exam
	3T. Diagnosis
	3U. Secondary patient
	3V. Previous appointments
	3W. Review of symptoms/systems (not associated with main problems
	3X. Social contact
	3Y. "Anything else" question
	3Z. Demographic/Contact Information
	3AA. Other
4. Gather information from other (family member, caregiver, etc.)	
	4A. Complaint(s) (chief, new, confirmation of reason for visit, list of, "told to come in")
	4B. Problem information (pre-existing, new, questions, concerns,

	etc.)
	4C. Patient's current medications (verbal, list, notes, bottles, etc.)
	4D. Medications
	4E. Patient pharmacy
	4F. Cost/access/insurance
	4G. Allergies and adverse reactions
	4H. Drug/alcohol use
	4I. Tobacco use
	4J. Exercise/diet
	4K. Vitals/weight/vision
	4L. Daily life activities
	4M. Support network, living situation, or help in emergency situation
	4N. Advanced medical directive/end of life
	4O. Family history
	4P. Patient home monitoring information
	4Q. Preventative screening
	4R. Test results
	4S. Physical exam
	4T. Diagnosis
	4U. Secondary patient
	4V. Previous appointments
	4W. Review of symptoms/systems (not associated with main

	problems
	4X. Social contact
	4Y. "Anything else" question
	4Z. Demographic/Contact Information
	4AA. Other
5. Review patient information	
	5A. Complaint(s) (chief, new, confirmation of reason for visit, list of)
	5B. Problem information (pre-existing, new, questions, concerns, told to come in, etc.)
	5C. Patient's current medications
	5D. Medications
	5E. Patient pharmacy
	5F. Cost/access/insurance
	5G. Allergies and adverse reactions
	5H. Drug/alcohol use
	5I. Tobacco use
	5J. Exercise/diet
	5K. Vitals/weight/vision
	5L. Daily life activities
	5M. Support network, living situation, or help in emergency situation
	5N. Advanced medical directive/end of life

	5O. Family history
	5P. Patient home monitoring information
	5Q. Preventative screening
	5R. Test results
	5S. Physical exam
	5T. Diagnosis
	5U. Secondary patient
	5V. Previous appointments
	5W. Nursing notes/clinic note
	5X. Past medical/surgical history/problem list
	5Y. Outside medical/counseling care
	5Z. Follow-up appointment information
	5AA. Patient paper forms
	5BB. Other
6. Document patient information	
	6A. Complaint(s) (chief, new, confirmation of reason for visit, list of, "told to come in")
	6B. Problem information (pre-existing, new, questions, concerns, etc.)
	6C. Patient's current medications
	6D. Medications
	6E. Patient pharmacy
	6F. Cost/access/insurance

	6G. Allergies and adverse reactions
	6H. Drug/alcohol use
	6I. Tobacco use
	6J. Exercise/diet
	6K. Vitals/weight/vision
	6L. Daily life activities
	6M. Support network, living situation, or help in emergency situation
	6N. Advanced medical directive/end of life
	6O. Family history
	6P. Patient home monitoring information
	6Q. Preventative screening
	6R. Test results
	6S. Physical exam
	6T. Diagnosis
	6U. Secondary patient
	6V. Previous appointments
	6W. Review of symptoms/systems (not associated with main problems
	6X. Past medical/surgical history/problem list
	6Y. Outside medical/counseling care
	6Z. Follow-up appointment information
	6AA. Patient paper forms

	6BB. Demographic/Contact Information
	6CC. Other
7. Perform	
	7A. Procedure
	7B. Vitals/vision/weight
	7C. Physical exam
	7D. Hand sanitization
	7E. Administer medication
	7F. Fill out patient form
	7G. Dictate
	7H. Telephone call/answer phone/pager
	7I. Calculation
	7J. Login to computer/EHR
	7K. Open template
	7L. Other
	7M. Delay (Dealing with a problem-computer, out of supply, etc.)
8. Recommend/discuss treatment options	
	8A. Medication
	8B. Diet/exercise
	8C. Test/preventive screening
	8D. Procedure
	8E. Follow-up appointment
	8F. Referral to specialist

	8G. Home remedy
	8H. Non-traditional treatment
	8I. Observation/wait and see/do nothing
	8J. Immunization
	8K. Home monitoring
	8L. Get additional information
	8M. Other
9. Look up	
	9A. Treatment information
	9B. Referral doctor
	9C. Previous care clinic, hospital, provider
	9D. Drug information
	9E. Pharmacist/Pharmacy
	9F. Other
10. Order	
	10A. Medication
	10B. Test
	10C. Referral to specialist
	10D. Procedure
	10E. Immunization
	10F. Other
11. Communicate	
	11A. PCP

	11B. Other healthcare provider
	11C. Other healthcare provider (external to clinic)
	11D. Other
12. Print/give patient	
	12A. Paper prescription
	12B. Medication information/instructions
	12C. Test order form
	12D. Sample medication
	12E. Disease/problem information
	12F. Home monitoring card/paper
	12G. Medical equipment
	12H. Follow-up appointment information
	12I. Appointment summary
	12J. Referral information
	12K. Other
13. Rooming wrap-up	
	13A. Patient instruction
	13B. Log out of computer/EHR
	13C. Collect
14. Transport/Escort	
	14A. Patient
	14B. Family, friends, caregivers, etc.
15. Leave room	

16. Post patient rooming procedure	
	16A. Chart/paperwork/labels to office/file room/circulation
	16B. Leave chart/paperwork/labels in door holder/clip
	16C. Flips door flags
17. Travel	

The 'Gather information from patient' and 'Gather information from other' major tasks have identical subtasks, and the 'Document' and 'Review' major tasks have subtasks that are almost identical to both of the 'Gather' subtasks. Additionally, all of these subtasks are nearly identical to the 'Gather', 'Review', and 'Document' subtasks seen in the physician task list. As with the physician task list, the task list allows for the addition of codes to note information sources or the presence of someone else in the room involved with care delivery.

D. Discussion

The comprehensive primary care nurse task list presented here was developed to be generic and easily customizable so may be adapted to other healthcare settings in order to facilitate the evaluation of clinic workflow. This task list provides the same information about primary care nurses that the task list developed by Wetterneck, et al. (2011) provides about the primary care physician; this information includes:

- The types of tasks performed by nurses in primary care.
- The potential sequence of tasks during a patient encounter.
- The data sources a nurse uses during a patient encounter.

- The contribution of other persons to the appointment.

It is important to note that this list is not intended to be all-inclusive or prescriptive; it is likely that specific tasks will vary in different countries, organizations, and even between individual nurses. Individual users are encouraged to modify, adapt, and update the task list to suit their needs and purposes, as it is intended to be customized as a tool for use.

The comparison of the primary care physician and primary care nurse task lists yields interesting results. The most obvious difference is that the nurse task list is longer than the physician, especially when third-level and fourth-level subtasks are included. The comparison also identifies the responsibilities that are "shared" between the physician and nurse, meaning those tasks that both the physician and nurse perform, as well as their individual responsibilities. Some examples of shared responsibilities include:

- The 'Gather from Patient' tasks.
- The 'Review' tasks.
- The 'Perform' tasks.
- The 'Recommend/discuss treatment options' tasks.
- The 'Order' tasks.
- The 'Communicate' tasks.
- The 'Print/give patient' tasks.

Some of the examples of the individual tasks, which only the nurse is responsible for, include:

- Gathering, reviewing, and documenting demographic/contact information from the patient.

- Gathering information from any person other than the patient.
- Looking up the patient's previous clinic and pharmacy.
- Transporting or escorting the patient or anyone else.
- All the post-patient rooming procedure and preliminary work tasks.

The potential applications of this task list, not combined with the primary care physician task list, are nearly identical to those identified in Wetterneck, et al. (2011), such as:

- Analyzing workflows before and after implementation of EHRs in order to ensure that healthcare quality is unaffected or improved.
- Identifying potential opportunities for improvement to nurse workflow.
- Understanding the impacts of healthcare IT, as well as the individual organization's IT needs.

The combination of the two lists leads to even more valuable applications, including the analysis of the entire patient experience instead of only one side of it. This is especially important given the transformation in primary care from a doctor-based model to a team-based model. Additionally, the two task lists allow for the exploration and evaluation of shared and individual tasks of physicians and nurses. This will lead to a clearer understanding of each team-member's roles and responsibilities, which will further facilitate the implementation of primary care teams, thus allowing for the full potential benefits of teams to be realized. These benefits include the potential for improved clinical outcomes and a reduction in physician workload (Grumbach & Bodenheimer, 2004).

There are, however, limitations to the use of this task list to analyze nurse workflows, which were also noted by Wetterneck, et al (2011). These limitations include:

- Coding density is not necessarily representative of the relative time spent on tasks in an encounter. However, this task list can be combined with methods to capture the time, or any other resource, spent on each task. That combination can then be used to analyze time demands, thus capturing key time requirements.
- The number of tasks coded is not necessarily representative of the amount of work being done, instead capturing the type of work being done.
- The list may not be complete, despite being developed and validated by observational data from a large pool of nurses. Specific tasks may vary and additions may be required, depending on the work context and the questions being investigated. These modifications are encouraged, as the task list was developed with quick and easy customization in mind.

Another limitation to this study, at this point in time, is the small dataset that was used to develop the task list. In the future, more nurses and more clinics, resulting in a larger total number of observations, should be used. The larger set of data will result in a more valid list, and as such is a required step in the future. Additionally, the proposed task list must be completed by including tasks associated with supporting the organization's and facilities daily work.

E. Conclusion

As demonstrated in the current literature, primary care is undergoing a period of rapid transformation. Thus, organizations and health care providers need to utilize every tool available to understand the entire patient encounter, in particular the workflow of all members of the primary care team. This understanding will allow for the complete analysis of both physician and nurse workflows before and after changes are implemented. Hence, this will allow the health care provider to ensure the quality of care and the patient experience remains consistent. These lists, the primary care physician list developed by Wetterneck, et al. (2011) and the nurse list developed in this study, combine to provide a complete first step towards providing the tools to fully understand and analyze workflows in a patient visit in primary care clinics. This allows for a potential reduction in cost and time to complete such an analyses, as well as facilitating the understanding and evaluation of clinic workflow.

IV. DEVELOPMENT OF A PRIMARY CARE NURSE TASK-BASED SIMULATION MODEL TO ANALYZE WORKFLOW

A. INTRODUCTION

As the name implies, primary care is the primary source of healthcare, with 66.5% of healthcare in the United States performed in primary care clinics (Agency for Healthcare Research and Quality, 2008). Naturally, primary care is critical to providing high quality medical care (Bates, Ebell, Gotlieb, Zapp & Mullins, 2003). Primary care is a key contributor to "promoting health, preventing debilitating disease and reducing disability" (Lionis, et al, 2009, p. 2). Despite the importance of primary care, it faces a number of challenges. For example, primary care is the first line of defense in healthcare, treating a wide variety of patients; this variation in patient types places a burden on the primary care providers. Furthermore, primary care clinics operate in an environment of "aggressive pricing, tough competition, and rapidly changing guidelines" (Alexopoulos et al., 2001, p. 1386), which places more stress on the organizations providing care. In addition, the organizations providing primary care must deal with customers who are conditioned to expect fast, high quality services (Swisher, Jacobson, Jun, Balci, 2001). As one might infer, these conditions combine to create a unique, challenging operating environment. The U. S. primary care system is characterized as fundamentally broken and is the most costly in the world (Bates, et al, 2003). Additionally, primary care is also undergoing a series of simultaneous transformations, which further exacerbates the problems posed by the environment.

1. Primary Care Transformations

The first of three key transformations is the movement from a doctor-based model to a team-based care model (Bodenheimer, 2011). As Bodenheimer and Laing (2007) note that "during the 15-minute visit, primary care physicians cannot provide acute, chronic, and preventive care while building meaningful relationships with their patients and managing multiple diagnoses…the 15-minute physician visit must be eliminated as the central institution of primary care" (p. 457). Bodenheimer and Laing (2007) go on to suggest that the physician visit be replaced with a team comprised of physicians and nurses. Grumback and Bodenheimer summarized the support for a team-based model nicely in 2004, stating that "medical settings in which physicians and nonphysician professionals work together as teams can demonstrate improved patient outcomes," (p. 1246) and "a well-functioning team with a clear division of labor might relieve physicians of some of their workload" (p. 1251). Support for these multidisciplinary teams, made up of doctors and nurses, was also noted in 2000 by Richards, Carley, Jenkins-Clarke, and Richards.

The second major transformation primary care is undergoing is the transition from traditional paper records to electronic medical records (EMRs). Bates, et al (2003) said "the delivery of excellent primary care…demands that providers have the necessary information when providing care" (p. 1). According to Wetterneck, et al (2011) EMRs "have the potential to revolutionise healthcare delivery," (p. 1) and Adams, Mann, and Bauchner (2003) also note that EMRs "have been proposed as one way to reduce practice variation and improve quality" (p. 626). Additional benefits include cost savings, reduced medical errors, and improved patient health and safety (Hillestad, et al, 2005). These benefits are due to EMRs improving access to patient information and data, improved communication, clinical decision support, and ease of documentation (Wetterneck, et al, 2011; Adams, et al, 2003). In order to realize these benefits, however, it is important to select the most appropriate technology considering the established workflow (Horsky, Gutnik, & Patel, 2006).

The third major transformation occurring in primary care is the shift towards patient-centered care. Morgan and Yoder define patient-centered care as “a holistic approach to delivering care that is respectful and individualized…where persons are empowered to be involved in health decisions” (2011, p.7). Ekman, et al (2011) also emphasize that patient centered-care is a model where the patient plays an active role in their care and the decision process. This transformation can offer improved quality of care, increased satisfaction with the healthcare system, and improved health outcomes (Morgan & Yoder, 2011).

All of the previously mentioned transformations significantly impact clinic operations, and the impacts of these changes need to be fully evaluated. The Institute of Medicine has emphasized that a systematic approach is necessary to move from the current state of healthcare to the ideal (2000). Best and Pugh (2006) also note that a “systemic analysis of the work, the worker, and the work organization,” can improve healthcare. This is because most errors in healthcare are due to “conflicting, incomplete, or suboptimal systems” (Carayon, et al, 2006, p. i50). One of the keys to evaluating a complete system is to evaluate all of the individuals involved in the system. As noted previously, the nurse is now considered a key member of the primary care team;

therefore, the nurse's workflow and tasks need to be evaluated. This is made difficult by the complexity of the nursing practice, which involves complex cognitive processes and psychomotor and affective skills (Potter, et al, 2005).

2. Discrete-Event Simulation in Healthcare

Discrete-event simulation (DES) has been identified as an effective tool to evaluate the complex primary care physician practice. Other studies have identified simulation as an excellent tool to use to analyze complete systems. LeBlanc, et al (2011, p. S27) state "simulation research will be an essential component of systematic and comprehensive efforts to make healthcare more effective, efficient, and safe." The key benefits of using DES include the ability to account for the uncertainty and variability intrinsic to healthcare, analyze and predict a system's performance, and perform what-if analyses. This is especially useful when experimentation with the system is not possible, as is usually the case in healthcare (Fone, et al, 2003).

As previously identified, there is a general lack of simulation models focusing on primary care. The few that do exist focus on the physician and are based on expert opinion. (Swisher & Jacobson, 2002; Côté, 1999; Weng & Houshmand, 1999) During the literature review, only two studies were found that developed simulations with a focus on nursing, and neither of them focused on primary care. The first developed a data-based simulation model that was used to evaluate the nurse-patient assignments in a hospital (Sundaramoorthi, Chen, Rosenberger, Kim, & Buckley-Behan, 2009). The second used a simulation model, also based on data, to evaluate nurse staffing alternatives and different patient populations (Draeger, 1992). This points out a gap in the literature: the lack of simulations focusing on primary care nursing.

B. RESEARCH OBJECTIVE

Previously, a DES model of a primary care physician was developed. This model was unique in that it is detailed to the task level and is very generic and easily customizable. The purpose of this study is to develop a similarly generic, easily customizable simulation model of the primary care nurse during a patient encounter that uses a similar conceptual framework and is based on observational data. To this end, a standardized primary care nurse task list was utilized. The model will represent the time the patient is physically present in the clinic during the nurse-patient interaction, from when the nurse is notified of the patient's arrival to when the nurse has completed the post-rooming procedure. Finally, the simulation model will be based on the movements and actions of the nurse, instead of the patient.

C. METHODS

1. Model Concept Development

As mentioned, the simulation model developed in this study is to follow a similar framework as the previously developed primary care physician model. This means that the patient encounter will be modeled from the nurse's perspective; that is, the nurse will be the entity that moves through the system while the patient is the resource. Schriber and Brunner (2005) define the entity as the object that initiates and responds to events, while the resource provides service to an entity. Brailsford (2007) describes the typical view of healthcare resources and entities, in which patients are modeled as entities, which flow through the healthcare system, and the nurses and doctors are the resources. Hay, Valentin, and Bijlsma (2006) previously made the argument for this modeling perspective. This alternative approach for modeling has two advantages over the traditional viewpoint. First, the model is more generic developed using this perspective; hence, customization to a different clinic will be easier and faster. Secondly, the new approach allows the representation of the specific sequence of tasks occurring during a patient encounter, which varies from patient to patient. This allows the more accurate representation of the reality of the decisions and processes occurring during a nurse's encounter with the patient.

2. Conceptual Framework

The framework of the model is based on the triage and treatment technique of **S**ubjective information, **O**bjective information, **A**ssess and **P**lan (SOAP). This allows the nurse to choose the next step in patient care after each individual task is completed. First, the nurse selects which section of SOAP is needed, and then the specific task to complete within that area. After that decision, and the completion of the task, the process is repeated until the nurse decides that they have finished their portion and the patient is ready to be seen by the physician. This process is seen in Figure 7. A key point of the nurse's process is that some of these steps may occur outside the patient room. However, as these tasks fall within the SOAP model, separate blocks are not shown here. This uniqueness must be addressed within the model.

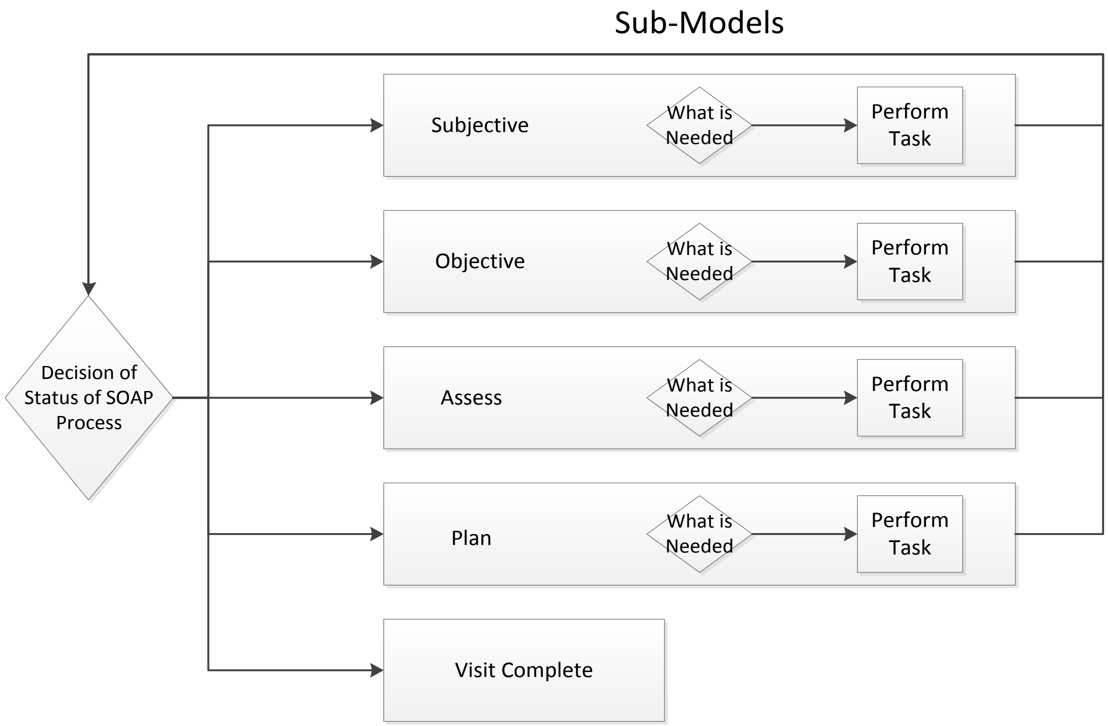

FIGURE 7- Global Methodology Framework for Nurse Model

3. Data Analysis

A secondary data analysis utilizing de-identified observational data from a recent study of clinician work at multiple primary care clinics in Wisconsin was performed (Grant: Agency for Healthcare Research and Quality (AHRQ) K08 HS17014, PI: Wetterneck). Two researchers performed tandem observations of nurse/physician pairs to collect the data (Wetterneck and Holman, 2011). Additional information, including insights regarding the patient's healthcare experience and/or the context of the data collection was utilized as necessary in order to develop a more accurate, complete model of the process. The study was approved by the University of Wisconsin institutional review board (IRB: IMD11-0389). The University of Louisville institutional review board approved the secondary analysis of the data (IRB: 12.0085).

A single clinic was selected for use in the study. The clinic was selected on several criteria, which follow:

- 100% participation of physicians and nursing teams
- Urban-based
- Electronic Medical Records (EMRs)
- 2+ years post EMR implementation

A key characteristic to note is that the same clinic was selected for use in this study and the development of the physician simulation. The basic clinic information is:

- 6 physicians (4 MDs and 2 Physician Assistants)
- 8 nurses
- Physician-Nurse team concept present
- Minimum of one half-day continuous observation of each physician/nurse team
- Approximately 24 total hours of physician/nurse observation performed
- 53 patient encounters observed and included in the data set

Only adult patient visits were included in the dataset. Specialties, like pediatrics and obstetric, were excluded. The data was used as time-stamped transcripts of events in a Word document.

Using the standardized nurse task list, the data was coded using the qualitative analysis software NVIVO© (GSR International). The original standardized task list was modified to consolidate all tasks related to patient medications into one task, following the recommendation to customize the task list as needed. The modified primary care nurse task list is shown in Appendix III. Two researchers independently coded observations, and the inter-rater reliability was acceptable at 87.9% (Boyatzis, 1998).

Once the coding was completed, a statistical analysis was performed to create Markov probability distribution tables. The tables considered several things to incorporate into the calculations:

- Task sequence position mean and standard deviation
- Application of normal distribution to task sequence
- Independent versus dependent tasks
- Tasks that occurred more than once during patient encounters.

Note that the presence of an underlying distribution of task sequence position is assumed. Therefore, the parametric normal distribution was applied to smooth the task sequence positions to allow for natural variation. The model was constructed using ARENA© simulation software (Rockwell Automation).

4. Model Flexibility, Validity, and Reliability

The model was designed to allow its customization by the simple changing of probability distribution table entities. Additionally, the use of the alternative modeling method again results in capturing both the mental and physical resources needed to treat a patient. Finally, in order to ensure the model matches reality, a series of checkpoints were inserted in the model to ensure that no specific task was performed more in one encounter than was observed in reality.

D. RESULTS

Figure 8 shows a high-level view of the completed model, while Figure 9 shows the main portion of the model consisting of the primary decision matrix.

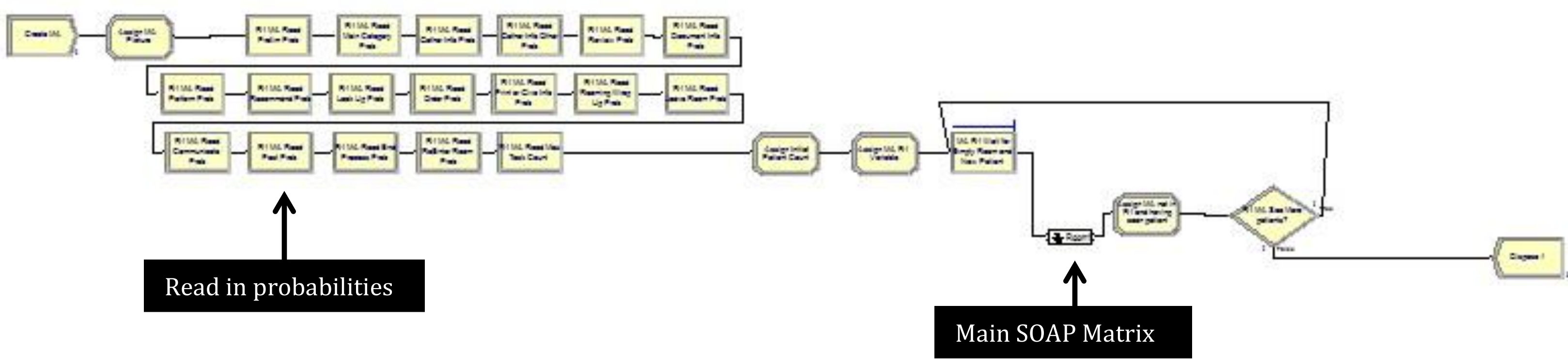

FIGURE 8-High Level Primary Care Nurse Model

Figure 9 also demonstrates the unique structure of the model using the alternative methodology; this figure is very similar to the high-level view of the completed physician simulation, as are the rest of the figures. This is a decision-based model, and as such it utilizes a high number of decision branches. The same basic format is seen within each main task's submodel. The overall number of individual main tasks is representative of the nurse task list's first-level tasks, such as enter room, gather information, et cetera.

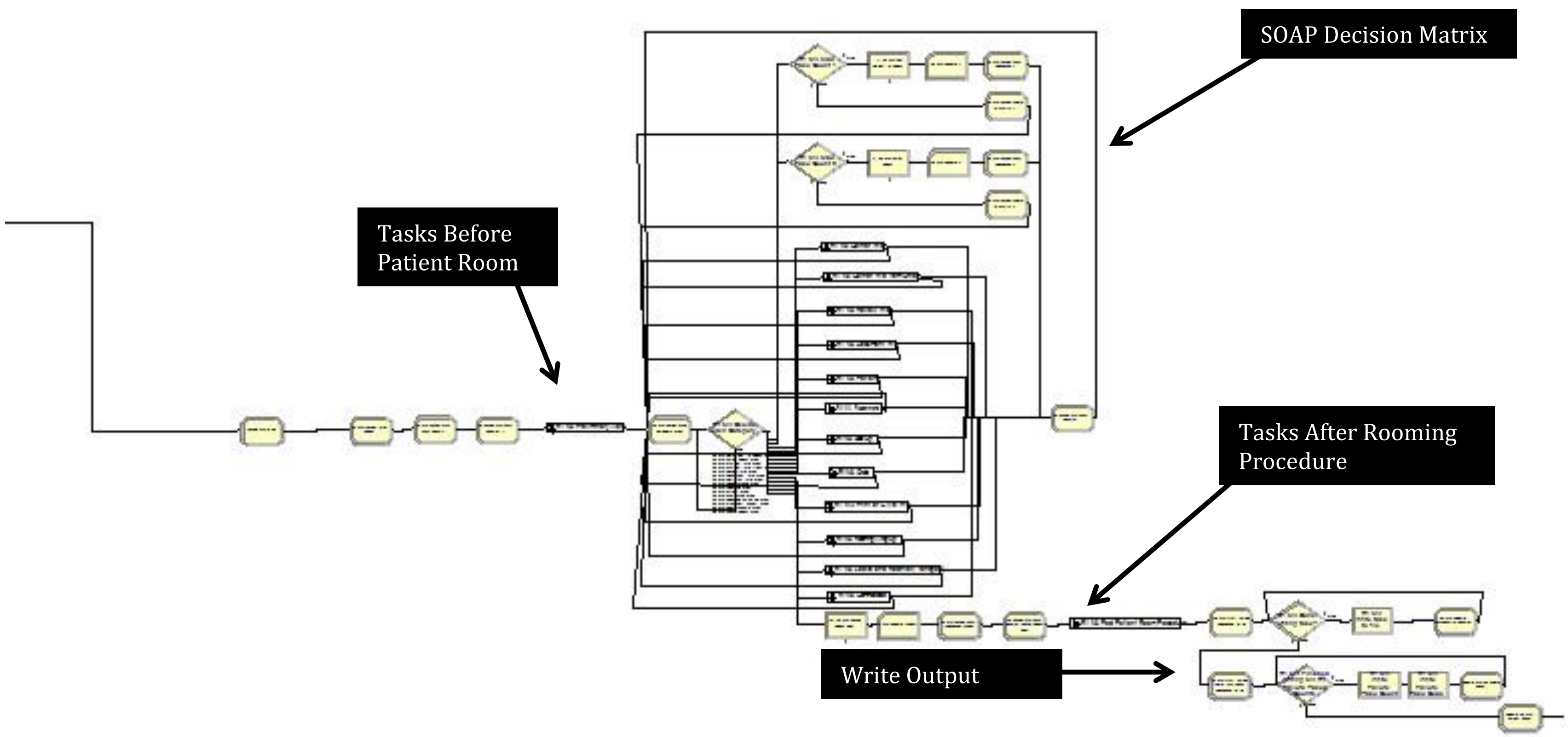

FIGURE 9-Main Decision Matrix in Nurse Model

The best way to understand the model is to walk through it step by step. First the nurse entity enters the model and goes through a series of Read/Write modules to read in the probability of each task occurring from a spreadsheet. This process is shown in detail in Figure 10. Then the nurse goes through a small decision matrix with tasks that occur outside of the patient room before the nurse and patient enter the room. This process is shown in detail in Figure 11. The nurse entity then enters a larger decision matrix that represents that tasks that occur once inside the patient room, shown in Figure 9. In both of these decision matrices, the nurse entity reaches a decide module that determines which first-level task should occur; this decision is based on probabilities considering both preceding tasks and the point the nurse is at during the encounter. The nurse is then routed to a submodel for the specific task; an example of these submodels is shown in Figure 12. Once there, the nurse entity goes through another decide module to determine the specific task, again taking into account the previous tasks and point in the appointment. The nurse entity is then routed through a series of modules that include the max count validity check, the completion of the task, and updating counters and variables to reflect the task that just occurred.

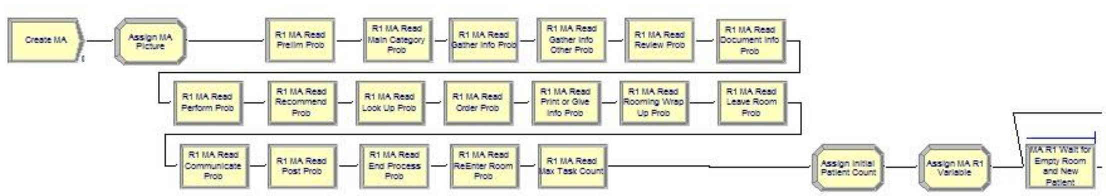

FIGURE 10-Beginning of Nurse Model

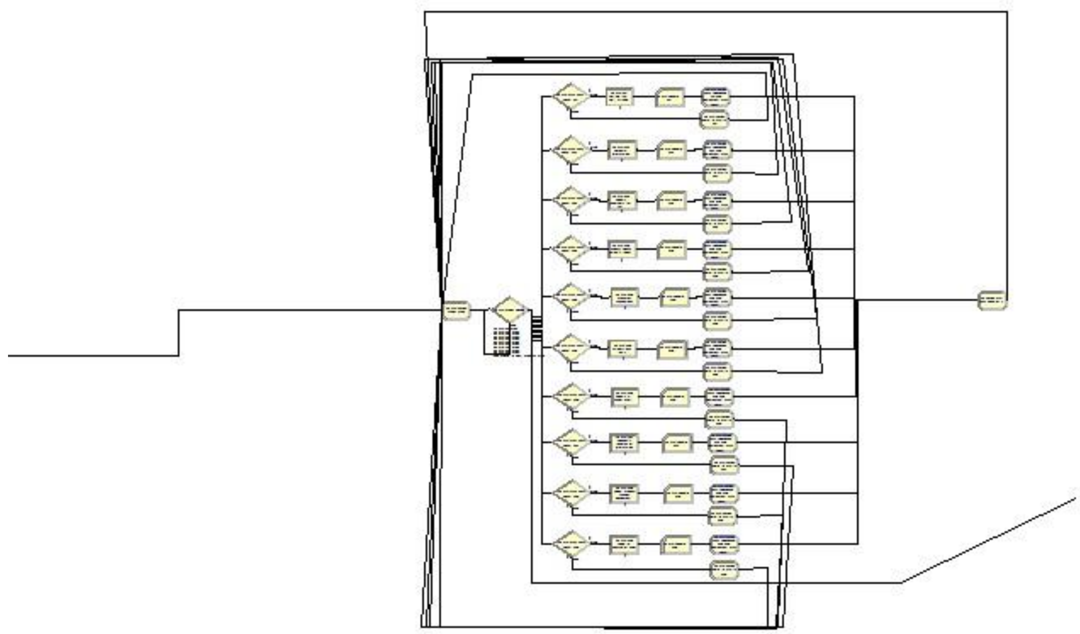

FIGURE 11-Tasks Occurring Before Entering Patient Room

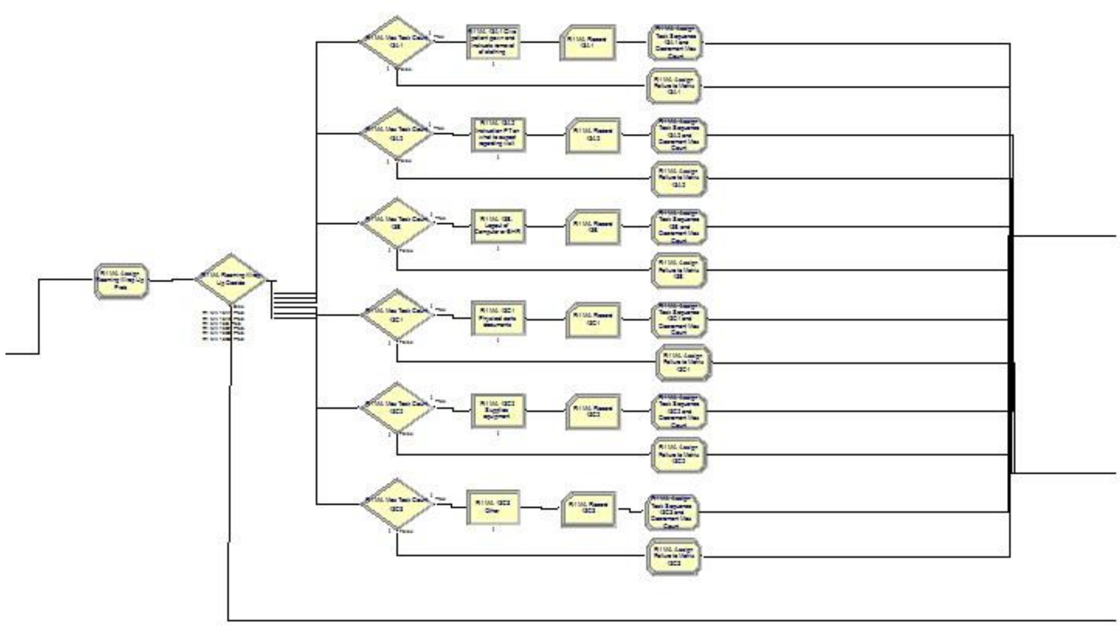

FIGURE 12-Task Submodel for Rooming Wrap-Up Task

After the nurse exits the submodel, the probability tables are updated for the next task, and the nurse entity returns to the first decide module. This continues until the nurse entity is routed to the final exit of the room. The nurse entity then goes through a submodel representing tasks that occur after exiting the room before the physician can see the patient. Finally, the entity goes through a series of modules that write the task sequence to file for later examination and analysis. Figure 13 and 14 show both of these processes; Figure 13 shows the modules that represent the tasks that occur outside of the patient room and writing the task sequence to file. Figure 14 shows the modules that occur at the end of the model. In order to convey the magnitude of the model, the basic statistics of the final developed model for a single nurse include 15 submodels which contain 273 Decide modules, 553 variables, 21 Read/Write modules, 256 Process modules, and 544 Assign modules.

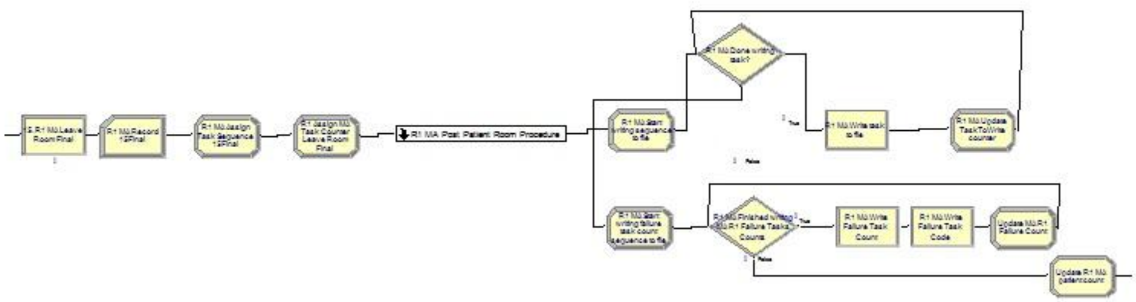

FIGURE 13-End of Nurse Decision Matrix

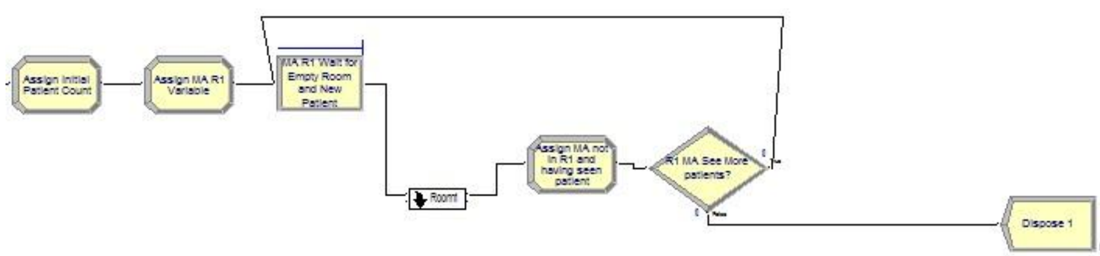

FIGURE 14-End of Nurse Model

An example of the outputs produced by the simulation model is shown in the following tables. Table VII shows the task sequence output from one patient encounter. Table VIII shows the failure output from the patient encounter, including the task number the failure occurred on and the attempted task code that failed. These failures represent instances where the model attempted to assign a task that had already been performed the maximum number of times.

TABLE VII

NURSE SIMULATION TASK SEQUENCE OUTPUT

Task Number	Task Code
1	0A
2	0B2
3	1
4	7B
5	7B
6	6K
7	2
8	3A
9	7J
10	7J
11	7K
12	5R
13	3G
14	7K
15	3G
16	7K
17	3G
18	7K
19	7K
20	3G
21	3I
22	5C
23	3C
24	5C
25	3G
26	6C
27	6A
28	3C
29	6C
30	6K
31	3C
32	6C
33	6K
34	3C
35	3C
36	7K
37	7B
38	3C
39	5C
40	5C
41	3C
42	3I
43	6K
44	7B
45	3C
46	3C
47	6K
48	3C
49	6K
50	3I
51	12K
52	15Final
53	11DPost

TABLE VIII

NURSE SIMULATION TASK FAILURE OUTPUT

Failure Number	**Task Number**	**Task Code**
1	3	15
2	3	15
3	4	1
4	4	1
5	5	1
6	5	1
7	5	15
8	9	15
9	12	7J
10	27	3G
11	45	7B
12	46	7B
13	47	7B
14	51	3G

1. Simulation Output

The task sequence and failure output is shown in Table VII and VIII, respectively. The task sequences generated by the simulation can be used in a variety of ways to improve primary care clinic operation. A brief case study was developed based on a set of assumptions in order to demonstrate the potential benefits of this simulation. The first assumption was that enough data were included in the development of the probability tables in order to generate valid predications. The second assumption used a triangular distribution with a minimum of 0.5 minutes, maximum of 1.5 minutes, and an average of one minute to estimate the processing time required for each individual task. Eventually, the time-stamped observations will be used to develop the process times required; however, currently there are not enough observations to develop valid processing time distributions. Figure 15 shows the triangular distribution.

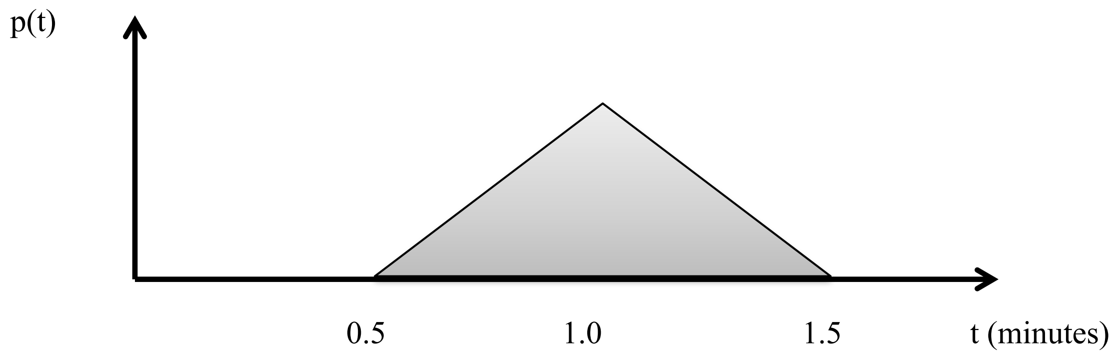

FIGURE 15-Triangular Distribution of Each Nursing Task's Process Time

There are two potential applications of this model. These are the use of simulated patient encounters to impact the scheduling of appointments and to make materials ordering more accurate. As an example of the first application, one day of patient encounters were simulated; one day is assumed to include fifteen patient appointments. The number of tasks was counted for each appointment, as well as the simulated time of each appointment. The expected range of time needed for the appointment, based on the number of tasks and the triangular distribution of each task's process time, was calculated. The number of tasks, expected range of appointment time, and simulated time are shown in Table IX. This shows that the average patient should be scheduled for between 28.9 and 86.7 minutes with the nurse, with the simulation showing an expected appointment length of 57.4 minutes. The scheduled nurse encounter should depend on the individual clinic's desired patient satisfaction. Assuming the clinic wanted to satisfy 80% of the patients, that is that 80% of the appointments are expected to be less than or equal to the scheduled time, the patient encounters with the nurse should be scheduled for 68.4 minutes. Although the task times used to estimate the encounter length, the potential is evident when one considers that clinic schedule appointments for twenty, thirty, forty-five, or sixty minutes. The output from this simulation could be used to make appointment scheduling more accurate. Further, it could be used to estimate the nursing encounter lengths of the overall clinic patient population or a specific population, such as patients with diabetes.

TABLE IX

SIMULATION OUTPUT TO IMPACT NURSE APPOINTMENT SCHEDULING

Patient	Number of Tasks	Possible Range of Time to Complete			Model's Estimated Time to Complete (minutes)
		Minimum Time (minutes)	Average Time (minutes)	Maximum Time (minutes)	
1	53	26.5	53	79.5	51.1
2	60	30	60	90	61.7
3	53	26.5	53	79.5	51.3
4	64	32	64	96	62.0
5	65	32.5	65	97.5	62.1
6	52	26	52	78	52.1
7	56	28	56	84	56.8
8	65	32.5	65	97.5	65.7
9	56	28	56	84	59.1
10	63	31.5	63	94.5	60.5
11	56	28	56	84	55.4
12	54	27	54	81	54.9
13	52	26	52	78	49.9
14	63	31.5	63	94.5	63.7
15	55	27.5	55	82.5	54.6
Average Patient	57.8	28.9	57.8	86.7	57.4

The second application explored is the use of the simulation output to improve the accuracy of the material handling order. The simulation model was used to generate one month's worth of patient encounters; that is, four weeks with the nurse working four days a week, with the nurse seeing fifteen patients a day, were simulated. Then, the task sequences were analyzed to generate frequency counts, which are shown in Table X. For this portion of the analysis, it is assumed that the same type and amount of supplies are used each time a task is completed in all appointments. Table X shows that, given the type and amount of supplies needed to complete each task and using the simulation output to estimate the number of times a task will be completed during a month, the materials required for the month can be estimated. Using this information, the materials order can be refined to be less wasteful.

TABLE X

NURSE TASK FREQUENCY COUNTS

Task	Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total Count
3C. Patient's current medications (verbal, list, notes, bottles, etc.)	114	112	105	99	104	111	96	119	101	101	107	128	122	110	121	110	1760
7K. Open template	92	74	95	99	83	99	104	96	91	88	92	96	109	93	102	86	1499
6K. Vitals/weight/Vision	86	73	76	75	66	73	79	79	69	73	70	82	83	67	75	71	1197
3G. Allergies and adverse reactions	73	75	74	73	74	74	73	71	72	73	72	70	71	68	69	67	1149
7B. Vitals/Vision/Weight	60	58	58	59	59	60	60	60	59	59	59	60	60	60	59	59	949
6C. Patient's current medications	52	46	62	52	69	51	54	61	49	56	59	57	50	47	55	59	879
3I. Tobacco use	59	40	48	50	48	41	59	43	45	34	48	38	39	47	54	31	724
5C. Patient's current medications	35	48	48	40	44	47	43	36	38	47	37	29	40	38	28	43	641
6A. Complaint(s) (chief, new, confirmation of reason for visit, list of, "told to come in")	30	41	24	32	37	27	30	29	36	37	33	32	35	32	34	34	523
3A. Complaint(s) (chief, new, confirmation of reason for visit, list of, "told to come in")	24	25	27	34	26	26	35	23	28	25	20	23	21	20	35	23	415
3E. Patient pharmacy	23	27	21	24	22	22	21	21	23	21	23	24	18	18	21	18	347
7J. Login to computer/EHR	17	16	20	16	21	22	19	21	22	20	22	23	22	22	17	25	325

5E. Patient pharmacy	14	16	16	13	14	13	19	20	19	13	14	14	12	18	18	18	251
0B(2). Collects paperwork for visit (hospital D/C, information/literature, etc.)	8	19	12	20	14	21	16	12	17	19	12	11	13	18	14	16	242
0A. Alerted that patient arrived and is in waiting room	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	240
15. Leave room-Final	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	240
1. Call patient from waiting room	15	13	14	12	14	13	13	15	15	13	15	13	14	14	12	13	218
5G. Allergies and adverse reactions	11	12	11	14	11	13	13	12	13	14	10	12	13	9	13	12	193
11D. Other	10	13	13	10	13	9	8	14	12	13	12	13	11	9	11	13	184
2. Enter room	10	11	10	12	9	9	12	10	11	10	12	13	10	9	7	8	163
3B. Problem information (pre-existing, new, questions, concerns, etc.)	9	6	9	7	8	9	6	5	8	10	13	12	9	11	6	12	140
5R. Test results	9	8	8	7	8	6	6	4	9	2	7	6	5	11	8	8	112
3H. Drug/alcohol use	9	4	3	6	4	6	8	3	4	10	5	3	6	2	7	7	87
13A(2). Instruction PT on what to expect regarding visit/procedure and waiting time for provider	7	3	7	7	5	6	10	5	2	3	7	6	5	2	9	0	84
11D. Other	7	3	1	5	3	8	4	6	5	5	5	4	5	6	6	4	77
3R. Test results	3	5	3	8	4	4	3	5	3	6	7	2	5	7	5	3	73
6S. Physical exam	5	2	2	8	7	3	8	4	3	3	6	5	3	4	3	4	70
0B(3). Checks/Cleans patients room	5	4	7	2	5	4	4	0	3	3	4	7	5	6	5	5	69

6I. Tobacco use	5	2	5	3	5	5	7	5	4	4	6	1	3	7	3	4	69
3U. Secondary patient	4	4	7	4	2	4	7	3	5	6	5	4	3	0	5	2	65
6E. Patient pharmacy	2	6	6	5	3	7	4	6	5	2	3	6	1	3	2	1	62
3S. Physical exam	3	2	3	5	4	4	6	3	5	2	6	3	5	6	1	2	60
12K. Other	6	2	3	6	3	6	2	3	3	2	4	4	6	1	5	3	59
3K. Vitals/weight/Vision	1	5	4	9	4	3	6	4	4	2	5	2	2	5	1	2	59
7D. Hand sanitization	6	2	2	3	1	5	3	4	4	4	5	0	1	2	5	4	51
7M. Delay (Dealing with a problem-computer, out of supply, etc.)	4	4	1	3	1	1	1	5	5	1	4	4	3	2	6	4	49
6B. Problem information (pre-existing, new, questions, concerns, etc.)	2	1	2	4	4	2	2	6	2	1	8	4	2	3	0	4	47
6G. Allergies and adverse reactions	3	2	3	1	4	1	3	8	3	1	5	1	2	4	2	3	46
5I. Tobacco use	1	2	5	3	3	5	3	1	5	2	3	3	3	2	2	2	45
17. Travel	3	1	1	2	1	4	4	1	2	2	1	1	3	4	4	3	37
5A. Complaint(s) (chief, new, confirmation of reason for visit, list of)	1	2	2	2	1	4	1	1	3	1	2	1	4	3	2	3	33
13C(2). Supplies/Equipment	5	1	2	1	0	1	5	0	3	0	1	3	3	0	1	1	27
13B. Log out of computer/EHR	2	0	1	3	1	1	3	0	2	0	1	2	1	2	2	0	21
16C. Flips door flags	2	1	1	3	1	0	1	0	1	0	0	0	0	1	2	0	13
13C(1). Physical charts/documents	0	1	1	1	0	1	1	0	2	0	0	1	1	0	1	0	10

16B. Leave chart/paperwork/labels in door holder/clip	0	0	0	0	0	2	3	0	0	0	1	1	1	1	0	0	9

E. DISCUSSION

The model developed in this study represents the second model constructed using the alternative methodology proposed previously. This shows that the methodology is viable for use in other situations in healthcare, and is encouraging in that it shows that the advantages translate well. The advantages demonstrated in this model include the following.

- The model mimics the nurse's actual procedure during a patient encounter, allowing the entity to move backwards and forwards through the SOAP procedure as needed.
- The model is generic and easily customizable to any nurse or practice.
- Any type of cost that can be quantified can be considered, including time, money, mental resources, physical resources, et cetera.
- The model can be modified to consider a variety of populations. One nurse can be considered, an entire practice, or a particular patient population.
- The model is based on real-world data, and will change as clinic data is updated or modified.

The argument in favor of real-world data was made in detail previously. Benefits of more accurate models based on real observation data include reducing procedural and medical errors and variation, increasing operational efficiency, and helping nurses be more thorough. Hence, the benefits outweigh the downfalls of the cost and time needed to collect the data. The limitation of the physician model not capturing all of the patient's waiting time is partially addressed by this model. This model captures the time the patient spends in the waiting room between the nurse being notified of the patient's arrival and the nurse calling the patient from the waiting room. The waiting time between the physician encounter and the nurse encounter is not captured yet. Once the physician and nurse models are linked, the full model will no longer have this limitation.

An additional limitation is the same as one of the individual physician model limitations. The nurse simulation model is very large, as demonstrated by the basic model statistics. The model size is due to the complexity required to capture the details needed to develop a task-level model that can be customized quickly. Again, traditional models may not be as large, but it is questionable if they will capture the same information.

1. Future Work

The linking of the primary care physician model and this model represent the next step in future work, capturing the patient encounter from the time that the patient arrives in the waiting room until the physician ends the appointment. This full model must then be validated and verified. The next logical extension of the complete simulation is to model the entire clinic (multiple teams functioning in multiple rooms). This will be examined to determine if organizational-level operations can be simulated with these types of models. The following stage of work focuses on examining the positive and negative impacts of EMR implementations in primary care. There are several possible avenues for expansion to explore in the future. One example is quantifying the mental resources needed to treat a patient, facilitating the evaluation of mental workloads of both members of the primary care team. Other areas for expansion include evaluating errors, re-work, and physician-nurse trust issues.

F. CONCLUSION

The goal of this study was to implement an alternative simulation modeling methodology that considers the nurse as the entity that moves through the system. The literature review revealed a need to focus on primary care nurses with simulation analysis, as there is currently a gap in the literature. The result is a data-based model that demonstrates a second successful implementation of the alternative modeling methodology previously proposed. This model can capture any resource that can be quantified, which could be a powerful tool to explore the impact of EMRs on primary care, the mental workload of primary care teams, errors, re-work, and physician-nurse trust issues.

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V. CONCLUSION

There are a series of conclusions that can be made from this three-part study. The first conclusion is that although traditional modeling perspectives may have been successful in the past, limiting future work to only those perspectives can limit the potential impact of future research. New, sometimes radically different, approaches are valuable and are needed to continue pushing the boundaries of the base of knowledge. The second conclusion that can be drawn is that two very different subspecialties in Industrial Engineering can be combined to perform more robust research in the future. The combination of qualitative methodologies from human factors, such as observation and task analysis, with operations research techniques, such as discrete-event simulation, is something to explore in the future. The final conclusion is one that has been made before, and that is simulation provides a viable tool to evaluate extremely important and complex systems, such as those found in healthcare.

There are three tools resulting from the completion of this study. The first tool is a simulation of a primary care physician that allows the prediction of specific task sequences performed during patient encounters. The model also generates output that allows the user to view instances in the model that tasks were selected in a sequence that would not occur in reality. The second tool produced is a task analysis list for the primary care nurse. This can be used to evaluate workflows, conduct time studies, et cetera; however, it was used to produce the third tool resulting from this study. This third tool is a simulation model of a primary care nurse. The simulation also predicts task sequences in patient encounters and provides output that documents errors found in those sequences.

A. Study Limitations

As with any study, there are limitations found in this research. Specifically, there are four limitations to consider. First, the simulation models of the primary care physician and nurse are not currently linked. The lack of linkage results in the second major limitation; that is, the time the patient waits between the nursing portion of the appointment and the physician encounter is not currently captured. The third major limitation is the relatively limited data set included in the models up to this point. Finally, the fourth major limitation focuses specifically on the nurse task analysis list. This list currently focuses on the time the patient is physically present in the clinic, not the downtime or time between patients, during which the nurse completes tasks important to the clinic's operation and infection control.

B. Recommendations for Future Work

Future research should first focus on completing the remaining two research objectives stated previously. That is, combining the physician and nurse simulation models to model an entire team. Then the expansion of the model to the clinic level, or multiple teams serving multiple rooms simultaneously, should be completed. The combination of the nurse and physician models will address two of the four major limitations just noted. To address the third major limitation, more data should be included in the models. There are two clinics remaining from the set of data collected using tandem observations (Grant: Agency for Healthcare Research and Quality (AHRQ) K08

HS17014, PI: Wetterneck). The observations from these clinics should be coded using the task lists and included in the complete model. This will be a big step in addressing the limitation of the small dataset. Also, the complete set of three clinics includes clinics using EMRs and those still using traditional paper records. Hence, this facilitates the next step of using the model to evaluate the different workflows associated with EMRs versus paper-based records, thus accomplishing the overall goal.

There are several other areas that have been identified that this model can be used to consider. One of these areas is the evaluation of procedural errors and re-work occurring during clinic visits. Another area is physician-nurse trust issues that have become especially important given the transformation to a team-based care model. A third area of interest is the quantification of the mental resources needed to treat a patient in primary care, which could produce interesting results. A final area of interest is using the simulation results to influence and improve patient scheduling policies in primary care clinics.

This leaves one previously mentioned limitation unaddressed. The nurse task analysis list, which was adequate to model the scope of the patient appointment included in the simulation model, is incomplete, as noted. The list should be expanded to include tasks that support organization and facility daily activities. These activities include infection control, tasks occurring between patients, et cetera. Further refinement of the list, utilizing observations from more clinics, is needed as well. This may not necessarily impact the simulation models resulting from this study, but will be important for future use of the task list by other researchers and care providers.

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APPENDIX I

TABLE XI

PRIMARY CARE PHYSICIAN TASK LIST*

1. Enter room	
1. Re-Enter room	
2. Gather Information	
	2A. Chief complaint
	2B. Problem information
	2C. Patient's current medications
	2E. Patient pharmacy
	2F. Cost/access/insurance
	2G. Allergies and adverse reactions
	2H. Drug/alcohol use
	2I. Tobacco use
	2J. Exercise/diet
	2K. Vitals/weight
	2L. Daily life activities

2M. Support network, living situation, or help in emergency situation

2N. Advanced medical directive/end of life

2O. Family history

2P. Patient home monitoring information

2Q. Preventative screening

2R. Test results

2S. Physical exam

2T. Diagnosis

2U. Secondary patient

2V. Previous appointments with same MD

2W. Review of symptoms/systems

- 2W(1). Skin
- 2W(2). Neurological
- 2W(3). Gastrointestinal
- 2W(4). Constitutional (fever, weight loss, etc.)
- 2W(5). Eyes
- 2W(6). Ears, nose, mouth and throat
- 2W(7). Cardiovascular
- 2W(8). Respiratory
- 2W(9). Sleep
- 2W(10). Psychiatric
- 2W(11). Musculoskeletal/joints/feet
- 2W(12). Hematological

2W(13). Sexual/genital/urinary

2X. Social contact

2Y. "Anything else" question

2Z. Other

---

3. Review patient information

3A. Chief complaint

3B. Problem information

3C. Patient's current medications

3D. Medications

3E. Patient pharmacy

3F. Cost/access/insurance

3G. Allergies and adverse reactions

3H. Drug/alcohol use

3I. Tobacco use

3J. Exercise/diet

3K. Vitals/weight

3L. Daily life activities

3M. Support network, living situation, or help in emergency situation

3N. Advanced medical directive/end of life

3O. Family history

3P. Patient home monitoring information

3Q. Preventative screening

3R. Test results

3S. Physical exam

3T. Diagnosis

3U. Secondary patient

3V. Previous appointments with same MD

3W. Nursing notes/clinic note

3X. Past medical/surgical history/problem list

3Y. Outside medical/counseling care

3Y(1). ER/urgent care

3Y(2). Specialist/other doctors

3Y(3). Hospitalizations

3Z. Follow-up appointment information

3AA. Patient paper forms

3BB. Other

---

4. Document patient information

4A. Chief complaint

4B. Problem information

4C. Patient's current medications

4D. Medications

4E. Patient pharmacy

4F. Cost/access/insurance

4G. Allergies and adverse reactions

4H. Drug/alcohol use

4I. Tobacco use

4J. Exercise/diet

4K. Vitals/weight

4L. Daily life activities

4M. Support network, living situation, or help in emergency situation

4N. Advanced medical directive/end of life

4O. Family history

4P. Patient home monitoring information

4Q. Preventative screening

4R. Test results

4S. Physical exam

4T. Diagnosis

4U. Secondary patient

4V. Treatment plan

4W. Review of symptoms/systems

  - 4W(1). Skin
  - 4W(2). Neurological
  - 4W(3). Gastrointestinal
  - 4W(4). Constitutional (fever, weight loss, etc.)
  - 4W(5). Eyes
  - 4W(6). Ears, nose, mouth and throat
  - 4W(7). Cardiovascular
  - 4W(8). Respiratory
  - 4W(9). Sleep

4W(10). Psychiatric

4W(11). Musculoskeletal/joints/feet

4W(12). Hematological

4W(13). Sexual/genital/urinary

4X. Past medical/surgical history/problem list

4Y. Outside medical/counseling care

4Y(1). ER/urgent care

4Y(2). Specialist/other doctors

4Y(3). Hospitalizations

4Z. Follow-up appointment information

4AA. Other

---

5. Perform

5A. Perform-Procedure

5B. Perform-Vitals

5C. Perform-Physical exam

5D. Perform-Hand sanitization

5E. Perform-Immunization

5F. Perform-Fill out patient form

5G. Perform-Dictate

5H. Perform-Phone call/answer phone/pager

5I. Perform-Calculation (BMI, Dosage, etc.)

5J. Perform-Login to computer/EHR -2

5J. Perform-Login to computer/EHR

5K. Perform-Open template

5L. Perform-Other

6. Recommend/discuss treatment options

6A. Medication

6B. Diet/exercise

6C. Test/preventive screening

6D. Procedure

6E. Follow-up appointment

6F. Referral to specialist

6G. Home remedy

6H. Non-traditional treatment

6I. Observation/wait and see/do nothing

6J. Immunization

6K. Home monitoring

6L. Get additional information

6M. Other

7. Look Up

7A. Look up-Treatment information

7B. Look up-Referral doctor

7C. Look up-Drug information

7D. Look up-Other

8. Order

8A. Order-Medication

8B. Order-Test

8C. Order-Referral to specialist

8D. Order-Procedure

8E. Order-Immunization

8F. Order-Other

---

9. Communicate

9A. Communicate-Nurse

9B. Communicate-Other healthcare provider

---

10. Print/Give Patient

10A. Paper prescription

10B. Medication information/instructions

10C. Test order form

10D. Sample medication

10E. Disease/problem information

10F. Home monitoring card/paper

10G. Medical equipment

10H. Follow-up appointment information

10I. Appointment summary

10J. Referral information

10K. Other

---

11. Appointment Wrap-Up

11A. Walk patient

11A(1). Nurse station

11A(2). Waiting room

11A(3). Labs

11A(4). Radiology

11A(5). Reception

11B. Go to (appointment not over)

11B(1). Office

11B(2). Nurse station

11B(3). Waiting room

11B(4). Labs

11B(5). Radiology

11B(6). Reception

11B(7). Sample medication cabinet

11B(8). Another patient

11B(9). Other

11C. Log out of computer/EHR

---

12. Leave room

12. Leave room-Final

*Modified table created with permission of Wetterneck et al (2011).

APPENDIX II

TABLE XII

A STANDARDIZED PRIMARY CARE NURSE TASK LIST

0. Preliminary Work Prior to PT Contact

- 0A. Alerted that patient arrived and is in waiting room
- 0B. Preparation for PT visit (specific to that PT)
  - 0B(1). Review PT information (visit history, hospital D/C, test results, etc.)
  - 0B(2). Collects paperwork for visit (hospital D/C, information/literature, etc.)
  - 0B(3). Checks/Cleans patients room
  - 0B(4). Prepares vaccinations
  - 0B(5). Orders labs/tests (either anticipation or provider)
  - 0B(6). Collects PT paper chart
  - 0B(7). Request records or information from person, group, hospital, etc.
  - 0B(8). Collect Medical supplies/equipment

0B(9). Login to Computer/HER

1. Call patient from waiting room

2. Enter room

3. Gather information from patient

    3A. Complaint(s) (chief, new, confirmation of reason for visit, list of, "told to come in")

    3B. Problem information (pre-existing, new, questions, concerns, etc.)

    3C. Patient's current medications (verbal, list, notes, bottles, etc.)

    3D. Medications

        3D(1). Side effects

        3D(2). Medication instructions

        3D(3). Compliance

        3D(4). Effectiveness

        3D(5). Evidence regarding medication treatment

        3D(6). Reason for medication

        3D(7). Refills needed

        3D(8). Drug interactions

        3D(9). Other

    3E. Patient pharmacy

    3F. Cost/access/insurance

    3G. Allergies and adverse reactions

    3H. Drug/alcohol use

    3I. Tobacco use

3J. Exercise/diet

3K. Vitals/weight/Vision

3L. Daily life activities

3M. Support network, living situation, or help in emergency situation

3N. Advanced medical directive/end of life

3O. Family history

3P. Patient home monitoring information

3Q. Preventative screening

3R. Test results

3S. Physical exam

3T. Diagnosis

3U. Secondary patient

3V. Previous appointments

- 3V(1). Same doctor
- 3V(2). Other Doctors

3W. Review of symptoms/systems (not associated with main problems

- 3W(1). Skin
- 3W(2). Neurological
- 3W(3). Gastrointestinal
- 3W(4). Constitutional (fever, weight loss, etc.)
- 3W(5). Eyes
- 3W(6). Ears, nose, mouth and throat
- 3W(7). Cardiovascular

3W(8). Respiratory

3W(9). Sleep

3W(10). Psychiatric

3W(11). Musculoskeletal/joints/feet

3W(12). Sexual/genital/urinary

3X. Social contact

3Y. "Anything else" question

3Z. Demographic/Contact Information

3AA. Other

---

4. Gather information from other (family member, caregiver, etc.)

4A. Complaint(s) (chief, new, confirmation of reason for visit, list of, "told to come in")

4B. Problem information (pre-existing, new, questions, concerns, etc.)

4C. Patient's current medications (verbal, list, notes, bottles, etc.)

4D. Medications

4D(1). Side effects

4D(2). Medication instructions

4D(3). Compliance

4D(4). Effectiveness

4D(5). Evidence regarding medication treatment

4D(6). Reason for medication

4D(7). Refills needed

4D(8). Drug interactions

4D(9). Other

4E. Patient pharmacy

4F. Cost/access/insurance

4G. Allergies and adverse reactions

4H. Drug/alcohol use

4I. Tobacco use

4J. Exercise/diet

4K. Vitals/weight/Vision

4L. Daily life activities

4M. Support network, living situation, or help in emergency situation

4N. Advanced medical directive/end of life

4O. Family history

4P. Patient home monitoring information

4Q. Preventative screening

4R. Test results

4S. Physical exam

4T. Diagnosis

4U. Secondary patient

4V. Previous appointments

4V(1). Same doctor

4V(2). Other Doctors

4W. Review of symptoms/systems (not associated with main problems

4W(1). Skin

4W(2). Neurological

4W(3). Gastrointestinal

4W(4). Constitutional (fever, weight loss, etc.)

4W(5). Eyes

4W(6). Ears, nose, mouth and throat

4W(7). Cardiovascular

4W(8). Respiratory

4W(9). Sleep

4W(10). Psychiatric

4W(11). Musculoskeletal/joints/feet

4W(12). Sexual/genital/urinary

4X. Social contact

4Y. "Anything else" question

4Z. Demographic/Contact Information

4AA. Other

---

5. Review patient information

5A. Complaint(s) (chief, new, confirmation of reason for visit, list of)

5B. Problem information (pre-existing, new, questions, concerns, told to come in, etc.)

5C. Patient's current medications

5D. Medications

5E. Patient pharmacy

5F. Cost/access/insurance

5G. Allergies and adverse reactions

5H. Drug/alcohol use

5I. Tobacco use

5J. Exercise/diet

5K. Vitals/weight/Vision

5L. Daily life activities

5M. Support network, living situation, or help in emergency situation

5N. Advanced medical directive/end of life

5O. Family history

5P. Patient home monitoring information

5Q. Preventative screening

5R. Test results

5S. Physical exam

5T. Diagnosis

5U. Secondary patient

5V. Previous appointments

5W. Nursing notes/clinic note

5X. Past medical/surgical history/problem list

5Y. Outside medical/counseling care

    5Y(1). ER/urgent care

    5Y(2). Specialist/other doctors

    5Y(3). Hospitalizations

5Z. Follow-up appointment information

5AA. Patient paper forms

5BB. Other

---

6. Document patient information

6A. Complaint(s) (chief, new, confirmation of reason for visit, list of, "told to come in")

6B. Problem information (pre-existing, new, questions, concerns, etc.)

6C. Patient's current medications

6D. Medications

6D(1). Side effects

6D(2). Medication instructions

6D(3). Compliance

6D(4). Effectiveness

6D(5). Evidence regarding medication treatment

6D(6). Reason for medication

6D(7). Refills needed

6D(8). Drug interactions

6D(9). Administering Medication during visit

6D(10). Other

6E. Patient pharmacy

6F. Cost/access/insurance

6G. Allergies and adverse reactions

6H. Drug/alcohol use

6I. Tobacco use

6J. Exercise/diet

6K. Vitals/weight/Vision

6L. Daily life activities

6M. Support network, living situation, or help in emergency situation

6N. Advanced medical directive/end of life

6O. Family history

6P. Patient home monitoring information

6Q. Preventative screening

6R. Test results

6S. Physical exam

6T. Diagnosis

6U. Secondary patient

6V. Previous appointments

- 6V(1). Same doctor (additional information)
- 6V(2). Other Doctors

6W. Review of symptoms/systems (not associated with main problems

- 6W(1). Skin
- 6W(2). Neurological
- 6W(3). Gastrointestinal
- 6W(4). Constitutional (fever, weight loss, etc.)
- 6W(5). Eyes
- 6W(6). Ears, nose, mouth and throat
- 6W(7). Cardiovascular

6W(8). Respiratory

6W(9). Sleep

6W(10). Psychiatric

6W(11). Musculoskeletal/joints/feet

6W(12). Sexual/genital/urinary

6X. Past medical/surgical history/problem list

6Y. Outside medical/counseling care

6Y(1). ER/urgent care

6Y(2). Specialist/other doctors

6Y(3). Hospitalizations

6Z. Follow-up appointment information

6AA. Patient paper forms

6BB. Demographic/Contact Information

6CC. Other

---

7. Perform

7A. Procedure

7B. Vitals/Vision/Weight

7C. Physical exam

7D. Hand sanitization

7E. Administer Medication

7E(1). Immunization

7E(2). Other

7F. Fill out patient form

7G. Dictate

7H. Telephone call/answer phone/pager

7I. Calculation

7I(1). BMI

7I(2). Medication dosage

7J. Login to computer/EHR

7K. Open template

7L. Other

7M. Delay (Dealing with a problem-computer, out of supply, etc.)

---

8. Recommend/discuss treatment options

8A. Medication

8B. Diet/exercise

8C. Test/preventive screening

8D. Procedure

8E. Follow-up appointment

8F. Referral to specialist

8G. Home remedy

8H. Non-traditional treatment

8I. Observation/wait and see/do nothing

8J. Immunization

8K. Home monitoring

8L. Get additional information

8M. Other

---

9. Look up

- 9A. Treatment information
- 9B. Referral doctor
- 9C. Previous care clinic, hospital, provider
- 9D. Drug Information
- 9E. Pharmacist/Pharmacy
- 9F. Other

10. Order

- 10A. Medication
- 10B. Test
- 10C. Referral to specialist
- 10D. Procedure
- 10E. Immunization
- 10F. Other

11. Communicate

- 11A. PCP
- 11B. Other healthcare provider
- 11C. Other healthcare provider (external to clinic)
- 11D. Other

12. Print/give patient

- 12A. Paper prescription
- 12B. Medication information/instructions
- 12C. Test order form

12D. Sample medication

12E. Disease/problem information

12F. Home monitoring card/paper

12G. Medical equipment

12H. Follow-up appointment information

12I. Appointment summary

12J. Referral information

12K. Other

---

13. Rooming wrap-up

13A. Patient Instruction

13A(1). Give patient gown and instructs removal of clothing necessary for physical exam

13A(2). Instruction PT on what to expect regarding visit/procedure and waiting time for provider

13B. Log out of computer/EHR

13C. Collect

13C(1). Physical charts/documents

13C(2). Supplies/Equipment

13C(3). Other

---

14. Transport/Escort

14A. Patient

14A(1). Office

14A(2). Nurse station

14A(3). Waiting room

14A(4). Labs

14A(5). Radiology

14A(6). Reception

14A(7). Sample medication cabinet

14A(8). Procedure Room

14A(9). Other

14B. Family, Friends, Caregivers, etc.

15. Leave room

16. Post patient rooming procedure

16A. Chart/paperwork/labels to office/file room/circulation

16B. Leave chart/paperwork/labels in door holder/clip

16C. Flips door flags

17. Travel

APPENDIX III

TABLE XIII

PRIMARY CARE NURSE TASK LIST

0. Preliminary Work Prior to PT Contact

 0A. Alerted that patient arrived and is in waiting room

 0B. Preparation for PT visit (specific to that PT)

  0B(1). Review PT information (visit history, hospital D/C, test results, etc.)

  0B(2). Collects paperwork for visit (hospital D/C, information/literature, etc.)

  0B(3). Checks/Cleans patients room

  0B(4). Prepares vaccinations

  0B(5). Orders labs/tests (either anticipation or provider)

  0B(6). Collects PT paper chart

  0B(7). Request records or information from person, group, hospital, etc.

  0B(8). Collect Medical supplies/equipment

0B(9). Login to Computer/HER

1. Call patient from waiting room
2. Enter room
3. Gather information from patient

3A. Complaint(s) (chief, new, confirmation of reason for visit, list of, "told to come in")

3B. Problem information (pre-existing, new, questions, concerns, etc.)

3C. Patient's current medications (verbal, list, notes, bottles, etc.)

3E. Patient pharmacy

3F. Cost/access/insurance

3G. Allergies and adverse reactions

3H. Drug/alcohol use

3I. Tobacco use

3J. Exercise/diet

3K. Vitals/weight/Vision

3L. Daily life activities

3M. Support network, living situation, or help in emergency situation

3N. Advanced medical directive/end of life

3O. Family history

3P. Patient home monitoring information

3Q. Preventative screening

3R. Test results

3S. Physical exam

3T. Diagnosis

3U. Secondary patient

3V. Previous appointments

3V(1). Same doctor

3V(2). Other Doctors

3W. Review of symptoms/systems (not associated with main problems

3W(1). Skin

3W(2). Neurological

3W(3). Gastrointestinal

3W(4). Constitutional (fever, weight loss, etc.)

3W(5). Eyes

3W(6). Ears, nose, mouth and throat

3W(7). Cardiovascular

3W(8). Respiratory

3W(9). Sleep

3W(10). Psychiatric

3W(11). Musculoskeletal/joints/feet

3W(12). Sexual/genital/urinary

3X. Social contact

3Y. "Anything else" question

3Z. Demographic/Contact Information

3AA. Other

---

4. Gather information from other (family member, caregiver, etc.)

4A. Complaint(s) (chief, new, confirmation of reason for visit, list of, "told to come in")

4B. Problem information (pre-existing, new, questions, concerns, etc.)

4C. Patient's current medications (verbal, list, notes, bottles, etc.)

4E. Patient pharmacy

4F. Cost/access/insurance

4G. Allergies and adverse reactions

4H. Drug/alcohol use

4I. Tobacco use

4J. Exercise/diet

4K. Vitals/weight/Vision

4L. Daily life activities

4M. Support network, living situation, or help in emergency situation

4N. Advanced medical directive/end of life

4O. Family history

4P. Patient home monitoring information

4Q. Preventative screening

4R. Test results

4S. Physical exam

4T. Diagnosis

4U. Secondary patient

4V. Previous appointments

4V(1). Same doctor

4V(2). Other Doctors

4W. Review of symptoms/systems (not associated with main problems

4W(1). Skin

4W(2). Neurological

4W(3). Gastrointestinal

4W(4). Constitutional (fever, weight loss, etc.)

4W(5). Eyes

4W(6). Ears, nose, mouth and throat

4W(7). Cardiovascular

4W(8). Respiratory

4W(9). Sleep

4W(10). Psychiatric

4W(11). Musculoskeletal/joints/feet

4W(12). Sexual/genital/urinary

4X. Social contact

4Y. "Anything else" question

4Z. Demographic/Contact Information

4AA. Other

---

5. Review patient information

5A. Complaint(s) (chief, new, confirmation of reason for visit, list of)

5B. Problem information (pre-existing, new, questions, concerns, told to come in, etc.)

5C. Patient's current medications

5E. Patient pharmacy

5F. Cost/access/insurance

5G. Allergies and adverse reactions

5H. Drug/alcohol use

5I. Tobacco use

5J. Exercise/diet

5K. Vitals/weight/Vision

5L. Daily life activities

5M. Support network, living situation, or help in emergency situation

5N. Advanced medical directive/end of life

5O. Family history

5P. Patient home monitoring information

5Q. Preventative screening

5R. Test results

5S. Physical exam

5T. Diagnosis

5U. Secondary patient

5V. Previous appointments

5W. Nursing notes/clinic note

5X. Past medical/surgical history/problem list

5Y. Outside medical/counseling care

    5Y(1). ER/urgent care

    5Y(2). Specialist/other doctors

5Y(3). Hospitalizations

5Z. Follow-up appointment information

5AA. Patient paper forms

5BB. Other

---

6. Document patient information

6A. Complaint(s) (chief, new, confirmation of reason for visit, list of, "told to come in")

6B. Problem information (pre-existing, new, questions, concerns, etc.)

6C. Patient's current medications

6E. Patient pharmacy

6F. Cost/access/insurance

6G. Allergies and adverse reactions

6H. Drug/alcohol use

6I. Tobacco use

6J. Exercise/diet

6K. Vitals/weight/Vision

6L. Daily life activities

6M. Support network, living situation, or help in emergency situation

6N. Advanced medical directive/end of life

6O. Family history

6P. Patient home monitoring information

6Q. Preventative screening

6R. Test results

6S. Physical exam

6T. Diagnosis

6U. Secondary patient

6V. Previous appointments

- 6V(1). Same doctor (additional information)
- 6V(2). Other Doctors

6W. Review of symptoms/systems (not associated with main problems

- 6W(1). Skin
- 6W(2). Neurological
- 6W(3). Gastrointestinal
- 6W(4). Constitutional (fever, weight loss, etc.)
- 6W(5). Eyes
- 6W(6). Ears, nose, mouth and throat
- 6W(7). Cardiovascular
- 6W(8). Respiratory
- 6W(9). Sleep
- 6W(10). Psychiatric
- 6W(11). Musculoskeletal/joints/feet
- 6W(12). Sexual/genital/urinary

6X. Past medical/surgical history/problem list

6Y. Outside medical/counseling care

- 6Y(1). ER/urgent care
- 6Y(2). Specialist/other doctors

6Y(3). Hospitalizations

6Z. Follow-up appointment information

6AA. Patient paper forms

6BB. Demographic/Contact Information

6CC. Other

---

7. Perform

7A. Procedure

7B. Vitals/Vision/Weight

7C. Physical exam

7D. Hand sanitization

7E. Administer Medication

7E(1). Immunization

7E(2). Other

7F. Fill out patient form

7G. Dictate

7H. Telephone call/answer phone/pager

7I. Calculation

7I(1). BMI

7I(2). Medication dosage

7J. Login to computer/EHR

7K. Open template

7L. Other

7M. Delay (Dealing with a problem-computer, out of supply, etc.)

---

8. Recommend/discuss treatment options

- 8A. Medication
- 8B. Diet/exercise
- 8C. Test/preventive screening
- 8D. Procedure
- 8E. Follow-up appointment
- 8F. Referral to specialist
- 8G. Home remedy
- 8H. Non-traditional treatment
- 8I. Observation/wait and see/do nothing
- 8J. Immunization
- 8K. Home monitoring
- 8L. Get additional information
- 8M. Other

9. Look up

- 9A. Treatment information
- 9B. Referral doctor
- 9C. Previous care clinic, hospital, provider
- 9D. Drug Information
- 9E. Pharmacist/Pharmacy
- 9F. Other

10. Order

- 10A. Medication

10B. Test

10C. Referral to specialist

10D. Procedure

10E. Immunization

10F. Other

---

11. Communicate

11A. PCP

11B. Other healthcare provider

11C. Other healthcare provider (external to clinic)

11D. Other

---

12. Print/give patient

12A. Paper prescription

12B. Medication information/instructions

12C. Test order form

12D. Sample medication

12E. Disease/problem information

12F. Home monitoring card/paper

12G. Medical equipment

12H. Follow-up appointment information

12I. Appointment summary

12J. Referral information

12K. Other

---

13. Rooming wrap-up

13A. Patient Instruction

13A(1). Give patient gown and instructs removal of clothing necessary for physical exam

13A(2). Instruction PT on what to expect regarding visit/procedure and waiting time for provider

13B. Log out of computer/EHR

13C. Collect

13C(1). Physical charts/documents

13C(2). Supplies/Equipment

13C(3). Other

---

14. Transport/Escort

14A. Patient

14A(1). Office

14A(2). Nurse station

14A(3). Waiting room

14A(4). Labs

14A(5). Radiology

14A(6). Reception

14A(7). Sample medication cabinet

14A(8). Procedure Room

14A(9). Other

14B. Family, Friends, Caregivers, etc.

---

15. Leave room

---

15. Leave room-Final

16. Post patient rooming procedure

    16A. Chart/paperwork/labels to office/file room/circulation

    16B. Leave chart/paperwork/labels in door holder/clip

    16C. Flips door flags

17. Travel

VITA

Abigail Rayburn Wooldridge was born on November 15, 1988 in Dallas, Texas to David and Miriam Wooldridge. She graduated from duPont Manual High School in Louisville, Kentucky in 2007 and began at the University of Louisville in August of 2007. In August of 2011, she received a Bachelor of Science in Industrial Engineering from the University of Louisville, passing the Fundamentals of Engineering Exam in April of 2011. While at the University of Louisville, she completed three cooperative education rotations at TechSolve, Inc. in Cincinnati, Ohio. Following graduation, she enrolled in the Masters of Engineering program in August of 2011. She began working for Advanced Solutions, Inc. in November of 2011 while still attending school as a full-time student. She was also involved in several societies while completing her undergraduate and Masters degrees, including the Institute of Industrial Engineers, Tau Beta Pi (2011-2012 President, 2011 Chapter Convention Delegate, 2011 National Awards Committee Chair), Alpha Pi Mu (2011-2012 Vice President), the Institute for Operations Research and the Management Sciences (2011-2012 Secretary), the Society of Women Engineers, the University Honors Program, and Sigma Kappa Sorority.