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NGOMSL SIMULATION MODEL IN AN EMERGENCY DEPARTMENT

Nithin Parameshwara
Jung Hyup Kim
Wenbin Guo

Department of Industrial and Manufacturing Systems Engineering
University of Missouri
E3437 Thomas & Lafferre Hall
Columbia, MO 65211, USA

Kalyan S Pasupathy

Emergency Department Clinical Engineering Learning Lab
Kern Center for the Science of Health Care Delivery
Mayo Clinic
200 First Street SW
Rochester, MN 55905, USA

ABSTRACT

Natural Goals Operators Methods and Selection Rules Language (NGOMSL) model of the clinical process in an Emergency Department (ED) was developed using Micro Saint Sharp. This model advanced our understanding of a care provider's cognitive behavior in a dynamic ED environment. It also revealed the understanding of proximal workflow in the ED and the workload related to clinical processes. The benefits of this study are (a) improved understanding of the relevant form factors of the clinical process that contribute to a heavy workload in the ED and (b) prevention of potential errors caused by the workload. To understand the current ED workflow, hierarchical task analysis (HTA) charts were developed. The HTA charts were used to understand the detailed process mappings of nurses in the ED. Based on this multi-level analysis of the HTA charts, the NGOMSL simulation model was developed.

1 INTRODUCTION

Patients mostly visit the emergency department (ED) to seek urgent care. The ED is the busiest and most unpredictable area in a hospital. Recently, most emergency departments have experienced dramatic increases in patient volume over the past decade. In 2015, a poll conducted by the American College of Emergency Physicians on 2,099 emergency physicians nationally showed that about 28% of the physicians surveyed saw significant increases in patient volume while 47% saw slight increases (Ungar and O'Donnell 2015). Owing to this overwhelming pressure to provide effective and complete patient care in a short period, the ED workflow is usually encapsulated by a great deal of complexity (Brailsford et al. 2004). The medical staff members in the ED have to provide efficient, consistent, and cost-effective care while attempting to keep patients satisfied and avoid malpractice risks. The incompatibility of demand and supply for service in the ED affects the emergency medical staff members' capability to provide effective patient care. Although effective patient care is crucial for making a more patient-oriented healthcare system, nurses are unable to make this transition because of an unbalanced and excessive workload attributed to patient care and processing of health records in the ED. One of the factors responsible for this notable increase in workload is the electronic medical record (EMR) system. The impact of EMR has received a lot of attention in recent years because the EMR promises potential benefits to the practice of medical care in the ED. However, electronic recording process requires more time to complete documentation as compared to paper records (Perry et al. 2013). In addition, the EMR with information system is the cause for increasing the cognitive workload of emergency care providers because the EMR has significantly influenced organizational practices to introduce new service models of healthcare (Vezyridis et al. 2011). The use of the EMR in the ED resulted in four- to five-fold increase in documentation time, which in turn has significantly increased the number of incomplete charts (Park et al. 2012). In addition, multiple interruptions and computer-related issues have increased the time spent by the emergency care providers during clinical processes. The lack of available functional computers interfered with nurses and physicians' ability to manage time, with the slow response being the most common problem (Kossman and Scheidenhelm 2008). Another factor responsible for the increased workload of the emergency medical staff was overcrowding of the ED (Derlet and Richards 2000). One of the main reasons for overcrowding is patients visiting the ED for non-urgent illnesses. Another notable reason for the increase in the workload of the emergency nurses is that the demand for nurses is growing because of increase in patient volume, but the supply of nurses is not adequate to meet the current demand. When there is a shortage of nurses, the workload of the existing nurses simultaneously increases. This shortage is projected to grow even more as future demand increases, and the nursing schools are not able to keep up with the increasing demand (Health, Services, Health, and Services 2002; Kuehn 2007).

The heavy workload has many important consequences in an unpredictable and busy emergency department. Many researchers in the past have shown that heavy workload on care providers working in a hospital adversely affects the patient safety (Carayon & Gürses 2005). Therefore, it is beneficial to develop a model which can predict the workload of the care providers performing different clinical processes in the emergency department. One of the models that are available to understand the task workflow and cognitive workload analysis related to the health care system is GOMS model (Saleem et al. 2009). It is an analytic method to represent skilled cognitive task performance in general (Card, Newell, and Moran 1983). GOMS is an evaluation model for the task, which is performed by a single user. It is normally used as a tool to evaluate the process of the user interface design (Kieras 1999). Natural GOMS Language (NGOMSL) is a language form of the GOMS model so that it can be precisely constructed in a structured way (Kieras 1988). The NGOMSL model has been used as a cognitive modeling technique to support description and prediction of human behavior in complex systems, such as pilot-automation and virtual driver (Fuller 2010; Gil and Kaber 2012). Magrabi (2008) and his research team investigated the feasibility of using a GOMSL model in a hospital setting. According to his research, however, there was some discrepancy between the task times estimated by GOMSL and the pilot user study because of clinical complexity of prescribing tasks, such as replacing a medication. Hence, to develop a more accurate model related to the workload of care providers in the ED, we conducted a time study on the care providers working in the emergency department at Mayo Clinic in Minnesota. Different activities performed by the care providers in the ED were evaluated by using hierarchical task analysis (HTA) charts. The HTA charts provided us with a comprehensive understanding of the process maps of care-providers clinical activities as well as EMR use in the ED. Also, we developed the NGOMSL model after identifying the overview of workflow mapping based on nurses' activities from the HTA charts. This model also provided the critical form factors for various processes in the ED. By using the emergency department's NGOMSL model, we had better insight into the activities performed by nurses in the ED at the Mayo Clinic and the workflow associated with doing clinical tasks.

2 METHODS

2.1 Time Study in the Emergency Department

A time study was conducted over the course of five days in July 2015 in an ED affiliated with the Mayo Clinic in Rochester, Minnesota. The first day was the training/planning session. In the remaining 4 days, we conducted the time study on all three shifts. In total, 36 hours of work activities were observed and recorded for 12 health care providers: seven nurses (21 hours) and five physicians (15 hours) working in the Mayo Clinic emergency department. Observers shadowed the emergency care providers for 180-minute periods. The observation time did not include meal break. Among the five physician participants, two physicians were observed during one of their regular morning shifts (8 a.m. to 11 a.m.), two during their regular noon shifts (4 p.m. to 7 p.m.), and the remaining one during the regular night shift (11 p.m. to 1 a.m.). The total observation time was about 15 hours.

Among the seven nurse participants, four were observed during their regular noon shift (4 p.m. to 7 p.m.), two during their regular morning shift (8 a.m. to 11 a.m.), and the remaining one during the regular night shift from (11 p.m. to 1 a.m.). The overall observation time for the nurses was 21 hours. A clipboard, stopwatch, and data collection form were used to collect time data. The data collection form was created based on the understanding of basic procedures that nurses and physicians follow in the ED. Using the standardized data collection form, the observers recorded the tasks being performed, the time taken to perform these tasks, and interruptions during these tasks. A stopwatch used for the study was running in 30-minute measurements in 1/100 increments of seconds. Two observers conducted the timed study. At the beginning of each of the observation sessions, participants were informed of the nature of the study and were encouraged to do the job as usual. A single observer shadowed a nurse or physician for the three-hour period. Each observer studied only one nurse or physician at a time. In addition, a nurse or physician was observed only once. There were no multiple observations on the same nurse or physician. The observers recorded descriptions of all activities while they occurred. If uncertain about the nature of the task, the observer was instructed to request a description of the task from the participant. To minimize the Hawthorne effect, the observer maintained a considerable distance from the participants and did not initiate any conversation with the nurses or the physicians. To maintain patient privacy, the observers did not enter the patient room as the part of research. The observer just noted down the start time and end time of the task and the nature of the task. During the study, the nurses or the physicians were not to be left alone. The observer did not affect the work of the nurses or physicians in any way. The nurses and physicians who participated were all full-time health care providers, having years of experience working in the ED. The concept of 100% performance is a critical element of time study and performance measures. The rating factor is applied to the observed time to obtain the normal time for the job. Since task execution depends on the worker's skill set, each worker is assigned a rating that accounts for worker's variability and will be acclimated to calculate the time taken to perform a particular task. In our case, all the care providers observed were experienced, we gave them a rating of 100%, but we can transmute it for less skilled /experienced care providers.

2.2 Time Data Analysis

After the time data had been collected from all the participants, the data was entered into a Microsoft Excel spreadsheet. The data were checked for discrepancies and inconsistencies. This process involved manually checking the time of activities and looking for any missing data. The data were also analyzed for activities that occurred simultaneously. This was done by viewing all the tasks where the times overlapped. For example, the task start time was noted when the nurse started the EMR charting, and the timing ceased when the EMR charting was done. If another task occurred at the same time, then that was noted as a separate task with its start and stop time. The recorded activities were then classified into seven major categories of the care providers' work determined using several work sampling literatures (Oddone, Guarisco, and Simel 1993; Pelletier and Duffield 2003) (Table 1): direct care, indirect care, documentation (EMR), professional communication, going out of ED, in-transit, social, and other.

The time spent on various categories was then summarized with a mean and SD. All data were rechecked for accuracy and reviewed by the research team before being finalized. According to the time study data, time spent by nurses and physicians on different clinical task are as below (see Table 2). The two categories of care providers differed significantly in amount of time spent in direct patient care ($P = 0.0228$), documentation ($P = 0.0008$) and transition time ($P = 0.0079$). Nurses spent most of their time performing direct patient care than the physician's, while physicians spent most of their time on charting than the emergency nurses. Within the categories of indirect care, professional communication, going out of ED and social there existed no significant difference between nurses and physicians.

Table 1: Healthcare Providers' Activities.

Work Task	**Definition**
Direct Care	Tasks directly involved with patient care (e.g., direct communication with the patient or family, bathing or taking the patient to the washroom, bringing food, applying dressings, transporting patients nursing procedures, and administering medication).
Indirect Care	All tasks indirectly related to patient care (e.g., reviewing results, planning care, washing hands, reviewing paper documentation, making telephone calls related to patient care, returning equipment, finding items for patients, getting medications, and preparing medications).
Documentation	Documentation and charting medication using electronic medical records (EMR).
Professional Communication	All medication and patient-related communication with another health professional (physicians, residents & nurses), including ward and patient handover on direct basis.
Going out of ED	Attending any emergency or work outside the ED.
In Transit	Movement between patient room and centrally located nurse station.
Social	All non-work communication (e.g., meal breaks, tea breaks, and personal calls).
Other	Any other tasks not included above.

Table 2: Time spent by care providers on different clinical tasks.

Work Task	**Time spent on different Tasks**			
	Nurses		**Physicians**	
	Minutes (mean ± SD)	**%**	**Minutes (mean ± SD)**	**%**
Direct Care	76.4 ± 29.31	45.2	32.9 ± 24.9	18.3
Indirect Care	9.06 ± 5.9	5	18.97 ± 15.99	6.3
Documentation	35.27 ± 11.83	19.6	78.65 ± 19.8	43.7
Professional Communication	19.01 ± 13.85	10.6	25.93 ± 16.05	14.4
Going out of ED	16.43 ± 14.5	7.8	28.2 ± 18.17	9.4
In-Transit	5.88 ± 1.77	3.3	2.87 ± 1.15	1.6
Social	8.31 ± 11.133	4.6	3.28 ± 4.35	1.5
Others	1.8 ± 1.3833	0.4	4.23 ± 5.7	1.4

2.3 Hierarchical Task Analysis

The specific task of each healthcare provider was analyzed after the data had been classified into different categories. By using task analysis procedures, a hierarchical task analysis (HTA) chart was created for each care provider observed. The HTA chart allows for a systematic breakdown of the care provider's workflow or procedure to define the actions, allow associations between specific actions and errors to be easily elicited, and permit more directed evaluation of specific technical skills (Cuschieri 2000). The HTA chart aided us in understanding the nurses' workflow with its high-level task and subtasks. After the high-level goals and sub-goals had been identified, a plan for each subtask was developed. The plan described the way to achieve a particular goal of each subtask and any conditions that must be fulfilled. By using the HTA charts created for every nurse, the overall HTA chart describing the overall process in the ED was created. Figure 1 shows the HTA for EMR charting up to subtask level 3 ("Levels" are the hierarchy of subtasks that are involved in an HTA chart) as an example. As you can see from the figure, the top-level goal is to chart on the EMR system. The task steps necessary to do this are listed as tasks 1–4 on the level 1 of the hierarchy. Plan 0 indicates the activities or sub-goals that should be carried out to achieve the goal. These activities are further broken down into operations at the lower levels. A full size of the HTA contains up to subtask level 5.

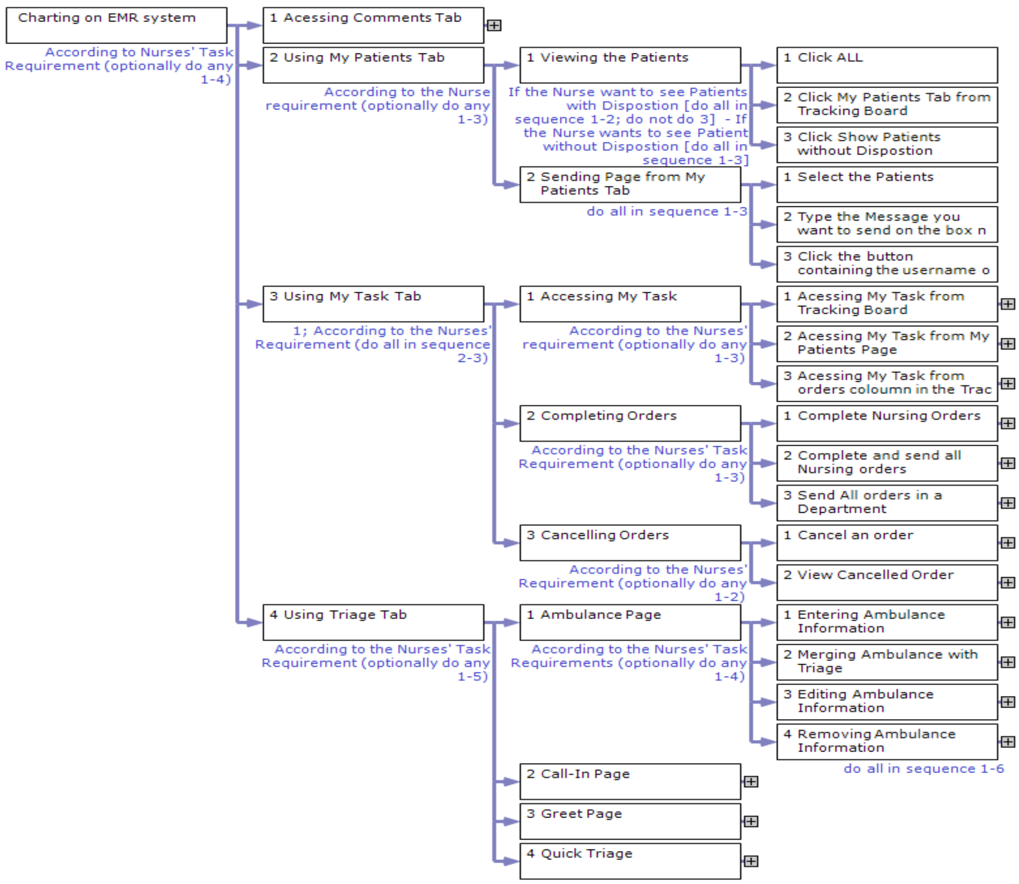

Figure 1: Level 3 Hierarchical Task Analysis (HTA) Chart for EMR charting.

3 MODEL DEVELOPMENT

As with any Natural Goals Operators Methods and Selection Rules Language (NGOMSL) modeling effort, the process must commence with an expertise of the system or of the tasks that are to be simulated. Therefore, for workload modeling, the integral HTA chart for the care providers, working in the ED, was used as an input guide to developing a sequence of tasks to be performed by individuals or teams. The HTA defined the task to allow for the assigning of working memory value. In addition, it helped us to understand the sequence, in which the tasks are to be performed, particularly the simultaneous tasks. The timing information, which was obtained from the time study for each task (usually in the form of mean time, standard deviation, and a distribution fit), was used as an input to allow the model to simulate variance across the described tasks. The main purpose of the modeling was to determine the level of the nurses' cumulative workload, at any point, while they are performing different clinical processes in the ED. The NGOMSL model provided us with a better understanding of the current functionality of the ED. After the HTA chart had been created and verified, the simulation model was developed to evaluate the workflow of the ED, using Micro Saint Sharp software.

3.1 Problem/Objective

The need for understanding important form factors that contribute to a nurse's workload during the different clinical processes is one of the important research topics to improve the quality of healthcare service in the ED. Hence, the objective of the ED nurse NGOMSL model is to evaluate the different clinical processes regarding the workload of the nurses in the ED. In addition, the model is designed to show us how to evaluate time taken to perform a clinical task.

3.2 ED Workflow Model Formulation

The ED nurse workflow was analyzed to understand the workload caused by multiple clinical processes in the ED. The following paragraphs show different tasks that were identified as the eight key elements to measure nurse workload calculation.

A. ***EMR System:*** It included updating basic vitals into the system, administrating and charting a patient medication, nursing narrative, and various other EMR tasks.
B. ***Performing Tasks in Patient Room*:** Patients in the ED were stabilized /treated by nurses. The nurse's tasks included observing and recording patient behavior, co-ordinating with different healthcare professionals to devise a care plan for patients, using medical equipment for the better ment of patients.
C. ***Going out of ED:*** A nurse transported a patient who was in need of an X-Ray or CT scan.
D. ***Consulting with Physician:*** A nurse discussed the current situation and plan for the patient with a physician; the nurse gives the doctor briefing about patient comfort and tendencies.
E. ***Consulting with Residents*:** A nurse discussed the current situation and plan for the patient with the residents or seeks clarifications regarding queries.
F. ***Assisting patients with their tasks*:** The task performed by a nurse including bathing/taking patient to the washroom, bringing food.
G. ***Medication:*** Getting medication from the cabinet, documenting and administering of medication.
H. ***Consulting with another nurse (colleague):*** A nurse interacted with other nurses to get the patient information.

3.3 ED Nurse NGOMSL Simulation Model

The NGOMSL model is a description of the knowledge that a user must possess to operate the system represented as elementary actions for effective usability evaluations. The NGOMSL procedure introduces a new technique in terms of a cognitive architecture called cognitive complexity theory (CCT) (Bovair, Kieras, and Polson 1990). CCT assumes a simple serial-stage architecture in which working memory triggers production rules that apply at a fixed rate. The contents of working memory or execute primitive external operators such as making a keystroke are altered by these rules. Attempts to define a higher-level notation to represent the content of a CCT resulted in the origin of the NGOMSL model. It is a structured natural language notation in which methods are represented in program form as a list of steps which contain operators, both external keystroke-level operators, and internal operators that represent operations of the CCT architectural mechanisms, such as adding and removing working memory information or setting up sub-goals (John and Kieras 1996). In this research, we used Micro Saint Sharp software to develop an NGOMSL model for the ED nurses. Micro Saint Sharp is based on the task network modeling and has been typically used to evaluate and improve the efficiency of man-made systems. It also has the capability to model both the physical and cognitive aspects of human performance, with regard to ergonomic design, mental workload, and human decision-making (Bloechle and Schunk 2003).

The ED Nurse NGOMSL model that was developed, using Micro Saint Sharp, consists of networks and tasks that represent a series of clinical processes. Each human or system task was defined as a single Method in the model. All activities, within the task network model, were represented as nodes and connected by arrows that denoted the sequence in which the tasks were performed. Figure 2 shows a screenshot of the

ED Nurse NGOMSL model. In this figure, an oval shape represented the tasks in which different resources were available to change the state of the model. The rectangle shape connected to the task denoted a network that represented a subsystem for another task network in the model. Tasks represented the lowest level of networks and consisted of various modeling elements, such as timing information, condition for execution, and beginning or ending effect.

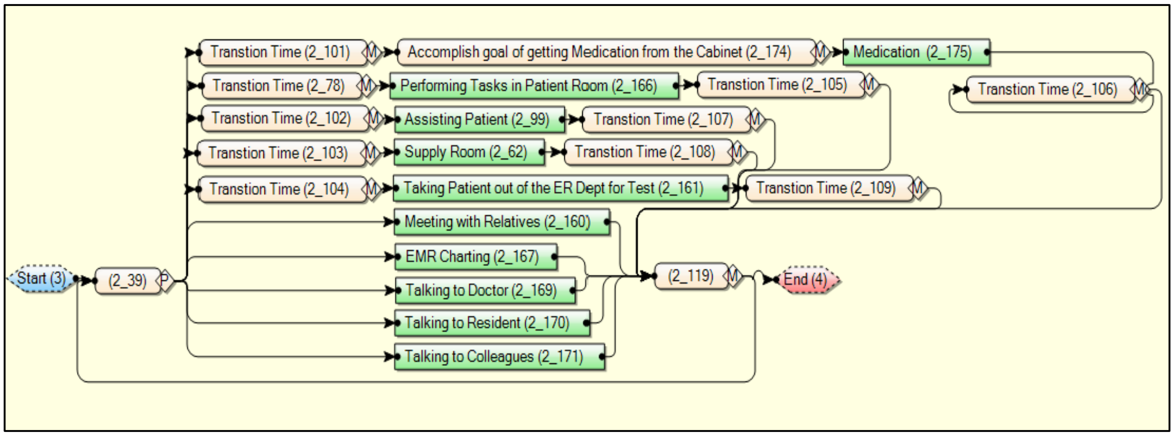

Figure 2: ED Nurse NGOMSL simulation model.

The ED Nurse NGOMSL model also consisted of variables that represented different properties of emergency nurses. The variables allowed us to change the characteristic of the simulation model. Each dynamic variable was designed to get the information we want from the model. There were two different types of dynamic variables in this simulation: the Model variable and the Data collection variable. Model variables were used to control how the model itself would run based on the input condition. Data collection variables were specifically used for data collection. For example, in the model, the "Assisting patients" task consisted of two operators: 1) taking the patient to the washroom, and 2) bringing food to the patient. The process times to perform these two operators based on the given ED condition were recorded in the model variables. On the other hand, the cognitive workload to perform each operator was recorded in the data collection variables. There are several assumptions in this model because of limited observation during the time study. Hence, the following assumptions have been applied in the ED Nurse NGOMSL model:

1. The patient remains in the same bed from arrival to discharge.
2. Every treatment is performed in the room, expect for undergoing a lab procedure or X-ray scan.
3. Each nurse has same patients during his or her entire shift.
4. A single nurse performs the clinical processes mentioned above.
5. The nurses considered in this model are independent (no interruption).
6. Any registration or triage activities were not included in this model.
7. The simulation model is based on first three hours of the morning, afternoon and night shift.

In the model, we constructed every clinical task out of the complex network with multiple physical/mental operators. Hence, the ED Nurse NGOMSL model allowed us to simulate the real-world task process in an ED environment by using a set of modeling templates (i.e. goals, operators, methods, and selection rules). The nurses' workflow in the simulation model was grouped into eight key methods that resulted in accomplishing the goal of each task performed by the ED nurse. Table 3 shows the "Going out of ER" method as an example. In this example, the main goal is *<Going out of ER>,* and its sub-goals are *Setting Patient test* and *Taking Patient out of ER.* All sub-goals must be accomplished to achieve the main goal. In this example (see Table 3), "*Recall the patient's name and test"* and "*Speak Regarding the test setup"* are internal and external operators. The method is a sequence of operators to achieve a sub-goal. For example, in the table below, the method for accomplishing the goal <Going out of ER Dept.> consists of Step 1: *Accomplish goal of Setting Patient Test,* Step 2*: Accomplish goal of Taking patient out of ER Dept,* and Step 3: *Return with Goal Accomplished.* If there is more than one option to accomplish the goal, then there should be a selection rule to represent the user's choice.

Table 3: Method for "Going out of ER".

Method to accomplish goal of <Going out of ER>
Step 1: **Accomplish goal: Setting Patient Test**
Step 2: **Accomplish goal: Taking patient out of ER Dept.**
Step 3: Return with Goal Accomplished
Selection rule set for goal: <Setting Patient Test>
If Patient Test is not pre-arranged, then **Accomplish goal: Call Test Centre**
If Patient Test is pre-arranged, then **Skip the step.**
Return with goal accomplished
Method to accomplish goal of < Accomplish goal: Call Test Centre >
Step 1: **Accomplish goal of Dialing Doctors Number**
Step 2: Recall the patient's name and the test you want to test
Step 3: Speak Regarding the test setup
Step 4: Listen to _ the reply and retain information
Step 5: Decide: IF you fully understand the information conveyed, then go to Next Step, Else Ask Questions
Step 6: Report Goal Accomplished of Setting up the Test
Method to accomplish goal of < Accomplish goal of Taking patient out of ER Dept.>
Step 1: Take patient out of the ER Dept. for tests
Step 2: Report Goal Accomplished taking patient out of ER

Based on the ED time study data at the Mayo Clinic, the time (mean ± SD) information and the distribution fit were denoted for different clinical tasks. According to the time study, the normal and lognormal distributions were the two distributions used while modeling the simulation. The selection process of the multiple exiting paths was controlled by the task sequencing conditions of the model. The number of items that the nurse had to remember, while performing the task, was mainly used for calculating the mental workload. To examine the effects of various clinical processes in the ED nurse's workflow, it is necessary to understand the contribution of the mental workload to the nurse's working in ED. Since workload is driven by task demands, it was suitable to measure the mental workload, based on the total number of the remembered items, to achieve the goal. Therefore, the density of working memory in the ED was used as a metric to evaluate the workload during clinical processes (Cao and Liu 2011; Keller 2002; Laughery 1998; Parks and Boucek Jr 1989; Sweller 1988; Wu and Liu 2006). Here, the working memory density is defined as a measure to indicate the level of effort that is exerted by nurses to accomplish the intended task goals. In the model, the methods were represented as a hierarchy of working memory of the nurse and total physical/mental operators used. Hence, the total number of items, remembered by the nurse during a task, was measured by the summation of all the working memory used by the nurse during the clinical task. The total number of statements in the simulation model was used to measure the total number of the physical/mental operator.

$$WM\_Density = \frac{Item\_Remembered}{TN\_Statment} \quad (1)$$

where**:**
WM_Density = measure to indicate a level of effort exerted by nurses.
Item_Remembered = summation of all the working memory used by a nurse during the simulation.
TN_Statment = the total number of operators in the simulation model.

The workload of each ED nurse was obtained by the fraction of Item_Remembered and the TN_Statment that have run in the simulation model. The calculated workload density calculated does not have any unit. It is a composite index denoting the workload. Workload density can be any value > 0, with zero being the lowest. Therefore, as the value of WM_Density increases, the workload of the nurse increases. By calculating the ratio of Item_Remembered and TN_Statment, the model analyzes the workload level of each clinical process. Table 4 shows the simulated workload result on the eight key elements in the ED. This result suggests that EMR charting and medication are two main tasks that heavily contribute to the nurse's workload in ED. The nurses exhibited relatively lower workload scores while consulting with others (physician, residents, and other nurses) and assisting patients. The NGOMSL simulation model also provides a graphical representation of the current workload during simulation runs. While the model was running, the usage of the nurse's working memory was calculated. Figure 3 shows a chart that plots simulation clock time and working memory.

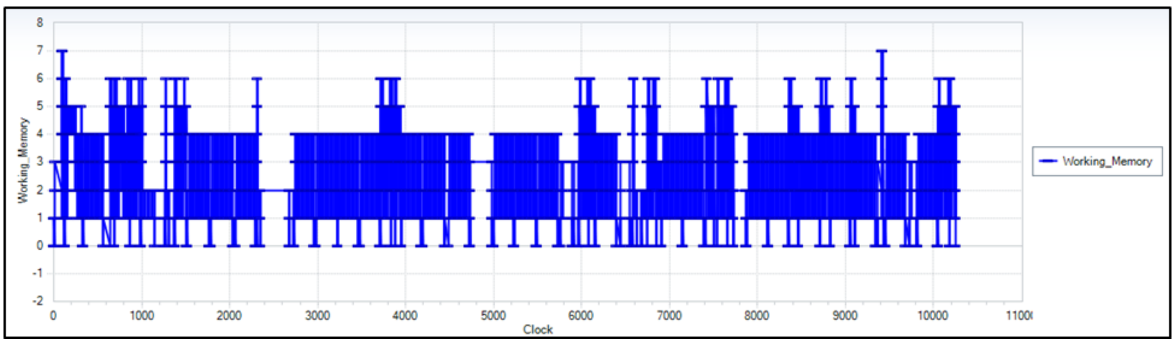

Figure 3: Visual results depicting the working memory usage of the ED nurse.

Table 4: Workload comparisons using WM_Density.

Key clinical processes in the ED	Mean	SD	95% CI
EMR System	3.4340	0.1763	(3.3644, 3.5036)
Medication	3.7428	0.2124	(3.6732, 3.8124)
Performing Tasks in Patient Room	2.5683	0.0076	(2.4987, 2.6379)
Going out of ED	2.4445	0.3653	(2.3749, 2.5141)
Consulting with Physician	1.3201	0.0358	(1.2505, 1.38969)
Consulting with Residents	1.7301	0.0536	(1.6605, 1.7997)
Assisting patients with their tasks	1.4158	0.3166	(1.3462, 1.4855)
Consulting with another nurse (colleague)	1.4281	0.0756	(1.3585, 1.4977)

For the validation of the ED Nurse NGOMSL model, the service time results obtained from the developed model were compared to the time study data by using one-way ANOVA (α = 0.05) (see Table 5). By comparing the output obtained from the simulation model and the data obtained from time study, we identified the variances between the model results and the actual data. This process was carried out until the discrepancies were within our level of significance. The comparison results showed that there was no significant difference between the service time means of both the time study and the simulation outcome. The process of validation was done for all the emergency department clinical processes and repeated multiple times. In addition, the HTA charts and NGOMSL model including logics for all possible activities were carefully reviewed and rated by multiple experienced raters. They rated our model based on the use of modeling logic and accuracy. The inter-rater reliability test was done to make sure there was no human error done while developing the HTA and NGOMSL model. The inter-rater reliability (percentage agreement) obtained was 87%, which was considered high enough to trust the model.

Table 5: Comparison of Time study and Simulated system.

Key clinical processes in the ED	Simulation Data		Time Study Data		ANOVA results
	Mean (Minutes)	SD	Mean (Minutes)	SD	P-value
EMR system	148.300	87.500	164.300	157.200	0.431
Medication	77.030	29.430	58.800	31.820	0.116
Performing Tasks in Patient Room	232.528	8.269	222.700	225.000	0.639
Going out of ED	360.300	250.200	269.000	303.400	0.332
Consulting with Physician	74.700	48.800	64.200	49.600	0.665
Consulting with Resident	54.030	14.830	52.000	17.640	0.860
Assisting patients with their task	95.300	129.400	101.800	123.700	0.885
Consulting with other nurse	56.400	62.600	54.400	59.600	0.900

4 DISCUSSION AND CONCLUSION

The main objective of the ED Nurse NGOMSL simulation model was to evaluate nurses' workload and the process time of different clinical process in the ED. The dynamic nature of nurses' workflow, along with constantly changing clinical processes, makes a measurement of workload difficult in the simulation setting. The NGOMSL simulation model can be used to strategize and prompt many beneficial changes. It can help us to understand the proximal workflow processes in the ED and its impact on the care providers and to identify the way to reduce their mental workloads. The input parameters of this simulation model can be easily tailored to a specific ED condition. It is useful in understanding the interaction between the different clinical processes and workloads. It is also beneficial to interpret the relationship between the change in one individual clinical process and the change in the overall workload. The objective of this study is to investigate the causes for a high workload, utilizing human factors approach to decrease the workload and eventually enhancing the working nature of the attendants, the quality of care, and the security of look up after patients.

There were several limitations of this study. Firstly, each nurse was only observed for three hours, which was a short time to make any solid conclusion on the nurses' workflow in an Emergency Department. In addition, whether a 3-hour observation period was at the beginning, middle or end of a shift can very well have been associated with the amount of time that was spent on different clinical tasks. Thus, although a large number of observations were made during both the day and night shifts, the distribution of those observation periods could have another level of variance to the estimated percentage time spent in those clinical tasks. Furthermore, the sample size of the observation data was small. We could only collect the time data from seven nurses and five physicians at the Mayo Clinic because the time study required labor-intensive work. It was impossible to shadow more than one nurse or physician at a time. As clinical processes expanded into multiple locations, it was especially difficult to monitor all workflows. For example, the observers were not allowed to enter a patient's room because of patient privacy issues, which prevented the gathering of information about tasks the medical staff did in the patients' rooms. One way to overcome this limitation is to use a real-time indoor tracking system. The idea of using the indoor tracking system is to employ radio-frequency identification (RFID) technology to record all service times and locations of the medical staff members in a real-time database system. Seeing the medical staff progress using the RFID system would help us to understand accurately the tasks performed by the nurses accurately. This way would be a much more effective way to capture the process time of all clinical tasks in the ED. Another limitation is that the current NGOMSL model did not consider any process interruptions caused by other events, such as emergency calls from a nurse or doctor. The interruptions from other healthcare providers commonly happen during the ED clinical tasks, but the model did not include the components related to the interruption factors. For future study, we will expand our current model to consider interruptions and distractions in the ED and their influence on nurses' workload in the ED.

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AUTHOR BIOGRAPHIES

NITHIN PARAMESHWARA is an M.S. candidate in Industrial Engineering at the University of Missouri-Columbia. His research interests include time and motion study, task analysis, and discrete event simulation. His email address is np3md@mail.missouri.edu.

JUNG HYUP KIM is an Assistant Professor in the Department of Industrial and Manufacturing Systems Engineering at the University of Missouri. He holds a Ph.D. in Industrial Engineering from the Pennsylvania State University, University Park. His research interests include human-computer interaction, human-in-the-loop simulation, and human performance. His email address is kijung@missouri.edu.

WENBIN GUO is an M.S. candidate in Industrial Engineering at the University of Missouri-Columbia. His research interests include human-computer interaction, eye tracking, and behavior modeling. His email address is wgk95@mail.missouri.edu.

KALYAN PASUPATHY is an Associate Professor of Health Systems Engineering in Mayo College of Medicine's Health Sciences Research Department and the Scientific Director of the Clinical Engineering Learning Lab at Mayo Clinic. Dr. Pasupathy has conducted several funded projects and has published over 45 peer-reviewed articles and a book on Health Informatics. Dr. Pasupathy is engaged in advancing science and translating knowledge to improve care delivery demonstrated through his academic and practice leadership roles. His email address is pasupathyk@mayo.edu.