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Healthcare Utilization Awareness And Labor Monitoring Methodology: A Theoretical I.M.S.E. Approach To Risk Minimization And Human Metrics Capturing In the Nursing Workforce

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HEALTHCARE UTILIZATION AWARENESS AND LABOR MONITORING METHODOLOGY: A THEORETICAL I.M.S.E. APPROACH TO RISK MINIMIZATION AND HUMAN METRICS CAPTURING IN THE NURSING WORKFORCE

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Dedication

This research is dedicated to the many I.M.S.E. engineers who are passionate about improving and innovating new solutions. This is especially dedicated to the late Luis Ernesto Reyes Sr., an engineer, a loving son, brother, father and graduate of UTEP who once told me that nothing is impossible.

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Abstract

The healthcare industry is so complex and dynamic that the development of any tool designed to promote positive patient outcomes nearly requires the developer to be an actual healthcare practitioner. Many healthcare tools exists that initially give the perception that there will be no future requirements that may hinder the tools' integrity, but more often than not, the unexpected occurs. The future is one unpredictable element of life that most engineers wish they could capture with optimal precision. I.M.S.E. (Industrial, Manufacturing and Systems Engineering) applications do not assist with fortune telling, but they do assist with creating robust tools designed to continuously adapt, integrate, innovate, define ingenuity and to improve a systems' quality of life.

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Chapter 1: Introduction

1.1 General

The workforce amongst various industries have different means of monitoring worker performance along with monitoring the amount of work carried out. These workers or employees can be salespersons, teachers, nurses, truck drivers, pilots and many more. An example of a tool that is used in some industries can be a software that allows the function of clocking in at the beginning of their shift. After many clock ins and clock outs, a time sheet will generate allowing supervisors and managers to visually capture how many hours per week of labor an employee has carried out. An example of monitoring performance can be a software that allows the employee to enter how many sales per week, students passed per semester, patients turned over per shift, or flights successfully landed per month, depending on the industry of course.

Tracking labor and performance rates may assist supervisors and executives to monitor job burn out, job satisfaction and create opportunity for empowering the employee. When a teams' awareness for utilization is increased and all individual's labor is monitored effectively, transparency may occur. From time to time, it is possible for employees to work in unsafe and risky environments creating the opportunity for ineffective labor. It is important for any leadership role to be aware of when these unsafe and risky situations occur. In other words, transparency at the front line employee level is paramount. Effective transparency may introduce the opportunity for executives to minimize the amount of mistakes they anticipate their employees to create. Optimization is key for a successful team. Essentially, an employee who is satisfied with their job, is empowered and never burned out will arguably perform at their optimal level. Why is it important that employees perform at their optimal level? From an I.M.S.E. (Industrial Manufacturing and Systems Engineering) point of view, it is paramount to have a lean and zero waste work environment. Having this type of systems thinking assists particular companies and or teams to be on the path towards maximized profitability.

Sometimes maximizing profit is not as easy as it sounds, because there can be intangibles that affect employee performance in the work force for example, the healthcare industry. This paper will be focusing on the healthcare industry specifically, the nurses amongst different units in a hospital. The motivation for this paper was initiated after reading, "The impact of operational failures on hospital nurses and their patients" by Anita L. Tucker. It discusses how operational failures that occur in a hospital ultimately lead to costs. It concludes that these failures are deemed redundant and that, "front-line workers do not control organizational processes responsible for the majority of failures they encounter and have a difficult task convincing powerful associates that these obstacles warrant solution efforts, making it likely operational failures will persist". The case study also mentions that work rounds occur so often that it seems that they are part of the process and not the problem. A work around occurs when a nurse does not have the information or resources necessary on hand right away to treat the patient instead, the nurse takes necessary measures to treat the patient by all means.

From an I.M.S.E. point of view, prescriptively, in order to have an optimized hospital unit, all patients shall be discharged as soon as possible while meeting the unit's mission, goals and standards. Adding, when the patient is discharged the bed shall be filled with the next available patient immediately. In order for this to happen, the nurses working in the unit shall work in a minimized risk environment with all information and materials handy and ready to treat the patient. In addition, the nurses shall have the appropriate skill sets and integrity with a teamwork mind set. However, in a descriptive, these things may seem to be more unrealistic. The healthcare industry is so dynamic and complex that applying I.M.S.E. tools to minimize costs and to maximize profit is difficult, as it requires a thorough and clear understanding of healthcare.

1.2 Problem Statement and Rationale

In the healthcare industry, many tools assist hospitals with budgeting, staffing, scheduling and nurse assigning. Some of these tools are more effective than others are while some are more expensive than others are. After extensive research, it has been discovered that even after

implementation of such tools, problems of interoperability, complexity and user friendliness still exist. This research will approach the ongoing problem of operational failures by developing a tool that increases unit utilization awareness while effectively monitoring individual nurse labor. In addition, the tool shall allow the user to effectively mitigate the risks that contribute to nurses creating operational failures. In parallel, the tool shall veer away from problems with interoperability, complexity and user friendliness.

Evidently, there are many costs in healthcare. In a prescriptive world in a hospital, a nurse attends and cares for a patient as soon as the patient requires care without any disruptions or interruptions. In the descriptive world these disruptions and interruptions are deemed inevitable according to Anita L. Tucker in "Operational Failures and Their Impact on Nurses and Patients", these interruptions have been identified as costly for the industry. This article expresses an obvious need to minimize these failures, which will be discussed in detail under chapter 2 section 2.1. Research suggests that there are key contributors that may increase the risks of creating an operational failure. These contributors are as follows; overworking or burnout of staff, decrease in job satisfaction, and lack of unit utilization awareness. In time, as a nurse continues to work with assignments with high acuity patients he or she may experience burnout ultimately affecting job performance. Research suggest that another contributor to low job performance is the lack of empowerment, which, in detail, will be discussed later

In an article titled "Hours per Patient Day: Not the Problem, Nor the Solution" by Karen K. Kirby it is stated that "Hours per patient day (HPPD) is a metric that is easy to use in determining budgeted FTE (Full Time Equivalent) and in comparing staffing across organizations." HPPD is a method utilized for staff leveling in order to be on budget. The difficult part in staff leveling in healthcare is that there is a need for automated patient acuity and nurse assigning. The paper also states that, "The combination of automated patient acuity, staffing, and human resource systems provide a wealth of information for determining the budgeted HPPD and in making defensible requests of adjustment in HPPD". The following is a list needs discovered from research:

- Need 1: The need to have a live, accessible and quantified workload distributor to promote equitable nurse assignments
- Need 2: The need to minimize the risk of creating operational failures by focusing on key contributors. These contributors consist of nurse job performance, overutilization of nurses (burnout), nurse empowerment and live unit utilization awareness.
- Need 3: The need to monitor quantified live individual nurse workloads, monitor unit utilization to promote transparency and to optimize nurse staffing.
- Need 4: The need to structure quantified information to promote actionable data for live and future decisions.
- Need 5: The need to capture new nursing performing metrics for purposes of innovation.

1.3 Theoretical Objectives

Nearly every hospital experience ongoing operational failures and face the difficult task of creating an optimized nurse staffing system. Innovation is key in attacking these areas. The objective for this study is to innovate a utilization awareness and labor monitoring methodology that can be used in the healthcare industry. From this methodology, the main goal will be to create a tool that will confer on the needs described in section 1.2 to improve overall quality of care and patient outcomes. The following is a list of the theoretical objectives for the tool discussed throughout this project.

- Objective 1: Improve patient assignment distribution for nursing personnel
- Objective 2: Increase awareness as to which nurses may need assistance with their assignments
- Objective 3: Reduce the amount of errors, risks and falls associated with unequitable patient distribution

- Objective 4: Promote accessible real time data to understand each units' workforce caseload for that day, week, month, etc.
- Objective 5: Promote accessible real time data to understand each unit's workforce needs
- Objective 6: Improve transparency of the enterprise where needed
- Objective 7: Promote the capability to generate data that can create on demand consolation services for risk reduction.

In theory, creating a tool that will allow the user to monitor live individual nurse labor and unit utilization, may assist with capturing the above objectives and provide the following general benefits:

- Benefit 1: Live unit team awareness
- Benefit 2: Live unit team utilization charts. A chart that will quantifiably notify and alert unit directors and managers when their unit is being underutilized or over utilized
- Benefit 3: Optimized staffing from shift to shift
- Benefit 4: Patient trends will be revealed
- Benefit 5: Live and historical nurse empowerment
- Benefit 6: The capacity to quantifiably monitor nurse burnout, passion fatigue, successful average patient turnover rate per nurse and unit, and attrition rate

These benefits at the moment stand as unverified and until the tool has been tested and practiced, these benefits are simply theoretical. In this research, it was challenging to prove the value of the theoretical tool. The validation and verification process for this research was challenging especially, because of the sensitivity level of the data that was pursued (past nurse assignments of a chosen hospital unit). Luckily, The University of Texas at El Paso has a unit simulator with students as nurses that assisted this research by providing simulated data. This was taken advantage of and leads to the next point.

1.4 Contribution

Implementing H.E.A.R.R.T. (Healthcare Enhancement And Risk Reduction Tool) in a true hospital setting consists of an immense amount of time due to the necessary verification, validation and testing. In order to deem the tool entirely feasible and valuable, the process of implementation is required. Due to constraints and limits of this project, this process did not occur. Nevertheless, verification and validation of the equation was carried out.

Behind H.E.A.R.R.T., there exists an equation that out-puts quantified individual nurse workloads and a unit utilization scores simultaneously. The University of Texas El Paso (UTEP) School of Nursing has given permission to create a prototype that reflects the simulated health science lab with nursing students and simulated patients. The prototype has been demonstrated to many different RN's, coordinators and nursing faculty from different hospitals along with nursing professors from UTEP. The simulated results from the prototype will later be discussed on whether or not the thesis hypothesis has been confirmed.

1.5 Scope and Limitations of Project

The scope of this paper shall cover specifically theoretically derived ideas solely based on extensive research. This research consist of analyzing scientific articles, interviewing healthcare professionals, presenting a prototype to potential stakeholders and testing of a software prototype in a university environment. For future work, currently, H.E.A.R.R.T. has been created for a telemetry unit in hospital called Banner Healthcare in Scottsdale, Arizona. The verification and validation is currently under way. This will be discussed in the section titled future work.

Based on the research carried out a methodology has emerged and from this methodology the opportunity to create a tool has presented itself. The name of the methodology is Healthcare Utilization Awareness And Labor Monitoring Methodology (H.U.A.L.M.M.) and the name of the tool is H.E.A.R.R.T. (Healthcare Enhancement And Risk Reduction Tool). H.E.A.R.R.T. is an approach at the least, to answer the needs described in section 1.2 titled problem statement and rationale. The tool shall be a software system that shall have multiple use cases. The information

shall be inserted by charge nurses (CRN's) and this information shall consist of individual RN's assignments with patients and their classified acuities. Acuity is the severity of the patient meaning the amount of care, resources and time a patient requires in order to successfully treat him or her.

The H.E.A.R.R.T. shall be standalone meaning no additional tasks are required from the CRN (charge nurse), other than the already required inputs the CRN shall enter to the current existing infrastructure the chosen unit practices. At the moment, H.E.A.R.R.T. can either be an add-on software that is integrated with the chosen units current infrastructure or H.E.A.R.R.T. can be implemented as the only systems that unit utilizes because, of its' robust capacity. H.E.A.R.R.T. shall generate ranked workloads of the RN's, for example, heaviest workload to the lightest in a quantifiable manner. H.E.A.R.R.T. is also designed to generate a team unit utilization score. A high unit score can be interpreted as the combination of high acuity and high bed occupancy. In other words, a high score will reflect high utilization and or over utilization of the unit as a whole. A low score shall reflect when the unit is either at high bed occupancy with all low patient acuities or interpreted as low bed occupancy with high patient acuities. The unit utilization scores and individual quantified nurse workloads are generated and saved for live and historical decision-making. At live time, the CRN will have the capability to continuously update patient acuities and the capability to generate an optimized and balanced unit assignment for the next shift. The CRN will have a complete visual, as will the unit directors and managers. Monitoring the live fluctuation unit utilization scores may even assist with staffing for the following shifts.

The limits of this research project are as follows:

- Limit 1: Testing in simulated environment vs real hospital setting
- Limit 2: Number of programmers to convert algorithm to software
- Limit 3: Access in researching other healthcare software tools

Implementation constraints of the H.E.A.R.R.T. are as follows:

- Constraint 1: Ability to adopt H.E.A.R.R.T. to culture of hospital unit
- Constraint 2: Ability to adapt and integrate H.E.A.R.R.T. to existing software infrastructure

- Constraint 3: Affordability of H.E.A.R.R.T. if proven valuable, verified, and validated

Theoretically, if it is possible to practice a methodology that is designed to mitigate all risks and acknowledges the objectives described in section 1.3, it will be possible to set a scope of different implementation goals. The main goal of this project is to create a tool from this methodology.

The following is a list of theoretical implementation goals of the tool (H.E.A.R.R.T.):

- Goal 1: Get data (past nurse assignments) from hospitals (preferably from various units and hospital systems) to validate equation
- Goal 2: Get H.E.A.R.R.T. into select hospitals for on the spot clinical trials
- Goal 3: Integrate H.E.A.R.R.T. with each unit's/facilities' charting system and operations
- Goal 4: Analyze caseload distribution so that stakeholders can understand how this will help their facility reduce risk
- Goal 5: Use this data to consult potential clients on how they can optimize the workforce and patient distribution for each unit

1.6 Thesis Outline

The textual material describing the entirety of this research has been broken down into chapters that consist of sections. The following is an outline of all chapters.

- Chapter 1: "Introduction"- This chapter presents sections titled general, problem statement and rationale, theoretical objectives, contribution, scope and limitation of project, thesis outline and thesis hypothesis.
- Chapter 2: "Literature Review"- This chapter defines sections titled operational failures, nurse labor, nurse empowerment and job performance, structuring healthcare data, Healthcare Tools and systems engineering analysis for H.E.A.R.R.T.

- Chapter3: “Methodology”- This chapter explains and describes the methodology and tool in sections titled dependencies, assumptions, detailed description of Healthcare Utilization Awareness And Labor Monitoring Methodology and operational analysis and detailed functionality for H.E.A.R.R.T.
- Chapter 4: “Simulation Results”- This chapter explains how the simulations were arranged and confirms or rejects the thesis hypothesis in sections titled Simulation Set up and Arrangement, and Hypothesis Review.
- Chapter 5: “Conclusion”- This chapter summarizes the entirety of the theoretical research project in sections titled area of improvement, future work and what this project contributes to IMSE community.

1.7 Thesis Hypothesis

Does having a live, accessible, and quantified nurse workload generator that promotes equitable nurse assignments give value to a hospital unit? Will a live unit utilization alert system expose the opportunity to capture new nursing metrics? Generating nurse assignments is a challenging task knowing that the variables taken into consideration are those of patients including some intangible factors. A charge nurse (CRN) is usually the one generating these assignments by means of educational and professional analysis. Although, research suggests that some CRN’s have software tools that assist them with patient acuity classification, it is still a challenge to optimize their units’ assignments.

Unit assignments may not be available for the unit managers and directors in a visual and scalable fashion right away. Having them available upon request with the hour-to-hour patient acuity changes may assist management with transparency. Knowing exactly what is going on in ones unit as patient acuities fluctuate may be beneficial. In some cases, the level of transparency can be valuable to all stakeholders including CEO’s and other executive positions. Adding, when nurse assignments are equitable it is ideal for a unit, especially when the unit directors and managers have constant visual access to these assignments. A unit can be the emergency

department, medical surgery, intensive care unit, telemetry, amongst others. Having the capacity to visualize ranked nurse workloads simultaneously with unit utilization in live fashion may expose value such as capturing human performance metrics that will assist executive positions in a hospital for decision-making. Having this capability may even impact and assist with minimizing operational failures. Hence, the thesis hypothesis is the following: if a verified, validated and tested algorithm is created and designed to output quantified workloads per nurse along with unit utilization scores simultaneously, unit directors and managers will have structured and actionable data that reflects the following. 1) When unequitable nurse assignments are generated 2) When a nurse is being over utilized 3) When a nurse is underutilized 4) When a unit is over utilized 4) When a unit is underutilized 5) When a unit requires many resources 6) Live productivity of individual nurses 7) and Live productivity of a unit. If these seven elements are accurately structured into actionable data, it is theorized that the needs, objectives and benefits described in chapter 1 can potentially be fulfilled.

Chapter 2: Literature Review

2.1 Operational Failures

Depending on the industry, an operational failure may or may not lead to the loss of a life. For example, when a materials handler employee orders the incorrect number of forklifts that are all too small, the forklift operator may be incapable of completing their tasks on time. This failure ultimately leads to inefficiency including loss of time and costs, but no loss of a persons' life. On the other hand, if a nurse administers medication that was incorrectly ordered and delivers that medication to the patient, then a serious and life threatening problem may result.

Not all operational failures are rooted directly from the employee associated with the operational failure. There are also outside systematic operational failures. At times, information is needed to carry out a task by an employee and that information may not be available. Take the following scenario for instance. A restaurant manager receives a party of ten and that party claims to have entered their request via online application. It was quickly realized that the restaurant never received the request and the manager was unable to serve the party at the appointed time with the appropriate amount of tables. From the customers point of view it may appear that the mistake is directly associated with the restaurant manager, but this may not in fact be entirely true. This operational failure leads to loss of revenue and loss of credibility. This cost was due to a malfunction in the system software found in the application that the customer was using to place their request.

Operational failures come in many forms in the work force of any industry. Since this research is focusing on healthcare, this section will discuss operational failures that occur in a hospital unit along with factors that increase the risk of creating these failures. "Operational failures in healthcare can hinder employees, potentially decreasing both productivity and quality of care." (Tucker 2004). It is true that a RN can be performing their skill sets in an optimized fashion and still have to perform a work around due to an operational failure. That specific operational failure can most definitely have been initiated from outside the unit as it was for the

restaurant manager as described earlier. Many operational failures are unavoidable for RN's, but at the same time, many failures are avoidable.

In a hospital unit, an operational failure is simply the time away from a patient when the patient requires care due to the caregiver experiencing interruptions and or when disruptions of system breakdowns occur. These breakdowns may include the following: not having the appropriate information and or not having the appropriate resources or material. Another system breakdown may include non-optimized nurse assignment generation. In a unit, the CRN creates the assignments for the RN's. The CRN uses their educated and professional judgement when creating these assignments. The factors of the assignments include the number of patients and their classified acuities. In essence, if a non-optimized assignment schedule is given out, it is arguable that this may lead to nurse work inefficiency.

According to Anita L. Tucker, "Highly interdependent front-line workers do not control organizational processes responsible for the majority of failures they encounter and have a difficult task convincing powerful associates that these obstacle warrant solution efforts, making it likely operational failures will persist". Furthermore, "Errors often are not viewed as learning opportunities, because employees can work around them quickly and they result from established work". In the case study presented in this article, it was found that operational failures ultimately lead to costs.

Table 2
Nine measures of failure impact

Name of measure	Definition	Impacts
1. Number of additional tasks	Number of additional tasks performed by RN to resolve the failure	Nurse
2. Direct time	Number of minutes RN spent explicitly on resolving the failure.	Nurse
3. Indirect time	Minutes RN spent on activities related to failure, but not necessary for resolution. Example: documenting or talking about it to other people	Nurse
4. Interruptions	Number of interruptions to RN's work caused by the failure or resolution.	Nurse
5. Direct delay	The number of minutes until the missing item was restored so that the nurse could complete the task.	Patient
6. Indirect delay	Minutes of delay after the failure was restored until the task was actually completed.	Patient
7. Risk	Subjective rating of the risk to patient safety	Patient
8. Number of people	Number of people the nurse contacted to resolve the failure	Hospital
9. Losses	Subjective rating of the tangible and intangible losses incurred by the hospital as a result of the failure. Includes wasted materials and loss of confidence in the organization.	Hospital

Figure 2.0: Measures of failure impact

(Note: Figure 2.0 is from the article and it describes a set of measured failures and who or what the failure impacts.)

Table 3
Weightings for interrupted or delayed tasks

	Ratings			
	Very low	Low	Moderate	Highest
Interruption	1 = Interruption is inconsequential such as when between tasks	2 = Tasks that posed low risk to pt safety if interrupted, but involved cognitive set-up time. Example: documentation	3 = Tasks that could result in medical errors if RN was distracted. Example: preparing medications	4 = Direct Pt care tasks done in presence of patient. Examples: Pt bathing, assessment, or passing medications
Delay	1 = Tasks not related to immediate patient care. Examples: personal time and assigning patients to rooms or nurses to patients	2 = Indirect patient care with no time requirements. Example: documentation	3 = Pt care tasks that were moderately time-sensitive due to pt comfort or health, but were scheduled at the discretion of RN. Examples: meals, bathing, or changing linens	4 = Pt care tasks scheduled for specific times. Examples: medication administration, preparing patients for surgery, laboratory tests, vital sign assessments, treatments
Risk	0 = No foreseeable risk to pt such as looking for ordering forms, housekeeping	1 = Failure caused discomfort to pt. Example: delayed food tray	2 = Potential for risk given other conditions being present. Examples: confusing orders, missing medication	3 = Failure by itself could potentially cause pt harm. Examples: last minute medication cancellations or missed orders
Losses	1 = Wasted material or medication	2 = Pt or RN was aware of failure potentially causing a loss of confidence in quality of care provided in hospital	3 = Pt procedure delayed by a few hrs or a procedure was performed unnecessarily	4 = Failure postponed Pt's procedure until following day

Figure 2.1: Weights for interruptions and delays

(Note: Figure 2.1 is from the article and it describes the various weights that were associated with delays and or tasks.)

Table 5
Cost and impact of operational failures analyzed by type, source, and response ($N = 194$)

		Problem			Error			Total		
Source	Who responds as a failure	No. (%)	Median cost (S.D.)	Median impact (S.D.)	No. (%)	Median cost (S.D.)	Median impact (S.D.)	No. (%)	Median cost (S.D.)	Median impact (S.D.)
Nurse	No one	8	US$3 ($16)	32 (18)[a]	7	US$76 (93)	40 (36)[d]	15	US$117 (75)	35 (27)
	Nurse only	2	US$367 (US$191)	59 (35)[b]	5	$175 (423)	49 (29)[e]	7	$558 (363)	53 (28)
	Nurse and manager	1	US$403 (US$11)	79[c]	0	–	–	1	US$403	79
	Total	11 (6%)	US$10 (US$190)	41 (25)	12 (6%)	US$117 (US$312)	44 (32)	23 (12%)	US$101 (US$260)	42 (28)
Unit	No one	26	US$3 (US$294)	29 (28)[f]	2	US$67 (78)	50 (5)[i]	28	US$5 (284)	31 (28)
	Nurse only	17	US$38 (US$182)	44 (25)[g]	3	US$59 (61)	46 (37)[j]	20	US$49 (169)	45 (26)
	Nurse and manager	5	US$2 (US$760)	40 (35)[h]	0	–	–	5	US$2 (760)	40 (35)
	Total	48 (25%)	US$11 (US$333)	36 (28)	5 (3%)	US$59 (US$58)	48 (26)	53 (27%)	US$12 (US$318)	37 (28)
Outside nursing unit	No one	34	US$93 (US$50)	37 (26)[k]	7	US$662 (308)	77 (20)[n]	41	US$126 (327)	44 (29)
	Nurse only	71	US$126 (US$33)	65 (22)[l]	4	US$431 (996)	63 (37)[o]	75	US$126 (358)	65 (23)
	Nurse and manager	2	US$363 (US$39)	86 (7)[m]	0	–	–	2	US$363 (56)	86 (7)
	Total	107 (55%)	US$124 (US$281)	56 (27)	11 (6%)	US$662 (US$603)	72 (26)	118 (61%)	US$127 (US$343)	58 (27)
	Total	166 (86%)	US$106 (293)	49 (29)	28 (14%)	US$121 (US$483)	55 (31)	226	US$117 (US$330)	50 (29)

Figure 2.2: Costs and impacts of operational failures

(Note: Figure 2.2 is from the article and it describes a table with actual costs that were associated with different types of failures.)

To be exact, it was found that 194 failures were discovered during the observance of 26 nurses in 9 different hospitals in the span of 239 hours. Although, it is stated that most failures are organization breakdowns, such as medication and material delivery, there still exist operational failures that may be rooted directly from the RN's in a unit. These contributors are as follows; overworking or burnout of staff, decrease in job satisfaction and lack of unit utilization awareness. In time, as a nurse continues to work with assignments with high acuity patients he or she may experience burnout ultimately affecting job performance. Research suggest that another contributor to low job performance is the lack of empowerment, which, in detail, will be discussed later In the next section, the disputable factors that increase the risk of RN's probability of creating operational failures are discussed. After all, in theory, targeting these factors to minimize the risk of creating an operational failure may theoretically lead to minimizing costs.

2.2 Nurse Labor

Depending on the amount of labor over a certain period of time, employees can have different workloads. If an employee has a heavier workload in the same amount of time versus his

or her associate, then that employee is utilized more. Monitoring utilization of employees with time is essential in all industries. From a managers and or supervisors point of view, having this capability will allow the opportunity to monitor job burn out (over utilization) along with job performance.

In the healthcare industry employees, specifically nurses, experience variation of workloads throughout their careers. Nurses work with patients of all types of acuities. Acuity is the amount of care, resources and time a patient requires in order to successfully care for him or her leading to a discharge without readmission. Productivity measured in a unit is based on patient turnover rate while meeting the units' mission, goals, standards and effectively utilizing capital and human resources. The more effective an RN is able to discharge their patients while meeting unit requirements (mission, goal, and standards) the more productive he or she is. Although, there are variables that can argue this point such as the attitudes and characters of an RN. Over all, when an RN is heavily utilized and is still able to turnover patients at an acceptable rate, that particular RNs' performance rate is higher. What happens when these high performing RN's are always given the heaviest workloads?

Sometimes over utilizing an employee is avoidable and sometimes it is not. Depending on the unit, it is possible that high performing, reliable nurses will usually get the heaviest workload. This decision is typically made by either the CRN or a manager, which may be the best decision, because after all, patients' lives are on the line. In other situations, novice nurses may also be consistently tasked with heavy workloads, because of uncontrollable factors and or problems.

After interviewing RNs from different units in different hospitals, a common problem was noticed. This problem was identified as having an understaffed unit. When a unit is understaffed, it is inevitable that nurses in that unit will be needed and utilized more than not. RNs are needed in general, according to Mark. W. Stanton in Hospital Nurse Staffing and Quality of Care, "Periods of high vacancy rates for RNs in hospitals have come and gone, but the current shortage is different. According to a 2002 report by the workforce commission of the American Hospital Association, the nursing shortage "reflects fundamental changes in population demographics,

career expectations, work attitudes and worker dissatisfaction." In fact, their present situation may well continue over the next two decades. A Federal Government study predicts that hospital nursing vacancies will reach 800,000 or 29 percent, by 2020. The number of nurses is expected to grow by only 6 percent by 2020, while demand for nursing care is expected to grow by 40 percent." (Stanton 2013). Although, in a 2009 study conducted by Peter I. Buerhaus, David I. Auerbach, and Douglas O. Staiger titled, The Recent Surge In Nurse Employment: Causes And Implications, it is stated that the anticipated recession may be impacted by a surge of nurse employment growth. Adding, many units are still experiencing staff shortages. It may appear the nurse employment recession is at a near end, but healthcare should not rely on recent studies that support this idea. This is backed by Douglas O. Staiger, as he states, "Employers and workforce policymakers should not be lulled into complacency by the current absence of a nursing shortage. Instead, they should anticipate that the current positive effect of a weak economy on the RN labor supply is likely to evaporate as the economy improves and that shortages will reemerge" (Staiger 2012).

What is the leading cause of understaffed units? Elizabeth J. Currie and Roy A. Carr Hill explain that, "high nurse turnover rates in nursing is an ongoing problem". When a hospital has high nurse turnover rates, this reflects why a unit is understaffed. Although this particular study does in fact mention that, "The reason for high turnover rates remain complex" and "No single reason for high turnover in nursing dominates", some reasons that nurses may leave their unit after a short period of working may be, because of experiencing overutilization in combination with other factors. These factors are leadership style, workplace stress and job satisfaction. Perhaps, nurses may be experiencing stress and low job satisfaction, because he or she may be over utilized too frequently. Ann Rudman and J. Petter Gustavsson seems to agree, "Research has consistently found that work situations characterized by high workloads and time pressure, as well as role conflicts and role ambiguities are associated with burnout" (Miller 2011).

It appears that it is paramount to monitor employee utilization to promote the avoidance of stress and job dissatisfaction. After much research, it is clear that when a nurse is over utilized too frequently and does not have the appropriate leadership support, risks increase. As an engineer,

the minimization of risks is a key factor when it comes to optimization. If it is at all possible to have balanced and equitable employee utilization across the board then, by all means, it shall be done as long as positive patient outcomes are also not at risk. Adding, over utilization of a nurse may potentially increase their chances of creating an operational failure. The next section will discuss the factor of over utilization.

2.2.1 Effects of Nurse Overutilization

"The impact of burnout on work performance and job satisfaction in nursing is well known. Burnout is known to influence job satisfaction, retention, and the nurses' sense of moral cohesion. Burnout has also been associated with negative patient outcomes." (Miller 2011). Burnout is an intangible factor that can be measured as consistent over utilization of an employee. It is debatable that RNs can handle consistent heavy workloads without showing any sign of burnout nor job dissatisfaction. These nurses may have between a few years to many years of experience. What is a fact is described by Ann Rudman and J. Petter Gustavsson stating that, "During the first three years of practice, every fifth nurse is at some point "burned out", and for the majority of novice nurses, the second year of practice seems especially stressful" in addition, "Those of younger age seem especially vulnerable to early-career burnout". This particular study makes it a point that it is an already known fact these early career RNs are particularly at risk especially when in an unsupportive practice environment.

How is burnout measured and recognized? Ann Rudman and J. Petter Gustavsson state that this metric may be noticed in two physical dimensions; "exhaustion and cynicism or disengagement" adding that "defensive behavior and emotional detachment" is also recognized. During an interview with Homero Guaderrama, a nurse practitioner from El Paso, Texas, this fact was confirmed verbally as he stated, "I can notice in a unit when some nurses are burned out, I can just see it and at times it is obvious. Their efforts aren't at the same level as when they started and he or she may even call into work more frequently".

The conclusion that Ann Rudman and J. Petter Gustavsson lead to, says that the study shows "a connection between supportive practice environments, where staff had an overall sense of workplace empowerment, and new graduates' experience of burnout and engagement at work". Hence, having the capability to monitor staff burnout more effectively may influence the supportive practice of the unit as a whole. H.E.A.R.R.T. is designed to have this capacity. The tool allows the user to visually notice in a quantified manner when a nurse is exposed to heavy workloads in live time and in a historical manner. Theoretically, the user of the tool may take action to make it known to the nurses that they are being considerate, aware and supportive of their high workload consistency. Now, nurses, directors, and managers are definitely aware when their unit is saturated with high acuity patience. What this means is that they do not need any one to confirm with them that they are being overworked, but having the capability to present to the RNs a historical data sheet of when he or she has been exposed to high utilization scores of a unit, may possibly bring supportive value. Joan F. Miller states that a concept used in hospitals is to "consider interventions to minimize the risk for burnout among developing and veteran professional nurses to sustain a commitment to excellence in the nursing profession". Such interventions can be mentoring programs and questionnaires to recognize when an RN is over utilized over time. H.E.A.R.R.T. will allow unit directors and managers to do the same thing, but essentially faster. This may be of value to the unit as a whole and will be later discussed in this paper in detail. In concluding this section of nurse burnout, "Burnout has serious implications for the nursing profession. Job dissatisfaction, moral distress, and turnover intent are among outcomes associated with burnout. Unmanageable workloads and reward-effort imbalance increase the risk for burnout among nurses. In addition, nurses report dissatisfaction with quality of work when dealing with stressor associated with burnout." (Miller 2011). This leads to the next point.

2.2.2 Nurse Job Satisfaction

In any industry, job satisfaction may be difficult to measure and recognize. In the nursing workforce, as mentioned earlier, burnout and lack of organization support may affect nurse job

satisfaction. This section and the next will discuss how job satisfaction and job performance are in parallel. Meaning, if a nurse is in content and satisfied with their co-workers, work environment, work management, and workloads, it is possible that the nurse is satisfied with their job. Theoretically, leading this particular nurse to perform at better rates while meeting units' goals, missions and standards versus those nurses who are not satisfied with their job.

According to Joan F. Miller, "When nurses share similar values, such as openness trust and loyalty, and when nurses feel patient care is central to ones work, job satisfaction improves.". Adding, "Manageable workloads and reward-effort balance are also associated with higher levels of job satisfaction. In contrast, high patient to nurse ratios were predictive burnout and job dissatisfaction." It may be true that having the capability of managing workloads and managing reward effort may increase job satisfaction for a nurse. Most units have a nurse to patient ratio that is a standard operational procedure (S.O.P.). According to research, a RN may from time to time go over the ratio. In real time, H.E.A.R.R.T. is designed to generate nurse workloads that promote accurate and equitable nurse assignments while meeting standards and S.O.P.'s. The assignments are based on the updated number of patients per nurse and the accurately classified patient acuities.

"Nurses associate high patient to nurse ratios with unmanageable workloads. Subsequent exhaustion and concern for safety and quality of care increase risk for job dissatisfaction." (Al-Dweik 2016). It is important to keep in mind that sometimes these unmanageable workloads can be associated with HPPD. Nurse hours may be cut do to census and budget leading to this hypothetical question; are heavy workloads in the nursing workforce unavoidable? According to research, this may be a question that is answered with a yes. Although admitted patients and their acuities are not controllable, some factors that influence job satisfaction may be manageable. If these factors are approached in a state of the art manner then, nurse job satisfaction may be impacted, influencing job performance. In the next section, a key factor that affects positive job performance and work effectiveness will be discussed. This key factor is known as nurse empowerment.

2.3 Nurse Empowerment and Job Performance

Like most industries, productivity is acknowledged and appraised for empowerment purposes. In the nursing workforce, the following model can define contribution to productivity:

Workers' Contribution to Productivity = Quality & Quantity of Work Done (+-) Contribution to Performance of Other Employees –Amount of Supervision Required (A.D. Sjarplin 1982)

The above model was created in 1982 and still holds true to today's healthcare industry. In chapter 16 page, 594 of Management and Leadership for Nurse Administrators by Linda Roussel it is stated that, "Measuring productivity is a function of the controlling process. To perform this measure, management establishes a measurement of productivity as the standard for each - department and unit. Inputs are reported to appropriate cost-center managers each month. Productivity measurement tools should be developed with input from the people being measured." (Roussel 2009). The complexity level and dynamics of the healthcare industry is high, because of this, means of appraising and empowering RNs in an effective manner can be challenging.

In a research conducted by Yong-Sook, it was revealed that, "Job characteristics, transformational leadership, and empowerment were found to directly and positively affect work effectiveness. In addition, job characteristics were found to have greater effectiveness on empowerment and work effectiveness that other factors do." (Yong-Sook 2014). In any industry, optimized job performance is paramount in pursuing a successful enterprise and having the capability to quantify this metric may contribute to enterprise optimization.

On a daily basis, a nurse may carry out a variety of tasks in order to treat the patients on their assignments with integrity and with the approach of a positive mind set. Consider the following, when credit is not given where it is due, and when leadership roles are not considerate of their front line workers, can these front line workers experience empowerment? In Work-Related Empowerment among Nurses: Literature Review by Al-Dweik G, Al Daken L,, Abu Snieneh H., Ahmad M., it is stated that, "Lack of empowerment has a significant negative impact on nurses, patient, and quality of health care. Study finding revealed that disempowered nurses

were ineffective, less satisfied with their jobs, and more vulnerable to burnout and leave their job or profession (Zurmehly 2009). Also, it has a negative impact on quality improvement process, decision making ability and job performance development (Casey 2010)". Adding, "In contrast, empowerment leads to increased personal health, job satisfaction, individual competence and self-esteem which in turn, increase perception of personal control which has a direct effect on improving health outcomes (Laverack 2006)." Tactics and or methods for empowering nurses come in different forms. Some of these forms may consist of letters from patients, letters of recognition from executive and or leadership organization and in the form of compensational evaluations.

As a unit director or manager, having the capacity to effectively empower a unit may positively affect job satisfaction of all nurses and more importantly their job performance. "Performance standards are derived from job analysis, job descriptions job evaluation, and other documents detailing the qualitative and quantitative aspects of jobs. Performance standards are established by authority, which may be the agency in which they are used or a professional association, such as the American Nurses Association (ANA)" (Roussel 2009). Evaluating positive job performance in the nursing workforce is unique and can definitely be challenging for leadership organization. "Performance evaluation includes standards for experience, complexities of the job, level of trust, and understanding of wok and mission" (Roussel 2009).

A challenge that unit managers and directors face in their career is gaining the trust and respect from their employees. In the article "Trust and Respect in the workplace: a Strategy for Addressing the Nursing Shortage" (Heather K. Spence Laschinger Joan Finegan), the author agrees that structural empowerment can positively affect organizational trust, job satisfaction, and organizational commitment. The authors hypothesized that "job satisfaction and organizational commitment ultimately benefit from efforts to improve employees' perception of empowerment." (Spence, Finegan 2005).

In the International Journal of Productivity and Quality Management a research was conducted that ultimately lead to a conclusion that "Hospital managers and decision makers need

to work towards the implementation of empowerment environment and focus on the factors promoting empowerment to enhance nurses' productivity and achieve positive health outcomes." It is important that nurses have a sense that their work weighs in on the positive patient outcomes. Ultimately when it comes to empowerment in the nursing workforce, "the factor that empowering nurses in health care setting could be personnel characteristics and nursing leadership style, social support, trust relationship between managers and subordinate, effective mentorship, continuous education programs. Furthermore, organizational factors which includes organizational climate, culture, and structure and justices significantly affecting nurse empowerment." (Al-Dweik G., Al Daken L., Abu Snieneh H., Ahmad M. 2015). It is clear that effectively empowering a hospital unit can be impactful in so many positive ways leading to positive patient outcomes. Studies support that, "Empowered nurses will be more satisfied and will empower their patient and provide them enough support to be adapted with their disease. This means that the nurse will do all assignments in an efficient way, so the quality of care will be improved (Laverack 2006). Adding, "Relationships between structural empowerment and patient safety culture among staff level, registered nurses (RN's) within adult critical care units (ACCU) revealed that structural empowerment and patient safety culture were significantly correlated." (Armellino 2010).

It can be a challenge for unit directors and managers to be entirely confident that they are using effective means to empower their unit. Research suggests that the factors that can promote and contribute to empowerment are the following (Fitzpatrick et al., 2011; Istomina et al., Kokanee et al., 2014; Swei et al., 2013):

- Higher level of education
- Nurses' motivation for professional improvement
- Work time and work independence related factors
- Teamwork and training
- Continuous improvement programs
- Efforts for top management commitment
- Organizational justice

- Health care recipient's satisfaction (patients feedback after discharge)

It is paramount to consider these factors when it comes to demonstrating leadership characteristics. After all, leadership style can also impede empowerment. Once these factors are taken into consideration on how one will approach his or her unit, one may ask, do I have the tools that will allow me to effectively deliver empowerment methodologies?

Capturing human metrics such as productivity rate, anticipated nurse turnover rate, engagement rates, burnout rate, absenteeism, relationship between acuity and adverse outcomes and attrition rate may assist with determining the appropriate and best time for conducting interventional, educational and team building programs. "In a time of nursing shortage, both the hospital and nurse managers should make every effort to ensure that nurses are exposed to empowering and high-quality work environments that make it possible for nurses to be better engaged in their work." (Wang, Liu 2015). Interventional, educational and team building programs are essential and powerful empowerment tools for nurse management. "To increase empowerment and thus nurse accountability, a program that starts with the executive leadership and then moves to management training and supervisor training is needed. Only when the leaders, managers, and supervisors have a common understanding for employee empowerment is it likely that the level of employee autonomy will increase. Then, the next logical step is to educate employees who may need training in problem-solving skills." (Roussel 2009).

In smaller units, the task of designing empowerment programs and determining which nurses shall be placed in such programs may not be so difficult. Now, imagine the complexity of completing the same task for a hundred bed unit with fifty nurses or more. What can make this task easier? What can assist leadership roles to truly understand what is going on in their unit every hour of the day to every day of the year? Even when leaders are equipped with emotional intelligence (emotional intelligence-the capacity for recognizing our own feelings and those of others, for motivating ourselves, and for managing emotions well in ourselves and in others (Roussel 2009)), it can still be a complex and challenging task to genuinely accomplish transparency within their unit. Tools that promote and assist leadership organization with

balancing processes, gaining relational transparency, increasing internalized moral perspectives, and team awareness are encourage to be implemented. Such tools can be categorized as either administrative information systems or clinical information systems. “Administrative information systems include a wide variety of systems that work to maintain information used in the daily operations of an organization. These include financial systems, human resource systems, nonclinical patient system such as registration and scheduling systems, and even nursing administrative systems that nurse leaders use.” (Roussel 2009). “Clinical information systems involve any system that is used in patient care and may not be nursing information systems. However, these systems are generally associated with nursing information system in hospitals, such as laboratory or medication administration system.” (Roussel 2009). According to research, many administrative and clinical software systems assist with making the appropriate decisions for optimization purposes. The level of transparency that the researched tools create remains uncertain due to the limitation of not being able to have user access. It is believed that having a tool that functions as an administration tool and clinical tool at the same time may be desired by leadership organizations in healthcare. H.E.A.R.R.T. is designed to function as both and this shall be discussed in a later section.

Many decisions are rooted from reliable and structured data. “Nurses and nursing management handle large amounts of data and information during any given day. Data are a collection of numbers, characters, or facts. These are usually gathered, because they are needed for analysis or some other action at a later time. Information is a set of data that has been interpreted covering some aspect of time, such as over the course of day.” (Roussel 2009). “Data collection, with the aid of computer and information technology helps to provide evidence as best practices supported by research. This collection of evidence-based is information provided as substantial database of knowledge that can be applied to everyday practice situations.” (Roussel 2009). The integrity of the collected data shall be accurate and valid. “Data integrity must be maintained so that current data are available when needed. If data integrity is less than optimal, it could result in inappropriate decisions that could possibly harm a patient. Quality data have characteristics that

can be identified. Data must be timely, accurate, rapidly and easily available, precise, clear, comprehensive, reliable regardless of whom collects it, easy to interpret, current, and appropriate for the user's needs." Although some software tools do generate data such as individual nurse workloads which promotes equitable nurse assignments and unit transparency, research suggests some issues for such software's exist. These issues shall be discussed in a later section. In the design of H.E.A.R.R.T., these issues were considered. Meaning, the data quality generated by H.E.A.R.R.T. shall be reliable, accurate, valid, and available at any given moment. Such data may assist with developing high quality programs for nurse empowerment whether it be for a particular live moment or for a moment that occurred months ago. Essentially, H.E.A.R.R.T. is an artificial intelligence that outputs useful data and has the capability to generate what if analysis' of a unit. It can simulate different scenarios regarding the unit assignment and may assist the user with making key decisions as far as the impact on the unit as team when he or she decides to create a particular unit assignment. The next section will discuss how unit utilization awareness improves transparency and may assist unit managers and directors in making key decisions at a quality level.

2.3.1 Unit Utilization Awareness

Unit utilization is simply defined by how busy a unit actually is. For example, if a unit of twenty beds has twenty patients with all patients of very high acuities then that unit may appear as rather busy. If all the same twenty patients, for whatever reason, were all of a sudden re-classified at very low acuities then the unit may be less busy. Utilization can and will fluctuate at any given moment, because patient acuities do change. Patient discharges and admissions may occur at any given moment as well causing the unit to be either busy or not as busy.

"Although they are interdependent, communication and information are different. Communications is perception, information logic. Information is formal and has no meaning. It is impersonal and not altered by emotion, values, expectation, and perceptions." (Roussel 2009). Unit utilization can be characterized as information and communication in one single step. For example, if unit utilization can be quantified and monitored by managers they are receiving information

directly from their unit. This information is essentially the unit communicating with their managers and directors to let them know exactly how busy the unit is as patient acuities are fluctuating at that live moment. These fluctuating scores are also reflection of when patients are being discharged or admitted. H.E.A.R.R.T. is unique, because it generates this type of data. "Artificial intelligence will be key enabler that will create generalist. It replaces experts, encapsulates, and capitalizes knowledge. Knowledge will be added to machines to become an extension of the user. A symbiotic relationship will exist between the manager and the expert machine." (Roussel 2009).

Having these scores handy and ready at any given moment may even improve communication between the nurses and their managers. "Recognizing the criticality of communication in reducing patient error, researchers are studying different interventions to improve communication and collaboration." (Hardin, Kaplow 2017). H.E.A.R.R.T. has the potential to assist healthcare management to create innovative interventions to improve communication and collaboration. In the Synergy for Clinical Excellence second edition, collaboration communication is described as "occurring when two or more members of the multidisciplinary team provide and receive input in a clear and accurate manner so that the recipient(s) can receive information, feedback, or both." (Hardin, Kaplow 2017). There are a few elements described on page 96 in the Synergy book that enhance teams' competency level of communication. One of these communication competency elements is "Choose effective communication tools and techniques, including information systems and communication technologies, to facilitate discussion and interactions that enhance team function." (Hardin and Kaplow 2017). Creating transparency within a unit is important for communication between the front line workers (nurses) and the leadership organization (managers and directors). After all, one of H.E.A.R.R.T.'s goals is to minimize any risks that may lead to any cost or failure. "There is increasing evidence suggesting that clinical errors are often related to ineffective communication patterns between members of a health care team. The Institute of Medicine report, To Err Is Human, discusses the problem of increasing errors in health care (Institute of Medicine, 1999). The report defines an error as "the failure of a planned action to be complete as intended or the use

of a wrong plan to achieve an aim" (IOM, 1999, p.3). Considering this definition, it is difficult to exclude communication as a major factor in errors. Ineffective communication, problems with communication flow, poor feedback, and difficulty in getting relevant patient information are all mentioned in the report." (Finkelman 2006).

2.4 Structuring Healthcare Data

As nurses consistently work with heavy assignments, he or she may naturally find it more challenging than usual to follow protocols and standards. H.E.A.R.R.T. is designed to generate individual workloads that allows managers to monitor as changes are made on the individual nurse assignment. As managers and directors continuously monitor their nurses' workloads, they may choose the "best" time to physically check into their unit and take appropriate action. Perhaps, the leadership team may even assist their nurses to remain focused to follow the appropriate standards and protocols. Of course, these statements were made theoretically speaking. Nevertheless, capturing actionable data is important in all industries. The question is, is the captured data structured enough to be proven seamless? In the healthcare industry, monitoring unit utilization and individual nurse workloads can create many benefits. Essentially, a stat sheet per unit and per nurse will be generated by H.E.A.R.R.T. These statistics can be a representation of human metrics such as average patient turnover rates, nurse over work (burnout), nurse attrition rate, optimal team (nurses) combination and perhaps even an optimal point of billing and coding. For example, does billing and coding seem to be more accurate and efficient when the unit utilization score is a 1.5 or 3.0? H.E.A.R.R.T. may have the capacity to truly find out.

In any industry, the front line workers in any team may be asked the following questions and he or she may answer with high accuracy without providing any data or statistics.

- Who is the team's highest performer?
- Who is the team's lowest performer?
- When is your team the busiest?
- During what time of the year do you notice your employees leaving their job?

- Which shift is most productive?
- When is the busiest time of the year?
- During what times of the day do you seem to be have more work? Why?
- During what times of the day do you seem to have less work? Why?
- During what time of the day do you notice your team needs assistance?
- Do you typically have heavier workloads than your coworkers? If yes, why?
- Do you find yourself having a longer shift than anticipated? If yes, why?

These questions can be asked to any team in any workforce industry. Someone who is not particularly a member of that team will not be able to answer these questions simply, because he or she is not a team member. The reason why these questions may all have similar answers without providing data or statistics can be due to tribal knowledge. Tribal knowledge is unwritten information that is commonly known by others within a company. This term is used most when referencing information that may need to be known by others outside the company in order to produce a quality product or service. Is it possible to capture and structure this type of information with artificial intelligence? If so, would it benefit the company?

The previously mentioned questions in bullet form can be asked to a particular team of a particular hospital unit. With tribal knowledge, the nurses may be able to answer these questions accurately. Accuracy will be measured by comparing everyone's answers and verifying that most answers are the same. It is proposed that H.E.A.R.R.T. can answer the same questions and answer with the same accuracy. This is artificial intelligence. It is up to the leadership team on what they decide to do with this data and information. "Technology has a roll to play. If you have better technology at the point of care, you can get better data in more useful form." Adding, "The actual gathering of large volumes of data is less of an issue than what's done with it afterwards, according to O'Donnell, "Sharing the information is where the value is delivered." (Healthcare Insights 2015).

Potentially, if every unit in a hospital practices H.E.A.R.R.T. and if every hospital practices H.E.A.R.R.T., then perhaps, many decisions will be easier to make. In addition,

transparency may appear to be optimized and may increase means of communication significantly. According to research, increasing means of communication can lead to fewer errors. The next section of this document will discuss the different software tools that are currently practiced in the healthcare industry.

2.5 Healthcare Tools

In the healthcare industry, there are many software tools that allow the user to collect informant and data to make key decisions. In recent years, much research has been conducted to prove that optimal nurse scheduling and nurse assignments are essential to increase quality of patient care. Adding, these two factors lead to increased positive patient outcomes and minimization of costs. Concertation on nurse workloads seems to be a popular focus for most units when it comes to searching for solutions that will positively impact their hospital. "Nurses' job satisfaction depends partly on their workload and their perceived ability to deliver high quality care. Nurse-sensitive indicators (including pressure ulcers, falls, medication errors, nosocomial infections , pain management, and patient satisfaction) depend largely on nursing care and are affected by nurses' ability to recognize and intervene when a patients' condition changes. Nursing workloads directly influence a nurses' ability to assists thoroughly and promote excellent patient outcomes. When patient assignments aren't equitable, nurses may feel inadequate and frustrated." (Kidd, Grove 2014). Another source agrees, "Optimal staffing is essential to providing professional nursing value. Existing nurse staffing systems are often antiquated and inflexible. Greater benefit can be derived from staffing models that consider the number of nurses and/or the nurse-to-patient ratios and can be adjusted to account for unit and shift level factors. Factors that influence nurse staffing needs include: patient complexity, acuity, or stability; number of admissions, discharges, and transfers; professional nursing and other staff skill level and expertise; physical space and layout of the nursing unit; and availability of or proximity to technological support or other resources." (American Nurses Association 2015). The same whitepaper also mentions the following:

Published studies show that appropriate nurse staffing helps achieve clinical and economic improvements in-patient care, including:

– Improvements in patient satisfaction and health-related quality of life

– Reduction/decrease in:

• Medical and medication errors

• Patient mortality, hospital readmissions, and length of stay

• Number of preventable events such as patient falls, pressure ulcers, central line infections, healthcare-associated infections (HAIs), and other complications related to hospitalizations

• Patient care costs through avoidance of unplanned readmissions

• Nurse fatigue, thus promoting nursing safety, nurse retention, and job satisfaction, which all contribute to safer patient care.

Research suggests that many hospital units are making efforts to implement tools that will promote equitable nurse assignments to improve quality of care. The next few sections will briefly describe some software tools that are currently practiced in the healthcare industry. Because of the limitation of direct access to software's, the description of functionality may not be completely accurate. In order to grasp an understanding of how each different software functions, two main sources were used which were interviews from users and internet search engines. Ultimately, at the end of this chapter, there will be a section describing how H.E.A.R.R.T. is different from these software's and how H.E.A.R.R.T. may bring additional value.

2.5.1 Visionware and Optilink by Kronos

Kronos is company that provides software tools used to manage data for industries such as banking, contract services, distribution, manufacturing, healthcare, higher education, retail, and state and local government. They focus on human capital management and workforce management solutions. In the healthcare industry, "Kronos for Health Systems helps providers create and manage an engaged workforce that supports the delivery of value –based healthcare. This blueprint

illustrates how Kronos solutions balance staff workloads, prove full workforce visibility, improve productivity, and automate recruiting, attendance policies, and more; allowing healthcare organizations to seamlessly manage their most valuable asset" (Kronos 2016). It is suggested to visit the Kronos website to fully understand Kronos mission, application and functions.

While conducting research it was found that UHS (Universal Healthcare Services, Inc.) Delaware uses Kronos product called Visionware. Informal interviews were conducted with Charles DeBusk (Vice President) along with email transfers. Other informal interviews with a CNO from Hospitals of Providence Sierra Campus benefited this research. Insight was gained as far as how effective and impactful some Kronos products really are. Via Visionware, productivity of each unit is measured in order to staff appropriately. According to Mr.Debusk, "Generally it is easier to know who was in a bed at midnight…" (Debusk 2015) referring to the inpatients. "Observation patients are trickier" (Debusk 2015), observation patients also need to be accounted for when staffing. These patients are a type of outpatient status, but still can spend several days in the unit. The following is a statement by CNO Erick Cazares regarding staffing via Optilink at his hospital, "In a nutshell, the current inpatient productivity is based on Hours Per Patient Day (HPPD), which is the amount of hours budgeted for each patient in room at midnight. However, it does not calculate all the patients that were cared for throughout the day (patients admitted, discharged, and transferred, also known as ADT index). An accurate acuity and staffing system would be able to guide and measure productivity on an hourly basis." (Eric Cazares 2015). Please note, "HPPD is a staffing metric that calculates the total number of productive hour's worked by nursing staff with direct patient care responsibilities on acute care units per patient day. There is no standard definition. Variations of this metric may exclude administrative hours, contact hours, etc. Metric can also be calculated as hours per patient week and other units of time." (American Nurses Association 2015). Visionware and Optilink do not appear to focus so much on patient distribution, but they do give nurse analytics on needs due to census. The following software's do focus on patient distribution for generating individual nurses' workloads.

2.5.2 Clairvia by Cerner

Figure 2.3: Clarvia Benefits

Clairvia is a scheduling system and acts as a predictive model to align nurses to patient needs in real time. This software leverages outcomes, interventions and observations to create a custom workload calculation based on each patient clinical condition. According to the Cerner website, "Clairvia continuously compares the incoming projected admission, discharge, transfer and workload demand with existing schedules. Managers are able to easily identify any pockets of over or under staffing and proactively adjust staffing needs." (Cerner 2014). "For the staff scheduled, Clairvia enables equitable patient assignments by matching the most qualified, available caregiver to each patient, takin into account staff competencies, continuity of care, the patients individual care needs and projected transitions of care." (Cerner 2014). Luckily, a RN from Banner Health who works in a Telemetry unit was able to provide insight on how the software functions. She, Heather Bonner, stated that the nurse assignments are based on acuity levels. These acuity levels can range from 1-15. A low number represents a low acuity patient and a high number

represents a higher acuity patient. Typically, in telemetry they get patients ranging from 6-8, a 7 is ideal, not easy but ideal for telemetry. A patient who has an acuity level of 6 and or under may be more for a medical surgery unit. An acuity of an 8 and or higher could be recognized as a patient who should be allocated to ICU (Intensive Care Unit). The problem is that, although a 7 is ideal for Telemetry, there are many times that a patient classified as a 10 will be in that unit. In addition, updates to the patient acuities are not available until hours later. Making shift to shift assignments challenging for optimization purposes.

Because of limited access to this software, a thorough understanding of Clairvia was not accomplished including the level of interoperability. The interfaces, user-friendliness and how the updates (patient acuity changes) are made still remains unclear. A great attribute about Clairvia is that it can be integrated to a unit's current HIT (Health Information technology) infrastructure. It is advised to browse the Cerner website if one would wish to inquire more about this software.

2.5.3 Acuity Aggregator by McKesson

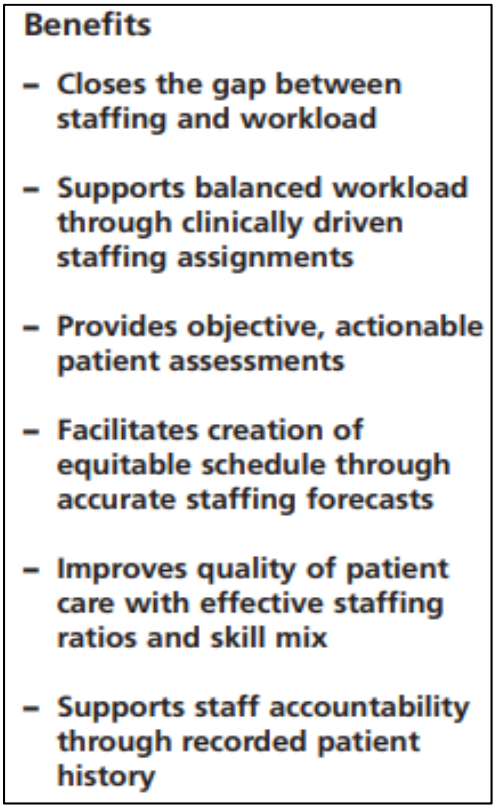

Figure 2.4: Acuity Aggregator Benefits

The Acuity Aggregator is an effective and impactful tool. Just like Cliarvia, Acuity Aggregator generates assignments based on patient acuity. What seems to limit this tool is that the tool relies on a documentation software that McKesson also provides. The Acuity Aggregator cannot be integrated with a units' current infrastructure unless that particular unit is using their software for documenting. There is evidence to support this according to a case study conducted in a hospital called Akron General Medical Center (available on their website). Additional findings from the Healthcare IT News confirms the issue with interoperability. "It's difficult to integrate with other systems and workflows are complex and difficult to manage interdepartmentally." (IT News 2017). A valuable attribute about the Acuity Aggregator is that it is web based. "Because the system is web-based, nurse managers can access the system remotely, monitoring their units from any location — including home. "Acuity Aggregator is the missing link. I can pull up the house-wide/unit census in the HIS and the staff list in ANSOS One-Staff, but the real information about the types of patients and the flow of ADT is found here," says Beth Srock, clinical manager, CCU/PCU." (McKesson 2012). Other keys attributes such as user friendliness and effectiveness remain unknown due to limited access. It would benefit this research to fully understand how easy it is for the user to navigate through the interfaces and know how many clicks of the mouse it takes to update patient acuities from the nurses' assignments.

2.5.4 Workforce Workload Manager for Healthcare by Kronos

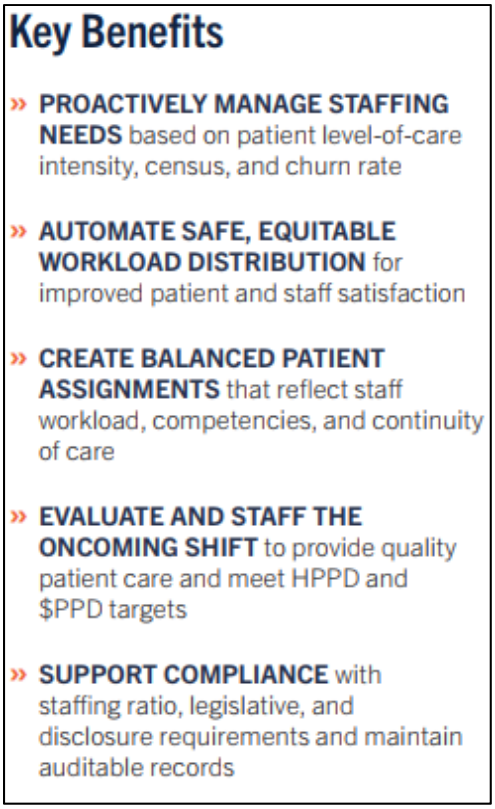

Figure 2.5: Workforce Workload Manager Benefits

Workforce Workload Manager (WWM) appears to be the best patient acuity based software tool between the previously mentioned tools. The key benefits are very similar to H.E.A.R.R.T. As a reminder, the research for H.E.A.R.R.T. began in 2014 the benefits for WWM was not published until 2016. Hence, this research was rigorous and required to remain updated at all times. Although these claimed benefits appear to be proven by practice, the tool lacks the functionality of simultaneous updated individual nurse workload with unit utilization scores. It remains unclear if WWM has this capacity. It is advised to visit the Kronos website and research WWM.

So far, Clairvia, Acuity Aggregator nor WWM, mention anything about generating "team" unit score's, just individual nurse workloads. The limited research has led to the conclusion that most acuity-based software's typically generate separate nurse workloads for means of monitoring labor levels of the unit. In addition, according to research there exist a few cons for these three tools determined by users.

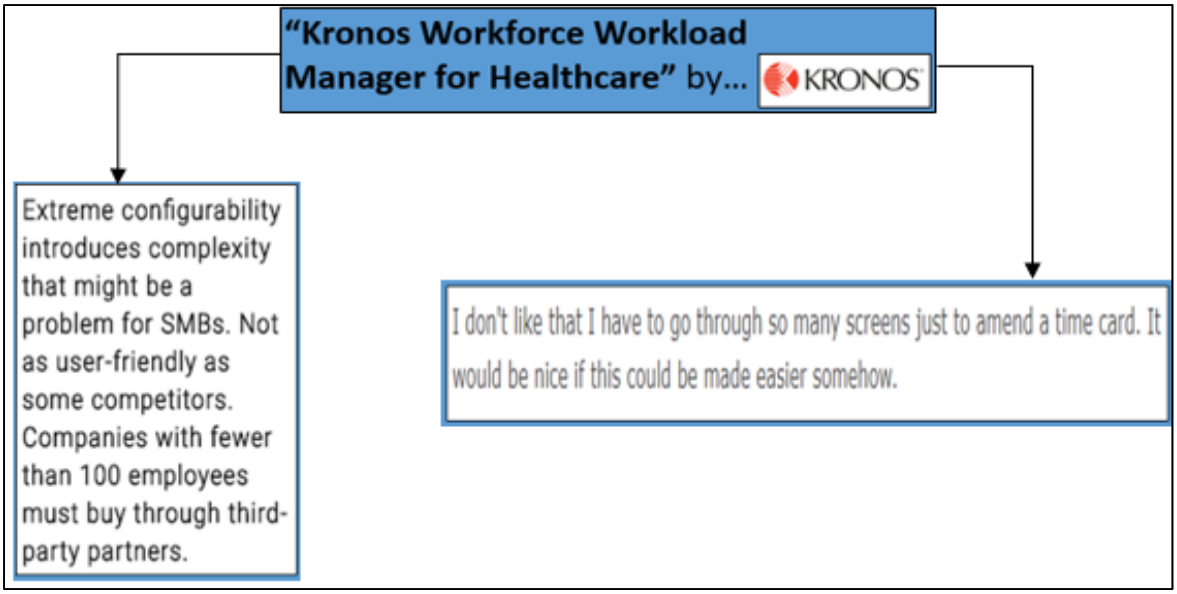

Figure 2.6: Diagram describing cons for WWM

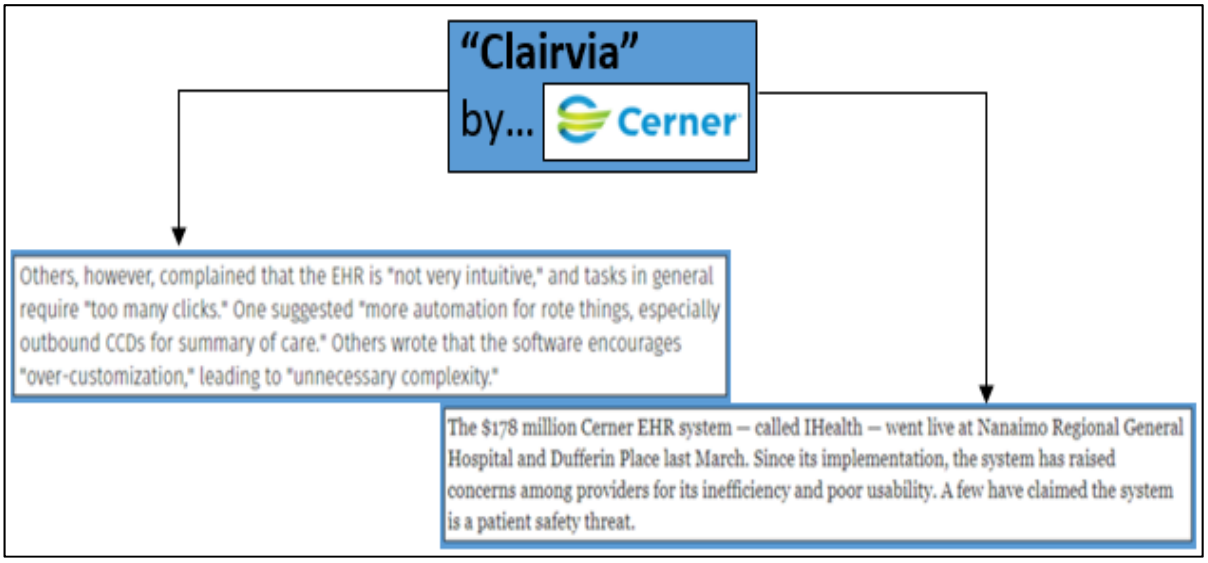

Figure 2.7: Diagram describing cons for Cairvia

Figure 2.8: Diagram describing cons for Acuity Aggregator

The above three diagrams were created based on what users had to say about them. All the claims were straight from website resources from different articles containing content regarding user reviews for different healthcare software tools. It is encouraged to visit these websites to become familiar with additional claims. Of course, these are just some. Nevertheless, it appears that all three tools rely on other software in order to operate. From the claims, it seems that interoperability is an issue along with user friendliness and complexity. In conclusion, these tools may potentially create risks.

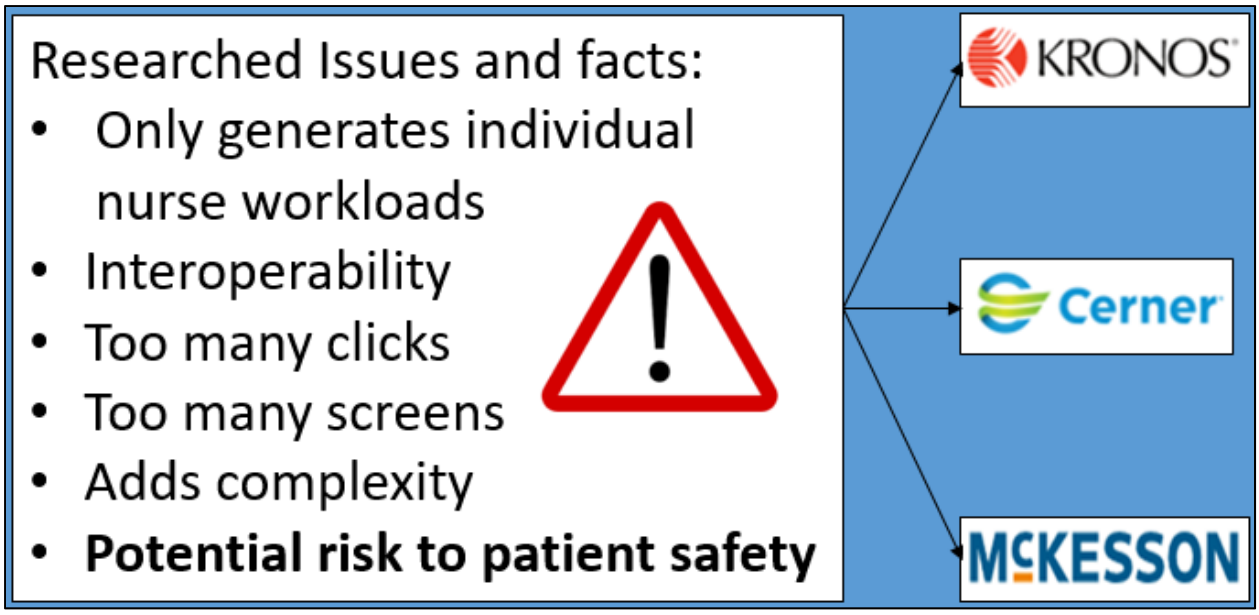

Figure 2.9: Potential risks for current software tools

Please note, one of the constraints for this project was the accessibility to these tools. The claim that these tools do not simultaneously generate individual nurse workload with unit utilization scores may be false. The only tool that definitely does not have this capacity is Clairvia. This is known, because of interviews with nurses that use this tool in a telemetry unit at Banner Health hospital in Scottsdale, Arizona. A prototype was actually designed for the unit, but this will be discussed in the future work section. The next section will discuss some aspects that may hinder the use of acuity-based tools. It will also discuss the appropriate steps one shall take in order to successfully implement such a tool.

2.5.5 Considerations for Patient Acuity Based Tools

It is paramount to avoid all costs including implementing ineffective tools that at first appear to be seamless. A prime example of this was found in an article provided by American Nurses Today. At the Indiana University Health Ball Memorial Hospital, a particular unit was not satisfied with their acuity assessment tool claiming, "Our increasingly dissatisfied nurses deemed it ineffective." (Kidd, Grove 2014). "The nurse manager and unit-based council agreed that equitable patient assignments and adequate unit staffing could be addressed by improving the tool". (Kidd, Grove 2014). In this specific unit, the nurses were required to classify each patient as a 1 (low acuity), 2 (medium acuity) or 3 (high acuity). The problem arose after the nurses would compare each assignments to one another and they would find that their workloads remained inequitable. The initial verification and validation process for this specific tool in this unit was not sufficient. Not until a reevaluation of the tool was conducted, were the nurses satisfied. To measure the impact of the new tool surveys were given to the team before and after the re-implementation. The re-implementation process could have been avoided if the team had considered who designed the tool and what verification and validation steps were carried out by the designer.

"The importance of validity and reliability for PCAS (Patient Acuity/Classification Systems) tools cannot be overstated. In fact, it has been observe that PCAS measures have all too often lacked evidence of validity and reliability" (Kidd, Grove 2014). "In order to assure that the

PCAS tools used in healthcare are as sound as possible, the validity and reliability of these systems should be well established when it is initially developed and/or purchased, and the ongoing reliability of the patient ratings should be assessed at lease annually for every staff member rating patients with a given measure." (Kidd, Grove 2014).

When developing PCAS, one should also consider the simplicity and efficiency. The tool should not be a burden nor should it add additional tasks or unnecessary workloads for the nurses. Education and training is also paramount when implementing PCAS. "All levels of staff need to have a common knowledge base about the system its purpose and their role in making it work. The PCAS and staffing requirements should be routine agenda items for general staff meetings. Issues can be resolved much easier when they are made known sooner rather than later." (Kidd, Grove 2014). The integration for interoperability should have a simple goal: minimizing time and maximizing benefits. Hospital units can develop their own PCAS that is unique and suitable. For example, "if the organization already has a staffing and scheduling system, patient ratings from the newly created PCAS may be integrated with the addition functions of the existing staffing system." (Kidd, Grove 2014). It is also possible for the organization to choose a vendor or outside resource to supply a PCAS. Regardless of what the organization chooses to do, the process will be complex. A "systems-integration approach that incorporates the fundamental building blocks of healthcare, form equipment and technology to clinical insight and workflow processes, is needed to take the next major leap in improving quality and safety." (Kidd, Grove 2014). H.E.A.R.R.T. may be that major leap in improving quality and safety. H.E.A.R.R.T. considers all levels of nursing in its design. These levels are the executive level, nursing management and staff nurses (front line). The next section will discuss the difference between H.E.A.R.R.T. and the other PCAS.

2.5.6 H.E.A.R.R.T.'s Unique Attributes

What is unique about H.E.A.R.R.T. is that it does not rely on other software systems for interoperability purposes. Meaning, H.E.A.R.R.T. will not provide services as a software package,

but rather one single tool, which may have a positive impact on cost reduction. The unique equation behind the software is extremely flexible and adaptable to any unit. The tool can simply pull the information from the units' current software infrastructure no matter how the unit classifies acuity. H.E.A.R.R.T. has the capacity to function as an add-on or a single system via on site or web based. The tool focuses on risk reduction for making patient distribution simpler, faster and safer. The unique equation is a single entity that integrates the current number of patients per bed and the updated patients' classified acuity. In one single step, the user may make an update to any patient acuity on an individual nurse assignment and it will affect the entire unit simultaneously. Because research was limited, it is not safe to state that H.E.A.R.R.T. is the only software that does this. Although, no other tools were discovered to have such capacity during the research.

The tool also considers standards such as nurse to patient ratio and the number of nurses required when all beds are full with in the unit. Another unique attribute about H.E.A.R.R.T. is that it alerts the users from all levels when these standards are at a threshold per individual nurse and per the entire team (unit). Per individual nurse, this is recognized as over working of the nurse and per the unit, it can be recognized as unit over utilization. In the I.M.S.E. world, there exists a tool called a control chart, which is practiced for quality purposes. This chart allows engineers to recognize at a specific time and or sample number when a process and or product is out of spec.

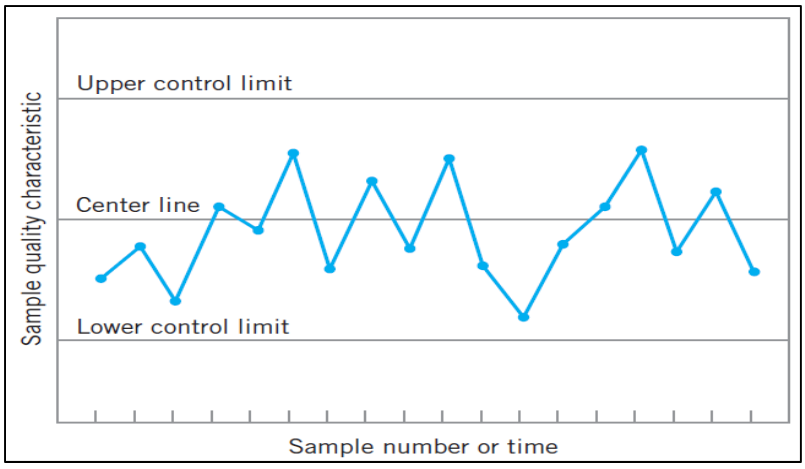

Figure 2.10: Example of a control chart

"The control chart is a graphical display of a quality characteristic that has been measured or computed from a sample versus the sample number or time. The chart contains a centerline that represents the average value of the quality characteristic corresponding to the in-control state. (That is, only chance causes are present.) Two other horizontal lines, called the upper control limit (UCL) and the lower control limit (LCL) are also shown on the chart. These control limits are chosen so that if the process is in control, nearly all of the sample points will fall between them. As long as the points plot within the control limits, the process is assumed to be in control, and no action is necessary. However, a point that plots outside of the control limits is interpreted as evidence that the process is out of control, and investigation and corrective action are required to find and eliminate the assignable cause or causes responsible for this behavior." (Douglas 2013)

Essentially, H.E.A.R.R.T. allows the capacity to generate a unique chart that is similar to a control chart. In this case, the sample quality characteristic will be the units' utilization score and the sample number will be time.

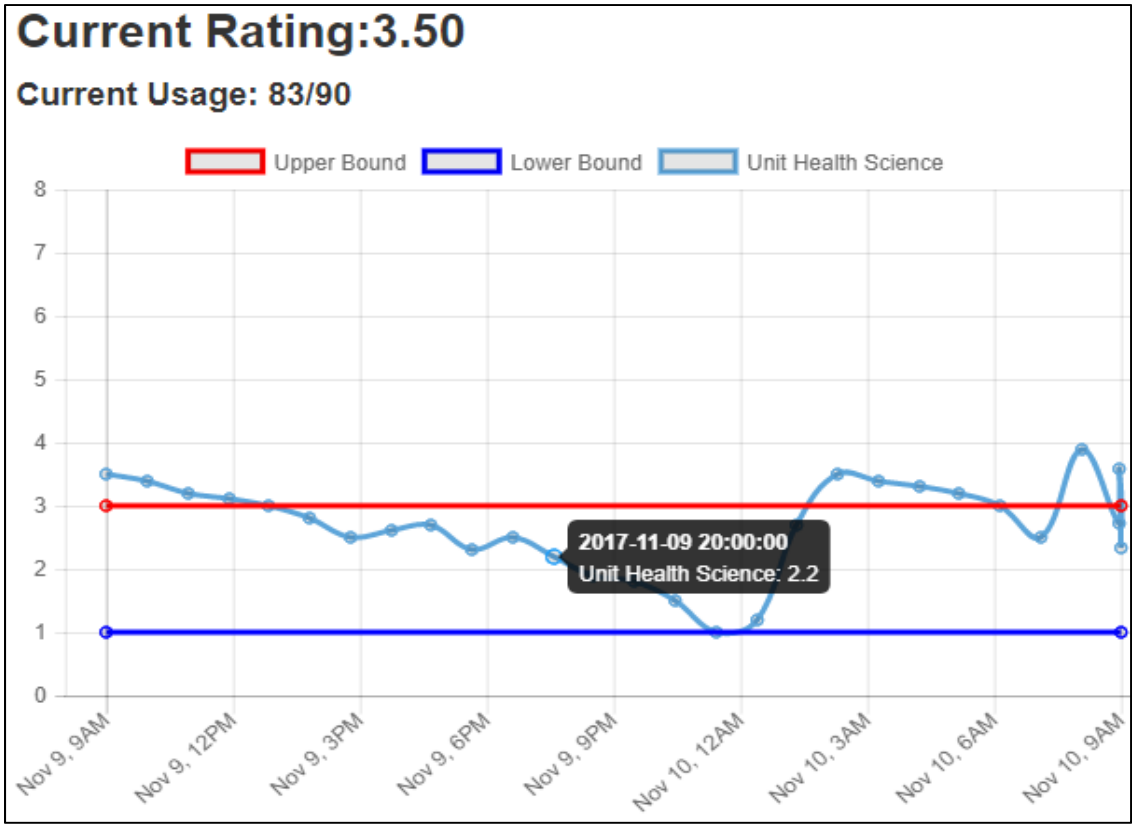

Figure 2.11: Unit utilization scores viewed as a control chart

In Figure 2.11, the current rating represents the unit utilization score and the current usage is the amount of patients per bed. In this case, the current utilization score is 3.50 while 83 out of the 90 beds are used. In addition, the red line represents the upper limit, the blue line represents the lower limit and the turquoise scatter plot represents the different fluctuating scores as they differ with time. In other words, the upper limit can be interpreted as heavily utilized and or busy unit. The lower limit reflects when the unit is not as utilized. To better understand the fluctuating turquoise scatter plot, when patient admissions occur the unit utilization score goes up and when individual patient acuity increases so does the teams' score. When there are discharges, the score goes down and when the patients' acuity goes down so does the team score. It is a simple concept that required much verification and validation which was complex, but very much achievable. The unit chosen for Figure 2.11 was a simulated unit from the health science building at UTEP, which will be discussed further in this document under chapter 4 Simulation Results.

H.E.A.R.R.T. allows the capability to make an update to any patient in live time via user-friendly interface. This can potentially assist the users to accurately and effectively prepare an optimized unit assignment. Once it recognized that the system is out of control, the appropriate actions can take place to bring the system back within spec. Of course, nurses cannot be manufactured and their patient's initial state of health is not controllable. The tool creates the opportunity to monitor a certain unit in live time via the control chart. "Specifying the control limits is one of the critical decisions that must be made in designing a control chart. By moving the control limits farther from the centerline, we decrease the risk of a type I error—that is, the risk of a point falling beyond the control limits, indicating an out-of-control condition when no assignable cause is present. However, widening the control limits will also increase the risk of a type II error—that is, the risk of a point falling between the control limits when the process is really out of control. If we move the control limits closer to the center line, the opposite effect is obtained: The risk of type I error is increased, while the risk of type II error is decreased" (Douglas C. 2007 Quality control). Determining the appropriate upper and lower limits for H.E.A.R.R.T. will require future work.

Potentially, H.E.A.R.R.T. has the capacity to act as an analytical and consulting tool for any unit no matter their policies, standards and means of patient acuity classification. H.E.A.R.R.T. will accurately quantify and store every nurses' workload in live time. The tool has a function that will allow the user to justify why he or she chose to classify their patient acuities the way that they did. The reasoning and justification will also be stored for future data analysis. This capability may assist with improving education for the unit as far as ultimately determining the true difference between all acuity levels. As a reminder, the tool does not determine patient acuity levels. The following sections will be technical, as it will describe the systems engineering behind the tool.

2.6 Systems Engineering Analysis for H.E.A.R.R.T.

Systems engineering applications are found in many industries. Systems thinking, if done properly, can be powerful and potentially improve the overall quality of a team. "Systems thinking

should be utilized to solve complex problems that involve many participants, recurring problems or those that have been made worse by past attempts to fix, and problems whose solutions are not obvious. Nurses must shift from short-term quick fix solution to looking toward long-term strategic thinking" (Malik 2015). Adding, "Systems thinking can impact team performance." (Hardin, Kaplow 2017). Working in teams versus silo is essential to attacking complex problems, because it improves the opportunity to understand problems as interrelationships rather than linear.

In a typical hospital organization, there are five general functions that are broken down into departments. From these departments data and information is either inserted and or inquired through different software systems. Generally, the goal is for the functional systems to communicate with one another for seamless interoperability:

- Financial- departments- insert and or inquire data
- Nursing- departments- insert and or inquire data
- Support- departments- insert and or inquire data
- Ancillary- departments- insert and or inquire data
- Medical Staff- departments- insert and or inquire data

As mentioned before, H.E.A.R.R.T. is unique, because it can be adapted and integrated to any healthcare unit no matter the design of the infrastructure. The organization can adapt H.E.A.R.R.T. as an add-on or, because of the many attributes and capacities; it can act as the only system utilized at all functional levels of the organization. Figure 2.12 (below) is a chart describing how H.E.A.R.R.T. is a system enabler to create data driven decisions.

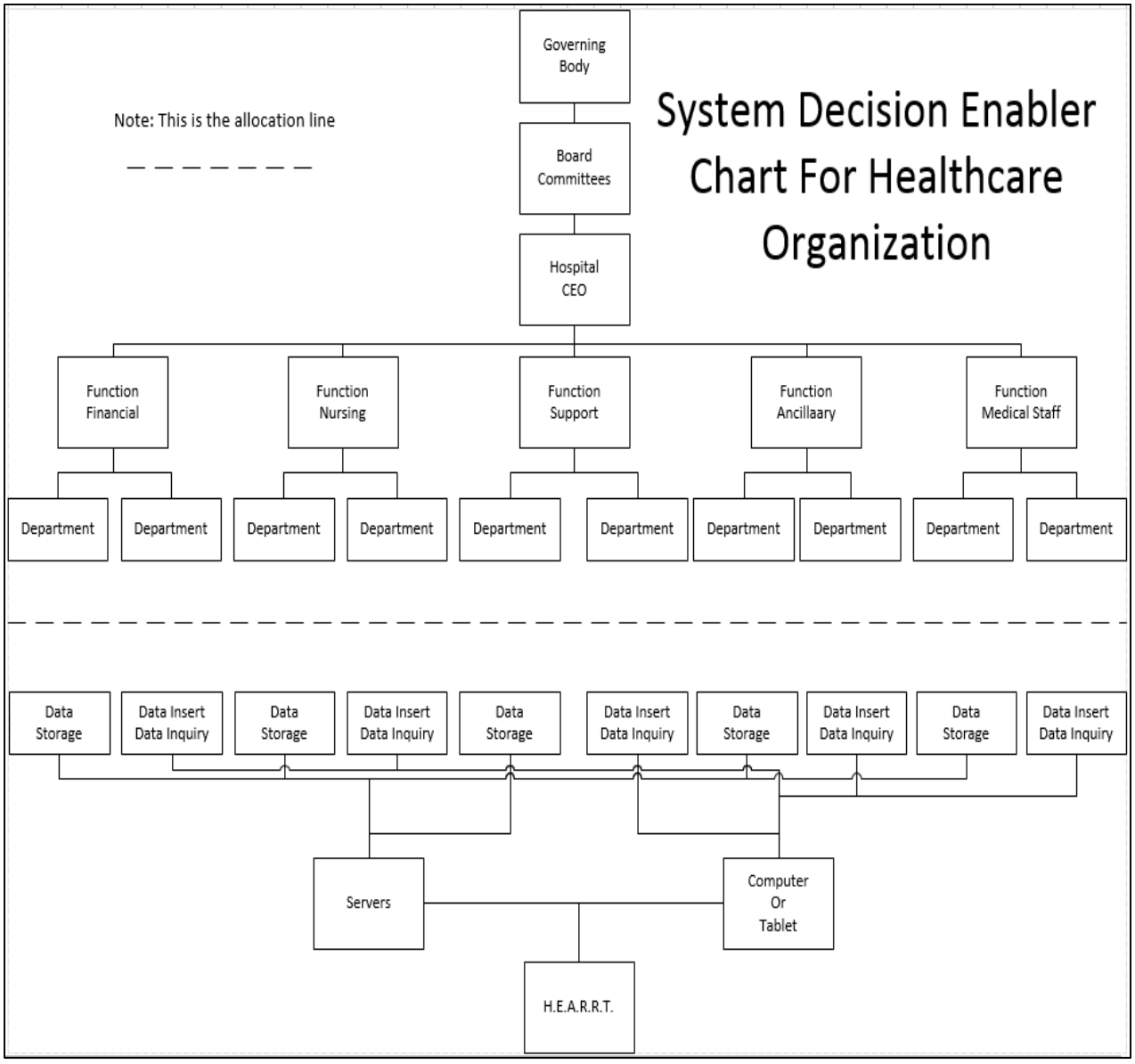

Figure 2.12: Healthcare system decision enabler chart

In the development any type of product, process or system, systems thinking is intuitively applied. All systems have to begin with a concept, a preliminary design, detail design and development, production, product in use (utilization), and lastly product disposal. Generally speaking, there are six phases of a product's system life cycle.

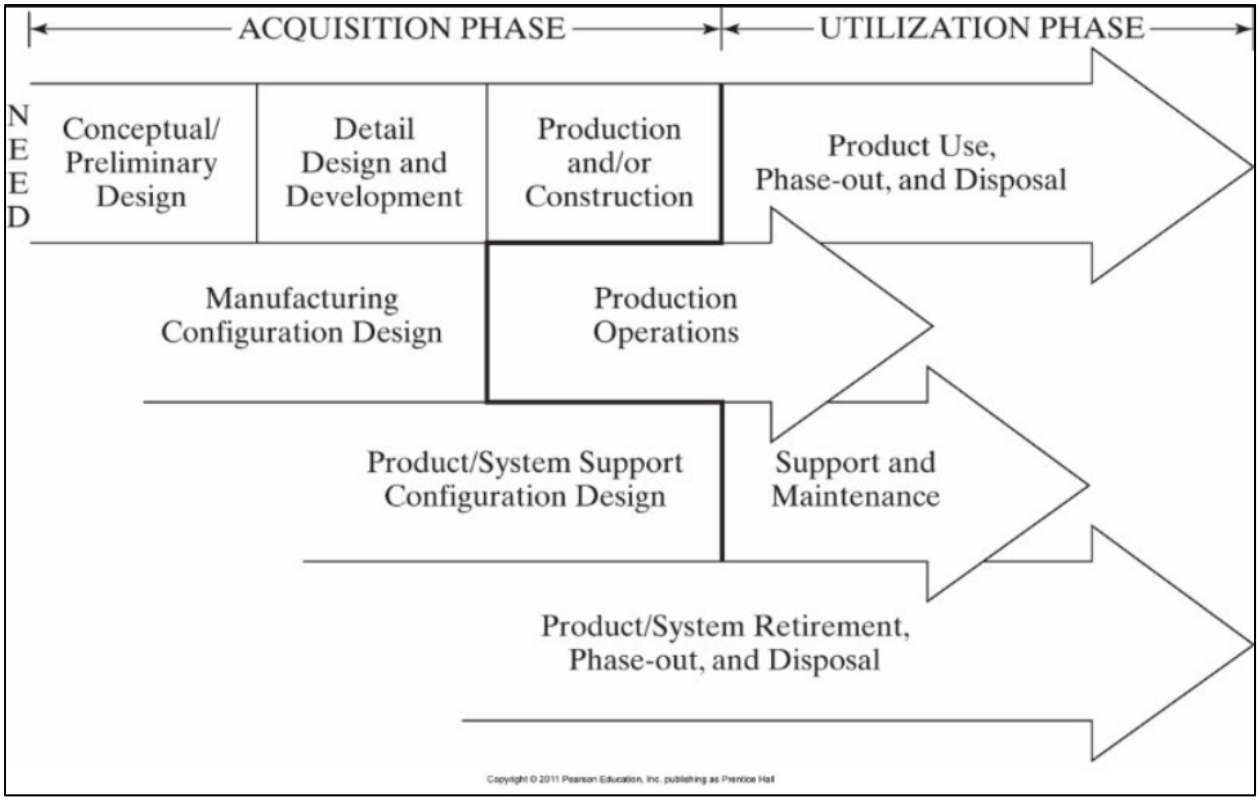

Figure 2.13: Generic system life cycle (Blanchard, Fabrycky 2011)

- Phase 1) Acquisition
- Phase 2) Utilization
- Phase 3) Design
- Phase 4) Startup
- Phase 5) Operation
- Phase 6) Retirement

Some of these phases may occur in parallel as it can be visually recognized in Figure 2.13. Theoretically speaking, in the development of H.E.A.R.R.T., these phases would be followed and the appropriate steps and or activities would take place. Because of the limitation of not being able to develop and integrate H.E.A.R.R.R.T. in a real hospital unit setting, a prototype designed for a simulated lab was developed. The goal of the prototype was to demonstrate to potential

stakeholders how H.E.A.R.R.T. would work and function if it were to operate with their infrastructure. This means that only the design aspect of the system life cycle was met for this particular project. The next section will discuss theoretical feasibility analysis, risk analysis, functional analysis, design analysis and the life cycle process in designing and developing a prototype for conceptual description purposes.

2.6.1 Feasibility Analysis for H.E.A.R.R.T.

Theoretically, before developing and designing a prototype for the UTEP simulated lab the first thing was to do is to create a feasibility analysis. Of course, by this point, creating acuity-based software's is feasible; this is backed by the previously discussed research. For this project, in determining if H.E.A.R.R.T. is feasible, a risk analysis and functional analysis shall be conducted.

2.6.1.1 Functional Analysis for H.E.A.R.R.T.

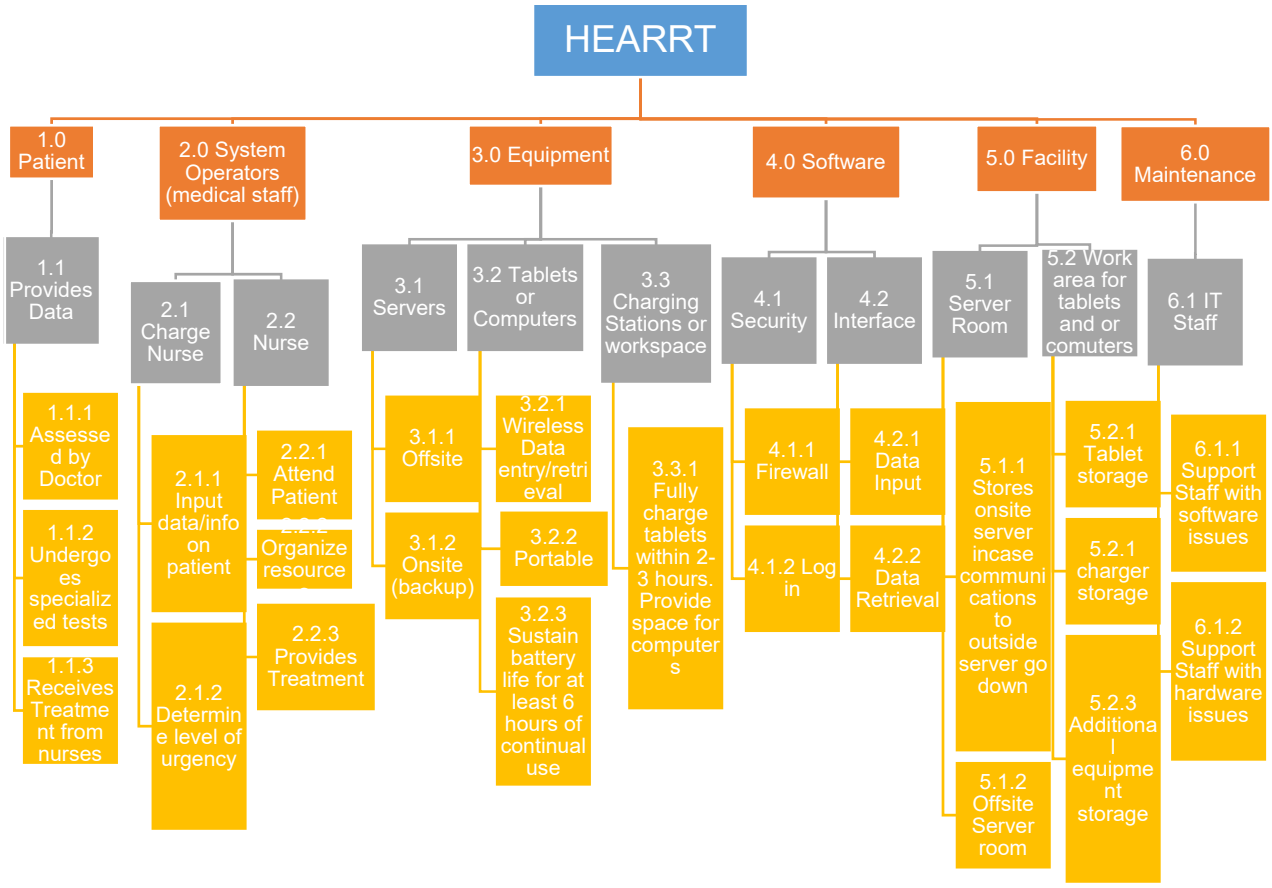

Figure 2.14: Functional analysis for H.E.A.R.R.T.

The above figure is broken down into three functional tiers with H.E.A.R.R.T. at the top of the hierarchy. This analysis describes the theoretical functionality of the software. Please note,

this is only a high-level analysis. If actual implementation were to occur, this analysis would be much more complex. This analysis is also under the assumption the software is an add-on.

2.6.1.2 Risk Analysis for H.E.A.R.R.T.

A risk analysis was conducted to align the technology objectives with the hospital units' objectives. Ultimately, this activity is carried out to decide if the proposed system is in fact feasable. Table 2.0 describes at a top level of what risks may be at stake when integrating the software.

Table 2.0: Risk analysis for H.E.A.R.R.T

Function	Failure Mode	Primary Effect	Severity	End Effect	Failure Cause	Corrective Action
Software Interoperability	No Interoperability between the units' infrastructure and HEARRT	Slow transition of getting the software's to communicate	2	Takes longer to generate individual nurse workload and unit utilization scores	The code for the interacting software's are not compatible	Reprogram the code
Cost effective	Going over budget	Hospital must devote more resources to system	4	Hospital loses money or needs to make cuts elsewhere	Over spending	Make HEARRT cost effective
Software Security	Data and patient information not secure	Patient confidentiality compromised	5	Compromised patient information/ lawsuit	No firewall or password protected access	Redundant security measures
24hr Communication	Communication to off-site server is lost	Communication to server lost	5	Can't input/access patient data from servers	Loss of connection	Have on-site server
24hr Power	No power	Connection to system is lost	5	Can't access patient data from the servers	Loss of electrical power	On-site power generators

Severity	1	2	3	4	5
Effect	Minimal	Some	Considerable	Major	Greatest

2.6.2 Waterfall Process

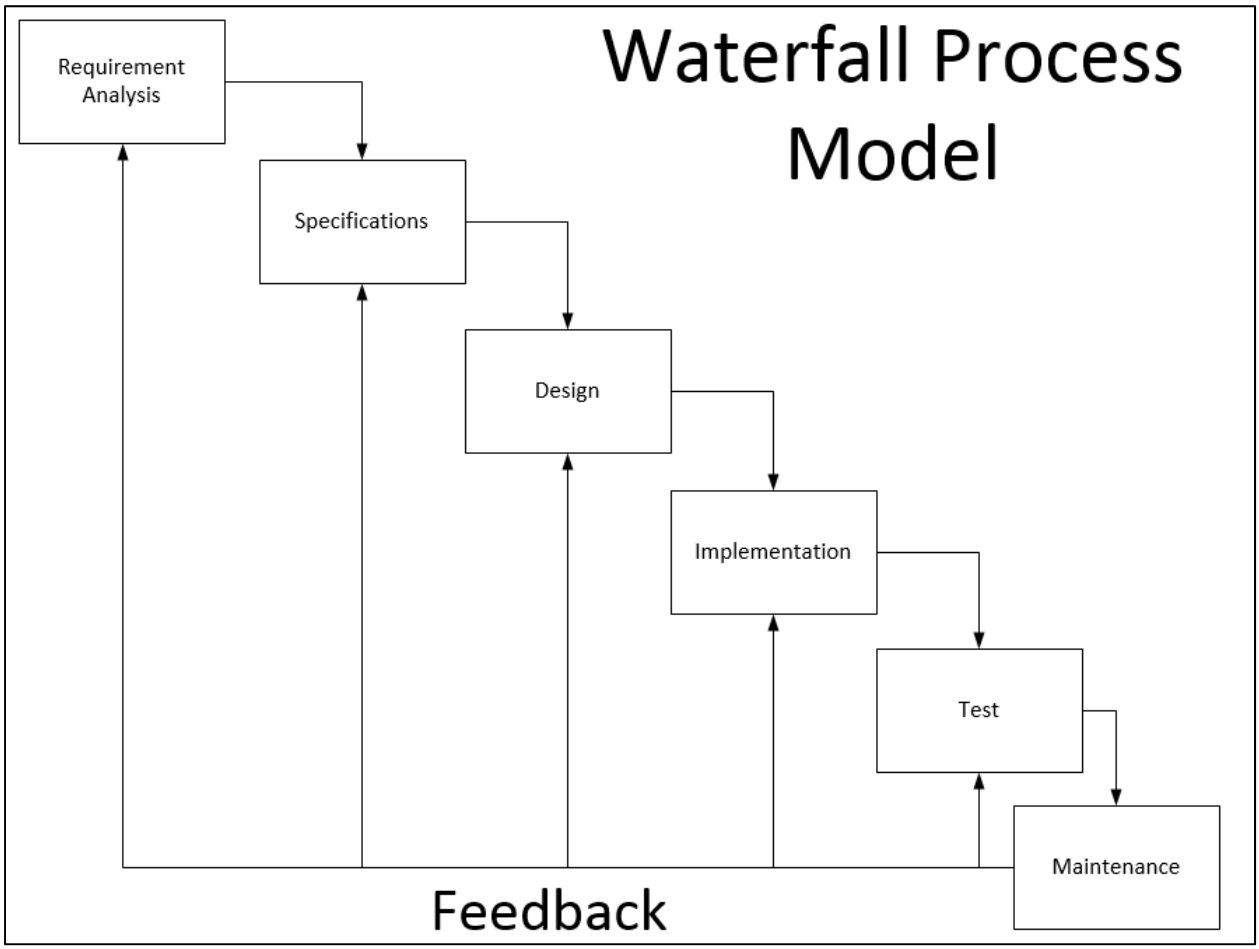

Figure 2.15: Waterfall process

This model can be very helpful and can be applied as a general guide in the development of software systems. The goal in designing the prototype for the simulated unit was to ensure that it functions as a conceptual tool. The prototype was not designed to be integrated, but rather to demonstrate how it works in broad terms (not including how it would work in its' operational environment).

2.6.3 Design Requirements for H.E.A.R.R.T.

As an add-on software, there are design requirements that shall be considered for development purposes. Table 2.1 theoretically describes these design requirements.

Table 2.1: Design requirements for H.E.A.R.R.T.

Area	Requirement	Specification
Data Storage	• Cloud Storage (outsource pay-per use) high security/reliability • In house storage for backup (dependent of hospital size) and keeping live patient data	• Pay-per-use • Back up storage dependent on hospital size
Communication	• Network connection (internet) • Backup servers have internet	• Network capable of Wi-Fi 802.11n(300Mbps) • Internet Standard
Data Input and Inquiry	• Tablets and or Computer • Units' current Software • Automatic information gathering (accurate/more reliable)	• Patient acuity classification (input) • Data associated with human metrics (inquiry) • Data associated with unit utilization scores (inquiry)
Display	• <7 inches (diag.) (for tablets) • Standard computer screen	• Small enough to carry big enough to use
Security	• Individual user credentials • HIPPA compliance	• Easy, quick • Simple tracking • No human error
HEARRT Code integration and interoperability	• Lowers cost, opens up opportunity to implement HEARRT in all unit's	• Language C++, Python, Java
Data Filter	• Structure Data • Decision making shall be easier	• Simple User Interface • Graphics and Tables

2.6.4 Requirements Verification Matrix for H.E.A.R.R.T.

Requirements documentation is essential for the quality and tractability of a project. Every requirement from system conception to system utilization shall be captured, verified and validated. "Throughout the elicitation activity and especially before finalizing the SRS (systems requirement specifications), raw requirements should be analyzed for problems and theses problems reconciled. Requirements analysis is the activity of analyzing requirements for problems." (Laplante 2014) This section will briefly discuss top-level requirements for H.E.A.R.R.T. and how the requirements would be documented, validated and verified. The below figure is a representation of a requirements document. Again, the complexity level of actual integration is not captured in

this requirements document. What is captured are the theoretical top-level requirements assuming that the system is an add-on.

Table 2.2: H.E.A.R.R.T. Requirement Document (HRD)

Requirement I.D.	Requirement	Requirement Type
1	The system shall be subsystem	Operational
2	The system shall be a software	Operational
3	The system shall be able to communicate with pre-existing software's	Operational
4	The system shall generate quantified nurse workloads	Functional
5	The system shall generate quantified unit utilization scores	Functional
6	The system shall allow the user to generate equitable nurse assignments	Functional
7	The system shall generate graphs and charts for analytics	Functional
8	The system shall generate data that promotes risk minimization and optimized patient outcomes	Functional
8	The system shall be user-friendly	Non-Functional
9	The system shall comply with HIPPA	Non-Functional
10	The system shall be cost effective	Non-Functional

From the requirements document, a requirement verification matrix can be augmented. "The objective of this VVT activity is to determine (1) the method of verifying each system and requirement (2) when it will be done within the lifecycle of the system and (3) the specific procedure according to which the verification will be accomplished." (Engel 2010). There can be

different procedures when it comes verification. Some of these procedures can be a System Test Description (SysTD), First Article Acceptance plan (FAAP), or Production Acceptance Plan (PAP).

Table 2.3a: Requirements verification matrix for H.E.A.R.R.T.

Requirement ID	Requirement Traceability	Verification Method						Verification Stage					Procedure ID
		None	Analysis	None	Demonstration	Test	Certification	Definition	Design	Implementation	Integration	Qualification	
1	HRD		X					X					FAAP
2	HRD		X						X				FAAP
3	HRD					X					X		SysTD
4	HRD					X			X				SysTD
5	HRD					X			X				SysTD
6	HRD					X					X		SysTD
7	HRD					X					X		SysTD

Table 2.3b: Requirements verification matrix for H.E.A.R.R.T.

Requirement ID	Requirement Traceability	Verification Method						Verification Stage					Procedure ID
		None	Analysis	None	Demonstration	Test	Certification	Definition	Design	Implementation	Integration	Qualification	
8	HRD					X					X		SysTD
9	HRD		X						X				PAP
10	HRD		X					X					PAP

Chapter 3: Methodology

A method is a particular procedure in approaching or accomplishing something. Once a need and or problem is defined the decision to how the solution will be formed to answer the particular need and or problem can sometimes be complex. Complex needs and problems typically require complex solutions. The methodology described in this research contains innovative roots. Meaning, it is original, unique and has never been applied before. In this chapter, the steps for the methodology will be described, but because of a pending patent, details regarding the equation will not be discussed. Although details for the equation are not involved, the verification and validation will be clearly defined.

3.1 Dependencies

Before applying the H.U.A.A.L.M.M. to a chosen unit, there are key dependencies that shall be considered, which are the following:

- The unit chosen to apply H.U.A.A.L.M.M. classifies acuity quantitatively
- The unit chosen to apply H.U.A.A.L.M.M. has a current software infrastructure to insert patient acuities
- The unit chosen to apply H.U.A.A.L.M.M. depends on a CRN for unit assignments

Although the methodology depends on the unit to have a preexisting software infrastructure to insert patient acuity, it is still possible to design H.E.A.R.R.T. for the chosen unit if they do not.

3.2 Assumptions

Before applying the H.U.A.A.L.M.M. to a chosen unit, there are key assumptions that shall be considered, which are the following:

- The unit chosen to apply H.U.A.A.L.M.M. is willing to participate
- The unit chosen to apply H.U.A.A.L.M.M. practices integrity as patient acuity updates are made
- The unit chosen to apply H.U.A.A.L.M.M. is an acute care unit

3.3 Detailed Description of Healthcare Utilization Awareness and Labor Monitoring Methodology (H.U.A.A.L.M.M)

The following are the steps for the methodology to successfully arrive to the components of creating an equation for a unit: Essentially, H.E.A.R.R.T. is derived from H.U.A.A.LM.M.

- Step 1) Choose hospital unit
- Step 2) Gather S.O.P.'s (Standardized Operational Procedures)

  -Number of beds in chosen unit

  -Budgeted or standard nurse to patient ratio

  -Number of nurses required when all beds are full

  -Means of patient acuity classification
- Step 3) Generate Equation
- Step 4) Verify the integrity of the equation
- Step 4.1) Create a simulated assignment/assignments for the chosen unit
- Step 4.2) Have all nurses in that particular unit to rank the workload from lightest to heaviest (educated and professional opinions only)
- Step 4.3) Have the H.E.A.R.R.T. for that unit to rank the workloads in the same fashion
- Step 4.4) Conduct an agreement analysis to validate the equation
- Step 5) Convert the equation to a software
- Step 5.1) Create simulations and get feedback from healthcare professionals (RN's, CRN's, Professors, Unit directors, Unit managers), potential stakeholders and users to answer the thesis hypothesis.

The next section will describe how the equation for H.E.A.R.RT. is verified and validated before it is converted into H.E.A.R.R.T.

3.4 Validation of The Equation

The chosen unit for verification and validation in this research was a theoretical unit. Over the span of three semesters, a mixture of registered nurses, charge nurses, directors and

coordinators from different hospitals and units participated in providing background information. A total of 29 samples were gathered and below is the background information each participant answered.

Please answer the following questions as precise and as professional as possible using your educational opinions by entering Yes or No or by filling in the blank line: Note, feel free to remain anonymous

Name_____ Position: _____ Unit: _____Hospital:_____

1) Does your unit classify patient acuity in a quantitative manner (e.g. 1=low, 2=medium, 3=high)?

2) If you answered yes to question 1, who gives the classification of the patient and when?

3) Does your unit have means of documenting your assigned patients via paper or software (computer) and when does the documenting of your patients occur?

4) In your professional opinion, what separates low, medium, high acuity patients?

5) How many patients are you as an RN allowed to be assigned? Do you ever go over that limit? If yes, how often?

6) Do you have CRN (Charge) experience? If yes, list what would make your job easier and more efficient?

7) Random Theoretical Scenario: Below is a unit assignment with 8 Nurses (N1-N8) and 31 patients and their classified acuities (1=low, 2=medium, 3=high). In this unit (32 beds) the budgeted limit is a maximum of 4 patients per nurse (1:4). Please, in your educated and professional opinion, rank the assignments from lightest to heaviest by listing the N# in the order you believe is accurate (e.g. N1, N4, N7, N# etc.).

Nurse	All patients and their acuities				
N1	2	1	2	2	2
N2	2	2	2	2	2
N3	1	2	1	1	
N4	3	3	3		
N5	3	2	2	3	1
N6	1	1			
N7	1	2	2	2	
N8	1	3	2		

(Note: N1 has 5 patients, N2 has 5 patients, N3 has 4 patients, N4 has 3 patients, N5 has 5 patients, N6 has 2 patients, N7 has 4 patients, and N8 has 3 patients.)

Enter workload ranking on this line (lightest to heaviest):_____

Figure 3.0: Questions Regarding Hospital Unit (Background Information)

In the background information (Figure 3.0), the S.O.P's are described for this unit: number of beds the unit has (32), the budgeted nurse to patient ratio (1:4), the means of acuity classification (1=low, 2=medium, 3=high) and the number of nurses required when all beds are full (8). It is paramount that all S.O.P's are gathered in order to generate an equation that will simultaneously generate individual nurse workloads and a unit utilization score.

Table 3.0: H.E.AR.R.T's results of workload rankings

Below are the results of the workload rankings N1 through N8 that H.E.A.R.R.T. generated:

Note: Below is a color code for N1-N8			Nurse	Patient's and their acuities					Workload
N1		Rank lightest	N1	2	1	2	2	2	4.25
N2			N2	2	2	2	2	2	4.75
N3			N3	1	2	1	1		1.5
N4			N4	3	3	3			7.5
N5		to heaviest	N5	3	2	2	3	1	7.75
N6			N6	1	1				0.5
N7			N7	1	2	2	2		2.5
N8		workload	N8	1	3	2			3.5
CRN, Director, Coordinator			Note: Standards and budget suggest that in this unit of 32 beds, nurses may not work with more than 4 patients **(1:4)**. Acuity Scale: **1=Low, 2=Medium, 3=High**						

Note: N1's workload is 4.25, N2 is 4.75, N3 is 1.5, N4 is 7.5, N5 is 7.75, N6 is 0.5, N7 is 2.5 and N8 is 3.5. If these quantified workloads were ranked lowest to highest, the ranking list would look like the following: N6, N3, N7, N8, N1, N2, N4, and N5.

Table's 3.1 through 3.6 are the results from all 29 participants' rankings from lightest to heaviest workloads regarding N1 through N8 (see table 3.0).

Table 3.1: Participant 1-5's results for workload rankings

RN	CRN	CRN	RN	RN
N6	N6	N6	N6	N6
N3	N3	N3	N3	N3
N7	N7	N7	N7	N8
N1	N8	N1	N8	N7
N2	N1	N2	N1	N1
N8	N2	N8	N2	N2
N5	N4	N5	N4	N5
N4	N5	N4	N5	N4

Table 3.2: Participant 6-10's results for workload rankings

RN	RN	RN	Asst Dir	RN
N6	N6	N6	N6	N6
N3	N3	N3	N3	N3
N8	N7	N8	N8	N7
N7	N2	N7	N7	N8
N1	N1	N1	N1	N1
N2	N8	N2	N2	N2
N4	N5	N4	N4	N4
N5	N4	N5	N5	N5

Table 3.3: Participant 11-16's results for workload rankings

CRN	RN	RN	RN	RN	Rn
N6	N6	N6	N6	N6	N6
N3	N3	N3	N3	N3	N3
N8	N7	N7	N7	N7	N8
N7	N2	N1	N1	N1	N7
N1	N8	N2	N2	N2	N1
N2	N1	N8	N	N8	N2
N4	N5	N4	N4	N5	N5
N5	N4	N5	N5	N4	N4

Table 3.4: Participant 17-21's results for workload rankings

CRN	CRN	RN	RN	RN
N6	N6	N6	N6	N6
N3	N3	N3	N3	N3
N7	N7	N8	N7	N7
N8	N8	N7	N1	N8
N1	N1	N1	N8	N1
N2	N2	N2	N2	N2
N4	N4	N4	N5	N5
N5	N5	N5	N4	N4

Table 3.5: Participant 22-26's results for workload rankings

RN	RN	RN	RN	RN
N6	N6	N6	N6	N6
N3	N3	N3	N3	N3
N7	N7	N7	N7	N7
N8	N1	N1	N8	N8
N1	N2	N2	N1	N1
N2	N8	N8	N2	N2
N4	N4	N4	N4	N4
N5	N5	N5	N5	N5

Table 3.6: Participant 27-29 and H.E.A.R.R.T.'s workload rankings

Coordinator	CRN	CRN	H.E.A.R.R.T	Workload
N6	N6	N6	N6	0.5
N3	N3	N3	N3	1.5
N7	N8	N7	N7	2.5
N8	N7	N8	N8	3.5
N1	N1	N1	N1	4.25
N2	N2	N2	N2	4.75
N4	N4	N4	N4	7.5
N5	N5	N5	N5	7.75

Note: the unit utilization score for this unit assignment at this moment is a 3.9 as the current bed usage is 31 out of the 32 beds. The lowest unit score this unit can have is a .03125. This score (.03125) is a reflection of when there is only 1 nurse working in the unit with only one patient of a low acuity. Of course, this scenario may never occur in real life; realistically this type of scenario is rare. The highest score this unit can have is a 12. This score is a reflection of when all 32 beds are full and all 32 patients are high acuities. Although this scenario is rare, it may occur. The lowest individual score a nurse may have in this unit is a .25, which is a representation of when the nurse is assigned only 1 patient of a low acuity. The highest individual score has no limit. For example,

it may be possible that some nurses in this unit are assigned seven patients of all high acuities, which is three patients over the standard. The individual score when this occurs is a 17.5. Although this scenario is unrealistic, because it is a risk to that individual nurse and is avoided at all costs, it is still possible. H.E.A.R.R.T. shall be accountable for any possible scenario and the tool takes into consideration all situations even when standards are not practiced.

In order to validate and verify the equation for this unit, an agreement analysis shall be conducted. The purpose of the agreement analysis for this specific research is to measure the accuracy, repeatability and reliability of classification between 29 participants versus H.E.A.R.R.T. An acceptable agreement between the standard (H.E.A.R.R.T.) and appraisers (29 participants) is .70 (70%) the higher the percent the higher the agreement a 1.0 (100%) is a perfect agreement and a 0.0 is no agreement. In addition, the agreement analysis will also measure the relationship between ranked data. An acceptable relationship correlation between ranked data is .70 (70%), no correlation is 0.0 and a 1.0 (100%) is a perfect relationship.

All Appraisers vs Standard

Assessment Agreement

# Inspected	# Matched	Percent	95% CI
8	1	12.50	(0.32, 52.65)

Matched: All appraisers' assessments agree with the known standard.

Fleiss' Kappa Statistics

Response	Kappa	SE Kappa	Z	P(vs > 0)
1	0.96059	0.0656532	14.6313	0.0000
2	1.00000	0.0656532	15.2315	0.0000
3	0.72414	0.0656532	11.0297	0.0000
4	0.29064	0.0656532	4.4269	0.0000
5	0.60288	0.0656532	9.1828	0.0000
6	0.60591	0.0656532	9.2290	0.0000
7	0.60591	0.0656532	9.2290	0.0000
8	0.60854	0.0656532	9.2690	0.0000
Overall	0.67461	0.0248381	27.1603	0.0000

Cohen's Kappa Statistics

Response	Kappa	SE Kappa	Z	P(vs > 0)
1	0.96059	0.0656532	14.6313	0.0000
2	1.00000	0.0656532	15.2315	0.0000
3	0.72414	0.0656532	11.0297	0.0000
4	0.29064	0.0656532	4.4269	0.0000
5	0.60394	0.0654719	9.2244	0.0000
6	0.60591	0.0656532	9.2290	0.0000
7	0.60591	0.0656532	9.2290	0.0000
8	0.61084	0.0645113	9.4687	0.0000
Overall	0.67488	0.0247993	27.2135	0.0000

Kendall's Correlation Coefficient

Coef	SE Coef	Z	P
0.883118	0.0536056	16.4514	0.0000

Figure 3.1: Agreement analysis results between 29 participants and H.E.A.R.R.T.

A tool called Minitab was used to conduct the analysis and, Figure 3.1 are the results. In this case, the appraisers are the 29 participants and the standard is the H.E.A.R.R.T. for the chosen unit. Please note, the methodology (H.U.A.A.L.M.M.) requires the agreement analysis to consider all nurses from the same unit, but due to limits and constraints, this did not occur. As mentioned earlier in this document, most of the 29 participants were from different hospital units. Nevertheless, the overall agreement analysis between the appraisers and the standard (Cohens Kappa) was 67.48% (see Figure 3.1 boxed in red) and it is believed that this percent

would in fact had been higher if all 29 participants were from the same unit. Figure 3.2 is a visual of each appraiser's percent agreement with the standard.

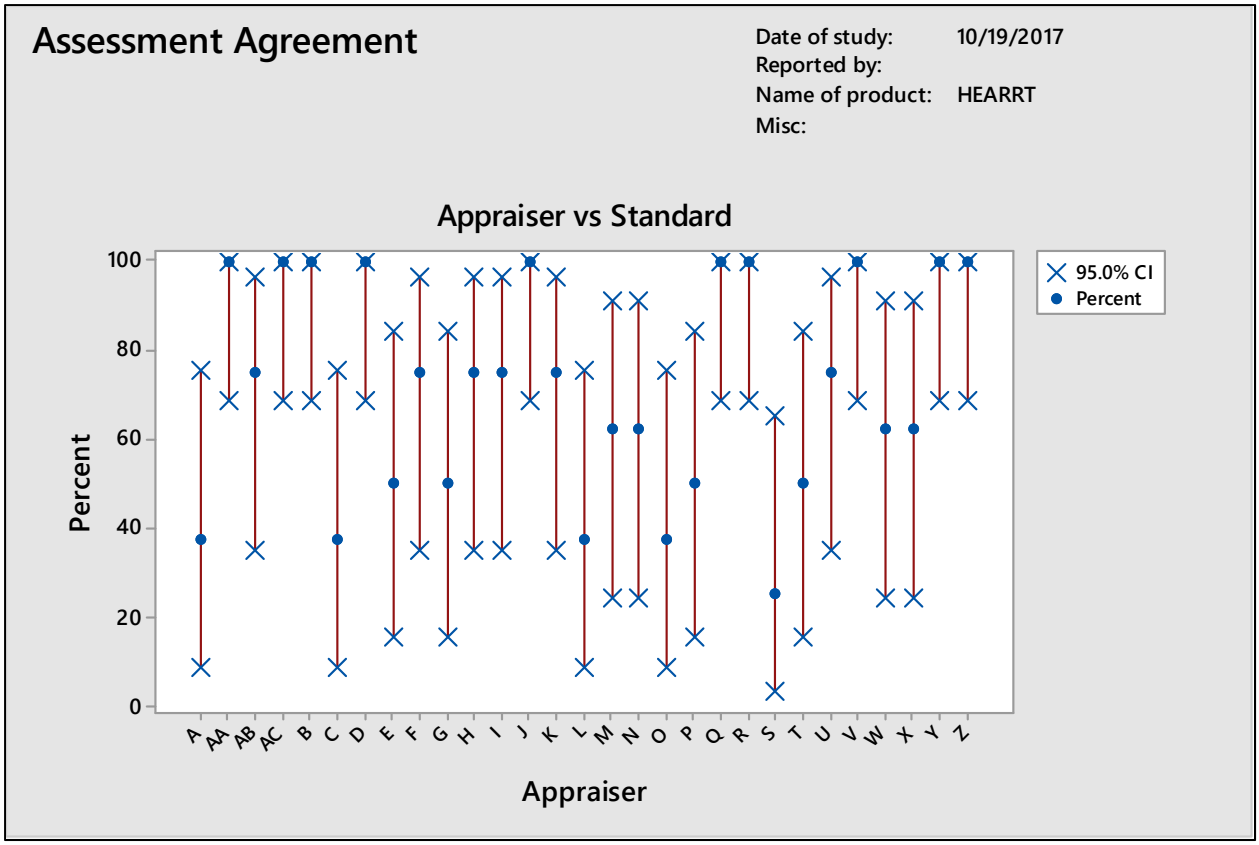

Figure 3.2: Assessment Agreement chart between appraisers and standard

In Figure 3.2, it is noticed that appraisers AA, AC, AD, D, J, Q, R, V, Y and Z from the 29 participants agree 100% with the standard. The relationship between the ranked data (Kendall's correlation) is an impressive 88.31% (see Figure 3.1 boxed in blue). The next section will discuss how H.E.A.R.R.T. is designed to operate along with the detailed theoretical functionality.

3.5 Operational Analysis and Detailed Functionality for H.E.A.R.R.T.

Throughout this document, small portions of H.E.A.R.R.T's functions and operations have been discussed via written description. This section will visually describe how it will operate as an add-on feature to a desired unit.

- Unit (acute care): Simulation Lab from UTEP health science building
- S.O.P's:

  -Number of beds = 90

  -Suggested/budgeted nurse to patient standard = 1:3

  -Number of nurses required when all beds are occupied = 30

  -Patient acuity means of classification = low, medium, high

Figure 3.3 describes how H.E.A.R.R.T. will function as an add-on to this simulated acute care unit from UTEP. The students played the role of nurses and a combination of students and dummies played the role of patients. First, the patient arrives into the chosen unit from either the hospital triage or another unit. Once the patient is in the unit (blue boxed boundary), the CRN will use their current software infrastructure to classify the patients acuity. Then, after this is executed, the H.E.A.R.R.T. will pull this information from their software and will generate updated, quantified individual nurse workloads. As the update is made, the H.E.A.R.R.T. will simultaneously update the teams' unit utilization score as previously mentioned in section 2.5.6. This information will then be available at different levels of the hospital. At the unit level, the CRN's will have the information available to them in order to generate equitable nurse assignment. At the leadership level (unit directors and managers), this information will be available to them in order to promote better communication and better means of monitoring their unit. At the executive level, this information will be available to them in order to promote future business decision making that will ultimately lead to increased profits for the enterprise. Theoretically speaking, this is how H.E.A.R.R.T. is anticipated to operate. Ultimately, if H.E.A.R.R.T. operates as planned, optimized transparency for the enterprise may occur.

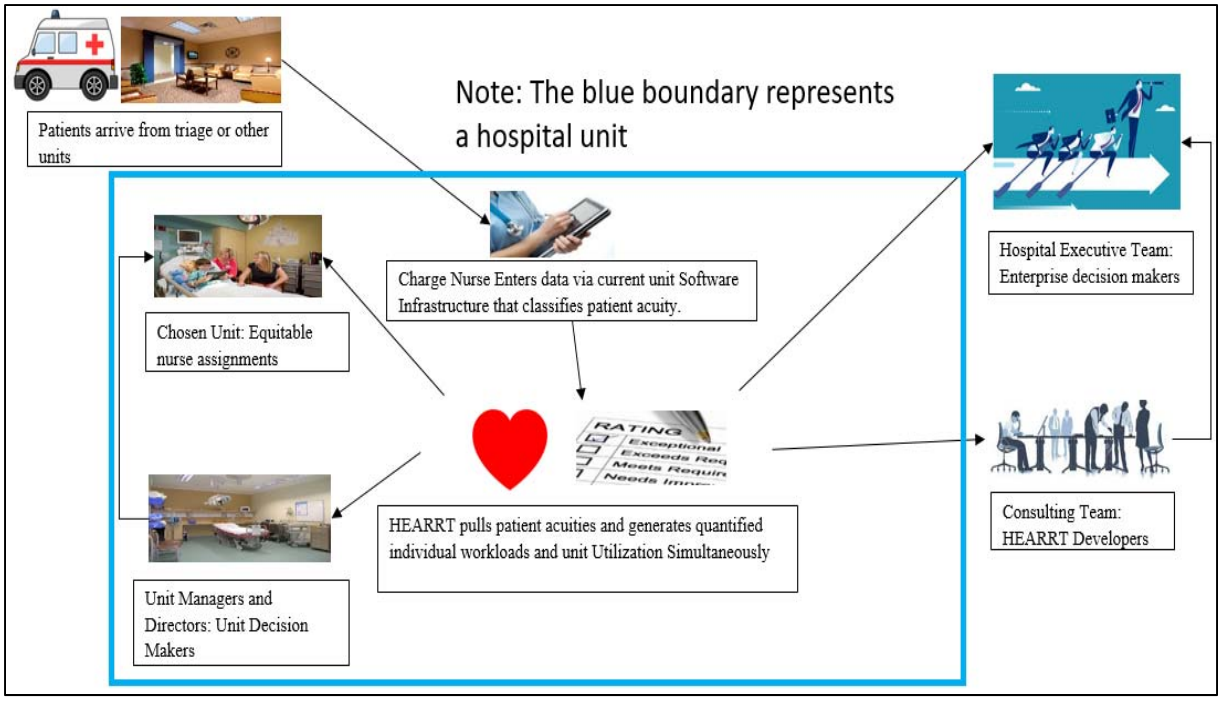

Figure 3.3: Operational analysis for H.E.A.R.R.T.

As a reminder, patient acuity, patient admissions and patient discharges influence the teams' unit utilization score. These scores will be stored into a cloud provided by serves and the appropriate users shall have access to these scores to assist with decision-making. Below (Figure 3.4a) is a reminder from section 2.5.6 of what these scores look like as the units current rating. Please note it is definitely possible for a unit score to be lower even if all beds are occupied. Figure 3.4a has a unit score of 3.50 with 83 of the 90 beds being used. Compare this to Figure 3.4b, which has a unit score of 2.69 and all 90 beds are occupied. This is simply because in Figure 3.4b, the 90 patients have significant lower acuities versus the 83 patients in Figure 3.4a.

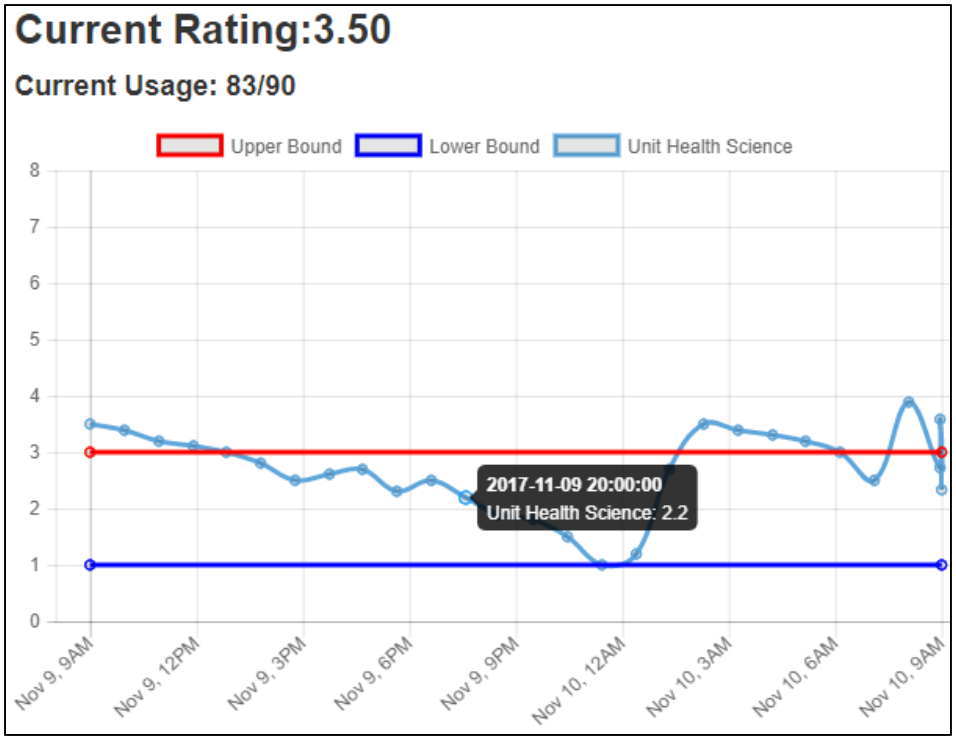

Figure 3.4a: Example of unit utilization scores generated by H.E.A.R.R.T.

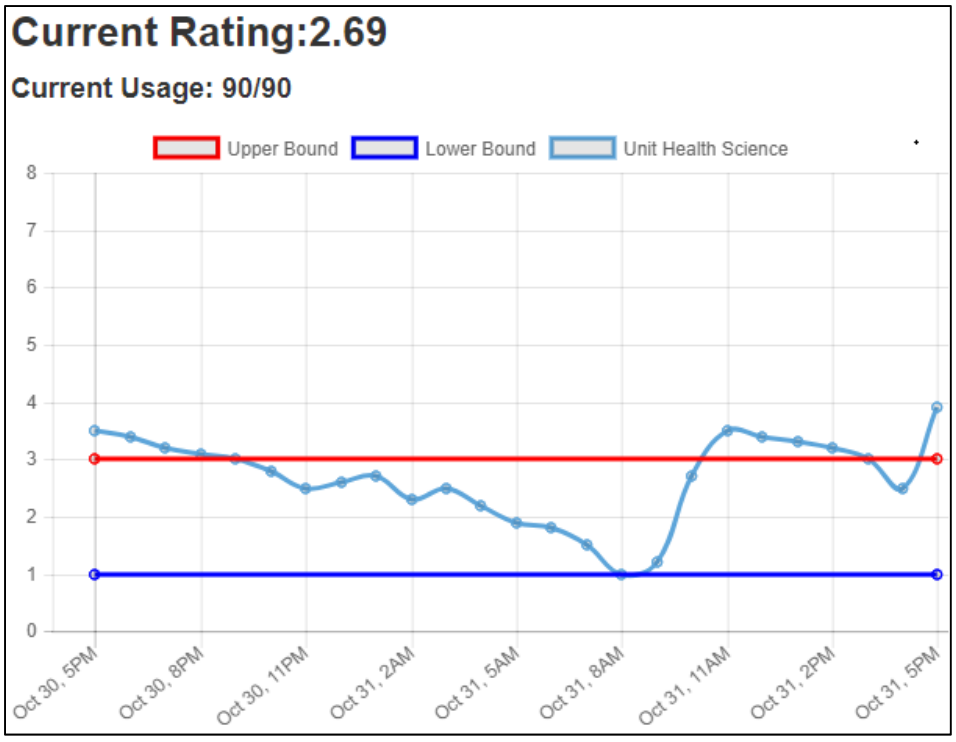

Figure 3.4b: Example of unit utilization scores generated by H.E.A.R.R.T.

In addition, individual nurse workload scores shall be generated, quantified and stored for live and historical analysis.

#	Name	Workload Ranking	# of Patients
1	D Marmolejo	8.00	4
2	M Shores	6.33	4
3	L Villalobos	6.33	4
4	V Molinar	5.67	4
5	M Urzua-Alvarado	5.00	3
6	M Hwang	5.00	3
7	H Marin	5.00	3
8	O Guzman	5.00	3
9	K Vickers	5.00	3
10	E Sifuentes	5.00	3
11	A Ortiz	5.00	3
12	J Rule	4.33	3
13	C Rodriguez	4.00	3
14	T Olson	4.00	3

Figure 3.5: Example depicting nurse workloads

To the far left of Figure 3.5 is the number of students playing the role of nurses with each student's name. The middle column lists the individual nurse workloads and to the far right are the number of patients each nurse is assigned. These are the first 14 nurses of the 30. The next figure (3.6) captures the individual scores of nurses 15-30.

15	P Piniera	4.00	3
16	A Lopez	4.00	3
17	D McGunegle	3.33	3
18	M Torres	3.33	3
19	B Rocha	3.00	3
20	S Saenz	3.00	2
21	D Rubio	3.00	2
22	J Oropeza	3.00	2
23	K Wilson	2.33	2
24	C Onate	2.33	2
25	L Ward	2.00	1
26	E Gutierrez	1.67	3
27	S Saldivar	1.33	2
28	J Ramos	1.33	2
29	J Valle	1.33	2
30	No Name	1.33	2

Figure 3.6: Example depicting individual nurse workloads

The current unit rating for this unit assignment is a 3.50 with 83 of the 90 beds occupied. Any update on any individual nurse workload will influence the unit score. H.E.A.R.R.T. also allows the user to review and analyze any nurses' individual assignment and make changes if desired. Below, (Figure 3.7) is an example of this, specifically nurse number 1 (D Marmolejo) who has a quantified workload of 8 and has 4 patients on her assignment.

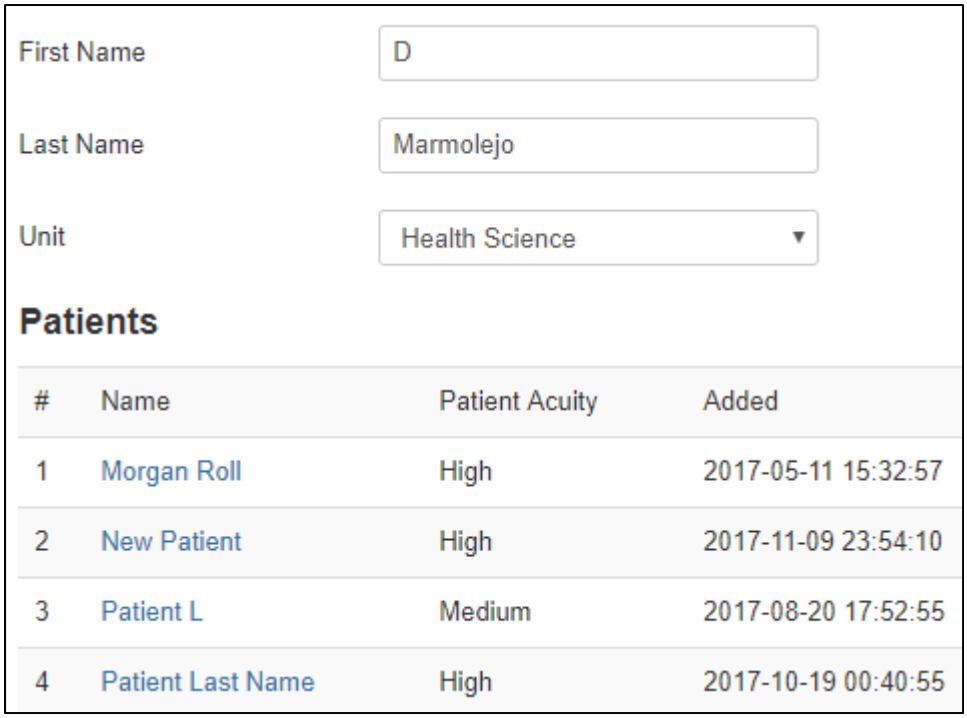

Figure 3.7: Nurse 1 analysis of individual workload

After clicking nurse number 1 the above figure (3.7) is what appears on the user interface. D Marmolejo has 4 patients with respective acuities of high, high, medium and high. If the CRN wishes to reassign any of these patients from nurse 1's assignment, he or she has the capability and opportunity. Below is an example of what happens after clicking "Patient Last Name" from D Marmolejos' assignment.

Figure 3.8a: Example depicting patient details

The user can now reassign this patient to another nurse and if necessary update any documentation for the patients justified condition. Figure 3.8b illustrates what happens after clicking the drop down from “Assigned Nurse”.

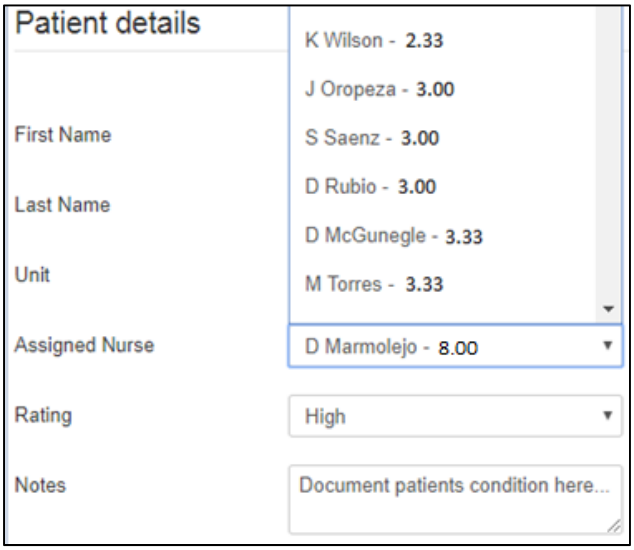

Figure 3.8b: Example depicting patient details

The user can either assign “Patient Last Name” to a nurse who has had this patient before (continuity of care), a nurse who has the lowest workload, a nurse who is considered a novice nurse or a nurse who is considered to have many years of experience. After clicking the drop down box from “Assigned Nurse”, the user has the option to choose any nurse they desire. Once the change is made, live individual workloads will be updated simultaneously with the unit score. In addition, when any patients’ acuity changes within the unit at any given moment, the user may make those changes easily.

#	Name	Patient Acuity	Nurse
1	Mannequin Patient	Low	E Gutierrez
2	Mannequin Patient	High	O Guzman
3	Jordan Flash	Medium	M Torres
4	Pat Macias	Low	M Torres
5	Pat Macias	Medium	K Vickers
6	Patient Name	High	K Vickers
7	Mannequin Patient	Medium	D McGunegle
8	Jordan Flash	High	J Oropeza
9	Patient New	High	L Villalobos
10	Mannequin Patient	Medium	S Saldivar
11	Patient Last	High	H Marin
12	Patient Last name	High	L Ward
13	Jordan Flash	High	V Molinar
14	Morgan Roll	Medium	L Villalobos

Figure 3.9a: Example depicting interface for patient acuity updates

The above figure lists 14 out of the 83 patients that are currently in the simulated unit. The names are listed on the left column, the patient acuities are listed in the middle column and the nurse each patient is assigned to is listed on the far right column. The current unit score is 3.5, theoretically speaking if one of the patients acuity changes from high to low, the score

should lower. The next illustration will show patient 13 (Jordan Flash) acuity change from high to low and patient 14 (Morgan Roll) acuity change from medium to low.

#	Name	Patient Acuity	Nurse
1	Mannequin Patient	Low	E Gutierrez
2	Mannequin Patient	High	O Guzman
3	Jordan Flash	Medium	M Torres
4	Pat Macias	Low	M Torres
5	Pat Macias	Medium	K Vickers
6	Patient Name	High	K Vickers
7	Mannequin Patient	Medium	D McGunegle
8	Jordan Flash	High	J Oropeza
9	Patient New	High	L Villalobos
10	Mannequin Patient	Medium	S Saldivar
11	Patient Last	High	H Marin
12	Patient Last name	High	L Ward
13	Jordan Flash	Low	V Molinar
14	Morgan Roll	Low	L Villalobos

Figure 3.9b: Example depicting interface for patient acuity updates

When these changes are made the new unit score changes from 3.50 to 3.43. This change is a 2% difference and may not seem as a significance, because this is only 2 patients out of the 83 whose acuities were lowered.

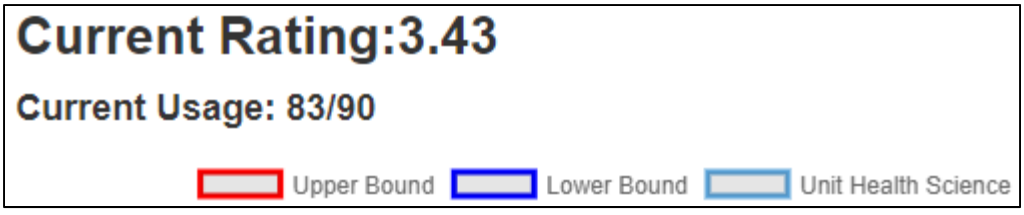

Figure 3.10: New unit score

Before these changes were made nurse 3 (L Villalobos) had an individual workload of a 6.33 and nurse 4 (M Molinar) had an individual workload of a 5.67. After the changes were made both nurses experienced a drop in workload.

#	Name	Workload Ranking	# of Patients
1	D Marmolejo	8.00	4
2	M Shores	6.33	4
3	L Villalobos	5.67	4
4	A Ortiz	5.00	3
5	M Hwang	5.00	3
6	H Marin	5.00	3
7	O Guzman	5.00	3
8	M Urzua-Alvarado	5.00	3
9	K Vickers	5.00	3
10	E Sifuentes	5.00	3
11	J Rule	4.33	3
12	C Rodriguez	4.00	3
13	T Olson	4.00	3
14	P Piniera	4.00	3
15	V Molinar	4.00	4

Figure 3.11: Updated nurse workload rankings

L Villalobos is now number 3 with an updated workload of a 5.67 and V Molinar is now 15 with an updated workload of a 4.00. Below illustrates their updated assignments.

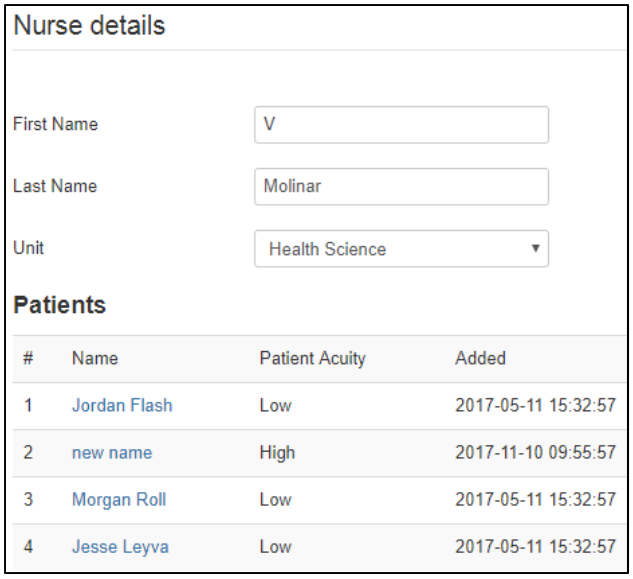

Figure 3.12a: Nurse assignment update

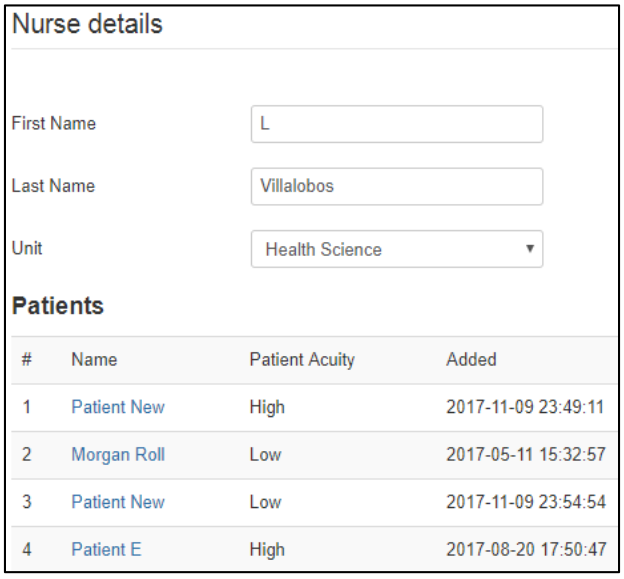

Figure 3.12b: Nurse assignment update

Next, a more significant impact will be simulated. The current unit score is 3.43 with 83 of the 90 beds occupied. The simulation will demonstrate what will occur when 5 patients from the first 15 patients at random are discharged, meaning these 5 random patients no longer require care and are no longer on any nurse assignments.

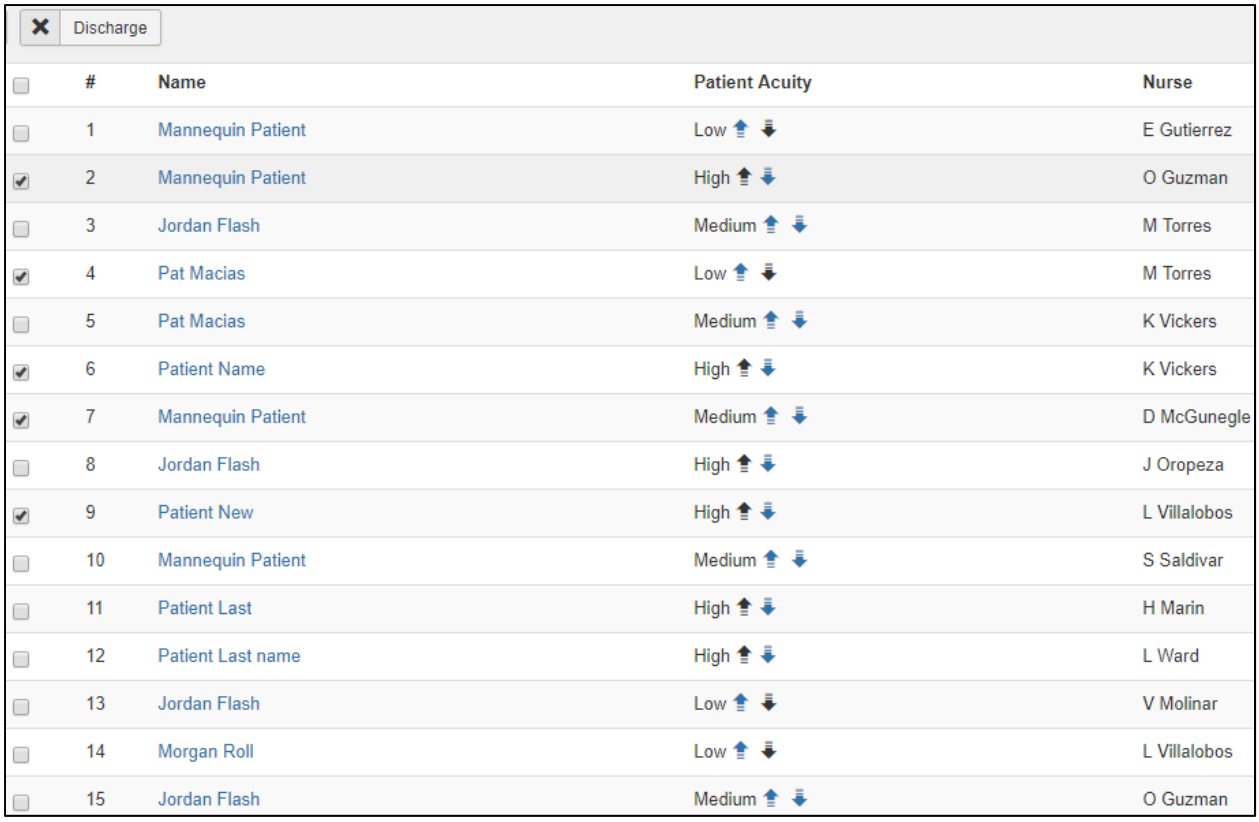

Figure 3.13: Selecting 5 patients to discharge

Figure 3.14: Example depicting updated unit score

The new unit score has now dropped to 2.99 with 78 of the 90 beds occupied. This is about a 13% drop in score. Below is an example of the updated individual nurse workloads.

#	Name	Workload Ranking	# of Patients
1	D Marmolejo	8.00	4
2	M Shores	6.33	4
3	E Sifuentes	5.00	3
4	A Ortiz	5.00	3
5	M Urzua-Alvarado	5.00	3
6	H Marin	5.00	3
7	M Hwang	5.00	3
8	J Rule	4.33	3
9	V Molinar	4.00	4
10	T Olson	4.00	3
11	A Lopez	4.00	3
12	P Piniera	4.00	3
13	C Rodriguez	4.00	3
14	K Vickers	3.00	2
15	J Oropeza	3.00	2
16	M Torres	3.00	2
17	O Guzman	3.00	2
18	D Rubio	3.00	2
19	S Saenz	3.00	2
20	B Rocha	3.00	3
21	L Villalobos	2.67	3
22	K Wilson	2.33	2
23	C Onate	2.33	2
24	D McGunegle	2.33	2
25	L Ward	2.00	1
26	E Gutierrez	1.67	3
27	S Saldivar	1.33	2
28	J Ramos	1.33	2
29	J Valle	1.33	2
30	No Name	1.33	2

Figure 3.15: Updated individual nurse workloads after 5 patient discharges

The next simulation will demonstrate how the user will add or admit a new patient.

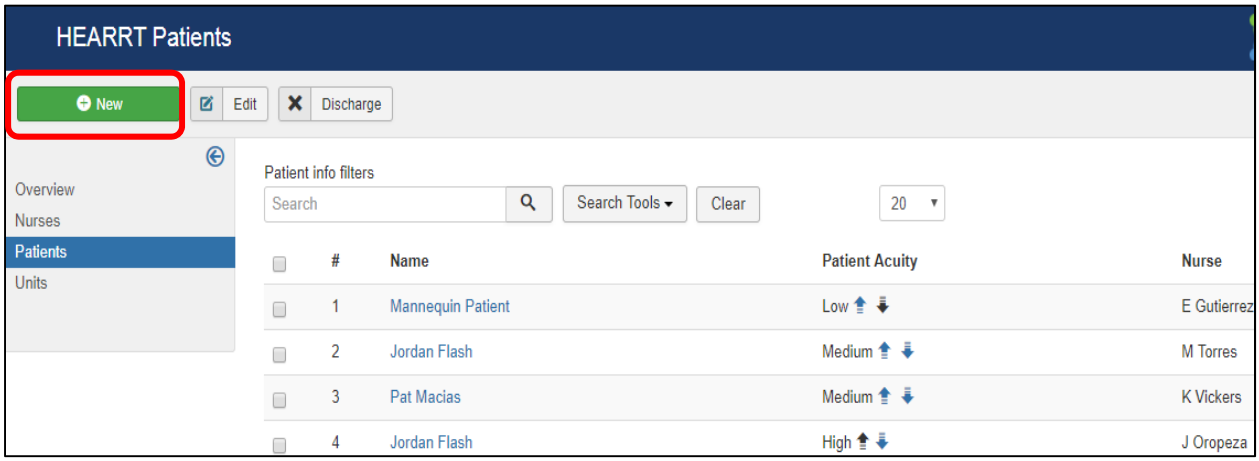

Figure 3.16: Adding or admitting new patient to unit

After clicking New (green button circled in red) the following window will open.

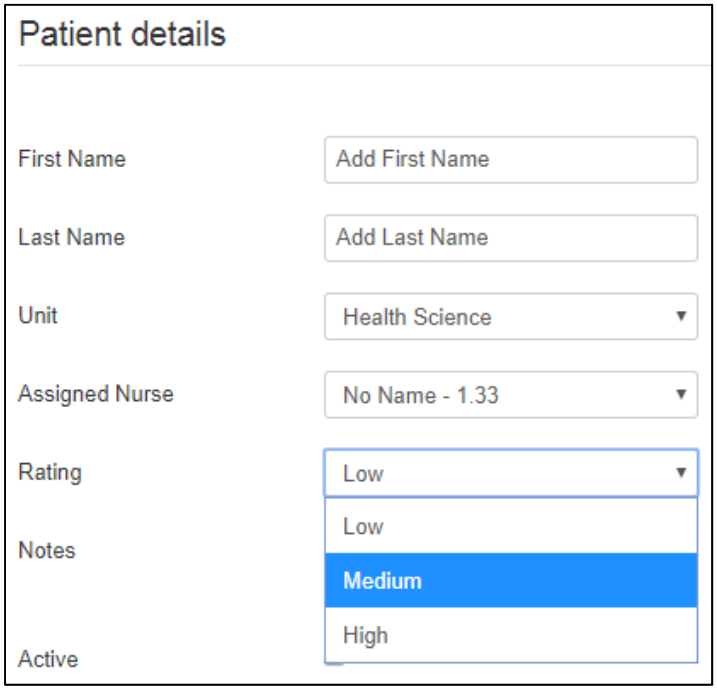

Figure 3.17: New patient details choosing acuity level

After classifying either low, medium or high the user shall document and justify the reasons as to why they chose this acuity level. In this case, the user chose Medium.

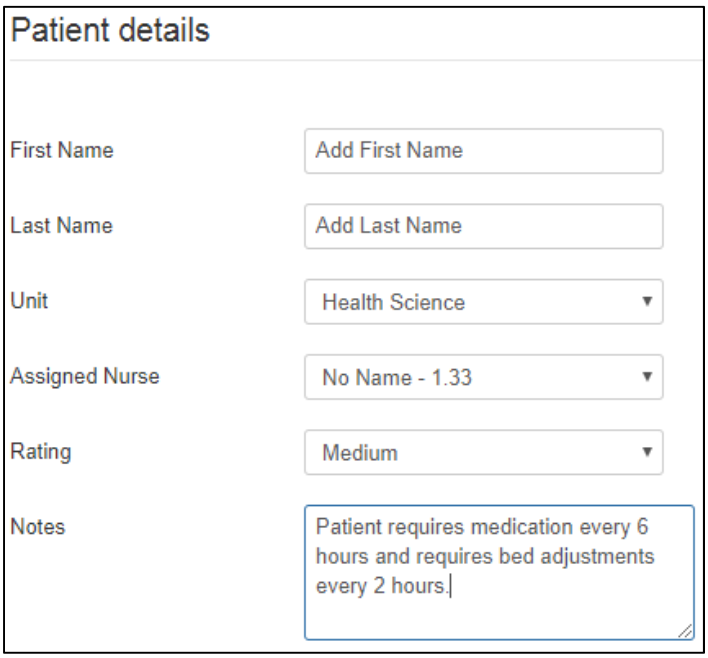

Figure 3.18: New patient details documenting patient

After documenting the patient, the user shall now assign this patient to a nurse by selecting the drop down “Assigned Nurse”. H.E.A.R.R.T. is designed to automatically suggest to the user to assign the new patient to nurse with the lowest workload, but of course, the user has option to choose whom they believe is the best choice.

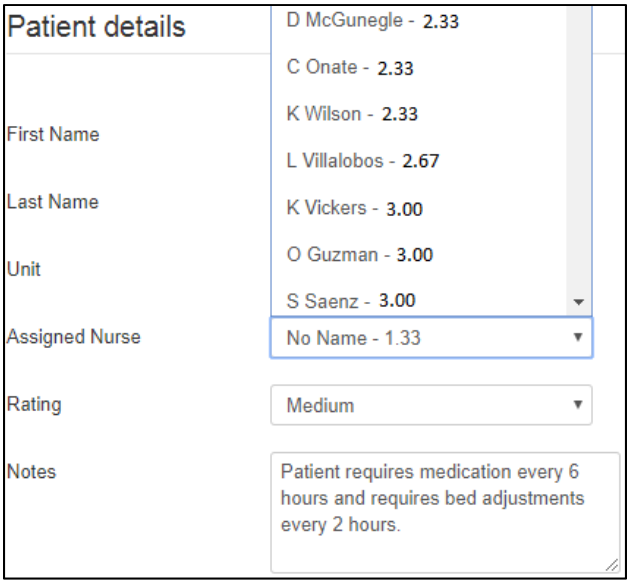

Figure 3.19: New patient details choosing a nurse to assign patient

In this simulation, the user chooses nurse “No Name”. When all updates are made that individual nurse workload shall increase simultaneously with the unit score. After adding this new patient to the unit, the updated individual workload is 2.33 with 3 patients. The previous individual workload for nurse “No Name” was 1.33 with 2 patients. The updated unit score is 3.05 with 79 of the 90 beds occupied please note, the previous score was 2.99 with 78 of the 90 beds occupied. This new score is a 2% overall increase.

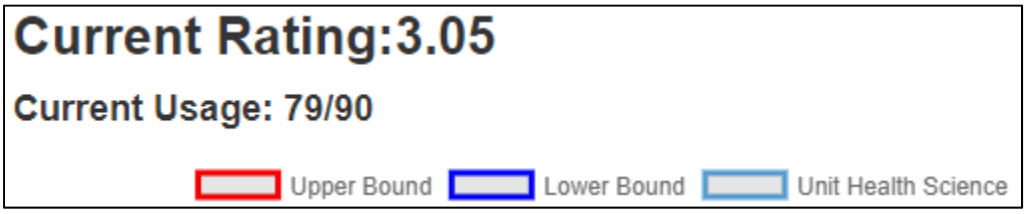

Figure 3.20: Updated unit score

H.E.A.R.R.T. is designed to present the opportunity to optimize every unit assignment from shift to shift while analyzing individual workload history and performance rates. This

function will be possible by using H.E.A.R.R.T.'s uniquely designed search engine. The analysis of such data presents the opportunity to effectively monitor over utilization of individual nurses and to effectively forecast unit scores for future preparation. This effective forecasting may assist the leadership roles to better prepare their unit with the optimized number of resources and material necessary for their nurses to treat patients with higher quality of care. In order to effectively ensure that H.E.A.R.R.T. does in fact bring value to the table after implementation, surveys must be conducted before and after the event. Because of limits and constraints, actual implementation did not occur for this research, but if it did, the survey would look something like the following:

1=Strongly agree, 2=Agree, 3=Nor agree or disagree, 4=Disagree, 5=Strongly disagree

- I am satisfied with my job. ____
- I enjoy working with the software tools in my unit. ____
- I feel I' am over worked more often than not. ____
- I am satisfied with the distribution of the assignments within my unit. ____
- I am satisfied with the way I am empowered at work. ____
- There is strong leadership support in my unit. ____
- My unit mangers, directors and or coordinators are aware of my daily workloads. ____
- Communication between the RN's and leadership support is effective. ____
- The software tools in my unit can be improved. ____
- I have a firm understanding of how the software tools function and operate. ____

Of course, these set of questions are preliminary and would need additional analysis from professionals. Nevertheless, it is paramount to conduct surveys in order to measure the impact of the implementation. This survey shall be answered by every nurse of the chosen unit before and

after the implementation of H.E.A.R.R.T. The surveys will determine the effectiveness and level of value that H.E.A.R.R.T. brings to the table.

Chapter 4: Simulation Results

Because real data gathering and implementation did not occur during this research, simulations were ran in order to answer the hypothesis question. The personnel chosen for the simulations consisted of RN's, CRN's and many professors from the UTEP nursing program. The next two sections will discuss how the simulations were arranged for the appropriate audience along with the hypothesis overview.

4.1 Simulation Set up and Arrangement

As mentioned before, the first H.E.A.R.RT. ever designed was for a simulated acute care unit. These simulations occurred in the health science building at the University of Texas El Paso by nursing students. After designing the conceptual prototype, many meetings were set up in order to receive their professional opinions and feedback. These meetings would occur in venues such as cafes, on campus or at actual hospital meeting rooms.

First, the audience was given an elevator speech regarding the purpose of the research. Then, different simulations similar to the ones in section 3.5 were demonstrated. Before carrying out a specific simulation, the audience was asked what they believed would occur when executing the action. For example, what do you believe will happen to the individual nurse workload when adding a patient to their assignment? What do you believe will happen to the unit score when adding a patient to a nurse assignment? What do you believe will happen to the unit score when many patients are discharged? What has a significant increase on the unit score, low acuity patients or high? Who do you believe the next patient should be assigned to? Then after executing the simulation their answers would be confirmed. All personnel's understood the concept of H.E.A.R.R.T., and in order to remain unbiased the question of; what are your thoughts and opinions of H.E.A.R.R.T., was asked versus specific questions.

4.2 Hypothesis Review

As a reminder, the hypothesis is the following: if a verified, validated, and tested algorithm is created and designed to output quantified workloads per nurse along with unit utilization scores

simultaneously, unit directors and managers will have structured and actionable data that reflects the following. 1) When unequitable nurse assignments are generated 2) When a nurse is being over utilized 3) When a nurse is underutilized 4) When a unit is over utilized 4) When a unit is underutilized 5) When a unit requires many resources 6) Live productivity of individual nurses 7) and Live productivity of a unit. If these seven elements are accurately structured into actionable data it is theorized that the needs, objectives and benefits described in chapter 1 can potentially be fulfilled.

With confidence, it is believed that the thoughts and opinions of the chosen subjects have accurately answered the thesis hypothesis. This project can potentially be the beginning of additional research that is required in order to implement H.E.A.R.R.T. in an actual hospital setting. The next chapter will discuss the conclusion of this project.

Chapter 5: Conclusion

The purpose of a thesis is to enable graduate students to gain a deeper understanding and knowledge towards the capacities of the practices learnt in their area of study. After extensive research, it is believed that this project shines a light of the many applications found in I.M.S.E. on the healthcare industry. The next sections will discuss the area of improvement, future work and ultimately, what this project contributes to the I.M.S.E. community.

5.1 Area of improvement

During this research, with time, a deeper understanding of what it takes to be a nurse in an acute care unit was gained. It was discovered that nurses make many decisions on a daily basis and the bottom line in a nurses eyes is the life of the patient. One of the goals of this project was to focus on the contributors that cause nurses to create operational failures. Then, minimize these costs associated with these failures. An area of improvement for this project should consist of getting a better understanding of how the nurse assistances and technicians affect the RNs individual workload. In addition, the means of gathering background information gathered from nurses can be improved. For example, only emails were used to send out the questionnaires when online tools could have made it easier. Doing this may lead to developing and designing H.E.A.R.R.T's for units faster.

5.2 Future Work

After successfully implementing H.E.A.R.R.T. into a real hospital setting, future work will venture out to discover how the methodology described in this research can be applied in other industries. Currently, future work is under way as far as potential implementation of H.E.A.R.R.T. At the moment, the patent for the equation is pending and the process of validating an equation for an actual unit is also pending. After validating and verifying the equation, H.E.A.R.R.T. will be developed for this unit. What benefits this new and upcoming project, is that the unit currently uses Clairvia by Cerner, which was discussed in detail in section 2.5 of this document. The unit is from Banner Health in Scottsdale Arizona, specifically telemetry. Within the next few months, it

is anticipated to gain a deeper knowledge of the reality of putting actual I.M.S.E. practices to the test, potentially leading to the study of business. This leads to the next and final point.

5.3 What This Project Contributes to the I.M.S.E. Community

Industrial, Manufacturing and Systems Engineering is arguably the foundation of all industries from all around the globe. Where there exists problems regarding process improvement, quality control, operations research, project management, requirements and methodologies I.M.S.E. has an answer for it. Whether if it cost savings or life savings this project has contributed to the proof of how effectively I.M.S.E. applications assist with the development of useful tools. Because of I.M.S.E., H.E.A.R.R.T. has the potential to continuously adapt, integrate, innovate, define ingenuity and improve a hospitals quality of care, ultimately leading to positive patient outcomes.

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Vita

Luis Reyes was born in El Paso, Texas. He moved to Castroville, Texas in 1998 where he graduated high school at Medina Valley. He completed college dual credits from Palo Alto community college and transferred to the University of Texas at El Paso in 2006. Initially, he studied to be a civil engineer then had a change in major where he switched to the I.M.S.E. (Industrial, Manufacturing and Systems Engineering) department in 2011. After pursuing industrial engineering, he acquired his Bachelor of Science degree in spring of 2014 with a minor in mathematics. He and his team were awarded best senior design that same year.

In the fall semester of 2015, he enrolled into graduate school at UTEP and the next year began work at SAIC (Science Applications International Corporation) as a systems engineer intern. He is a member of SHS (Society for Health Systems) where he attends the HSPIC (Healthcare Process Improvement Conference) to become more familiar with the industry. He plans to someday, implement H.E.A.R.R.T. into a real hospital setting.