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Waleed Abo Hamad

Technological University Dublin, waleed.abohamad@tudublin.ie

John Crowe

Technological University Dublin, john.crowe@tudublin.ie

Amr Arisha

Technological University Dublin

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TOWARDS LEANER HEALTHCARE FACILITY: APPLICATION OF SIMULATION MODELLING AND VALUE STREAM MAPPING

Waleed Abo Hamad, John Crowe, Amr Arisha

3S Group, College of Business,
Dublin Institute of Technology (DIT),
Aungier Street, Dublin2, Ireland

ABSTRACT
Recently, the application of lean thinking in healthcare has grown significantly in response to rising demand caused by population growth, ageing and high expectations of service quality. However, insufficient justifications and lack of quantifiable evidence are the main obstacles to convince healthcare executives to adopt lean. Therefore, this paper presents a methodology that integrates lean tools with simulation to enhance the quality of patient care in healthcare facilities. This enables healthcare organisations to dedicate more time and effort to patient care without extra cost to the organisation or to the patient. Value stream mapping is used to identify value-added and non-value-added activities.. Then, a comprehensive simulation model is developed to account for the variability and complexity of healthcare processes and to assess the gains of proposed improvement strategies. An extensive analysis of results is provided and presented to managers to illustrate the potential benefits of adapting lean practices.

Keywords: lean thinking, modelling and simulation, value stream mapping, healthcare management

1. INTRODUCTION

Science and technology are advancing at a rapid pace; however, the healthcare delivery systems world-wide struggle to cope, especially in their ability to provide high-quality service levels consistently. Healthcare systems are in need of fundamental changes in the way care services are managed. Many patients, doctors, nurses, and healthcare providers are concerned that the care delivered is not, essentially, the care that should be received. The frustration levels of both patients and clinicians have probably never been higher. Policy makers, healthcare providers and managers should provide the quality of care that meets people's needs while improving the efficiency of their business processes based on the best scientific knowledge available. Yet there is strong evidence that this frequently is not the case. Large numbers of disciplined review bodies have reported the scale and gravity in healthcare problems world-wide. More systematic and sophisticated approaches are needed to analyse and manage healthcare processes and to support decision makers and healthcare managers in the provision of informed decisions and strategies for delivering safe and effective care.

Accordingly, many healthcare organisations have recently adopted Lean management as the performance improvement approach for their systems (Poksinska, 2010). The Lean approach seeks improvements within the existing processes of an organisation without substantial reorganisation requiring high investments (Bahensky et al., 2005).(Mahfouz et al., 2011) The main step in Lean healthcare thinking is to put the patient in the foreground and include time and comfort as key performance measures of the system (Womack and Jones, 2003). Lean strategies eliminate process steps that do not add value for patient care, while enhancing those that are valuable and essential. As a result, staff members feel empowered to improve care processes (Spear, 2005). However, insufficient justifications and lack of quantifiable evidence are the main obstacles to convince healthcare executives to adopt lean management. Therefore, this paper presents a framework that integrates lean techniques with simulation to enhance the quality of patient care in healthcare facilities.

2. PROPOSED FRAMEWORK

The proposed framework is a simulation-based lean decision support model for healthcare application.There are three distinct phases to the framework; (1) identification, (2) development and (3) assessment, as illustrated in Figure 1. The framework phases will be discussed in detail in Section 3. The remainder of this section will introduce the core domains that are the foundations of the framework. They are; value stream mapping (VSM), Simulation-based VSM and Healthcare Application.

2.1. Value Stream Mapping

The logic behind lean thinking is pursuing the optimization of value streams from the consumption point of view by eliminating waste and non-value added activities. In order to identify the sources of waste, non-value added activities and opportunities of improvement, value added activities have to be mapped using systematic tools and techniques – VSM technique (Rother and Shook, 1998). A value stream can be defined as the collection of activities (value added and non-value added) that are operated to produce a product or service or a combination of both to a customer

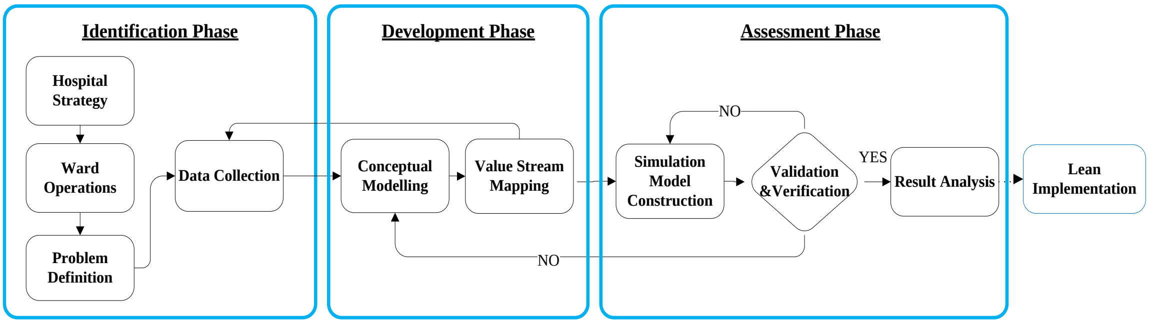

Figure 1. Framework Overview

(Singh et al., 2006). These actions consider both information and materials flow within the overall system (Abdulmalek and Rajgopal, 2007). The VSM technique demonstrates the material and information flow, maps out value-added and non-value-added activities and provides information about time-based performance. This VSM technique is based on generating a current state map that shows the current performance and conditions of the studied systems and a future state map which serves as the target of improvement actions. VSM has been effectively integrated into several applications, manufacturing and non-manufacturing, due to its simplicity and effectiveness (Tapping and Shuker, 2003). Although the lean concept originated in the automobile industry, the increased application of lean practices in healthcare, has seen growth in the popularity of modelling tool such as VSM (Kim et al., 2006). VSM, as a lean implementation tool, has been successfully utilized in many different healthcare systems, from small physician clinics (Lummus et al., 2006) to more complex systems such as emergency departments (Cookson et al., 2011).

VSM is very effective in presenting system parameters such as operations' cycle time and resources capacity and availability; however it does not have the ability to analyse the system settings impact on performance. Similarly, it is also difficult to know if the best future state regarding to the desired level of system performance is achieved. Moreover, value stream maps do not include information regarding variability (i.e. system variations and uncertainty) (Standridge and Marvel, 2006). Hence, it is required to integrate VSM with another technique that can handle system variation, show dynamics between system components and validate the future state before the real implementation of the improvement steps. Modelling and simulation capabilities can fulfil this requirement.

2.2. Simulation-based VSM

Simulation can be used to master new business concepts such as agile and lean management (van der Zee and Slomp, 2005). The benefits of using simulation as part of lean and six sigma projects was emphasized by (Ferrin et al., 2005). Unlike VSM, simulation offers more thorough analysis of a system's data including the examination of variability, the determination as to whether the data is homogenous, and the estimation of the probability distribution that fits the data patterns. This kind of in-depth analysis of data enables simulation to be used to support continuous improvement (Adams et al., 1999) and to model systems' future state map showing the ideal state that the system can pursued over time. The advantage of utilizing simulation approach in a lean context is not limited to the phase of developing a future state map but is extended to selecting the best alternative to the current system status. To address its limitations, Shararah et al. (2011) effectively integrated VSM with the more analytically powerful discrete event simulation software and noted that combing both techniques created useful synergies.

The simulation model in this paper is developed over two main phases; (1) creating a conceptual model for the ward drug round and (2) developing a discrete event simulation model that mimics the real-life activities of the drug round. These phases will be discussed in more detail in Section 3.

2.3. Hospital Ward - A Case Study

From an overview perspective, the hospital ward is the location to which patients from the Emergency Department (ED), inter and intra hospital transfer are transported to. Many wards, classified as inpatient wards, also have outpatient facilities. This is due to the location of the specialty medical service provided by the hospital. The arrival rates, patient types and dependency levels of patients are varied and stochastic. This complexity impacts upon operational functionality and exacerbates and exposes inherent flaws within the work systems. Consequences of operational issues at ward level can have detrimental affects upon the patient, staff, ward and the hospital as a going concern. In short, operational failures, aside from clinical and medical issues, can impact seriously upon a hospitals ability to function. It is estimated that on average operating costs of a hospital account for up to 70% of the overall cost of a hospital (Chaudhury, 2005).

The hospital ward is seldom used as a unit of measure or analysis from the perspective of operations research (Ancarani et al., 2009). More common is the use of the hospital as the unit of measurement with respect to efficiency. This can be explained by the heterogeneous nature of the production processes among hospital wards, the complexity of the information required and the related difficulty in obtaining it (Ancarani et al., 2009). There are a number of benefits to improvement of operational processes within the hospital ward with the goal of providing more time to care for patients. A reduced length of stay (LOS) for the patient may consequently lead to a reduction in excess bed cost per patient, a reduction in staff sicknesses and absences and stock reduction (Improvement, 2011). As outlined in the NHS's Productive Ward series, the aim of the process improvement programs is to release more time for medical staff to have with patients. More direct care is of importance in a number of ways. Patient focused care or more direct care for patients can bring about a reduction in staff costs without compromising care quality or patient satisfaction (Chaudhury, 2005). So there is now an emphasis to improve operational processes at ward level to attempt to free up more time for direct care for patients.

The majority of wards that are currently operational in Ireland are multi occupancy wards. Aside from the medical/nursing advantage of such a design, operational issues exist with this design. Patient transfers within and without of the multi occupancy wards, which can average six to nine times daily, can represent a significant higher cost in added paper work, housekeeping, patient transport and medication transport (Bobrow and Thomas, 1994), (Gallant and Lanning, 2001).

The university hospital partner in this research is one of the leading university hospitals in the Republic of Ireland. This 570-bed hospital provides primary, specialised, and tertiary healthcare services. It was agreed with the hospital executive managers to carry out a pilot over a 10 week period on a 30 bedded acute surgical ward to implement the proposed framework. The purpose of this pilot is to highlight non-value added activities with the end result of reducing operational costs, increase staff utilization and most importantly improve patient care within the ward. The detailed implementation of the framework is explained in the next section.

3. FRAMEWORK IMPLEMENTATION

There are three main phases (Figure 1); Identification Phase; Development Phase; and Assessment Phase.

3.1. Identification Phase

The identification phase focuses on system understanding and process analysis. Qualitative research was used in the analysis stage through the collection of primary data of the studied ward. Several field visits, interviews and process analysis sessions are conducted with ward managers in order to frame an understanding about the main parameters and generate an understanding of the ward processes where 25 processes have been identified. A detailed flowchart for each process has been developed and validated with the nursing staff to reflect all the activities within each process. For example, a detailed flowchart of all the activities within the drug round process is given in Figure 2.

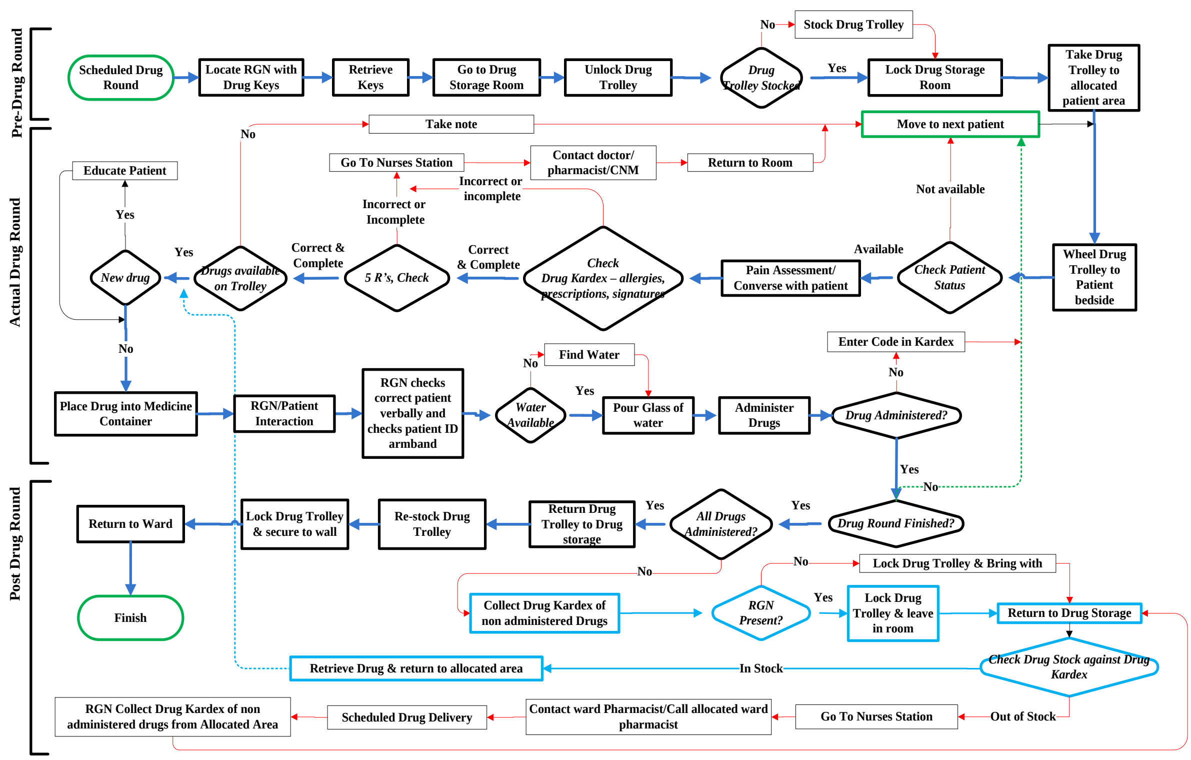

Figure 2. A detailed flowchart of all the activities of the drug round process

3.2. Development Phase

In the development phase, using data and charts developed in the first phase, a VSM was built from the descriptive data for each process in the ward. As discussed earlier, a VSM is based on generating a current state map that shows the current performance and conditions of the processes of the studied ward and a future state map which serves as the performance improvement target. Identifying the value adding activities was the initial step towards creating the current state map. The ward staff current awareness of lean concepts and practices was also a key topic in the discussions and interviews. Meetings were also held with a number of staff nurses with the aim of determining the essential value added and non-value added activities.

Figure 3 shows the current state VSM of the drug round process. A senior nurse manager in the studied ward was interviewed to gather general information about drug round activities and to verify the current state of the system identified in the flowchart (Figure 2). 14 primary processes are mapped along with the cycle time accumulation through each process during a 12 patient drugs round. The cycle timeline is separated into two categories; value added time (green) and non-value added time (red). The VSM is based on value and non-value added time with respect to staff. Time spent in value-added activities direct to the patient are underlined and only represent 23% overall cycle time at 2700 seconds. The activity times circled in red are the parameters chosen for the assessment phase of the framework.

3.3. Assessment Phase

A quantitative model-driven methodology is applied to generate models representing the causal relationships between the lean practices and systems' performance. Based on the detailed flowchart, the current state map and the empirical data analysis, a comprehensive simulation model was developed. Accordingly, the top-level of the simulation model defined the overall process structure, and sub-level blocks comprised additional modules with more details. The main entities for the simulation were patients and nursing staff, where each patient is assigned a set of attributes that represent their location and dependency level. A database was used to save the measured time for all the activities within each process after each simulation run (i.e., replicate), followed by exporting these measures in a tabular form for analysis and validation.

To reduce the model development cycle time and to increase the confidence in the simulation model results, verification and validation were carried out all the way through the development phase to confirm the model represents the actual patient flow. After each model development phase, the model was verified and validated with respect to other previously completed phases. For the verification process, the model logic is verified to ensure that the work flow is mapped correctly. This was achieved by visual tracking of patients and staff using animation and by checking intermediate output values. A warm-up period of one week was found to mitigate any bias introduced by the initial conditions of the simulation model.

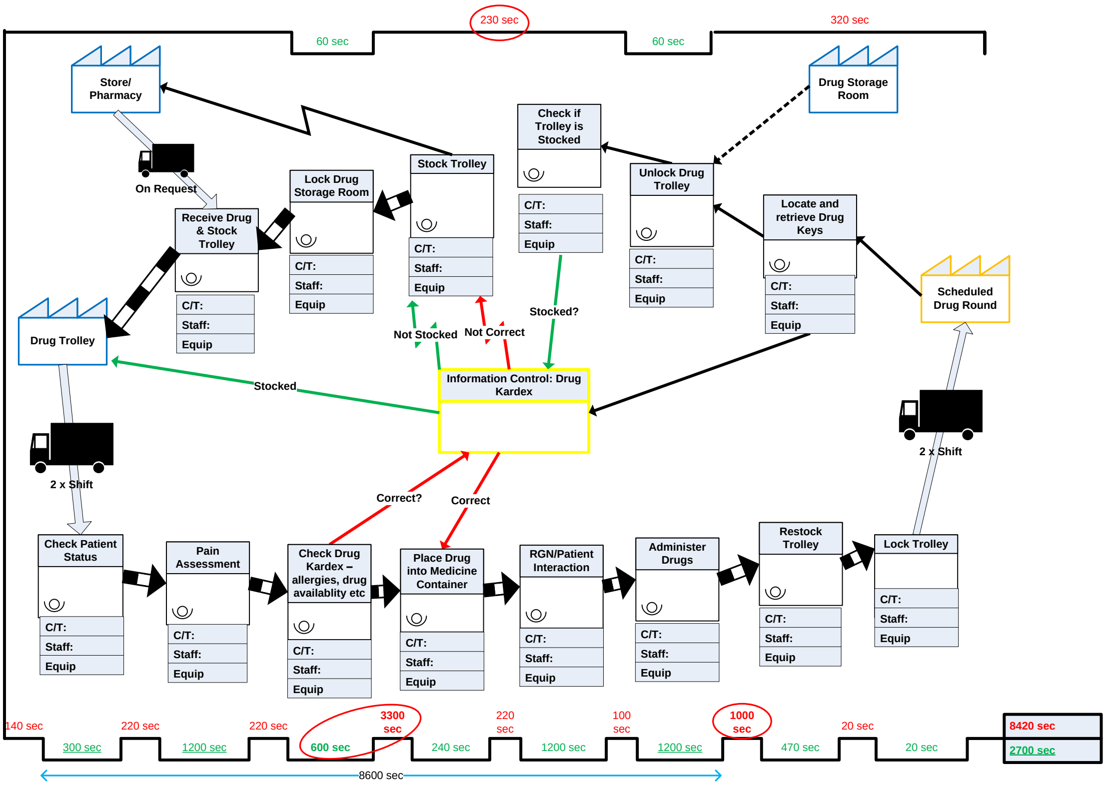

Figure 3. Current State VSM for Drugs Round Process

4. RESULT AND DISCUSSION

In order to show the benefits of the proposed methodology, the discussion in this section is only limited to one process, the drug round process, which was selected by the ward managers to be fully investigated. Regarding the drug round process, the initial findings from the VSM led to 19 standard operations and up to 15 alternative operations when variation occurred (e.g. drug not available, patient allergies etc.). The drug round process was then broken down to three main stages: pre-drug round, actual drug round, and post drug round (Figure 2). The observed timing information highlighted that the overall process takes on average 2.8hrs in order to complete a drug round by a nursing staff for two rooms, each with 6 patients.

As shown in Table 1, 78% of the time is spent in non-value added activities for patients. This highlights the need for improvement in order to increase the time to care for patients by reducing the workload of nursing staff.

Table 1 Analysis of the current state map of the Ward

	Current State (mins)
Pre-Drug Round	10.60
Drug Round per Patient	13.75
Post-Drug Round	09.18
Overall (12 Patient)	173.2
value added	7.5 (22%)
non-value Added	26.03(78%)

Consequently, the ward managers suggested three lean practices (i.e. scenarios) to be tested using the ward simulation model. The first scenario is assuming that the drug trolley is always stocked in the pre-drug round stage. The second scenario is that all the drugs had been successfully administered in the actual drug round (i.e. no rework needed in the post-drug round). Finally, scenario three is to consider no variances in the actual drug round (i.e. all prescriptions are correct and all the required drugs are in the drug trolley). The simulation results for all the scenarios against the baseline (i.e. current state) are shown in Table 2.

Table 2 Simulation results of all the scenarios against the baseline

	Base Line	Scenario 1	Scenario 2	Scenario 3
Pre-Drug Round	010.60	8.5 (-20%)	010.60	010.60
Drug Round per Patient	013.75	013.75	013.75	10.45 (-24%)
Post-Drug Round	009.18	009.18	002.8 (-69%)	02.27 (-75%)
Overall (12 Patients)	173.20	170.4 (-02%)	165.6 (-04%)	136.6 (-21%)

The simulation results shows that scenario three has resulted in a significant reduction in overall cycle time (i.e. time needed to complete the process) by 21% while scenario's 1 and 2 have a limited impact with a decrease in the cycle time by 2% and 4% respectively. Additionally, the value added activities have been increased from 22% to 32% by adapting more lean practices (Figure 2).

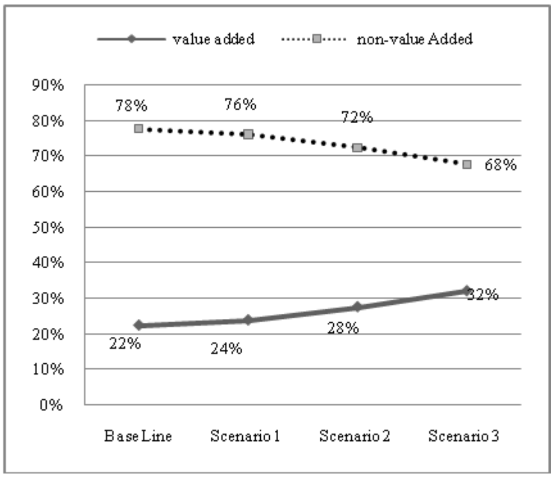

Figure 3 The impact of all the scenarios on the value-added and non-value-added activities

Accordingly, the integrated methodology has shown the ward managers and nursing director the potential benefits of applying lean thinking. This has resulted in initiating a lean training across all departments in the hospital where the framework will be used to assess the impact of proposed practices prior to their implementation.

CONCLUSION

Lean thinking is regarded as a systematic approach used to identify and eliminate waste or non-value added activities in a process through continuous improvement. Lean thinking is a philosophy that can be applied to a variety of organisations since its focus is on improving process performance. Most service organisations are made up of a series of processes, or a set of activities or steps intended to create value for those who are dependent on them – customers. Lean is now being successfully applied to healthcare applications as it reduced the slack on service time. This enables healthcare facilities to reduce operation costs and improve service quality. In order to identify the sources of waste, non-value added activities and opportunities of improvement, value added activities have to be mapped using systematic tools and techniques such as value stream mapping (VSM) technique. VSM is very effective in presenting system parameters such as operations' cycle time and resources capacity and availability; however it does not have the ability to analyse the system settings impact on performance. Unlike VSM, simulation modelling can handle system variation, show dynamics between system components and validate the proposed improvement steps before the real implementation. Therefore, an integrated simulation-based VSM methodology was developed and applied to an acute surgical ward in a teaching hospital in Dublin. The developed framework allowed senior decision makers in the hospital to plan and visualise how new ward layouts will operate (i.e. single-bedded rooms). Moreover, they were able to foresee the consequences of different scenarios and strategies on ward performance before implementation takes place.

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AUTHORS BIOGRAPHY

WALEED ABO-HAMAD, Ph.D. is a Senior researcher in 3S Group (A research unit in Dublin Institute of Technology (DIT) specialized in complex systems simulation and optimization). He joined the 3S group in 2008 having spent four years as a researcher in Cairo University-Egypt where he received his B.Sc. and M.Sc. degrees in Computer Science. He received his Ph.D in process optimization from DIT and is currently a project manager at DIT. His research interests include

Modelling and Simulation, Optimization, Computational Intelligence, Machine Learning and Cooperative Intelligent Systems. His email address is Waleed.Abohamad@dit.ie.

JOHN CROWE is a researcher and assistant lecturer in Dublin Institute of Technology (DIT). He joined the 3S group in 2009 with five years industry experience in logistics and inventory analysis. He received his B.Sc. degree specialized in Supply Chain Management from DIT with first class honors. Mr. Crowe won several outstanding prizes during his study time in DIT. In 2009, John successfully won a three year research scholarship with the Irish Research Council for Science, Engineering and Technology (IRCSET). He is currently working towards completing his PhD in Dublin Institute of Technology. John has published several articles in innovation in education and simulation international conferences. His research interests include supply chain management, simulation modelling application in business process analysis, system dynamics and simulation-based learning and education. His email address is john.crowe@dit.ie.

AMR ARISHA, Ph.D. is the director of the 3S Group and the head of international business department in college of business in Dublin Institute of Technology. He Joined DIT in 2005, he received his PhD Industrial Engineering from Dublin City University (DCU).Intel-Ireland has sponsored his research from 2000 - 2005. Dr. Arisha has published many journal and international conference articles in the area of manufacturing systems simulation and scheduling. His research interests include analysis and optimization of complex dynamic systems in manufacturing and service industries using stochastic simulation modelling, and optimisation techniques. His research also includes Supply Chain Management, Operations Excellence, Project Management, Virtual Reality applications in Business Process Analysis, and Optimization for Process Improvement. He is a member in IIE, IMECH, IEI, ESE, ORS, IEEE and ASME. His e-mail address is amr.arisha@dit.ie.