LEAN MANAGEMENT TOOLS APPLIED TO HOSPITAL FACILITIES: THE CASE OF AN OPERATIVE UNIT OF INTENSIVE CARE

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ABSTRACT

This paper presents the results of a simulation study that has involved a public Facility Healthcare, in particular an operative unit of intensive care. This unit represents the core of a healthcare facility where patients with abnormal vital signs as a result of diseases of the medical or surgical treatment of trauma are greeted. The approach proposed in this research work begins with the study and analysis of the processes that take place within the unit of intensive care; after that tools and methods of lean management are applied by using a Modeling & Simulation based approach. The work illustrates the improvement obtained with the application of Kanban technique and the 5S method. To this end, a simulation model of the intensive care unit considering the main processes and activities has been developed. Main goal of simulation was to see to which extent the operative unit is improved after the changes implemented through lean management tools and methods. The simulation model highlights the delays due to poor internal organization and the improvements achieved by redesigning the flows, minimizing the pathways and reengineering the layout of the operative unit. The results obtained by using the simulation model have been transferred to the real system with a relevant increase of the intensive care unit performances (giving a quantitative measure of the value added to care and wellness of patients).

Keywords: Health care facilities, Lean Management, Modeling & Simulation, Kanban

1. INTRODUCTION

Many manufacturing companies, sought to master the principles of lean thinking, other industries were also struggling with process improvement and health care was one of these industries. The core idea of the Lean approach is to maximize value for customers while using fewer resources and minimizing waste. Lean management theory has a long history of success in manufacturing. As matter of fact, the same Lean principles and tools that are applied in manufacturing plants are directly applicable to the health care facilities (Ross and Simon., 2012). Indeed, the root cause for failures is often the same both for manufacturing and health care systems, e.g. breakdowns in communications and misunderstanding the needs of customers. In the literature, there are many articles that focus on the use of Lean management techniques in health care and give descriptions of Lean theories, tools, empirical studies and applications about improvement of processes and service delivery; as mentioned by Machado et al. (2010), the Lean approach is a tested methodology for improving the way work gets done. Lean has been spreading slowly and inexorably from industry to industry for over half a century as its principles have been fine tuned, tested, demonstrated and proved.

Another important aspect to consider is the improvement of processes through modeling and simulation based approaches. Indeed, there is a large availability of discrete event simulation models that have been used in different domains: from industry to supply chain (consider for instance Rego Monteil et al. 2013), from healthcare to business management, from training to complex systems design (i.e. Bruzzone and Longo 2013). Simulation modeling is a way to test changes and give ideas for improvements before the implementation or tests in the real system. The focus of this work is oriented on the use of simulation as decision support in health care facility management. Indeed Lean management and discrete-event simulation (DES) can be jointly used for improvement of processes and service delivery (Robinson et al., 2012). Rarely they are used together. Different examples of simulation applications in health care can be found in research literature, to mention a few: Holm et al. (2013) deal with the improvement of hospital beds utilization through simulation and optimization; Weerawat et al. (2013) presents a generic discrete-event simulation model for outpatient clinics in a large public hospital.
Bruzzone et al. (2011) use simulation to analyze obesity epidemics.
Bruzzone et al. (2013) propose a simulation model to improve the overall efficiency of a healthcare facility showing how discrete event simulation can be

profitably used to design correctly doctors and nurses workloads as well as resources utilization.

Simulation offers immediate feedback about proposed changes, allows analysis of scenarios and promotes communication on building a shared system view and understanding of how a complex system works (Longo et al., 2013; Forsberg et al., 2011). As for mathematical models for medical parameters that can be easily embedded in simulation models, meaningful applications and case studies can be found in Winkler et al. (2013) and Winkler et al. (2011).

Case studies of Lean improvement simulation-based are oriented primarily on Emergency Department (Zeltyn at al., 2011) where there is a continuous flow of patients, leading to the medical personnel overload and to excessive waiting times to receive proper care. These adverse effects directly affect the patient satisfaction levels, the ability of the medical professionals to attend promptly to patients' health issues and generate unnecessary costs. Identifying the sources of waste and improving all the processes involved is the most suitable way to provide a better care and higher patient satisfaction and to increase the operational efficiency and the ability of the medical professionals to intervene on time (Khurma et al., 2008).

This research work begins with an experimental approach in a healthcare facility that includes the operative unit of intensive therapy and resuscitation, where we have addressed our studies. The experimental approach begins with the study and analysis of the operative unit, carrying out interview, data collection, processes and activities mapping. An important premise is that the production and delivery of health services in this operative unit is a complex task, where human and material resources should be planned and synchronized to ensure the effectiveness of the action and the expected result. The fundamental phases of this research work were:

- Interview and data collection in the intensive care unit;
- Conceptual models and simulation model development;
- Simulation analysis of the current system;
- Identification of strengths, weaknesses and actions to improve.
- redesign of the processes by using the simulation model jointly with all the technical and legislative references
- Simulation results transfer in the real system;
- Implementation of pilot projects with continuous support and methodological advice;
- Training of the operators involved to the new processes

Building the simulation model has revealed quite a difficult task due to the complexity of the processes, activities and procedures of the operative unit. There are many variables to consider and different entities flows. The simulation model was built on the real layout of the operative unit, identifying the location of patients' rooms, the beds, medicines and materials, equipment, paths followed by the staff and patients, entry rooms, doctors and nurses locations. The simulation model has been developed by using the simulation software Anylogic. The main goal of the simulation model was to see to which extent the operative unit can be improved by implementing lean tools and methods. The simulation model and the use of lean tools and methods have highlighted the delays due to poor internal organization and the improvements achieved by redesigning the flows, minimizing the pathways and reengineering the layout of the operative unit. The results obtained by using the simulation model and the lean tools and methods were both qualitatively and quantitatively relevant.

2. LEAN MANAGEMENT APPROACHES APPLIED TO HEALTHCARE FACILITIES

The basic idea of Lean Management is fundamentally that the healthcare organisation should be obsessively focussed on the most effective means of producing value for their patients. The Lean management contributes with a set of principles and tools to disentangle the various forms of waste and tackle their root causes. Used separately, these tools are helpful. Used together, in a planned, disciplined and co-ordinated way, they can chip away at accumulated layers of waste to release the organisation's real potential (Jones et al., 2006). To better clarify this concept we denote some possible approaches as explained in Jones et al. (2006):

- focus on improving the end-to-end process;
- where things are hard to see, make them as visible as possible so that everyone can see when and if there is a problem;
- where responsibilities are not clear, create detailed, standardised processes to avoid error, ambiguity and confusion – and as a springboard for improvement;
- where there is unnecessary work or waste, whether it is in the form of excess inventory, excess processing, excess movement of people or things, waiting and queuing, redesign the work;
- where problems are not resolved, ferret out their root cause.

Furthermore, targets must be clearly defined and achieved on regular basis. Targets can be achieved by using a Patients' perspective (everything is done to create a value-added for the patient), by pulling resources and work where needed in order to reduce queuing, bottleneck and waste, by analyzing all the processes steps by steps to understand how processes activities affect each other.

Lean also means a correct understanding and elimination of waste. The elimination of waste passes through the involvement of all the people working in the same unit. Indeed, most of the people are usually reluctant to changes; they must be opportunely convinced that changes are needed to improve the overall system performances as part of a continuous improvement process. Workers need also to be fully involved in the change, so they can promote it, discover and eliminate all the sources of waste.

2.1 Lean Tools applied in operative care unit

The application of Lean tools to an operative care unit encompasses a combination of the following steps:

1. Observe a problem, phenomenon, practice, activity;
2. Formulate a hypothesis to explain why the issue and how the process might be modified to yield an improvement;
3. Predict the result of the improvements;
4. Test the prediction by implementing the changes;
5. Reassess the hypothesis and prediction, based on the test results;

The first method that has been applied was the process mapping. Mapping the process of the operative unit has required the involvement of all the staff. For each work shift, physicians, nurses, technicians have used and filled ad-hoc forms to capture specific information about activities carried out, starting and ending time, type of activity, problems encountered and notes about how to improve the activity considered.

Particular emphasis was given to the administration of the therapy process. Indeed, the activities that characterize this process have many inefficiencies in different areas including external supply, internal organization, optimal arrangement of resources and medicines, control methods. For this reason it was useful to use the 5S method that is a specific method for organizing a workspace. The goal of the 5S method is to organize the work area in the way that needed objects are found easily and quickly and the work can be done more efficiently by creating smooth workflow. 5S refers to the five Japanese words “seiri, seiton, seiso, seiketsu, shitsuke”. In English these words mean “organize, orderliness, cleanliness, standardize, discipline”. In order to maintain the 5S acronym, five related English words beginning with the letter S have been adopted: “sort, straighten, scrub, standardize and sustain” (Zidel, 2006). Every word describes a step in the 5S work space transformation process. The first step “Sort” is the elimination of all the unneeded items from the work area. There is no space for useless things so storage of not needed items is absolutely unnecessary.

The second step “Straighten” means that items must be placed in well defined positions in order to reduce or eliminate time for searching. Items should be easily found and used. Those items that are frequently used should be placed closer to the workplace compared to rarely used items. A better overview of storage areas can simply be achieved by implementing a labeling system. The third step “Scrub” describes the need of a clean environment. Everything should be well cleaned and bright to provide a more comfortable workspace and subsequently increase efficiency and quality. Keep clean and orderly helps to the discovery of problems. The fourth step “Standardize” helps to define and formalize new standards of accommodation, order and clean achieved by the implementation of the first three S’s. The fifth step “Sustain” is about maintaining and improvement standards and results achieved. Everyone is responsible for maintaining goals. Accordingly, communication is fundamental during this phase. Staff must be instructed to this new kind of system and educated on how to implement, use and, most importantly, maintain it (Machado V. et al., 2010). In the Table 2, attached to the paper, the actions to be undertaken during the implementation of the method 5S are shown.

Another method is the Visual Management that is closely linked to the 5S method and helps in arranging a well-ordered and organized workplace. The use of signs, lines, labels, lists and colour coding facilitates materials searching and picking. Visual management can help in pointing out whether the process was operating correctly or not and what kinds of quality problems and errors were occurring (Fillingham, 2007). Finally, a way to handle a system of planning and control is the Kanban. In Japanese it means card, and it is used in the stages of production or services by operators to notify the warehouse that a stock-out is going to occur. We can distinguish three different types of kanban:

- kanban movement that is used to signal to the upstream stage that the material can be taken from the warehouse and transferred to a specified destination;
- kanban production which signals to the manufacturing process to enable the machining of a certain component that will be then deposited in a small warehouse;
- kanban sales used to signal the necessity of material to an external supplier.

In our work, we used the kanban movement which provides information on the category of material, the amount of material required, warehouse picking and delivery destination. By creating a Kanban, the operative unit will avoid stock-out occurrences as well as calls to the hospital pharmacy for an emergency delivery.

3. THE OPERATIVE UNIT OF INTENSIVE CARE AND RESUSCITATION

The Intensive Care Unit and Resuscitation (ICUR) analyzed in this paper is located in a public healthcare facility in Southern Italy and it is operating since 70s’. The ICUR activities take place without interruption H24, 7 days a week and 365 days per year. The organization aims at responding to emergencies and to "critical events" immediately when patients are in danger of life. For this reason, it is necessary to have a well trained staff, always ready to react and understand what is happening both inside and outside the hospital. The ICUR consists of four major zones:

- The Patient's Care Zone and the Clinical Support Zone are two zones that include the patients' rooms and adjacent areas; their primary functions are the direct patients' care.
- The Unit Support Zone refers to areas of the unit where administrative, materials management, and staff support functions take place.
- The Family Support Zone refers to areas designed to support families and visitors.

The Patient's Care Zone includes two rooms with seven beds, called "open space", and a room with two beds. Each bedroom is connected to a sophisticated monitoring system that ensures the constant monitoring of patient's vital functions and it is equipped with all the necessary equipment to provide respiratory care and infuse fluids, foods and medications.

The operative unit includes the following key-personnel:

- The Head Physician is a medical specialist in anesthesia and intensive care and he/she assumes the ultimate responsibility for clinical and organizational choices. He/she coordinates the work of physicians and nurses. He/she also establishes operational objectives and, in collaboration with the nursing coordinator, helps to achieve them through leadership and correct stimulation of all the operators involved. The Head Physician responds directly to the Director of the Hospital.
- The Senior Physician can replace the Head Physician taking the same tasks and responsibilities in case of Head Physician absence. He/she is a medical specialist in anesthesia and intensive care, which follows the day by day clinical course of hospitalized patients. He/she guides and coordinates the work of physicians, ensuring the continuity and adequacy of treatment choices. He/she draws up internal guidelines in agreement with other physicians and supervises their correct application. Coordination capabilities and high clinical skills are required.
- The Medical Assistant that supports both the Head and the Senior Physicians. He/she has the fundamental task to execute immediately the necessary life-saving procedures, safeguarding the well-being of patients admitted to the ICUR in cases of serious alteration of vital functions (e.g., cardiac, respiratory, neurological, metabolic problems). He/she also deals with emergencies arising outside the hospital (helicopter and ambulance).
- The Head Nurse is responsible for the care and clinical decisions laid down by the head physician and his staff; the Hear Nurse is also responsible for the organization of resources and materials and coordinates all nurses and support workers. The Head Nurse contributes to achieve organizational and clinical goals and spurs of all the involved nurses. He/She collaborates to guidelines drafting for procedures and protocols. The Head Nurse is also in charge of medicines and medical products logistics management.
- The Professional Nurse belongs to the paramedical personnel administering therapies to the patients. The Professional Nurse carries out the activities for health prevention, care and preservation autonomously, based on laws, ethics and professional practice. Professional Nurses perform also several essential tasks, such as continuous monitoring of the patient, administration of the therapy prescribed by physicians, the hygienic care and the patient transport (if needed).
- The Technical Operator supports the operative unit by carrying out tasks for the nursing care, such as delivery of biological materials for laboratory tests, disinfection / sterilization of medical equipment, warehouse management materials. The Technical Operator works directly with nurses in the hygienic care and transport of patients.
  - The ICUR is also characterized by the presence of machineries and equipment that surround the patient: mechanical ventilators that help respiratory muscles in case of respiratory failure;
  - infusion pumps that ensure fluid administration (drugs, food, etc.);
  - aspirations systems needed to remove bronchial secretions from lungs;
  - monitors used to display continuously the patient's vital signs (heart rate, pressure, temperature, etc.). Monitors emit many types of alarms, each with its own meaning, than can be heard anywhere in the operative unit. Each monitor is also connected to a central screen that allows the simultaneous observation of all hospitalized patients.

4. INTERVIEW AND DATA COLLECTION IN THE ICUR

At the beginning, the ICUR team thought there was too much variation in their work to apply any method, concept or tool that would help them. To this end, the very first action was to create a Current Value Stream map. The map included all processing steps from the moment the patients enter in operative unit until they are discharged. In order to map all the processes and activities correctly, we spent a 6 months period in the ICUR. Data collection for processes mapping has been done by using an ad-hoc template (see figure 1), where for each task (activity) of a specific process a number of information, including criticalities, were reported. The survey was carried out by professional nurses, for a period of thirty days and for all three daily shifts. In addition, the processes were extensively analysed, observing all the activities, the operators' paths and the layout of the operative unit. All the information collected revealed a clear situation of non-organization. Each process presented problems mostly dependent on the hospital management policies (e.g. underpowered staff, too stressful shifts, etc.), on motivational factors (e.g., lack of professional recognition, lack of interest, lack of autonomy, lack of professional involvement), on poor communications and internal organization (lack of rules and procedures, inhomogeneous working groups, disorganized supply of medicines, non-optimal layout, etc.). To this end, table 1 shows different types of criticalities and their occurrence percentage over 90 observations collected during a 3 months period. In percentage terms, we can see that the most critical process refers to materials management. This process has a direct impact on the medical treatment of patients, because the time used to search for a medication or medical material in the warehouse (or in the worst case of missing material), decreases the time devoted to patients care.

In addition, there were other inefficiencies:

- medicines and medical equipment was positioned in the ward based on experience;
- Medicines and products could not be found immediately due to poor containers organization.
- The medicines and products inventory position were not updated according to medicines and products, consumed and ordered
- Quantity ordered for each medicine and product was often based on experience with consequent stock-out occurrences or excessive inventories (the latter may cause problems in other hospital department)
- Stock-out occurrences in case of emergency situations, force the staff to require medicines and products to the hospital pharmacy or in other operative units;
- the hospital pharmacy provides products based on historical data that are not in line with real demand;

<table>
<tr><td colspan="2">DATE :</td><td>Start Time :</td><td>Name:</td><td colspan="2">Surname:</td></tr>
<tr><td colspan="2">No. Observation:</td><td>End Time :</td><td colspan="3">SHIFT
Morning ☐ Afternoon ☐ Night ☐</td></tr>
<tr><td colspan="6">Key-Personal : Physician ☐ Nurse ☐ Technical Operator ☐</td></tr>
<tr><td colspan="6">DATA COLLECTION</td></tr>
<tr><td>PROCESS</td><td colspan="2">ACTIVITY</td><td>START TIME [hh:mm]</td><td>END TIME [hh:mm]</td><td>CRITICALITY</td></tr>
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Figure 1: Form for data Collection within the ICUR

Table 1: Criticalities description and frequencies

Criticality description	**Frequency measuring in 12 weeks**	**Percent on 90 observations**
Interruption of the therapy administration for physician assistance	16	18%
Interruption of the therapy administration due to urgency intervention on broken machinery (absence of preventive maintenance)	36	40%
Patients waiting for CAT	10	11%
Picking material in the operative unit warehouse	44	49%
Missing material in the ICUR	64	71%
Presence of only two nurses during the shift (under sizing)	8	9%
Lack of information	20	22%
Lack of materials on dressing carts	28	31%
Work overload (reduced time for each patient)	20	22%
Poor knowledge of medical electrical equipment	32	36%

- the warehouse of the ICUR contained many low rotating products;
- optimal locations for medications and medical materials within the ward had not been identified;
- medical electrical equipment had not been controlled after use (absence of preventive maintenance);
- Personnel was not perfectly trained to use new medical electrical equipment;

All the anomalies described above represent a waste which substantially decreases the time devoted to patients and the vision of value-added activities.
A significant problem within their Value Stream was the lack of standardization in terms of how different team members carry out their assessment, testing, care and treatment. Therefore, many meetings were planned and organized with the goal of developing standard practices to increase the time for patient care and provide the optimum care (improve quality and service).
In the following, we will describe some improvement actions implemented in the ICU. In particular, we will refer to the logistics management of medicines and medical materials.

5. THE ICUR SIMULATION MODEL

The main idea behind our research work was to develop a discrete event simulation model able to recreate the complexity of the ICUR (as described in the previous sections). The proposed simulation model has been used as test bed to show how Lean tools and methods can be profitably used to improve the ICUR performances. The following section describes all the steps of the simulation model development.

1st Step - Environment representation

A 2D layout of the ICUR has been imported in AnyLogic and has been referred to create a transportation network defining the paths of the staff and patients, rooms and bed's location, medicines, materials and equipment storages, entry rooms. Within the network, a rectangle represents an entry or exit point, the idle position of some resources, a destination point in the facility. A line is the path followed by the entities moving among rectangles. This way, we define a network topology where entities and resources are directly traceable.

2nd Step – Defining the network resources pool

According to the AnyLogic Library, the resources network can be of three types: moving, portable and static. In our model, physicians and nurses are moving resources. Stretchers, tools, equipment, medicines medical material are portable resources. Procedures rooms, therapy, beds assignment, placement of patient records are the static ones.

3rd Step – Animating Patients and Resources

The third step was to draw animations to depict patients, doctors, nurses, stretchers, equipment, medicines.

4th Step – Creating a Flowchart for each process

This model has been built considering five fundamental processes.

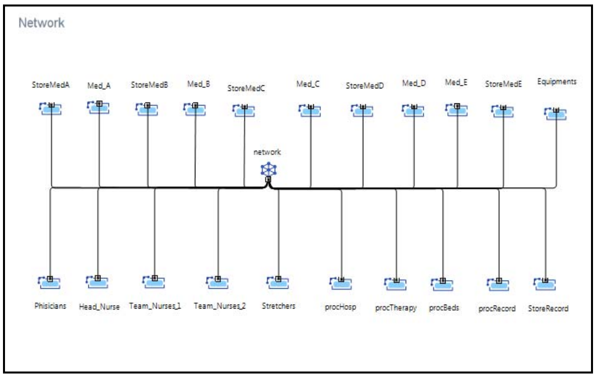

Figure 2: Simulation Model network and resources objects

Patients' Arrival process:
Only serious patients with disease that involve vital organs are admitted into the ICUR. Critical patients may arrive from two different sources: from the Emergency Room or from other operative units. During the six months period spent at the ICUR we observed 276 incoming patients, 57% coming from other operative units and 43% from the emergency room. The average hospitalization time is 20 days. When patients arrive, nurses are required to take the incoming stretcher, attach the patient to different machineries (to monitor vital parameters) and then to move the patient to the bed location. The figure 3 depicts the flow chart of the Patients' arrival process.

Patient record creation process
For each patient arrived into the ICUR, the physician creates a medical record, where all the information about the patient and the therapy are stored (the figure 3 also shows the Patient record creation process).

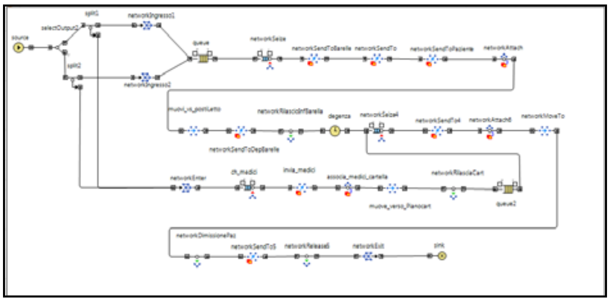

Figure 3: Simulation model Flow Chart: Patient Arrival Process and Patient record creation process

Hygienic care process
The process is repeated three times per day. For each patient and every 8 hours, two nurses perform the hygienic care process. The figure 4 depicts the flow chart of the hygienic care process.

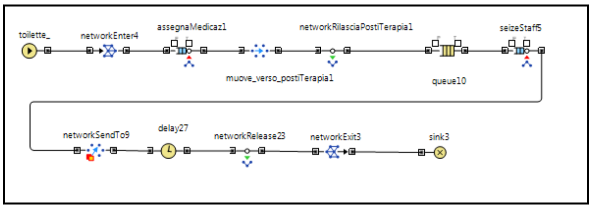

Figure 4: Simulation model Flow Chart: Hygienic care process

Medication and monitoring process:
Patients in the ICUR require continuous monitoring, vital functions stabilization and / or invasive procedures. "Intensive care" is the highest available level of continuous treatment of the patient. In this process, each patient represents a static entity that requires the intervention of nurses several times a day. The figure 5 depicts the flow chart of the Medication and Monitoring Process.

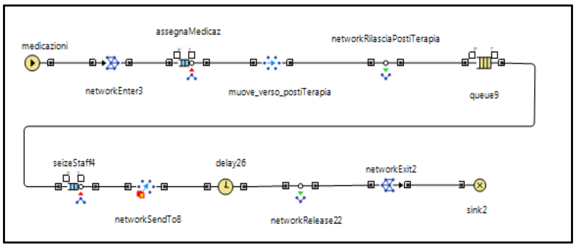

Figure 5: Simulation model Flow Chart: Medication and monitoring process

Therapy administration process:
This process is the core of our analysis. Here, wastes entail less time for patients care. Based on the data analysis, the simulation model allows distinguishing five types of medications necessary to maintain life and nutrition of patients. These medications (each one made up of specific products) are stored in different points inside the operative unit, causing inconvenient and delays in picking operations and therapy administration. The simulation model demonstrates the benefits achieved applying lean methods that lead to the design of a new layout and to the definition of new logics for storage and inventory management. The process is trigged three times/day according to a well-defined schedule and all nurses are required to read the medical record, to pick medications in the storage location, to prepare products, medicines and medical devices and finally to perform therapy administration at bed position. The figure 6 depicts the flow chart of the therapy administration process.

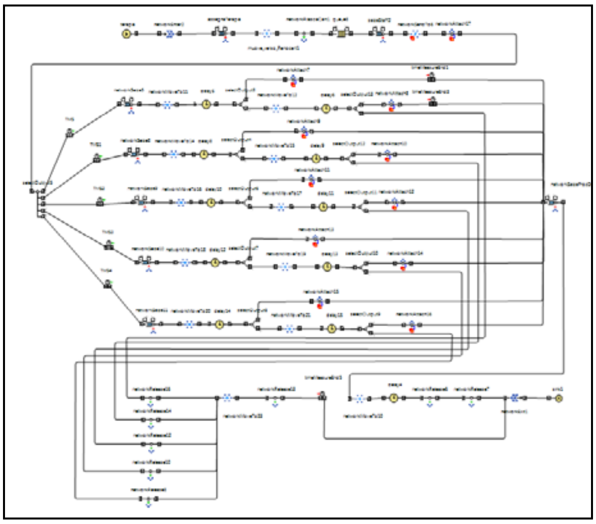

Figure 6: Simulation model Flow Chart: Therapy administration process

The five processes described above have been implemented as part of the simulation model that seeks to recreate the ICUR complexity. During the simulation runs it is possible to assess time savings (that can be devoted to patients), if the labor organization is optimized and if it is grounded on clear operational methodology with a smooth flow of activities. The last step of our simulation study is the simulation experimentations and results analysis.

6. ANALYSIS AND SIMULATION RESULTS

The main goal of the simulation model is to assess if the performances of the operative unit are improved after the changes implemented as a result of the lean methods application. Indeed the simulation model is able to highlight the delays due to poor internal organization and the improvements achieved by redesigning the flows, minimizing the pathways and reengineering the layout of the operative unit.
Simulation experiments were carried out considering three different scenarios. The first scenario simulates the ICUR as it is; indeed it happens frequently (as shown in table 1) that when nurses prepare the therapy, because of the lack of medicines in the ward, they are obliged to reach the warehouse and look for medicines, materials and machineries into warehouse shelves. This operation, when repeated many times during the same day for multiple patients, inevitably generates a waste of time. The figure 7 shows the simulation results of the therapy administration in the scenario 1. The process begins with the medical record reading, then the nurse, according to the ward situation may be required to move into the storage and search for medicines, materials and machineries. The simulation model evaluates and average time of about 17.8 minutes between medical record reading and the therapy administration.

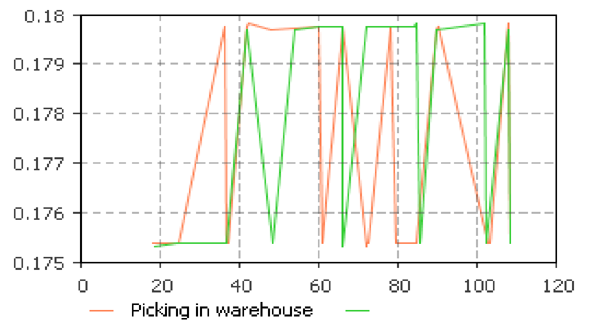

Figure 7: average therapy administration time for scenario 1

On average, only 50% of the total therapy administration time is dedicated to the patient, while the remaining 50% of the time is wasted by walking, searching for medicines, materials and machineries.

As additional results for scenario 1, the simulation model has evaluated a 57% average utilization level of the nurses team. While this value can be regarded as a good utilization level, it is worth mentioning that on average, only 50% of the nurse busy time is dedicated to the patient.

As far as the second scenario is concerned, this can be regarded as the worst scenario. Indeed, in this case nurses search for medicine in the ward, but it can happen that the nurses is redirected to the warehouse where a stock-out occurs (some medicines or materials are missing or a machineries is unavailable due maintenance operations). As matter of facts, in the scenario 2 the waste of time increases even more. The stock-out occurrence is communicated to the Head Nurse that, in turn, sends a new order to the hospital pharmacy. Only when the materials and medicine will be available, the therapy will be administered. The average time between the medical record reading and the therapy administration in scenario 2 is about 22.6 minutes (see figure 8).

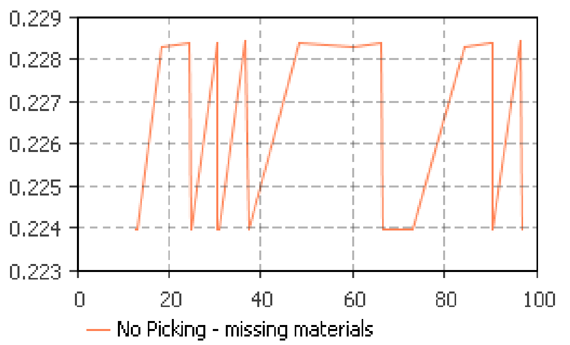

Figure 8: average therapy administration time for scenario 2

The scenario 2 is the worst situation in terms of value added for the wellness of the patient. Indeed in this case the nurse wastes additional time to communicate with the Head Nurse and, in turn, the Head Nurse must place the order to the Hospital Pharmacy. The simulation model evaluates that in this case only 14% of the total nurses busy time is dedicated to the patient. As far as the nurses utilization level is concerned, the simulation model evaluates an average value of 63%. While this result seems to be even better compared to scenario 1, conversely the nurses spend more time for materials and medicine searching as well as for communications without a real value added for the patient.

As far as the third scenario is concerned, this case considers the use of lean methods and tools described in the previous sections (e.g. the 5S method, the kanban method, layout optimization, etc.). In this case, medications, medical materials and machineries are always available in the department. Thanks to Kanban the replenishment is performed on time and a safety stock has also been added. In figure 9 we can note that the average time that elapses between the medical record reading and the therapy administration is about 9.9 minutes.

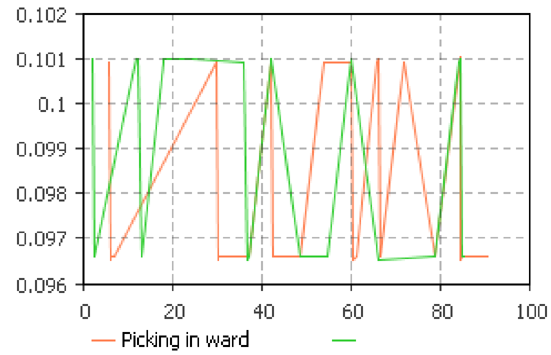

Figure 9: average therapy administration time for scenario 3

The simulation results for the scenario 3 clearly shows that most of the nurses busy time is dedicated to the patient, passive times that do not provide value added to the patient cannot be further reduced, therefore we can assert that the value added for the patient is 100%. The average nurses utilization level is about 30%; while this value may appear as very low, on the contrary it gives the possibility to carry out other patients care therefore assigning more patients to one nurse (workload optimization).

To summarize the simulation results, we can assert that in scenario 1, on the average one hour is wasted over 8-hours shift; in scenario 2, on the average one hour and half is wasted, while scenario 3 represents the best situation with no waste of time

The table 2 summarizes the simulation results for the three scenarios.

Table 2: Simulation results for the three scenarios

Scenario	Time to picking [minutes]	Value added to the patient (Wellness)	Cumulated time waste (on 100 picking) [minutes]	Average time wasted in one work shift [hours]
Scenario 1	17.8	50 %	800	1
Scenario 2	22.6	14 %	1200	1.5
Scenario 3	9.9	100 %	0	0

7. CONCLUSIONS

Like in all operative units of intensive care, the staff works under enormous stress and the workload has continued to increase during the last years. Usually this type of environment creates an atmosphere of frustration and anxiety for all staff due to particulars conditions of patients. In this particular scenario, the Intensive Care Unit team that we presented in this research work was introduced to the results of the simulation and to the Lean concepts through dedicated training courses. The period of training and information lasted for a week involving 15 physicians, 25 nurses and 1 technician. The Lean methods and tools as well as simulation results were successfully transferred to the real system with a relevant increase of the overall performances.

The implementation of Lean methods and tools can help any organization to launch its Lean transformation and improvement. This is even more important for Hospitals that cannot continue to operate as they have done in the past. Even considering the ongoing financial crises (at least in Italy) hospitals need to ensure their processes with much more value added work and such work must be totally directed on patients.

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