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Lean Management Practices Applied to System Healthcare Facilities

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Abstract

This thesis concerns the results of a simulation study that has involved the Surgical Department and Intensive Care Unit of a public healthcare facility located in South Italy. After a preliminary work devoted to map the processes and after data collection and analysis, Lean Tools have been studied before and simulation models have been developed after. The models, that have been validated by stakeholders and through comparison with real data, can be used for evaluating actual and maximum capacities but also for testing alternative scenarios before the implementation in the real system. Moreover, thanks to the model parametrization, the proposed tools can be easily adopted in other similar facilities or for evaluating different configurations in terms of resources allocation and availability. In addition, the simulation models have been equipped with build-in functions implementing the “pull method” and "kanban" from Lean Management practices showing that substantial performance improvements can be achieved . The most healthcare organizations push patients from one area to another, from wards to operating blocks, without knowing when the patient will be treated. Instead, according the pull method, thanks to a definitive scheduling and some basic preconditions such as continuous checking and resources availability, patients are pulled when they are actually needed and as a result wastes are reduced and productivity is enhanced. The effects of the pull method implementation are accurately investigated in the simulated environment that has served as playground to assess the potential impact of the proposed approach. Regarding Intensive Care Unit, 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 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. The hospitals need to ensure their processes with much more value added work and such work must be totally directed on patients.

Questa tesi riguarda i risultati di uno studio di simulazione che ha coinvolto il reparto di chirurgia e terapia intensiva di una struttura sanitaria pubblica situata nel Sud Italia. Dopo lo studio di strumenti di Lean Management sono stati prima mappati i processi, raccolti e analizzati i dati, successivamente sono stati sviluppati modelli di simulazione. I modelli, che sono stati convalidati dalle parti interessate, attraverso il confronto con i dati reali, possono essere utilizzati per la valutazione delle capacità attuali e massime, ma anche per testare scenari alternativi prima di effettuare cambiamenti nel sistema reale. Inoltre, grazie al modello di parametrizzazione, gli strumenti proposti possono essere facilmente adottate ad altre strutture simili o per valutare diverse configurazioni in termini di allocazione e la disponibilità delle risorse. Inoltre, i modelli di simulazione costruiti con funzioni integrate del "metodo pull" e "kanban", mostrano che possono essere raggiunti dei miglioramenti delle prestazioni sostanziali. Le maggior parte delle organizzazioni sanitarie spostano i pazienti da una zona all'altra, da reparti a reparti, senza sapere quando verrà effettivamente eseguito il trattamento. Invece, secondo il metodo pull, grazie ad una programmazione definitiva e ad alcune condizioni di base come il controllo continuo dei processi e la disponibilità delle risorse, i pazienti vengono presi in carico quando effettivamente è necessario e di conseguenza gli sprechi sono ridotti e la produttività aumenta. Gli effetti dell'attuazione metodo pull sono stati accuratamente studiati in un ambiente simulato che ha consentito di valutare l'impatto potenziale dell'approccio proposto. Per quanto riguarda la terapia intensiva, abbiamo notato che il personale lavora sotto enorme stress e con un carico di lavoro, negli ultimi anni, sempre in aumento. In questo scenario particolare, il team di terapia intensiva è stato coinvolto nei risultati della simulazione e formato sui concetti del Lean Management. I metodi e gli strumenti Lean nonché i risultati della simulazione sono stati trasferiti con successo al sistema vero e proprio, con un rilevante incremento delle prestazioni complessive. In generale possiamo dire che l'implementazione di metodi e strumenti Lean può aiutare qualsiasi organizzazione a dare inizio alla trasformazione snella dei processi e di miglioramento continuo. Questa trasformazione è ancora più importante per gli ospedali che non possono continuare a operare come hanno fatto in passato. Infatti devono garantire i loro processi fornendo lavoro con valore aggiunto e tale lavoro deve essere totalmente destinato ai pazienti.

SUMMARY

CHAPTER 1: LEAN MANAGEMENT: Principles, Tools and Methods

1.1 Introduction

The core idea of the Lean approach is to maximize value for customers 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). In fact,the root cause for failures is often the same both for manufacturing and health care systems, e.g. breakdowns in communications and misunderstanding about 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 the 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: 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. 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. 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) proposes a simulation model to improve the overall efficiency of a healthcare facility showing how a 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, also 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 based on improvement of Lean simulation 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, affect 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).The basic idea of Lean Management is fundamentally that the healthcare organization 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 coordinated way, they can chip away at accumulated layers of waste and 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 step by step all the processes 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. In fact, 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.

1.2 Origins of Lean Management

In the 1980s, the automotive industry in the United States was losing market share compared with foreign competitors, particularly Japanese automakers, who manufactured cost-competitive automobiles with fewer defects and higher customer satisfaction. When researchers traveled to Japan to discover the secret of their success, they found an entirely different system of production—which they called "lean manufacturing" (because higher-quality output was obtained at half the cost in half the time of traditional manufacturing methods). During the last 10–15 years, companies using these lean manufacturing practices report productivity improvements in the triple digits, defect rates falling by orders of magnitude, significantly shortened order-to-delivery times, increased customer satisfaction, and greatly reduced employee turnover. The concepts are revolutionizing manufacturing in the United States. Lean manufacturing is often described as a Japanese phenomenon, but the system was invented by one company—Toyota Motor Company. As Toyota perfected its system and began making huge strides domestically, other Japanese manufacturers took note and copied its system. What American researchers saw and reported as a Japanese method was actually just Japanese manufacturers copying Toyota more quickly than did American companies. "Muda" is a Japanese word that means waste. Any human activity which absorbs resources and creates no value is waste, that is to say "Muda":

- Errors and defects that involve reconstructions, production of something that does not need (grows warehouses)
- unnecessaries procedures
- movement of personnel and goods transportation from place to place without having utility
- groups of workers idle and waiting, due to delay for errors in an activity up stream

As you can see "muda" it is much more than an inconvenience. The first thing that teaches Lean theory is "learning to see" to eliminate waste and produce more with a lower consumption of resources. However, before we explore these concepts, we want to show, through a comparison, as the Lean management incorporates the concepts of Total Quality Management giving continuity(see Table 1.1)

Total Quality Management	**Lean Management**
The worker must think in this way will be productive	All resources with experience and creativity need to be involved in the organization
All company employees must be trained and formed according to the principles of Total Quality	All company employees must be trained and formed according to the principles of lean thinking
Reduce stocks to highlight defects and clear them	Zero inventory and eliminate obstacles that prevent the sliding of value stream
Introduction of the concept of "kaizen" =continuous improvement with small steps	Introduction of the concept of "perfection" = search of perfection through continuous improvement
Company goal is customer satisfaction	The company's objective to enable partnerships both inside and outside the company among all players in the supply chain(suppliers and customers)

Table 1.1 : Comparison between TQM and Lean management

As described above it is clear that the lean thinking moves in a logic of continuity with the total quality by acquiring a series of concepts and working methods (eg. the working groups "kaizen"). In addition to Total Quality Management, Lean Management uses other methods and techniques, such as the business process reengineering (BPR), the systems just in time (JIT), concurrent engineering, management by value, etc.
In both models is the concept of radical improvement (in Japanese "Kaikaku"), which begins from the top management and requires great changes. A complete organizational intervention can be done in two ways: Top-Down and Bottom-Up. Figure 1.1 depicts the logic.

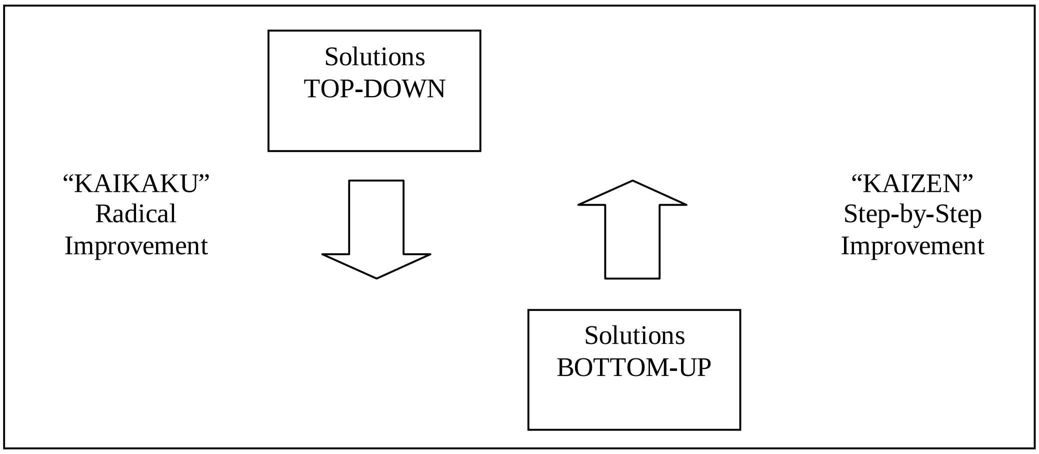

Figure 1.1: Ways of intervention organizational

It worth recalling that the Lean Management, is not based on new theories and it is not revolutionary, but it moves in a logic of continuity with previous theories and has the merit of being able to give an order to the organizational activities, defining specific objectives. Lean management is a theory that must be applied in its entirety: only in this way you will get results.

1.3 Lean Principles

The basic principles of logic Lean Management are five:

- Defining the Value ("VALUE")
- Identify the value stream ("VALUE STREAM")
- Slide the flow ("FLOW")
- Make sure that the flow is pulled ("PULL")
- Achieving perfection ("PERFECTION")

1.3.1 Defining Value ("VALUE")

Taiichi Ohno, engineer, famous for being one of the founders and for showing the Toyota Production System(1988), has shown seven types of "muda" or wastes, and then Womack and Jones(1997) have added an eighth:

1. **Overproduction** – Producing more than the customer demands. The corresponding Lean principle is to manufacture based upon a pull system, or producing products just as customers order them. Anything produced beyond this (buffer or safety stocks, work-in-process inventories, etc.) ties up valuable labor and material resources that might otherwise be used to respond to customer demand.
2. **Waiting** – This includes waiting for material, information, equipment, tools, etc. Lean demands that all resources are provided on a *just-in-time* (JIT) basis – not too soon, not too late.
3. **Transportation** – Material should be delivered to its point of use. Instead of raw materials being shipped from the vendor to a receiving location, processed, moved into a warehouse, and then transported to the assembly line, Lean demands that the material be shipped directly from the vendor to the location in the

assembly line where it will be used. The Lean term for this technique is called point-of-use-storage (POUS).

4. **Non-Value-Added-Processing** – Some of the more common examples of this are *reworking* (the product or service should have been done correctly the first time), *deburring* (parts should have been produced without burrs, properly designed and maintained tooling), and *inspecting* (parts should have been produced using statistical process control techniques to eliminate or minimize the amount of inspection required). A technique called *Value Stream Mapping* is frequently used to help identify non-valued-added steps in the process (for both manufacturers and service organizations).
5. **Excess Inventory** – Related to Overproduction, inventory beyond that needed to meet customer demands negatively impacts cash flow and uses valuable floor space. One of the most important benefits for implementing Lean Principles in manufacturing organizations is the elimination or postponement of plans for expansion of warehouse space.
6. **Defects** – Production defects and service errors waste resources in four ways. First, materials are consumed. Second, the labor used to produce the part (or provide the service) the first time cannot be recovered. Third, labor is required to rework the product (or redo the service). Fourth, labor is required to address any forthcoming customer complaints.
7. **Excess Motion** – Unnecessary motion is caused by poor workflow, poor layout, housekeeping, and inconsistent or undocumented work methods. Value Stream Mapping is also used to identify this type of waste.
8. **Underutilized People** – This includes underutilization of mental, creative, and physical skills and abilities, where non-Lean environments only recognize underutilization of physical attributes. Some of the more common causes for this waste include – poor workflow, organizational culture, inadequate hiring practices, poor or non-existent training, and high employee turnover.

This list of wastes can be applied not only to the production and manufacturing companies but also to order management and product development. The definition of "value" is a difficult task, it is defined by the customer and takes on a specific meaning only when a product/service satisfy the needs.

1.3.2 Identify the value stream (“VALUE STREAM”)

The value stream for a product consists of all activities necessary to transform the raw materials into finished products. Each sector(both manufacturing and services) is characterized by three core activities:

- **Definition of the product/service:** from the idea through detailed design and engineering until to the launch in production/service delivery;
- **Information management:** from order entry to detailed scheduling until the delivery of product/service;
- **Physical transformation**: from the raw material to a finished product/service to the client.

Associated with these three activities are three streams/main processes:

- Design/development of the product/service;
- Order management;
- Production of the goods / service delivery.

The concept of value stream is exactly the same both for physical products(company manufacturing machinery or other), that for the services (transport company etc.). The second step of lean management(after the definition of the value) is the identification of the value stream for each product or family of products. The analysis of value stream always puts out lots of "muda" through the mapping of activities into three categories:

1. **Activities that create value** (all those whose cost can be transferred to the customer);
2. **Activities that do not create value but necessary** (can not be eliminated with existing product development, order management and production);
3. **Activities that do not create value and not necessary** (they can be eliminated immediately).

It is indispensable in this second phase of lean management to perform a detailed mapping of the flows. Particularly suitable for the production area is the method of "mapping the flow of material and information", as described by Rotherand Shook(1999).

The main purposes of this method are:

- Visualize the flow of materials and information;
- Bring out wastes and indicate where to improve the flow;
- Define priority actions to improve the flow.

The method consists of four distinct operating steps:

1. Identification and selection of product families on which to conduct the analysis;
2. Stream mapping current production;
3. Stream mapping future with details of improvements;
4. Defining the plan to implement the new flow.

1.3.3 Slide the flow ("FLOW")

Once value has been precisely specified, the value stream for a specific product fully mapped by the enterprise, and wasteful steps eliminated, it's time to make the remaining steps flow. These lean principles entail probably the greatest departure from traditional thinking. We relate to a world of functions and departments, a conviction that activities ought to be grouped by type so they can be performed more efficiently and managed more easily. Also, it is common sense to perform like activities in batches where products flow through different sequences and operations in batches. This creates wait times (bottlenecks) while the product waits for the next operation or sequence, or departments change over to the type of activity the product needs next. Traditional firms believe that, since this keeps everyone busy, it's efficient. Things work better when you focus on the product and its needs, rather than the organization or the equipment, so that all the activities needed to design, order, and produce a product, occur in continuous flow. Womack and Jones' research shows that plants in North America and Europe, where production activities were rearranged from departments and batches to continuous flow [process flow], present a productivity doubled and a dramatic reductions of errors and scrap. The re-engineering movement in the United States has recognized that departmentalized thinking is not best and has tried to shift the focus from organizational categories [departments] to value added processes. The problem is that the engineers have not gone far enough. Conceptually, they are still dealing with disconnected and collective processes rather than looking at the whole value stream for major breakthroughs and managing the entire flow of value-added activities for specific products. Also, the re-engineering frequently results in a collapse of employee morale and a regression of the organization to the norm as soon as the re-engineers are gone. The lean alternative is: Redefine the work of functions, departments and firms so they can make a positive contribution to value creation and Address the real needs of employees at every point along the stream so it is actually in their interest to make value flow.

1.3.4 Make sure that the flow is pulled ("PULL")

The results of converting from departments and batches to product teams and flow is that the times required to go from concept to launch, sale to delivery, and raw material to the customer fall dramatically. When flow is introduced, products requiring years to design are done in months, orders taking days to process are completed in hours, and the weeks or months of throughput time for conventional physical production are reduced to minutes or days. Truly lean systems can make any product currently in production in any combination such that shifting demand can be easily accommodated immediately. You can let the customer pulls the product as needed rather than pushing them the product, as they are often unwanted. Customer demand becomes much more stable when customers know they can get what they want when they need it and when producers stop periodic price discounting campaigns designed to sell goods already made that no one wants.

1.3.5 Achieving of the perfection ("PERFECTION")

As the organization begins to accurately specify value, identify the entire value stream, adds to the value the steps for specific products with flow continuously, and lets customers pull value from the enterprise, something remarkable surfaces. People begin to realize there is no end to the process of reducing effort, time, space, cost, and mistakes while offering a product with lean principles. Perfection, the fifth and final principle of lean thinking, seems achievable. The other principles interact with each other, getting value to flow faster always exposes hidden waste in the value stream. The harder you pull, the more the obstacles to flow are revealed so they can be removed. Dedicated product teams in direct dialogue with customers always find ways to specify value more accurately and often learn ways to enhance flow and pull as well. In a truly lean system, everyone gets involved, subcontractors, first tier suppliers, systems integrators or assemblers, distributors, customers, employees can see everything so it is easy to discover better ways to create value. Also, there are instant and positive feedbacks for employees making improvements, a key feature of lean principles and a powerful element to continuous improvement. The plant personnel is a vital element in successful implementation of Lean Principles. Employee involvement and accountability process improvement helps improve both product reliability and employee morale.At this point, if you switch from one system towards and lots to a system product team and flows pulled by the customer, further improvements are possible.The table1.2 below compares the two systems:

Feature	**Lean Management**	**Lots and Wards**
Lots size	Tending the lot "unit" (or minimum needed to answer the actual question)	Lots size bound by the set-uptimes(of the order of hours)
Duration of the throughput time(lead time)	Lead time very nearest to the time technician	Lead time 20-50times the time technical
Production process organization	- Organization of the production process by product family - Machines simple and reliable - Quality controlled in process	- Organization of the production process per ward - Complex machines - Quality controlled at the end
Size warehouse	- Stock PF tending to zero - WIP tending to minimum technical	- Finished product warehouse increased based on forecast - WIP high due to high Lead Time
Production programming	- Production programming leveled and "Pull". - Check daily and "on demand".	- Production programming "push" based on forecasts. - Grouping for minimum lots - Progress based on final balance repeated requests to production

Table 1.2 : Model comparison "Lean Management" and "Lots System"

Regarding human resources, in carrying out a Lean project, it is necessary to involve all employees in a transversal way, and including all business functions. To do that, we must take into account the following factors:

- The organizational structure should be based on team;
- the business functions are considered as "reservoir" of resources for each team;
- the resources assigned to the team depend on the team leader;
- the groups must be created for improvement ("kaizen groups");
- it is necessary to define new tasks in the reorganization because some jobs are not needed anymore.

It is clear that this organizational revolution creates problems in the management of human resources and complications in the company structure. For this reason are required strong leadership skills.

1.4 Lean Management Tools

In order to reduce or eliminate the above wastes, Lean practitioners utilize many Lean tools. Successful practitioners recognize that, although most of these may be implemented as stand-alone programs, few have significant impact when used alone. Additionally, the sequence of implementation affects the overall impact, and implementing some out of order may actually produce negative results (for example, you should address quick change over and quality before reducing batch sizes). The more common tools are listed below. Note that some are used only in manufacturing organizations, but most apply equally to service industries.

1.4.1 5-S Method

The 5S method is the tool for helping the analysis of processes running on the workplace. The 5S is the methodology of creating and maintaining well organized, clean, high effective and high quality workplace. Its result is the effective organization of the workplace, reduction of work's environment, elimination of losses connected with failures and breaks, improvement of the quality and safety of work [2-4]. The philosophy of the 5S has its roots in Japan. Name 5S is the acronym of five Japanese words of the following meanings:

- **Seiri** (sorting, organization of the workplace, elimination of unnecessary materials). Refers to the practice of sorting through all the tools, materials, etc., in the work area and keeping only essential items. Everything else is stored or discarded. This leads to fewer hazards and less clutter to interfere with productive work.
- **Seiton** (set in order, place for everything). Focuses on the need for the workplace in order. Tools, equipment, and materials must be systematically arranged for the easiest and the most efficient access. There must be a place for everything, and everything must be in its place.
- **Seiso** (shine, cleaning, removing of wastes, dust etc.). Indicates the need to keep the workplace clean as well as neat. Cleaning in Japanese companies is a daily activity. At the end of each shift, the work area is cleaned up and everything is restored to its place.
- **Seiketsu** (standardize, constant place for things, constant rules of organization, storage and keeping cleanness). Allows for control and consistency. Basic housekeeping standards apply everywhere in the facility. Everyone knows exactly what his or her responsibilities are. House keeping duties are part of regular work routines.
- **Shitsuke** (sustain , automatic realization of above-mentioned rules). Refers to maintaining standards and keeping the facility in safe and efficient order day after day, year after year.

Implementing the 5S rules should begin from trainings of productive workers in the range of the 5S's elements and advantages from their usage. It is important that all participants of trainings will understand the need of using the 5S rules on the own workplace and agree with the changes. During trainings it is essential to train the usage of all rules on the clear example, so that every participant can understand the methodology of realization of the 5S's elements. Very important is that these rules do not refer only to the productive positions, but also to the warehouse, office positions and others**.** The advantages of implementing the 5S rules can be summarized in follows table 1.3:

Type S	**Advantages**
Seiri (sorting)	- process improvement by costs' reduction - stock decreasing - better usage of the working area - prevention of losing tools
Seiton(set in order)	- process improvement (increasing of effectiveness and efficiency) - shortening of the time of seeking necessary things - safety improvement
Seiso (shine)	- increasing of machines' efficiency - maintenance the cleanness of devices - maintenance and improvement of the machines' efficiency - maintenance the clean workplace, easy to check - quick informing about damages (potential sources of damages) - improvement of the work environment - elimination of the accidents' reasons
Seiketsu (standardize)	- safety increasing and reduction of the industry pollution, - working out the procedures defining the course of processes
Shitsuke (sustain)	- increasing of the awareness and morale - decreasing of mistakes quantity resulting from the inattention - proceedings according to decisions - improvement of the internal communication processes - improvement of the human relations

Table 1.3 : The advantages of implementing the 5S rules

1.4.2 Visual Management Method

Visual management is closely linked to the 5S method and helps to arrange a workplace in a well ordered and organized way for example in Manos et al. (2006). Signs, lines, labels, lists and colour coding eliminate guessing, searching and hoarding for information and material. Visual management may provide flow by designing them in a way so that employees can simply "go-and-see what is happening and exactly the next problem they should be solving without disturbing other staff from their value added tasks" (Fillingham, 2007). Furthermore, it can help to point out whether or not the process was operating correctly and what kinds of quality problems and errors were occurring (Fillingham, 2007). It can support efficient time management for example in operation theatres as described by Koning et al. (2006). For example, at the weekly staff meeting a specially can be designed graph to show the operating rooms start times for the previous week. The feedback from this control system can be used to continually monitor the operating rooms starting and times and provide input on how to improve processes even further. The simple posting of graphic images can remind staff of doing standard work (Ballé and Régnier, 2007) or communicate to employees important information where the whole culture changing plans were provided by images throughout the organization. The best known visual tool is called "kanban" which means sign board. It visually displays what's needed to keep a process moving informing when to make, move or get materials from the external supplier. A kanban may signal for example that an item requires replenishing (Zidel, 2006). The signal can take any form. It may be a card, an alarm a light or simply a square on the floor or a bin which shows that something is missing if it's empty. Thus it is the perfect tool for applying 5S, establishing jidoka (react at first defect) and providing JIT (Just-In-Time). A further visual tool is "andon" which means light. It is most commonly a light or an audible signal, but may be any signal used to bring attention to a particular situation (Zidel, 2006) like occurring of errors and safety lacks.

1.4.3 Poka-Yoke Method

Poka-yoke was coined in Japan during the 1960s by Shigeo Shingo who was one of the industrial engineers at Toyota. Shigeo Shingo is also credited with creating and formalizing Zero Quality Control (poka-yoke techniques to correct possible defects and inspections to have defects equals zero). The initial term was baka-yoke, which means 'fool-proofing'. In 1963, a worker of Arakawa Body Company refused to use baka-yoke mechanisms in her work area, because of the term's dishonourable and offensive connotation. Hence, the term was changed to poka-yoke, which means 'mistake-proofing' or more literally avoiding (yokeru) inadvertent errors (poka). Ideally, poka-yokes ensure that proper conditions exist before actually executing a process step, preventing defects from occurring in the first place. Where this is not possible, poka-yokes perform a detective function, eliminating defects in the process as early as possible**.** Poka-yoke helps people and processes work right the first time. Poka-yoke refers to techniques that make it impossible to make mistakes. These techniques can drive defects out of products and processes and substantially improve quality and reliability. It can be thought of as an extension of FMEA - Failure Mode and Effect Analysis . It can also be used to fine tune improvements and process designs from six-sigma Define - Measure - Analyze - Improve - Control (DMAIC) projects. The use of simple poka-yoke ideas and methods in a product and a process design can eliminate both human and mechanical errors. Poka-yoke can be used whenever something can go wrong or an error can be made. It is a technique, a tool that can be applied to any type of process be it in manufacturing or the service industry. Errors can be many types:

1. **Processing errors** : Process operation missed or not performed per the standard operating procedure.
2. **Setup errors:** Using the wrong tooling or setting machine adjustments incorrectly.
3. **Missing parts** :Not all parts included in the assembly, welding, or other processes.
4. **Improper part/item**: Wrong part used in the process.
5. **Operations error**: Carrying out an operation incorrectly; having the incorrect version of the specification.
6. **Measurement error**: Errors in machine adjustment, test measurement or dimensions of a part coming in from a supplier.

Steps process in applying poka-yoke are:

- Identify the operation or process
- Analyze the 5-whys and understand the ways a process can fail.

- Decide the right poka-yoke approach (preventing an error being made), or an attention type (highlighting that an error has been made). A error can be electrical, mechanical, procedural, visual, human or any other form that prevents incorrect execution of a process step.
- Determine whether a contact - use of shape, size or other physical attributes for detection, constant number - error triggered if a certain number of actions are not made sequence method - use of a checklist to ensure completing all process steps is appropriate.
- Trial the method and see if it works.
- Train the operator, review performance and measure success.

1.4.4 Value Stream Mapping (VSM)

Value Stream Mapping (VSM) is a mapping tool that is used to map a productive process or an entire supply chain networks. It maps not only material flows but also the information flows of the signal and control production. Tapping et al. (2002) introduced a step by step procedure to perform a VSM analysis. The first step consists in the selection of a product family as the target for the improvement and in the construction of the "Current State Map" (CSM) for the selected product value stream. The CSM must be based on a set of data collected directly on the shop floor and should be drawn using the set of standard icons shown in Figure 1.2.

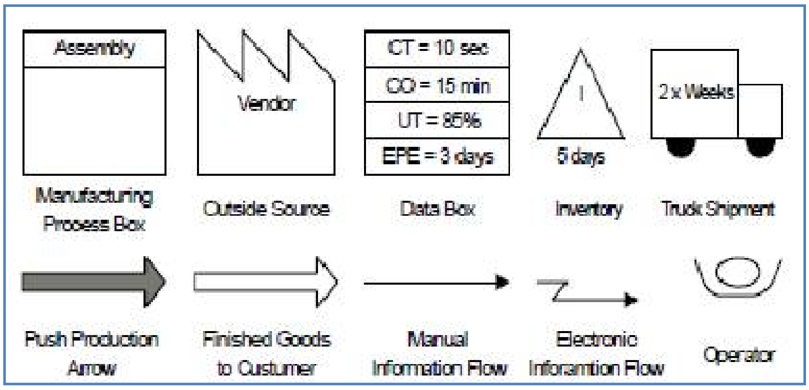

Figure 1.2: Actual State Map Icons

The next step consists in the identification and analysis of the wastes encountered along the value stream. Finally a "Future State Map" (FSM) is design to represent the ideal production process without the removed wastes. Also the FSM should be drawn using a set of standard icons shown in Figure 1.3 and it can be obtained answering eight questions reported in Table 1.4 (Lian and Van Landeghem, 2002).

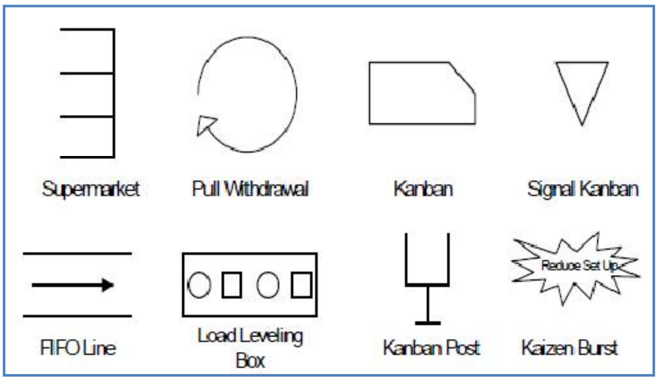

Figure 1.3: Future State MapIcons

Future State Questions	
Basic Questions	1. What is the takt time? Will production produce to finished goods supermarket or directly to shipping? 2. Where can continuous flow processing be utilized? 3. Is there a need for a supermarket pull system within the value stream (kanban – con wip) ? 4. What single point in the production chain will be used to schedule production ?
Heijunka Questions (Production leveling)	5. How will the production be leveled at the pacemaker process ? 6. What increment of work will be consistently released from the pacemaker process (pitch) ?
Kaizen Questions (Improvment)	7. What process improvements will be needed?

Table 1.4: Design Question for Future State Map

In respect to other mapping techniques, VSM offers several advantages:

- it forms the basis for Lean Production implementation;
- it relates the manufacturing process internal to the facility to the whole Supply Chain;
- it displays both the product flow and the information flow;
- it links “Products Planning” and “Demand Forecast” to “Production Scheduling” and to “Flow Shop Control”;
- it includes information related to production time as well as information related to inventory levels.

Unfortunately VSM has also two main drawbacks:

- basically it is a paper and pencil based technique, thus the accuracy level is limited and the number of versions that can be handled is low;
- in real settings, many companies are of a “high variety-low volume type”, meaning that many value streams are composed of hundreds of industrial parts and products.

Thus this complication cannot be addressed with the standard method. In particular VSM can be effectively used only for productive systems characterized by linear product routings. If the production process is complex, the VSM application breaks down as it fails to map value streams characterized by multiple flows that merge. This typically happens for products described by a complex Bill of Material (BOM), manufactured in a job shop facility. In such cases Rother and Shook (1999) suggested to map only the key elements of the flow and to “draw one flow over another” if necessary. Still no decisional process is proposed to choose the key elements of the value stream. Furthermore, identifying which flows are identical or even similar, is not a trivial activity for anyone, but the easiest of the real production process. In technical literature these problems have been firstly addressed in three different works. McDonald et al (2002) applied VSM to a “three parallel lines assembly process” using discrete event simulation to define the basic parameters for the FSM. They demonstrated that, in case of production complexity, simulation can provide important information for the FSM implementation. Lyan and Van Landeghem (2002), followed a similar approach to map a “two parallel line” push system. Two simulation models were built for the push and pull systems. Two simulation models were built for the push and pull systems respectively and the key measurements such as lead times, throughput rates, value added ratios were compared as well as evaluated. Khaswala and Irani (2004) improved a welding job shop facility by aim of a new mapping approach called “Value Network Mapping”. This technique was derived from an integration of PFAST (Production Flow Analysis and Simplification Toolkit) and VSM (Irani and Zhou, 2003). It was proved that this approach supports facility improvements, such as the creation of manufacturing cells and improvements in the current material handling methods. Braglia et al. (2006) proposed an alternative and innovative framework for a structured application of VSM to products requiring non-linear value streams. The framework is based on a recursive procedure and integrates the classic VSM technique with different tools derived from the manufacturing engineering area. The underlying idea among the method was to execute a preliminary analysis to identify the longer critical production path by aim of the Temporized Bill of Material (TBOM). Clearly the improvement process will start from the critical path that is responsible for the whole Lead Time of the productive process. Once the critical path has been identified, possible improvements are searched, considering all sharing with secondary paths as further constraints. Finally, when the main value stream has been improved, a new path may become the critical one. Thus the analysis proceeds iteratively until the optimum is reached or the Work in Process (WIP) level has decreased under the desired level. In that way the framework makes it possible to explore the overall production process determining the correct order of the path to be improved.

1.4.5 5-Why Method

The 5-Why method helps to determine the cause-effect relationships in a problem or a failure event. It can be used whenever the real cause of a problem or situation is not clear. Using the 5-Whys is a simple way to try solving a stated problem without a large detailed investigation requiring many resources. When problems involve human factors this method is the least stressful on participants. It is one of the simplest investigation tools easily completed without statistical analysis. Also known as a Why-Tree, it is supposedly a simple form of root cause analysis. By repeatedly asking the question, 'Why?' Most obvious explanations have yet more underlying problems. But it is never certain that you have found the root cause unless there is real evidence to confirm it**.** You start with a statement of the situation and ask why it occurred. You then turn the answer to the first question into a second "Why" question. The next answer becomes the third "Why" question and so on. By refusing to be satisfied with each answer you increase the odds of finding the underlying root cause of the event. Though this technique is called '5-Whys', five is a rule of thumb. You may ask more or less Whys before finding the root of a problem (there is a school of thought that 7 'whys' is better; that 5 'whys' is not enough to uncover the real latent truth that initiated the event).Implied in the Five "Whys" root cause analysis tool, though not often stated openly, is the use of a cause and effect tree - known as a Why Tree. The method is also called Fault Tree Analysis. It is best to build the Why Tree first so that the interactions of causes can be seen. Sometimes only one cause sets off an event, other times multiple causes are necessary to produce an effect. The Why Tree for even a simple problem can grow huge, with numerous cause-effect branches. The 5-Why method uses a Why Table to sequential list the questions and their answers.

1.4.6 SMED (Single-Minute Exchange of Dies) Method

SMED (Single-Minute Exchange of Dies) is a system for dramatically reducing the time it takes to complete equipment changeovers. The essence of the SMED system is to convert as many changeover steps as possible to "external" (performed while the equipment is running), and to simplify and streamline the remaining steps. The name Single-Minute Exchange of Dies comes from the goal of reducing changeover times to the "single" digits (i.e. less than 10 minutes).

A successful SMED program will have the following benefits:

- Lower manufacturing cost (faster changeovers mean less equipment down time);
- Smaller lot sizes (faster changeovers enable more frequent product changes);
- Improved responsiveness to customer demand (smaller lot sizes enable more flexible scheduling);
- Lower inventory levels (smaller lot sizes result in lower inventory levels);
- Smoother startups (standardized changeover processes improve consistency and quality).

In SMED, changeovers are made up of steps that are termed "elements". There are two types of elements:

- Internal Elements (elements that must be completed while the equipment is stopped);
- External Elements (elements that can be completed while the equipment is running).

The SMED process focuses on making as many elements as possible external, and simplifying and streamlining all elements. Virtually every manufacturing company that performs changeovers can benefit from SMED. That does not mean, however, that SMED should be the first priority. In the real world, companies have finite resources, and those resources should be directed to where they will generate the best return. For most companies, the first priority should be ensuring that there is a clear understanding of where productive time is being lost, and that decisions on improvement initiatives are made based on hard data. That means putting a system in place to collect and analyze manufacturing performance data. The de facto standard for manufacturing performance data is measuring OEE (Overall Equipment Effectiveness) with an additional breakdown of OEE loss categories into the Six Big Losses and a detailed breakdown of OEE Availability losses into Down Time Reason Codes (including codes for tracking changeover time). Once a system for measuring manufacturing performance is in place collect data for at least two weeks to gain a clear picture of where productive time is being lost. If changeovers represent a significant percentage of lost productive time (e.g. at least 20%) consider proceeding with a SMED program. Otherwise, consider first focusing on a TPM (Total Productive Maintenance) program. Following is described a step-by-step roadmap for a simple and practical SMED implementation.

Step One – Identify Pilot Area:

In this step, the target area for the pilot SMED program is selected. The ideal equipment will have the following characteristics:

- The changeover is long enough to have significant room for improvement, but not too long as to be overwhelming in scope (e.g. a one hour changeover presents a good balance).
- There is large variation in changeover times (e.g. changeover times range from one to three hours).
- There are multiple opportunities to perform the changeover each week (so proposed improvements can be quickly tested).
- Employees familiar with the equipment (operators, maintenance personnel, quality assurance, and supervisors) are engaged and motivated.
- The equipment is a constraint/bottleneck – thus improvements will bring immediate benefits. If constraint equipment is selected, minimize the potential risk by building temporary stock and otherwise ensuring that unanticipated down time can be tolerated.

In order to create a wide base of support for the SMED project, include the full spectrum of associated employees in the selection process, and work hard to create a consensus within the team as to the target equipment choice. Once the target equipment has been selected, record a baseline time for the changeover. Changeover time should be measured as the time between production of the last good part (at full speed) and production of the first good part (at full speed). Be cognizant of the “Hawthorne Effect”; changeover times may temporarily improve as a simple result of observing the process. When possible, use prior data to baseline the changeover time.

Step Two – Identify Elements:

In this step, the team works together to identify all of the elements of the changeover. The most effective way of doing this is to videotape the entire changeover and then work from the videotape to create an ordered list of elements, each of which includes:

- Description (what work is performed);
- Cost in Time (how long the element takes to complete).

Some useful tips for this step:

- A typical changeover will result in 30 to 50 elements being documented;
- A fast method of capturing elements is to create a series of post-it notes that are stuck to a wall in the order in which they are performed during the changeover;
- Be sure to capture both “human” elements (elements where the operator is doing something) and “equipment” elements (elements where the equipment is doing something). As discussed later, the human elements are usually easiest to optimize;
- While videotaping the changeover have several observers taking notes. Sometimes the observers will notice things that are missed on the videotape;
- Only observe – let the changeover take its normal course.

The deliverable from this step should be a complete list of changeover elements, each with a description and a time “cost”.

Step Three – Separate External Elements

In this step, elements of the changeover process, that can be performed with little or no change while the equipment is running, are identified and moved “external” to the changeover (i.e. performed before or after the changeover). It is not unusual for changeover times to be cut nearly in half with this step alone. For each element the team should ask the following question: can this element, as currently performed or with minimal change, be completed while the equipment is running? If the answer is yes, categorize the element as external and move it before or after the changeover, as appropriate.

Examples of candidate elements for such treatment include:

- Retrieval of parts, tools, materials, and/or instructions.
- Inspection of parts, tools, and/or materials.
- Cleaning tasks that can be performed while the process is running.
- Quality checks for the last production run.

The deliverable from this step should be an updated list of changeover elements, split into three parts: External Elements (Before Changeover), Internal Elements (During Changeover), and External Elements (After Changeover).

Step Four – Convert Internal Elements to External

In this step, the current changeover process is carefully examined, with the goal of converting as many internal elements to external as possible. For each internal element, the team should ask the following questions: if there was a way to make this element external, what would it be? How could we do it?This will result in a list of elements that are candidates for further action. This list should be prioritized so the most promising candidates are acted on first. Fundamentally, this comes down to performing a cost/benefit analysis for each candidate element:

- Cost as measured by the materials and labor needed to make the necessary changes.
- Benefit as measured by the time that will be eliminated from the changeover.

Once the list has been prioritized work can begin on making the necessary changes.Examples of techniques that can be used to convert internal elements to external are:

- Prepare parts in advance (e.g. preheat dies in advance of the changeover);
- Use duplicate jigs (e.g. perform alignment and other adjustments in advance of the changeover);
- Modularize equipment (e.g. replace a printer instead of adjusting the print head so the printer can be configured for a new part number in advance of the changeover);
- Modify equipment (e.g. add guarding to enable safe cleaning while the process is running).

The deliverable from this step should be an updated list of changeover elements, with fewer internal elements, and additional external elements (performed before or after the changeover).

Step Five – Streamline Remaining Elements

In this step, the remaining elements are reviewed with an eye towards streamlining and simplifying, so they can be completed in less time. First priority should be given to internal elements to support the primary goal of shortening the changeover time. For each element, the team should ask the following questions: how can this element be completed in less time? How can we simplify this element? As in the previous step, a simple cost/benefit analysis should be used to prioritize action on elements.

- Eliminate bolts (e.g. use quick release mechanisms or other types of functional clamps)
- Eliminate adjustments (e.g. use standardized numerical settings; convert adjustments to multiple fixed settings; use visible centerlines; use shims to standardize die size)
- Eliminate motion (e.g. organize the work space)
- Eliminate waiting (e.g. make first article inspection a high priority for QA)
- Standardize hardware (e.g. so fewer tools are needed)
- Create parallel operations (e.g. note that with multiple operators working on the same equipment close attention must be paid to potential safety issues)
- Mechanize (normally this is considered a last resort)

The deliverable from this step should be a set of updated work instructions for the changeover (i.e. creating standardized work) and a significantly faster changeover time.

When implementing SMED is helpful to recognize that there are two broad categories of improvement: Human (achieved through preparation and organization); Technical (achieved through engineering). Experience has taught that the human elements are typically much faster and less expensive to improve than the technical elements. In other words, the quick wins are usually with the human elements. It is appropriate to avoid the temptation, especially with technically proficient teams, of over-focus on technical elements. Instead, focus first on the human elements.

1.4.7 OEE (Overall Equipment Effectiveness)Method

OEE (Overall Equipment Effectiveness) is a “best practices” metric that identifies the percentage of planned production time that is truly productive. An OEE score of 100% represents perfect production: manufacturing only good parts, as fast as possible, with no down time.OEE is useful as both a benchmark and a baseline:

- As a benchmark it can be used to compare the performance of a given production asset to industry standards, to similar in-house assets, or to results for different shifts working on the same asset.
- As a baseline it can be used to track progress over time in eliminating waste from a given production asset.

As a benchmark, are considered following OEE scores:

- An OEE score of 100% is perfect production: manufacturing only good parts, as fast as possible, with no down time.
- An OEE score of 85% is considered world class for discrete manufacturers. For many companies, it is a suitable long-term goal.
- An OEE score of 60% is fairly typical for discrete manufacturers, but indicates there is substantial room for improvement.
- An OEE score of 40% is not at all uncommon for manufacturing companies that are just starting to track and improve their manufacturing performance. It is a low score and in most cases can be easily improved through straightforward measures (e.g. by tracking down time reasons and addressing the largest sources of down time – one at a time).

OEE is the ratio of Fully Productive Time to Planned Production Time. In practice this is calculated as:

(Good Pieces x Ideal Cycle Time) / Planned Production Time

Let's define some terms:

- Good Pieces (pieces that are manufactured without any defects)
- Ideal Cycle Time (the theoretical fastest possible time to manufacture one piece)
- Planned Production Time (the total time that the production asset is scheduled for production)
- Fully Productive Time (producing only good pieces, as fast as possible, with no down time)

The preferred way to calculate OEE is mathematically equivalent to the simple formula described above, but it provides a much richer understanding of waste in the manufacturing process by breaking it down into three measurable categories: **Availability**, **Performance**, **Quality**.

Availability takes into account Down Time Loss, which includes all events that stop planned production for an appreciable length of time (typically several minutes or longer). It is calculated as the ratio of Operating Time to Planned Production Time, where Operating Time is simply Planned Production Time less Down Time:

Operating Time / Planned Production Time

Performance takes into account Speed Loss, which includes all factors that cause the production asset to operate at less than the maximum possible speed when running. It is calculated as the ratio of Net Operating Time to Operating Time. In practice, it is calculated as:

(Ideal Cycle Time x Total Pieces) / Operating Time

Ideal Cycle Time is the theoretical fastest possible time to manufacture one piece. Therefore, when it is multiplied by Total Pieces the result is Net Operating Time – the theoretical fastest possible time to manufacture the total quantity of pieces.

Quality takes into account Quality Loss, which factors out manufactured pieces that do not meet quality standards, including pieces that require rework. It is calculated as the ratio of Fully Productive Time (fastest possible time for Good Pieces) to Net Operating Time (fastest possible time for Total Pieces). In practice it is calculated as:

Good Pieces / Total Pieces

OEE takes into account all losses (Down Time Loss, Speed Loss, and Quality Loss), resulting in a measure of truly productive manufacturing time. It is calculated as the ratio of Fully Productive Time to Planned Production Time. In practice, it is calculated as:

Availability x Performance x Quality

If the equations for Availability, Performance, and Quality are substituted in the above equation and then reduced to their simplest terms the result is:

(Good Pieces x Ideal Cycle Time) / Planned Production Time

This is the “simplest” OEE calculation described earlier. It can be seen that multiplying Good Pieces by Ideal Cycle Time results in Fully Productive Time (manufacturing only good parts, as fast as possible, with no down time).OEE is a great tool for managers, but for plant floor employees it can be a bit abstract. Plant floor employees will perform best when they are given goals that are real-time, easily interpreted and highly motivational.

1.4.8 “Hoshin Kanri” Method

Hoshin Kanri (also called Policy Deployment) is a method for ensuring that the strategic goals of a company drive progress and action at every level within that company. This eliminates the waste that comes from inconsistent direction and poor communication. Hoshin Kanri strives to get every employee pulling in the same direction at the same time. It achieves this by aligning the goals of the company (Strategy) with the plans of middle management (Tactics) and the work performed by all employees (Operations).

Hoshin Kanri starts with a strategic plan (e.g. an annual plan) that is developed by top management to further the long range goals of the company. This plan should be carefully crafted to address a small number of critical issues. Key items to consider when developing the strategic plan are:

Focus on Five: Focus on five goals (or less). The mere act of writing down goals can create a (false) feeling of progress – and more goals feels like more progress. In reality, a goal only expresses intent. Taking action is the hard part. Every company has finite resources and energy and a limited attention span. Focusing on a small number of goals makes success far more likely than dissipating energy across dozens of goals.

Effectiveness First :There is a well-known distinction between efficiency and effectiveness: efficiency is doing things right while effectiveness is doing the right things. Strategic goals need to be effective – doing the right things to take the company to the next level. If a goal doesn’t have that kind of broad impact it’s probably not strategic.

Evolution vs. Revolution : Goals can be evolutionary (incremental goals usually achieved through continuous improvement) or revolutionary (breakthrough changes with dramatic scope). Both are legitimate and important forms of improvement.

Top Down Consensus: Top management is responsible for developing the strategic plan – it’s one of their most important responsibilities. But taking the time to consult with middle management serves two useful purposes:

- It provides additional perspective and feedback that helps craft stronger, more informed strategies;
- It creates a sense of shared responsibility for the plan and significantly more buy-in from middle management.

Careful KPIs : Key Performance Indicators (KPIs) provide the means for tracking progress towards goals. They also have a considerable ability to drive behavior. So choose KPIs with care. It is essential to think through whether the selected KPIs will drive the desired behavior without unintended side effects. For example, more than one company has found that a single-minded pursuit of efficiency can lead to unintended consequences such as excess inventory (larger batches means less changeovers) and reduced quality (a subtle “fix it later” pressure creeps in to keep lines running).

Own the Goal :Every goal should have an owner – a facilitator and coach who has the skills and authority to successfully sees the goal through to conclusion.

- As a facilitator, the goal owner will remove roadblocks and smooth the path to progress;
- As a coach, the goal owner will track progress and intercede if things get off track.

At a departmental level, mid-level managers develop tactics that will best achieve the goals as laid out by top management. One of the most important aspects of this process is "a back and forth" exchange with top management to ensure that the strategy and goals are well understood, that there is strong alignment between strategy and tactics, and that the KPIs are meaningful and appropriate. Tactics may change throughout the course of fulfilling the strategy; flexibility and adaptability are important characteristics of the process. As a result it is helpful to have regular progress reviews (e.g. monthly), at which time results are evaluated and tactics are recalibrated. At the plant floor level, supervisors and team leaders work out the operational details to implement the tactics as laid out by mid-level managers. Once again, is necessary to ensure that activities at the plant floor (and other areas of the company) are strongly aligned with tactics and strategy. This is the level where goals and plans are transformed into results. This is "gemba" (the place where real action occurs). Therefore, managers should stay closely connected to activity at this level. So far the steps have focused on cascading strategic goals down through levels of the company; from top management all the way down to the plant floor. Equally important is the flow of information in the other direction – information about progress and results. It is this second flow that creates a closed loop system – enabling control and adjustment of the entire process. Progress should be tracked continuously and reviewed formally on a regular basis (e.g. monthly). These progress checkpoints provide an opportunity for adjustment of tactics and their associated operational details. Hoshin Kanri is not as well-known or "popular" as some of the other lean tools – but it is an extremely valuable tool. Although it fits most naturally within a well-developed lean culture, where continuous improvement is firmly ingrained at all levels of a company, virtually any organization can benefit from its core principles:

- Visionary strategic planning (focusing on the things that really matter);
- Catchball (building workable plans through consensus);
- Measuring progress (carefully selecting KPIs that will drive the desired behavior);
- Closing the loop (using regular follow-up to keep progress on track).

It should be pretty obvious that a flattened management structure is beneficial to Hoshin Kanri. The fewer levels there are, the easier it is to cascade goals down and the fewer opportunities there are for strategy to be diminished through successive layers of translation. Fewer layers also means faster decision making.

1.4.9 3P - Method

3P method is view as one of the most powerful and transformative advanced manufacturing tools, and it is typically only used by organizations that have experience in implementing other lean methods. Whereas kaizen and other lean methods take a production process as a given and seek to make improvements, the Production Preparation Process (3P) focuses on eliminating waste through product and process design. 3P seeks to meet customer requirements by starting with a clean product development slate to rapidly create and test potential product and process designs that require the least time, material, and capital resources. This method typically involves a diverse group of individuals in a multi-day creative process to identify several alternative ways to meet the customer's needs using different product or process designs. 3P typically results in products that are less complex, easier to manufacture (often referred to as "design for manufacturability"), and easier to use and maintain. 3P can also design production processes that eliminate multiple process steps and that utilize homemade, right-sized equipment that better meet production needs. Ultimately, 3P methods represent a dramatic shift from the continuous, incremental improvement of existing processes sought with kaizen events. Instead, 3P offers potential to make "quantum leap" design improvements that can improve performance and eliminate waste to a level beyond that which can be achieved through the continual improvement of existing processes. With 3P, the teams spend several days (with singular focus on the 3P event) working to develop multiple alternatives for each process step and evaluating each alternative against manufacturing criteria (e.g., designated takt time) and a preferred cost. The goal is typically to develop a process or product design that meets customer requirements best in the "least waste way". The typical steps in a 3P event are described below:

- *Define Product or Process Design Objectives/Needs*: The team seeks to understand the core customer needs that need to be met. If a product or product prototype is available, the project team breaks it down into component parts and raw materials to assess the function that each plays.
- *Diagramming*: A fishbone diagram or other type of illustration is created to demonstrate the flow from raw material to finish product. The project team then analyzes each branch of the diagram (or each illustration) and brainstorms key words (e.g., roll, rotate, form, bend) to describe the change (or "transformation") made at each branch.
- *Find and Analyze Examples in Nature*: The project team then tries to find examples of each process keyword in the natural world. For example, forming can be found in nature when a heavy animal such as an elephant walks on mud, or when water pressure shapes rocks in a river. Similar examples are grouped and examples that best exemplify the process key word researched to better understand how

the examples occur in nature. Here, team members place heavy emphasis on how nature works in the example and why. Once the unique qualities of the natural process are dissected, team members then discuss how the natural process can be applied to the given manufacturing process step.

- *Sketch and Evaluate the Process*: Sub-teams are formed and each sub-member is required to draw different ways to accomplish the process in question. Each of the sketches is evaluated and the best is chosen (along with any good features from the sketches that are not chosen) for a mock-up.
- *Build, Present, and Select Process Prototypes*: The team prototypes and then evaluates the chosen process, spending several days (if necessary) working with different variations of the mock-up to ensure it will meet criteria.

- *Hold Design Review*: Once a concept has been selected for additional refinement, it is presented to a larger group (including the original product designers) for feedback.
- *Develop Project Implementation plan*: If the project is selected to proceed, the team selects a project implementation leader who helps determine the schedule, process, resource requirements, and distribution of responsibilities for completion.

Potential Benefits of 3P method can be so summarized:

- 3P has many similarities to Design for Environment methods, in that both focus on eliminating waste at the product and process design stage. These techniques can have a profound impact of environmental quality by avoiding design approaches that produce detrimental environmental impacts. 3P looks to nature for design models, where processes are inherently waste free.
- 3P often results in right-sized equipment that lowers the material and energy requirements for production. Right-sized equipment also takes up less space, reducing the environmental impacts associated with that space (e.g., heating, cooling, lighting, cleaning and maintenance materials, building materials, land use).
- 3P's focus on reducing the complexity of the production process ("design for manufacturability") can eliminate process steps or substitute one process step or another that requires less time, materials, or capital. In many cases, environmentally sensitive processes are targeted for elimination, since they are often time consuming, resource intensive, and capital intensive.
- 3P encourages product designs that are less complex. This often translates into using fewer parts and fewer types of materials. Such designs typically improve the ease of disassembly and recycling for products, characteristics that are encouraged by public environmental agencies.
(from Vaughn et al. 2002)

1.5 Lean Management in the Public Sector

Around the world you want to deliver better education, better health care, better pensions, and better transportation services. But the funds required to meet such expectations are enormous—particularly in the many developed economies where populations are aging and the public sector's productivity hasn't kept pace with that of the private sector. The need to get value for money from governments at all levels is therefore under the spotlight as never before. But cost-cutting programs that seek savings of 1 to 3 percent a year will not be enough and in some cases may even weaken the quality of service.To address the problem, public-sector leaders are looking with growing interest at "lean" techniques long used in private industry. From the repair of military vehicles to the processing of income tax returns, from surgery to urban planning, lean is showing that it can not only improve public services but also transform them for the better. Crucially for the public sector, a lean approach breaks with the prevailing view that there has to be a trade-off between the quality of public services and the cost of providing them.By improving an "operating system"—the configuration of assets, material resources, and staff—a lean approach can cut costs dramatically, typically by 15 to 30 percent. But cost savings are only a part of lean's appeal, as demonstrated by the experience of Toyota Motor, the pioneer of these techniques in the 1950s and the only consistently profitable volume car manufacturer. Lean aims to optimize costs, quality, and customer service constantly. It does so by engaging and equipping employees to focus on creating and delivering value in the eyes of the customer and eliminating whatever doesn't contribute to this goal. Contrary to popular belief, lean is about making a process or operation efficient, not about cutting resources. A lean system is designed to eliminate waste, variability, and inflexibility, though given the variety and complexity of many processes there can be no one-size-fits-all lean template. The needs of customers and the organization's goals and values drive the design. But some important themes and principles of the lean approach do pose specific challenges for public-sector organizations. All activities must be tested to ensure that they add value for the customer. Double-checking to be sure that they do reminds the organization of its purpose and ensures that processes are efficient. A car manufacturer or a retailer that fails to add value finds that its customers go elsewhere. But in government departments and other public organizations, putting customers first may be more difficult. Defining value for customers in the public sector can also be elusive. Costs, quality, and lead times are all important considerations in a lean system, but social value and the equitable provision of services are more difficult to measure. In health care, for example, how can a government balance the desire to give current patients the best possible treatment with the need to deliver care to people still on the waiting list? One way to identify - and then focus on - the customer is to discuss these issues with the staff, ensuring that any improvement effort is framed with the customer very much in mind. Even in processes such as the criminal-justice system, is necessary to reframe and challenge traditional ideas and approaches. The developers of a lean system identify end-to-end processes from a customer's perspective and then design and manage the system to keep information and materials flowing smoothly through those processes. However, public-sector managers sometimes lack the skills, experience, and mind-set to take this approach. As in the private sector, the only way to understand and manage a process is to see how it works. Yet public-sector managers don't always see themselves as supervising or managing an "operation," and it is unusual for a single person to be responsible for an entire process. In addition, top-down targets tend to focus on a single part of the operation, to the detriment of the process as a whole. Compounding these difficulties is the growing propensity of governments to use outsourcing as a cost-cutting measure without always considering the impact of the outsourced service on the overall process flow. For all these reasons, senior executives must learn the details of any process for which they are accountable. In many cases, senior managers and executives are flying blind or, at best, relying on data and reports that fail to capture the complexity of the system and the experience of those working within it. To lead an organization that constantly strives to improve, the chief executive of a hospital, a social-service agency, or a prison must therefore spend at least one day a week on the "shop floor."Applying lean is difficult in the private sector, and more so in the public sector. Successful lean transformations must close the capability gap early in the process, so managers and staff can make the transition to a new way of working. Closing the gap typically involves hiring a few people with lean expertise and experience from outside the public sector to seed the transformation and build new internal capabilities.

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CHAPTER 2: Simulation Models in Healthcare

2.1 Introduction

As companies continue to look for more efficient ways to run their business, improve work flow and increase profits, they increasingly turn to lean manufacturing, which is used by best-in-class operations to improve their processes, achieve their goals and gain a competitive edge. Process simulation has become an increasingly important and integral tool as businesses look for ways to strip nonvalue-adding steps from their processes and maximize human and equipment effectiveness, all parts of lean manufacturing. The beauty of process simulation is that, while it complements and aids in lean manufacturing, it can also stand alone to improve business processes. Process simulation is a technology that allows the analysis of complex systems through statistically valid means. Through a software interface, the user creates a computerized version of a process, otherwise known as a "model." The model construction is a basic flowchart with great additional capabilities. It is the interface a company uses to build a model of its business process. After flowcharting the process, the user inputs information about how the process operates. After the model is built and verified, it can be manipulated to do two critical things: analyze current operations to identify problem areas and test various ideas for improvement. The latest improvements in simulation software have made it an excellent tool for enhancing lean manufacturing, which strives to eliminate eight wastes: overproduction, motion, inventory, waiting, transportation, defects, underutilized people and extra processing. What you get from using Discrete Event Simulation Software during and after a Lean implementation is:

- An accurate prediction of likely cost savings of introducing Lean to your manufacturing process;
- A detailed understanding of exactly how the parameters impact overall performance;
- The ability to test out any number of combinations of parameter values and decide the ones that are best for your implementation;
- Accurate predictions of the speed of response that customers will see;
- A tool for empowering employees by allowing their process improvement ideas to be tested with easy to understand visual and numerical feedback on the idea’s effectiveness;

This research is motivated by the view that manufacturing systems research has not yet provided a complete understanding of Lean management implementation. There is a great deal of writing about how the system should work after the transition from push to pull, but little about the transition process or the associated costs. The primary sources are anecdotal accounts and analytical models that represent only special cases of production control. While these provide some insight, better understanding is needed, especially for managers who are changing production control policies in order to implement Lean manufacturing. Moreover, this research is motivated by my personal experience as a practitioner of Lean principles in real world manufacturing systems. Lean principles are radically different from the way most factories operate day-to-day. As a result, they are often received with a fair amount of suspicion and mistrust. Many Lean case studies focus on the miraculous turnaround of businesses on the brink of disaster. Businesses in such a situation are much more willing to gamble on radical change. The Lean literature has little to offer a reasonably successful, risk-averse manufacturing enterprise seeking to weigh the costs and benefits of implementing Lean practices. This is especially true when considering how transforming the manufacturing system will disrupt normal operations and how much the transformation itself will cost. How much does Lean cost? This is the question that I ask, and I believe simulation of Lean transition is the answer.

2.2 Simulation Model Approach

Simulation modeling is the principal means of exploring production control. Numerous sources describe the use of simulation for predicting performance, comparing alternatives, and optimizing system designs. In many cases, simulation studies have been used to gain insight into the behavior of manufacturing systems under different types of control policies (e.g., different dispatching rules) or to determine the accuracy of analytical models. The behavior of a system as it evolves over time is studied by developing a simulation model. The model naturally takes the input of assumptions and gathered information concerning the operation of the system. The assumptions and information are represented by mathematical, logical and symbolic relationships between the entities or objects of the system. Once the model has been validated and verified, it can be used to investigate a wide variety of ‘what if’ questions about the real world process. Potential changes or disruptions of the system can first be simulated in order to see the effects and impacts on the system’s outcomes. In addition, simulation can be applied in the design phase of a process, before it is actually built. Therefore, simulation can be used as an analysis tool for predicting effects on the system as well as a design tool for predicting the performance of such (Fishman, 2001). The objective of this dissertation is to build simulation models of healthcare systems undergoing changes in management policies, through Lean principles, in order to better understand the mechanisms and improvements of those changes. Simulation is a technique - not a technology - to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner. The diverse applications of simulation in healthcare can be categorized by 11 dimensions (David Gaba, 2004):

- aims and purposes of the simulation activity;
- unit of participation;
- experience level of participants;
- health care domain;
- professional discipline of participants;
- type of knowledge, skill, attitudes, or behaviours addressed;
- the simulated patient's age;
- technology applicable or required;
- site of simulation;
- extent of direct participation;
- method of feedback used.

Simulation is arguably the most commonly used Operational Research technique and it has been widely used in the health care domain, chiefly because of the advantages it has over other techniques in its flexibility, ability to deal with variability and uncertainty, and its use of graphical interfaces to facilitate communication and comprehension by health care professionals. These features have often made simulation the technique of choice in modeling health care systems, which may involve complex biological, organizational and human behavioral processes, and multidisciplinary teams of modelers (e.g. epidemiologists, clinicians, managers, nurses, or health economists). There are two types approach to simulation: discrete event simulation (DES) and system dynamics (SD). Discrete event simulation models systems as networks of queues and activities, where state changes in the system occur at discrete points of time. The objects in the system are distinct individuals, each possessing characteristics that determine what happens to that individual, and the activity durations are sampled for each individual from probability distributions. System dynamics models a system as a series of stocks and flows, in which the state changes are continuous. A system dynamics model considers the entities as a continuous quantity, rather like a fluid, flowing through a system of reservoirs or tanks connected by pipes. The rates of flow are controlled by valves, and so the time spent in each reservoir is modeled by fixing the rates of inflow and outflow. Although the state changes are regarded as continuous, the underlying equations used to solve the model are difference equations (usually solved by numerical integration) which discretise time using a time-slicing approach. System dynamics is essentially deterministic whereas discrete event simulation is stochastic. System dynamics can be used qualitatively and has strong links with the problem structuring approach of causal link or influence diagrams, and so there is a tendency to use system dynamics at a higher, more strategic level in order to gain insight into the interrelations between the different parts of a complex system. Discrete event simulation, on the other hand, has traditionally been used at a more operational or tactical level to answer specific questions; for example, in the healthcare domain, to solve resource allocation problems or to compare and evaluate medical interventions.

2.2.1 Discrete event simulation (DES)

DES is arguably the most widely used OR technique in practice. It is used to model systems that can be viewed as a queuing network. Individual objects (entities) pass through a series of activities, in between which they wait in queues. The rules governing the order in which these activities occur and the conditions for them to take place can be extremely complex. Each individual entity can be given characteristics that determine what happens to that individual in the system. The durations of the activities are usually sampled from probability distribution functions. The modeler has almost unlimited flexibility in the choice of these functions and the logic governing the flow of entities around the system. DES models make frequent use of animation and graphics, and can be made interactive; all these features are very useful for communication with clients.

The models produce a vast range of output, often showing the whole distribution of possible outcomes in addition to summary measures. However each simulation run or iteration only represents one realization of the system (one possible outcome), and highly variable systems require many iterations. Reducing the variance of the simulation results can be extremely important, and the interpretation of results needs care. Model validation is an important issue because of the quantitative nature of the results. DES models have traditionally been applied at a tactical, operational level. They are by definition stochastic in nature and deal with distinct entities, scheduled activities, queues and decision rules. DES models are simulated in unequal time-steps (when "something happens"); the model is almost always simulated, and DES requires large amounts of quantitative, numerical data. The aim of these models is often comparison of scenarios, prediction, or optimizing specified performance criteria.

2.2.2 System Dynamics (DES)

System dynamics (SD) is an analytical modeling methodology that combines two distinct aspects; one qualitative and one quantitative, with the aim of enhancing the understanding of an identified problem and improving comprehension of the structure of the problem and the relationships present between relevant variables. Because of the flexibility of the process, along with its ability to combine both qualitative and quantitative information, SD has been applied in many different fields of study including project management, defense analysis and health care. The qualitative aspect of SD was not initially considered to be a very important part of the approach. However in recent years the benefits of focusing on this aspect have been increasingly appreciated. The initial discussion of the problem being modeled works to identify the elements considered fundamental to the system and those that are likely to generate an influence in the problem situation. SD models are mainly used at a strategic or conceptual level; they are basically deterministic, and they treat simulated objects as a continuous mass. The aim of an SD model is usually to gain an understanding of feedback dynamics and long-term system behavior, does not attempt optimization or point prediction, but it is capable of modeling very large complex systems and can deliver a wealth of qualitative and quantitative output measures. SD is less good at detailed resource allocation problems. Parameter estimation and validation are less of an issue with SD than with DES.

2.3 Simulation-Based Training (SBT) in Healthcare

Healthcare is an inherently multidisciplinary task where the effectiveness of patient care relies on the interaction of individuals from highly diverse backgrounds in terms of expertise, training, and experience. For example, a trauma team may consist of several nurses, allied health professionals, a surgeon, an emergency room doctor, and several specialist physicians. All of these individuals have received extensive training in their respective disciplines, but have generally not received formalized training on how to interact with one another. These heterogeneous teams often function in an environment characterized by high stress, high stakes outcomes, and time pressure. An emphasis on teamwork and team training is a hallmark of high reliability organizations such as those in aviation and nuclear power generation industries. The successes in increasing safety via team training in these industries has been translated into successful interventions with team training components in medical domains as well beginning with anesthesiology, emergency medicine, and others such as the healthcare system at large. Essentially, it has been recognized that individual competence in clinical skills is not enough; team coordination, communication, and cooperation skills are essential to effective and safe performance. The use of simulation based training (CBT) provides unique opportunities to train and assess teamwork skills. As shown in Figure 2.1, SBT is an approach to training that incorporates five phases: information, demonstration, practice, feedback, and remediation. Teamwork is inherently dynamic as it depends on the interactions of team members. Because SBT provides opportunities for teams to engage in dynamic practice in contextualized task environments that replicate aspects of the "real world " task environment, the social dynamics of teamwork can be effectively trained and evaluated.

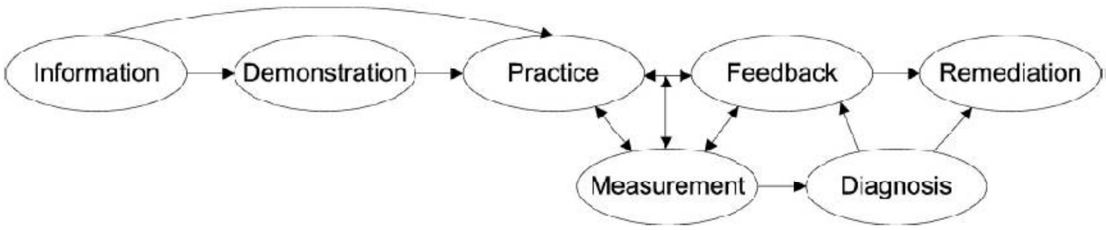

Figure 2.1: The role of measurement and performance diagnosis in SBT (from Salas et al., 2007)

Measurement has been identified as the heart of patient safety, meaning that the healthcare system's ability to improve its processes and create a safer environment, and better patient outcomes must be based upon quality measurement practices. This is particularly true in the context of training where quality measurement practices guide learning and corrective feedback as well as helping to ensure that healthcare operators possess the requisite competencies for effective on the job performance. As illustrated in Figure 2.1, performance measurement plays a central role in SBT. Measuring team performance in complex work environments is difficult in general, and medical teams are no exception. It has been shown recently that many of the performance measures that the Medicare system uses as indicators of quality of care delivery are only weakly related to important clinical outcomes such as mortality rates. Does this mean that the performance measures often used are not sensitive to the aspects that influence patient outcomes. That is, the chosen performance measures do not capture the critical aspects of performance. Clinical outcomes are influenced by many factors, and the performance measures chosen simply do not represent enough of these factors to be useful indicators of quality. This illustrates the danger of using poorly conceived measurement. Deficient measurement begets deficient decisions.

2.3.1 Best practices in SBT

Performance measurement can be viewed as an investment in time, effort, and other resources that pays off in terms of decision quality. For the purposes of training, the two most important decisions a measurement system can address are:

1. what meaningful feedback should be given to the team and each individual member;
2. what further training is required by the team or individual members;

This section presents a set of best practices in the development of team performance measurement systems designed to inform these two decisions. These best practices are summarized in Table 2.1. The goal is to provide heuristics for increasing the quality of decisions made and the action taken based on the results of team performance measures collected in SBT. This will lead to better training outcomes (eg, increased learning) and ultimately better team performance in the clinical setting.

Best practice	**Description**	**Action**
Building measures on the theory	Use theory to answer questions about what to measure	Capture aspects of: Input → Process → Output
Define measures to meet specific learning outcomes	Define the specific learning outcomes of measurement at the beginning of the development process	Design the measurement system to capture information necessary for making decisions about the learning outcomes (eg, have they been met?)
Acquire capability and competencies	Team performance measures should be rooted in the individual and team competencies being trained	Explicitly link performance measures to the individual and team competencies targeted for training
Measure multiple levels of performance	Team performance depends on and is influenced by factors not only occurring at the team level	Performance measures must be sensitive to differences in individual and team performance

	(eg, communication) but by organizational and multi team system factors such as safety culture and individual performance level .	
Link Measures to Scenario Events	Critical events offer team members the opportunity to perform behaviors associated with the competencies targeted for training.	Link performance measures to opportunities to perform (ie, events) in the simulation
Focus on Observable Behaviors	Measuring observable behavior allows to provide corrective feedback	Observers identify discrete behaviors without make judgments about the quality of performance over time or in some general way.
Embed multiple measures from different sources	Different measurement sources provide unique information	Generate a plan for rapidly integrating multiple sources of measurement
Acquire processes performance in addition to outcomes	Team performance measurement should provide information not only about the end result of performance, but about how the team reached that performance outcome	Team performance measurement should provide information on how to correct team processes
Create analysis capability	Team performance measurement should provide information about the causes of effective and ineffective performance	The analysis of a measurement system can be developed by creating rich, detailed, and informative performance profiles.
Train observers and structured observation protocols	Observers focus their attention and increase the reliability of their measurements	Each observer should go through a brief training and possess structured observation protocols
Post-training debrief and facilitate re-training	Team performance measurement for training purposes should provide a basis for generating feedback as well as making decisions about what additional training a team or its individual members needs	Team performance measurement should be quickly translated into feedback and decisions about required future training

Table 2.1: Best practices Simulation-Based Training

These best practices are based upon work in many diverse application domains. Organizations in military and aviation industries tend to employ SBT in a centralized manner, with dedicated simulation centers and the adoption of standardized training practices. Simulation in healthcare differs in this respect with simulation use trending toward distribution throughout the system as opposed to a centralized center. This poses several challenges (eg, access to specialized resources and personnel, the possibility of many people duplicating efforts, etc.); however, it does not change the need to develop quality team performance measurement.

2.4 Potential of simulation in Healthcare

Simulation has a broad application potential in healthcare, which can be classified in a few major directions, formed around different disciplines or sub-disciplines. The following is a more general classification of healthcare simulation (Barjis, 2011):

- *Clinical Simulation*: simulation is mainly used to study, analyse, and replicate the behaviour of certain diseases including biological processes in human body;
- *Operational Simulation*: simulation is mainly used for capturing, analyzing, and studying healthcare operations, service delivery, scheduling, healthcare business processes, and patient flow;

- *Managerial Simulation*: simulation is mainly used as a tool for managerial purposes, decision making, policy implementation, and strategic planning;
- *Educational Simulation*: Simulation is used for training and educational purposes, where virtual environments and virtual and physical objects are extensively used to augment and enrich simulation experiment ;

The above classification is rather a departure point for a more pinpoint taxonomy of topics and only suggests the vast space of simulation applicability in relation to the healthcare domain. In each of the above directions, simulation can be used for analysis and design, learning and training, research and communication purposes. An elaborated classification of healthcare simulation can be found in (Gaba, 2004), in which the author divides the healthcare simulation ‘‘application space’’ into 11 dimensions, each of which represents a different attribute of simulation.

Brailsford (2007) classifies healthcare simulation models into three groups:

- Models of the human body, frequently called “disease models”, including biological processes in healthy individuals.
- Models for tactical purposes at the healthcare unit level (clinic, ward, department, hospital).
- Models for strategic purposes comprising system-wide models which often do not model individual patients at all.

All of these classifications demonstrate just how extensive the application space and potential of healthcare simulation are. However, the current research and practice of healthcare simulation are rather in the development phase compared to engineering fields. The full potential of healthcare simulation has yet to unfold, be explored and demonstrated.

Healthcare decision makers need reliable tools to support them in decision making for adapting policies to help cutting costs or reducing waiting time, and to provide visualization which allows them to rehearse innovative ideas before they are implemented. The tools should facilitate an evidence-based and informed decision making environment. Simulation models, especially with transparency into their structure and underlying variables, which can be easily understood and trusted by decision makers, are a helpful tool in decision support, communication and discussion of ideas and polices, and analysis of scenarios.The complexity of healthcare processes is growing exponentially, with various services like laboratories being outsourced, multiplication of specialties, and extreme mobility of patients resulting from competition in the free market. Modern hospitals are complex systems of distributed subsystems with intricate healthcare processes, human interactions, and inter-organizational workflows. For example, citizens easily can plan a different healthcare service based on less waiting time, prominent quality, or many other factors that lead them beyond their local, regional or even national borders. This makes healthcare processes more interconnected and more complex, and simulation can be a way of tackling such complexity. Thus, the complexity of healthcare systems makes simulation a potential tool for healthcare analysts. Healthcare simulation as a whole is facing a myriad of interesting scientific challenges, which open up a fascinating research domain for simulation researchers and practitioners. The real risk of simulation is in verification and validation, which is a subject of extensive research. Without profound verification and validation, it would be risky, if not disastrous, to make any decisions or forecasts based on the model outcomes. While the model-verification challenge can be relatively easy to overcome if using innovative modeling approaches, model validation, especially for complex models, is quite a challenge. One of the approaches to enhance model verification is an emerging approach of Collaborative, Participative, Interactive Modeling (Barjis, 2009) in which models are designed collaboratively with participation of the users and business-process owners. Validation, however, is quite a different issue. Developing a valid simulation model, designing valid experiments based on the model, and carrying out a rigorous analysis of the experiments’ results pose a significant research challenge.

2.4.1 Literature analysis about the simulation in Healthcare

Discrete Event Simulation (DES) is one of many different tools and methods used in the analysis and improvement of health-care systems. There are many applications of non-simulation techniques, such as heuristic optimization, likewise, there are simulations other than discrete event approaches, such as system dynamics (SD) and agent-based modeling. Occasional references to these other approaches are made in this section, but the main focus is DES modeling of patient flows through hospital facilities. Early reviews include England and Roberts (1978), which examines reports of 92 simulation models, and gives some idea of the long history of simulation. This paper also reviews the other modelling approaches in health care and of the efforts to implement simulation models, despite limited computing power. However, it seems that in the 1960s and 1970s, few studies reported any successful use of models. The authors argue that barriers to implementation include a lack of economic incentives, no vested authority, non-quantifiable data, dehumanizing formulations, and no commitment to follow up. Perhaps the only difference today is that we have very large electronic data sets available. Ten years later, Smith-Daniels et al (1988) takes a broader look at Operational Research applications in health care, including simulation. It argues that, prior to the 1980s, research efforts often failed during the implementation phase because it became impossible to balance the conflicting objectives of physicians, nurses, hospital administrators, boards of directors, and other health-care professionals. However, the authors argue that the growth and establishment of large health-care organizations permit to take decisions regarding capacity and resources are better defined due to the clearer objectives of these large organizations. Although this is a step towards successful implementation of models, it is clearly not enough on its own. Lehaney and Hlupic (1995) come closer to the current era of simple-to-use simulation software tools, though it covers the era immediately prior to their introduction. Computing power was limited in that era, but the review points out the prospective potential of simulation in health care by examining existing literature. Although it is not a review specific to simulation, Flagle (2002) reviews some origins of Operational Research in health care, including simulation. Brennan et al (2006), suggests a taxonomy of model structures for economic evaluation of health technologies and, in so doing, identifies the role of DES in health economics. However, from Fone et al (2003), authors that attempts to model whole hospitals are rare. One possible reason (Günal, 2008) is the difficulty of representing the complexity of hospital activity within a simulation model that must, like all models, be a simplification. Appropriate simplification can be a surprisingly complex process and it may be easier to carve off one part of hospital activity, for example an Accident & Emergency (A&E) department or outpatient clinic, rather than attempting a model with much broader scope. The survey revealed that most of the models are of discrete parts of hospitals, such as emergency rooms, clinics, and operating rooms. Furthermore, Robinson et al. (2012) made analysis from a theoretical and an empirical perspective about the potential complementary roles of DES and lean in healthcare. These roles are demonstrated through three examples of DES in action with lean. The work demonstrates how the fusion of DES with lean can improve both stakeholder engagement with DES and the impact of lean. Forsberg et al. (2011) proposed steps essential for the success of simulation projects, not just in the computer, but also in clinical reality, presenting a novel concept combining simulation modeling with the established plan-do-study-act cycle for improvement. Khurma et al. (2008) base their survey on overcrowding of the Emergency Departments (EDs) in Canadian hospitals, leading to the medical personnel overload, and the excessive waiting times to receive proper care. These adverse effects directly impact the patient satisfaction levels, the ability of the medical professionals to attend promptly to patients' health issues, and generate unnecessary costs. A combination of Lean tools were used to analyze, assess and improve the current situation. Simulation models based on current and future (desired) states were developed. Comparative analysis of both enabled verification of feasibility of proposed solutions, and provided quantifiable results. Sergey et al. (2011) focus their research on workforce staffing problems over varying horizons time. First, they demonstrate that simulation model can support real-time control, which enables short-term prediction and operational planning (physician and nurse staffing) for several hours or days ahead. Then they present a new simulation-based technique that implements the concept of offered-load and discover that it performs better than a common alternative. Finally there is evaluation ED staff scheduling that adjusts for midterm changes (tactical horizon, several weeks or months ahead).

2.4.2 Specific healthcare applications

- *Accident & Emergency units*

Accident & Emergency units seem the most popular area for simulation modelling in health care, which may not be surprising, as they are relatively self-contained and have easily observable processes that cover relatively short time periods of a few hours. It may also be true that improvements in performance are easier to demonstrate and link to specific actions, which may not be true elsewhere in health care. Hence, reports of A&E simulations easily outnumber models of other hospital units. Ferrin et al (2007) demonstrates a DES model (EDSim) that is used to develop processes for increasing throughput in an emergency department (ED) in the USA as part of a system that permitted the diversion of ambulances in peak demand periods, which had financial implications for the client ED. Their investigations included the introduction of discharge lounges, shortening the length of stay (LoS), and bypassing triage. EDSim is intended as reusable software for use by their company that specializes in the analysis and improvement of A&Es. Miller et al (2006) also discusses the use of EDSim, but with a special focus on data collection using Radio Frequency Identification (RFID) tags. These tags are electronic devices, which can be attached to entities such as patients and doctors to periodically report their locations to a server computer, thus enabling automated data collection. Interestingly, they report that using RFID tags in this way, though seemingly attractive, offers no significant cost:benefits over data collected using expert opinion. Difficulties faced by the project team included patients removing tags and the cost of lost tags. There are many other examples of A&E models that are built for specific hospitals and in great detail such as Duguay and Chetouane (2007) and Takakuwa and Shiozaki (2004). In these two studies, physical layouts of the emergency departments, very detailed care processes, staff shifts, diagnosis and expertise-based service times, bed ready times, and test results transfer times are all included in the models. Though these models incorporate much detail, the use of these models is very limited for example, solving waiting time issues in a specific treatment room or a specific type of patient.

- *Inpatient facilities*

Modelling inpatient care has been also an active research area for many years. DES is used for many purposes in this field, though mainly for testing mathematical models developed. Patient flows to hospital beds, bed occupancy, and LoS are common goals. For example, Millard (1994) uses compartmental modelling approaches to model bed occupancy. The methodology does not include the explicit use of DES, however in some papers Millard and others use DES to demonstrate how their mathematical models might be used in real life. Proudlove et al (2007) suggests that, in health-care modelling, a combination of simplicity and supportive presentation is more important than aiming at a complex and detailed representation when trying to support people to develop their thinking. They illustrate the argument with two examples in which simple Excel-based bed simulation models were built for clients and conclude that providing simple tools can help local system owners make sense of their systems. Bagust et al (1999) is an influential paper that reports a simulation of inpatient beds for emergency admissions using Excel spreadsheets, concluding that the risk of a hospital bed shortage is low when mean bed occupancy remains under 85%. This simple yet effective model demonstrates that bed crises occur not necessarily because of poor management but because of the nature of stochastic arrivals. Harper and Shahani (2002), which presents a flexible but very detailed simulation model that is used for investigating operational level inpatient-related questions. This model uses the TOCHSIM simulation executive and is written in the Delphi programming language. It is used in a number of hospitals and, being detailed, requires substantial user inputs.

- *Outpatient clinics*

It is not surprising that outpatient clinics are also commonly modelled using DES as they have some common characteristics with A&Es. However, outpatients do have some important differences from A&E departments and the focus tends to be on scheduling and capacity planning, as in Levy et al (1989), Hashimoto and Bell (1996), Guo et al (2004). However most of the studies in the literature mainly focus on 'micro' waiting in outpatient clinics; that is the waiting time when patients arrive in the clinic and wait till doctors call them for treatment. The delay is generally in a matter of minutes. What is more significant for patients is that the delay between patients' need for specialist treatment (referral date) and actual date of treatment (outpatient clinic date). This type of delay is 'macro' level compared to inpatient waiting. There are many other examples of outpatient clinic models that are built for specific hospitals and for specific specialties including Wijewickrama and Takakuwa (2005) and Takakuwa and Katagiri (2007). These two specific models are very detailed simulations of outpatient clinics in a large hospital and incorporate layouts of four floors of the hospital and include all possible patient pathways, service times, and all human resources.

- *Other hospital units*

The literature has also many examples of DES models of other hospital units not mentioned above, including simulation models of intensive care units, laboratories, operating theatres, surgical suites, pharmacies, and screening units. Especially popular units studied are operating rooms and critical care units. Among the many other examples of unit-specific simulation models is Blake et al (1995), which began as an attempt at a generic whole hospital model, started by building a surgical unit, intending to extend its use to other units. They rejected the concept of building a completely general model of a surgical unit. Instead, they chose building a base model (Operating Room Scheduling Simulation) as part of the decision support tool they built and tailor it for other sites. However, even building the base model took 6 months and 3–4 months to customize it for each site. The model is actually a 'trace driven' model that is patient arrivals and service events are generated directly from historical data of the hospital.

- *Whole hospital simulations*

It is impossible and impractical to have a whole hospital DES model that includes everything in a hospital: all models are simplifications (Pidd, 2003). An appropriate level of abstraction and scope must be chosen when attempting whole hospital simulation. The literature has very few examples of such studies. Surprisingly, though, Fetter and Thompson (1965) is a very early example of DES that reports a whole hospital simulation, with a special interest in maternity processes. The aim of this work was to give a decision support tool to hospital administrations to predict the consequences of design changes and alternative policies. They created three models of hospital subsystems:

1. maternity suite;
2. a surgical pavilion;
3. outpatient clinic

The maternity model was used to analyse patient load and bed occupancy. The surgical pavilion model is, apparently, simple to support experiments with surgical schedules. Unscheduled surgeries have priorities and are generated according to a probability distribution. The last model is an outpatient clinic model. It starts from the schedule of the doctors and can generate detailed reports showing waiting times of patients, idle times of doctors, etc. The models were independent of each other. Cochran and Bharti (2006) reports a study in which the objective was to balance bed unit utilizations in a 400-bed hospital. After starting with a queuing network approach, they decided to use DES to cope with the complexity of hospital operations. However this model does not extend its use to the pre-admission phases, and is limited to bed-related operations. Van der Meer et al (2005), on the other hand, covers the phases an elective patient passes through, though only for a single specialty, orthopaedics. The objective in this study was to reduce elective patients' waiting times. Although their model is very detailed and specific to the hospital studied, the use of DES is suggested as a good communication tool between the stakeholders and modellers, as also suggested by Eldabi and Paul (2001), and Baldwin et al (2004). Brailsford et al (2004) reports a study of the use of SD to model emergency and on-demand health care in Nottingham, UK. The paper includes a representation of patient flows through different departments in a hospital. The model covers the whole health system from NHS Direct to outpatient clinics and A&E departments. A supplementary DES model was also built for an A&E department. The benefits derived from the various applications of simulation may be direct, stemming from immediately discernable improved performance of individuals and teams. This might result in efficiencies in care and reduced errors that more than offset the costs of simulation based training. Many benefits probably depend on long term cumulative synergies. Long term benefits may be apparent only if simulation is applied consistently over a long period of time (which is probably the case in aviation). The current system of education, training, and maintenance of proficiency has itself never been tested rigorously to determine whether it achieves its stated goals.

2.5 Strategic impact of simulation in Healthcare

Modeling is a powerful tool for engaging healthcare personnel across the care pathway in service redesign exercises, involving everyone on the need for change and acceptance of new service models or ways of working. It enables a highly collaborative approach to resolving complex challenges, bringing all stakeholders together in pursuit of a joint endeavor. This can be particularly relevant in the context of the dialogue between commissioners and providers, where systems modeling can provide an important input and evidence base for discussion and policy support. The modeling and simulation review process is also increasingly proving an ideal platform for involving service users, who bring a unique perspective and expertise to the table. Involving service users makes it possible for clinicians and operations managers to realistically map patient experience; for example, gaining insights on where disconnects between departments or services occur or a better understanding of patient expectations and likely behaviors in terms of how they will use a service. It can also enable meaningful consultation with patient groups, providing powerful evidence that can help to leverage acceptance in relation to changes to long standing services, or the closure and relocation of resources such as wards, clinics or hospitals. Simulation, modeling and systems thinking is increasingly pushing forward national and regional healthcare strategies and helping to transform the quality and cost of care delivery. Today's modelling and simulation techniques are also being brought to bear on a wide range of operational challenges. These include using queuing theory to allocate and share scarce specialist mental health assessment slots between teams; applying modelling techniques to predict ambulance response times and plan rosters; and using scenario planning to allocate capacity between medical, surgical and cardiac beds on 'service lines' in paediatric intensive care. Techniques such as discrete event simulation can build in uncertainties (such as patient preferences and future demand) and variability (such as patient and clinician behaviours) together with a more sophisticated understanding of interactions (using network analysis, for example). This means modelling is able to predict more accurately how services might be used and how savings could be made.

2.6 Examples of simulation in Healthcare

A first example regards a larger study known as the Emergency Care On Demand (ECOD) , focused on the at the time increasing pressure on emergency medical service use and consequent increasing number of hospital admissions. This was having a detrimental effect on, amongst other things, the waiting times for treatment amongst those attending, difficulty in managing hospital wards at greater than expected capacity, and frequent cancellations of routine admissions for surgery. The project posed four main research questions, based around identifying the current configuration of the system, more precisely defining the present level of demand, how the system could be developed, and to what extent community preferences were driving use of Accident and Emergency (A&E). Before any modeling was undertaken, a conceptual map of the system was drawn up, which was elaborated on in a series of interviews with healthcare staff and patient representatives. The final process map was used as the basis for the system model. Based on the initial conceptual map, the project created a System Dynamics (SD) model which represented the essential elements of the emergency medical services. This choice centred on the need to model large numbers of patients, the importance of studying feedback effects, and the fact that precise estimates of KPIs (Key Performance Indicators) were less important than overall trends. Projections from the model suggested that if emergency admissions continued to rise at the rates experienced, average bed occupancy levels would be unmanageably high within two to three years. The most promising intervention was found to be the diversion of selected elderly patients to specialist investigation centres. The model was used to investigate patient flows and bottlenecks and as a tool for provoking and facilitating discussion. The steering group for ECOD used the model to test and evaluate different scenarios of care. However, the primary use of the model was for promoting greater understanding of the dynamics of the system rather than in generating numerical outputs. The essentially generic framework adopted and the model's use of routinely collected data means that this approach can readily be adapted elsewhere (Brailsford S, et al., 2004). In figure 2.2. is shown a screenshot from the Systems Dynamic model In figure 2.2. is shown a screenshot from the Systems Dynamic model.

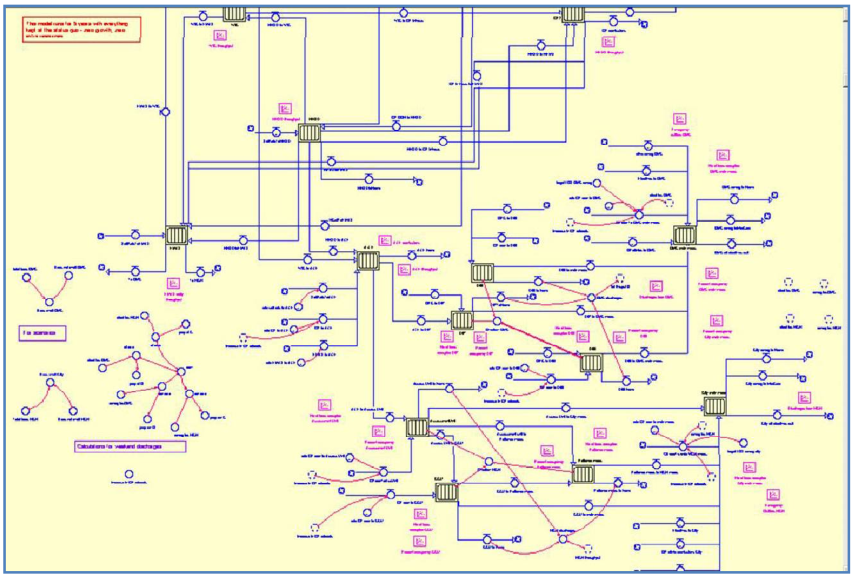

Figure 2.2: Screen shot from the Systems Dynamic model

The value of modelling has also had an impact on the shaping of healthcare policy: for example, using a simulation model to test the consequences of charging hospitals for late discharges revealed that this would actually result in late discharge volumes growing. The findings led to a major rework of national policy.
A example of discrete event simulation can be used to model patient pathways, demonstrating dramatic improvements in care through modelling alternative scenarios leading to implemented changes in service delivery. Thrombolysis with the clot-busting drug alteplase is currently the only licensed treatment worldwide for acute ischemic stroke. The benefit is critically dependent on time from stroke onset to treatment with an exponential decay in the odds of a favourable outcome from one 90-minute interval to the next up to 4.5 hours. It is therefore crucial to minimise in-hospital treatment delays. Computer simulation and quantitative analysis was used to evaluate proposed changes prior to any implementation. A key benefit of this model was a visualisation of patient pathways which provided a basis for communication and helped bridge barriers between different departments within hospitals. It allowed clinicians from the A&E department, the acute stroke unit and the South West Ambulance Trust to work together and identify optimal changes to the stroke pathway ahead of any changes to the real process. The pathway was modelled as it operated at the start of the study. A number of potential changes to the pathway were then evaluated using the model and compared against each other. The benefit was quantified in terms of treatment speed and used published research to convert these figures to additional patients with no disability post stroke.
The study recommended two changes that carried little to no cost for the pilot hospital:

- Paramedics now ring a dedicated acute stroke phone number to alert clinicians to the imminent arrival of potential stroke patients. This allows emergency resources to be in place as the patient arrives to the emergency department.
- Triage nurses now share information with the Stroke Unit to facilitate patient management. The latest quarter figures (see figure 2.3) from the Royal Devon and Exeter NHS Foundation Trust show that since study commencement in 2011 door to treatment times have fallen from 100 to 50 minutes on average and an increase in treatment rates from 4% to 16%. In real terms this equates to 100 strokes receiving treatment per year compared to 25 at study commencement in 2011.
  (**Exeter Impact Award, Winner 2013**)

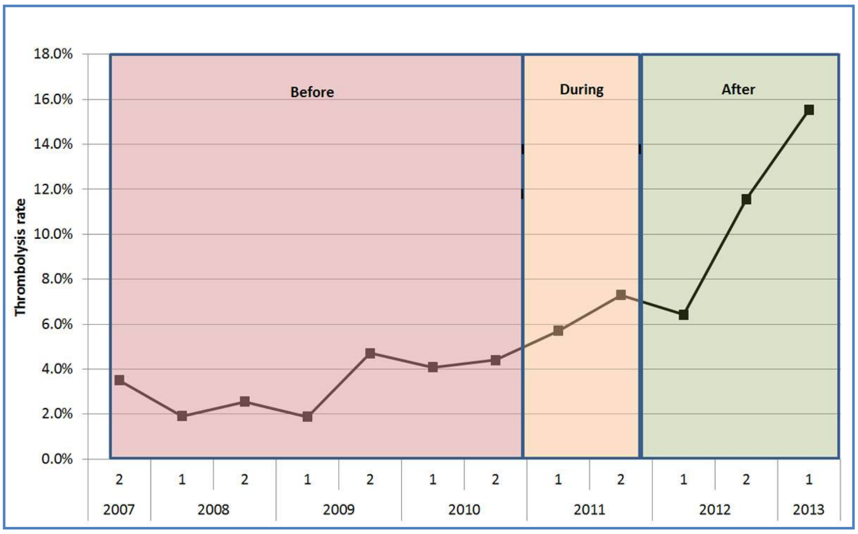

Figure 2.3: Graph showing impact on rate of Thrombolysis resulting from project

2.7 Future of the simulation in Healthcare

From 2004 onwards, there has been a steady progress of simulation in Healthcare. The Society for Medical Simulation (SMS) in the USA and the Society in Europe for Simulation Applied to Medicine (SESAM) provided technical and political leadership for the simulation community. Individual schools, training programs, and hospitals (not all) adopted systematic simulation training for certain domains and disciplines. Typical targets were students and trainees (for example residents), although continuing education for experienced personnel caught on, and hospitals began to train specific work units. A variety of organizations around the world began to promulgate the use of simulators. In some cases there were advantages of the specific applications of particular types of simulation; However, in many other cases, institutions and organizations have acted with caution, given the difficulty to conduct definitive studies of their success, but motivated by the continuing dissatisfaction of traditional approaches. The long term cumulative effects of the application of simulation would yield important synergisms over long periods of time. In some cases, physicians, nurses, and health personnel were trained together in the classroom, through frequent and diverse simulations, by concluding clinical training ‘‘on the wards.’’ The experience with those who adopted simulation early convinced those waiting for further information. There are a number of reasons why modelling and simulation approaches are becoming an essential tool for healthcare leaders to address key strategic and operational healthcare delivery challenges at a regional and local level:

- More opportunities for collaborative working between modellers and healthcare leaders through local resources and research funding
- The growing availability of modelling and simulation resources that can be applied without the need to build a model from scratch
- Efforts to build local capacity to engage with these tools produce regional champions and spread expertise within the system Healthcare leaders are looking to harness the huge increase in data within their organisations and apply the added value of modelling and simulation to data analytics to understand:
- what’s happened
- what could happen
- what’s best

An important message for healthcare professionals is that these are tools that you can use.
Ownership of the models and the experience of their development is often as important as the finished models. Put simply, the ‘modelling’ is often at least as important as the ‘model’ itself. It is critical therefore that healthcare staff are engaged in the process of modelling. This highlights the importance of capability and capacity building within the health service to understand and take full advantage of modelling and simulation techniques. Is need activate a range of initiatives focused on providing resources to support skills development for healthcare staff to raise awareness, build ‘in-house’ skills, and promote more projects in this area.

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http://www.exeter.ac.uk/impactawards/winners2013/ Project: Optimising emergency stroke treatment to reduce disability)

3.1 Private Healthcare Facility

The private healthcare facility that has been investigated in this research work is located in the South of Italy, accredited to the National Health Service since 1980. In its actual configuration it has 4 fully functional units, namely urology, gynecology, ophthalmology and surgery. Moreover, one day surgery services (that do not require overnight hospitalization or maximum one night hospital stay) and outpatient cares (i.e. echocardiography, echocolordoppler, computed axial tomography, blood analysis, etc.) are provided. In terms of size, the hospital can be categorized as a medium-size hospital with 78 beds that are allocated as follows:

- gynecology 10 beds;
- ophthalmology 13 beds;
- urology 30 beds;
- surgery 30 beds;
- 6 beds for day hospital.

As an example the layout of the ophthalmology department is shown in figure 3.1.
For each unit the staff consists of:

- A Head Physician responsible for the operative unit as well as for the patients’ clinical pathway.
- A Senior Physician that can replace the Head Physician in his absence taking on his tasks and responsibilities. Additional Senior Physician’s tasks include filling out patients’ case histories along the whole clinical pathway.
- Three Medical Assistants that cooperate with the Head and the Senior Physician.
- A Head Nurse that is responsible for implementing the clinical decisions taken by the head physician and his staff. To fulfill this task the Head Nurse has to confer with and manage his/her subordinates, namely Professional Nurses, Healthcare Workers and Auxiliary Workers.
- Two Professional Nurses that administer therapies and treatments.
- Two Healthcare Workers support Professional Nurses in basic healthcare operations that do not require specific knowledge such as disconnecting a drip, replacing the urine bag and assisting patients in personal hygiene care.
- An Auxiliary Worker in charge of cleaning up the operative unit.
- A Maintenance Technician that is entrusted with equipment and machines maintenance.
- The administrative personnel in charge of all the administrative processes and issues.

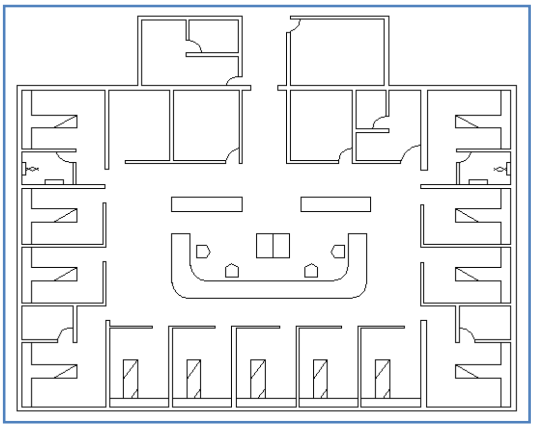

Figure 3.1: Ophthalmology department layout

3.1.1 Organizational aspects

The core business is represented by the urology department, but there are a number of activities to support health, which involve the use of specific professional resources:

- Laboratory analysis involves the use of a manager and two laboratory technicians;
- The Radiology involves the employment of a primary and a radiologist;
- The anesthesia service that uses a primary and an anesthesiologist;

All professionals respond to the Health Director, which contributes to the management of the processes of strategic planning and annual planning, and to the function of internal purchasing, through the allocation of resources to objectives and macro-structure of the company.

The administrative sector is managed by the Administrative Manager that performs the function of management and coordination of the administrative department of the following offices:Accounting Office;

- Bursar's Office;
- Acceptance Office ;
- Office Service Quality ;
- Office of Public Relations.

Primary activities that make up the process of providing the hospital treatment can be grouped into:

- Reservation and acceptance;
- Anamnesis;
- Diagnosis;
- Therapy;
- Rehabilitation;
- Discharge.

Support activities to the primary activities or the entire process, are grouped into:

- Formation;
- Administration;
- Informative system;
- Hotel services;
- Personnel Management.

Between the ancillary activities are not there scientific research, because the private health center does not carry out research and medical experimentation.

The private health care facility defines its objectives taking into account the satisfaction of the needs of patients. To satisfy patients and respond to their needs in an optimal way, many activities are carried out concerning:

- Preventive measures to prevent the occurrence of non-compliance;
- Internal audits and external;
- Monitoring and measurement of processes with the aim of identifying the levels of effectiveness and efficiency;
- Continuous monitoring of products / services;
- Corrective actions;

The private health care facility makes fill to the patients two different questionnaires, one for those which take a hospitalization, and another for external patients who receive only medical care. The questionnaires have similar questions and must be completed anonymously. From the data analyzed in the year 2014 approximately 63% of patients gave a good assessment of the health facility. The critical issues, mainly concerning the capacity of waiting rooms, which do not contain all patients who go to the private facility for diagnostic tests, private visits or any emergencies. This criticality creates confusion among patients, prevalently elders, who need to move from one floor to another, causing obstruction to healthcare professionals of the structure.

3.2 Public Healthcare Facility

The public healthcare facility that has been investigated in this research work is also located in the South of Italy. It operates non-profit, and is included in the Health Service of the Region of Calabria. The functions carried out are aimed at protecting, promoting and improving the health of the population. It also owns the Emergency Department and Emergency Acceptance "DEA" second level. The DEA is an aggregation of functional units that maintain their autonomy and responsibility for clinical care, but who recognize their interdependence by adopting a common code of conduct of care, in order to ensure, in connection with the structures operating in the area, a response rapid and complete. The public health facility is also central "HUB" for all hospitals "SPOKE" of the province. The Model "Hub" & "Spoke" was adopted by the regions for the logistical management of hospital care in territory. The centers "Spoke" have the function of patient selection and, in the case of gravity clinical care, transfer to a referral center "Hub". They also have the task of discharge from the centers Hub patients who require less intensive care assistance. The model is based on a very simple concept; some patients, given the complexity of the pathology, require highly specialized care, usually among the most expensive, which cannot be provided by all structures, for obvious reasons of economic convenience. For this reason, there are specialized centers of high level, the centers Hub precisely, capable of providing a highly qualified service in one or more branches of medicine. This model aims to provide health care to more effective citizen without duplication or waste of important human and financial resources. Patients with severe disease are hospitalized in facilities Hub, while the other patients in less serious conditions may be assisted by facilities less specialized, but still be able to provide adequate care. The model is implemented in those services with a high level of technology or by low levels of activity.

3.2.1 Institutional aspects

The **Director General** has full powers of management, as well as the legal representative of the healthcare facility. The competences of the DG are:

- Appointment of the Director of Administration;
- Appointment of Medical Director;
- Definition of the multiannual strategic plans and annual plans of activities
- Definition of the objectives, priorities, programs and general guidelines for administrative actions
- Definition of the Economic and Financial Planning
- The selection of human resources
- The approval of purchases of goods and services, and procurement

The **Board of Auditors** is appointed by the Director General, is composed of five members selected from among:

- Two from the Regional Council
- One from the Ministry of Economy
- One by the Conference of Mayors

The board of auditors exercises control on the administrative and accounting regularity, also is responsible for:

- supervises compliance of the regulations
- controls the economic management of the health facility
- performs quarterly reports to the Regional Government regarding the management of the health facility

The **Medical Director** contributes to the economic and administrative management of the hospital, also is mainly engaged in management of clinical care involving all the professional medical and health workers to achieve the following objectives:

- clinical and organizational efficiency
- quality of technical-professional
- ensuring access of all citizens to health services and continuity of care

In addition:

- manages health services: organizational-management and medical technology
- coordinates the activities of the Departments

- provides opinions to the Director General
- carries out inspection functions
- collaborates with the Director of Administration
- prepares the annual health report

The **Administrative Director** participates in the process of programming and strategic planning and annual planning. He contributes to the economic management of the hospital in order to ensure:

- the balance between funding and guaranteed levels of care
- the balance between resources and production costs

In addition:

- collaborates on formulating of the health plan
- carries out inspection function
- collaborates allocation of objectives and resources to departmental structures
- collaborates with the Director General and Medical

3.2.2 Organizational aspects

The health facility is composed of departments which have the autonomy to arrange and manage human resources, equipment and logistics. The Department has functions of planning, direction, coordination, consultation and control. The operating units of the Department are: simple and complex units.
The organs of the Department are:

- **Director of Department:** is nominated by Director General, chosen from among the managers of the unit complex, and remains in charge until the decline of the Director General.
- **Committee of Department**: is a collective body, consultative and representative who assists the Director of the Department in its functions. This organism is appointed by the Director General.

The healthcare facility in its actual configuration is composed from Departments. The Departments are composed from Operative Units as indicated below:

- **Department of Services**

The Department of Services is designed to ensure the users internal and external efficiency and effectiveness of the services through a synergy between the different operating unitsU.O. Pathological anatomy

- U.O. Farmacy
- U.O. Nuclear medicine
- U.O. Neuroradiology
- U.O. Clinical pathology, microbiology and virology, medical genetics
- U.O. Radiology
- U.O. Diagnostic cytology cancer prevention
- U.O. Pain therapy

- **Department of surgery and surgical specialties**

The Surgical Department is designed to provide benefits of general and specialized surgery through criteria of appropriateness and quality. The task is to integrate and supporting the activities of surgical urgencyU.O. General Surgery

- U.O. Thoracic Surgery
- U.O. Neurosurgery
- U.O. Ophthalmology
- U.O. Otorhinolaryngologist
- U.O. Orthopedic and Traumatology
- U.O. Urology
- U.O. Vitreoretinal surgery and Neurophthalmology

- **Department Medical and medical specialties**

The role of the Department Medical is to respond to the demand from the Emergency Room by addressing all cases of Medicine due to epidemics, seasonality and an aging population.

- U.O. Cardiology
- U.O. Dermatology
- U.O. Diabetology and Endocrinology
- U.O. Gastroenterology
- U.O. Geriatrics
- U.O. Infectious diseases
- U.O. General medicine
- U.O. Nephrology
- U.O. Epilepsy center
- U.O. Pneumology
- U.O. Psychiatry
- U.O. Rheumatology
- U.O. Neonatology, intensive care child
- U.O. Gynecology and Obstetrics
- U.O. Pediatrics

- **Department of Emergency-Urgency**

The Department of Emergency-Urgency ensures the processes of management and diagnostic and therapeutic treatment of critical patients

- U.O. Anesthesiology and Intensive Care
- U.O. Transplant Center
- U.O. Vascular Surgery
- U.O. Immunotransfusion
- U.O. Echography

- **Department of Onco-Hematology and Radiotherapy**

The Department of Onco-Hematology and Radiotherapy aims to improve and life expectancy of patients with oncological diseases and hematological.

- U.O. Regional center bone marrow transplants and cell therapies
- U.O. Hematology
- U.O. Physical health
- U.O. Oncology
- U.O. Radiotherapy

In the health facility there is also the center for the collection, validation and transport of cord blood units for transplantation, research and cellular therapy. Regarding the System of Information and Communication Technology , this presents criticality because it requires integration in all operating units. The health facility needs to develop methodologies and tools to promote the integration and continuity between hospital and territory. Waiting times for outpatient services, sometimes very long are partly due to organizational difficulties but mainly to the difficulty of the territory to ensure the outpatient services of the first level. In this healthcare facility is necessary to highlight the absence of auxiliary operators through which can be increased the capacity for growth and improvement of the standards of care. At this deficiency was remedied through collaborative activities with some voluntary associations. The numerical shortages also affect the nursing staff. From the quality point of view, the lack of operators has prevented and prevents the application of training continuous, essential to keep up with innovation of health care. The healthcare facility after it has entered into an agreement with the Provincial Department of Health, has decided to integrate the service of reservation in order to facilitate access to specialist outpatient services to users throughout the metropolitan area. This agreement will create a "Central Booking Office", whose function will be to:

- make reservations of specialist outpatient visits in real time at local structures outpatient and hospital;
- provide to citizens an efficient service optimizing the time and manner of access to facilities and outpatient services able to : reducing waiting times, to give the possibility to choose between different facilities and among alternatives of timetable, to facilitate multiple access more performance at the same time, planning ahead cycles of performance
- improve the use of existing resources by ensuring the necessary information and activities of the various Departments; increase capacity of the "front office" service and the reduction of displacement of the patients;
- ensure the diagnostics continuity of customer , allowing the choice of physician with whom to start the course of treatment;

3.2.3 Case Study: The Intensive Care Unit and Resuscitation (ICUR)

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. The layout of the ICUR is shown in figure 3.2.

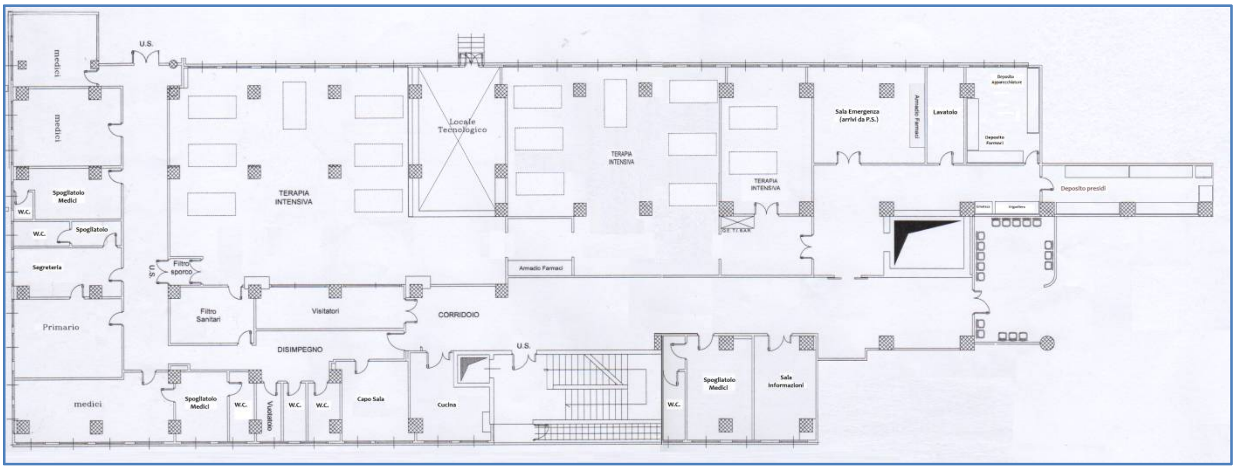

Figure 3.2: Intensive Care Unit and Resuscitation layout

3.2.4 Case Study 2: The Operating Block

The activities carried out in the operating room are inherently dangerous to the patient and operators. From a careful analysis of medical processes that take place in the operating department, errors related to the stage of admission of the patient, the management of instrument and principals sterile (textile devices and instruments surgery) are the main cause of adversity borne by the patient. With a view to improving the organization and implementation of the Ministerial Recommendations regarding safety of care in the operating room, must be carried out activities related to:

1. Preoperative surgical checklist (Preparation Surgical intervention)
2. Acceptance of the patient in the operating room;
3. Proper management of surgical instruments;
4. Count devices textiles;
5. Safety requirements for the opening and closing of the operating room;

A frequent cause of medical errors and adverse events, which may result in serious harm to patients, is represented by the failures of communication, such as omission of information, wrong interpretations, conflicts existing between the team members. The Ministerial Manual for safety in the operating room, in promoting effective communication, emphasizes three aspects particularly decisive to consider: the pre-operative and post-operative activities, the characteristics of the patient's in health records. The Director of U.O. must encourage interdisciplinary discussions to ensure adequate planning and preparation of each surgery, by strengthening communication processes within the team. The application of the checklist in all stages facilitates this communication. The working time for the Surgical Department is from 8:00 until 15:00 from Monday until Friday. Nonetheless, some surgeries are often performed outside these hours and in weekends, because emergency patients needing surgery may arrive 24 hours a day, 7 days a week. The operating room department has a total workforce of approximately 30 people, among which are surgery assistants, anaesthesia-assistants, scrubs nurses and nurses circulating . Furthermore, 6 anaesthetists and 16 surgeons from 8 different medical specialties attend the operating rooms for performing the actual surgeries. We distinguish the following types the primary processes in the operating room department :

- Elective Surgery, General Anesthesia
- Elective Surgery, Regional Anesthesia
- Emergency Surgery
- Outpatient Surgery

The Department of Operating Rooms (ORs) consists of eight operating rooms. Adjacent to these operating Rooms there are: preparation areas, to waiting and recovery. The outpatient surgeries take place outside the operating block. Each operating room is assigned to a surgical specialty. Below are indicated the surgical specialties activated in the operating block:OR Neurosurgery

- OR General Surgery (two rooms)
- OR Vascular
- OR Orthopedic Surgery
- OR Ear-Nose-Throat Surgery
- OR Gynecology Surgery
- OR Urology Surgery

The layout of the Operating Block is shown in figure 3.3:

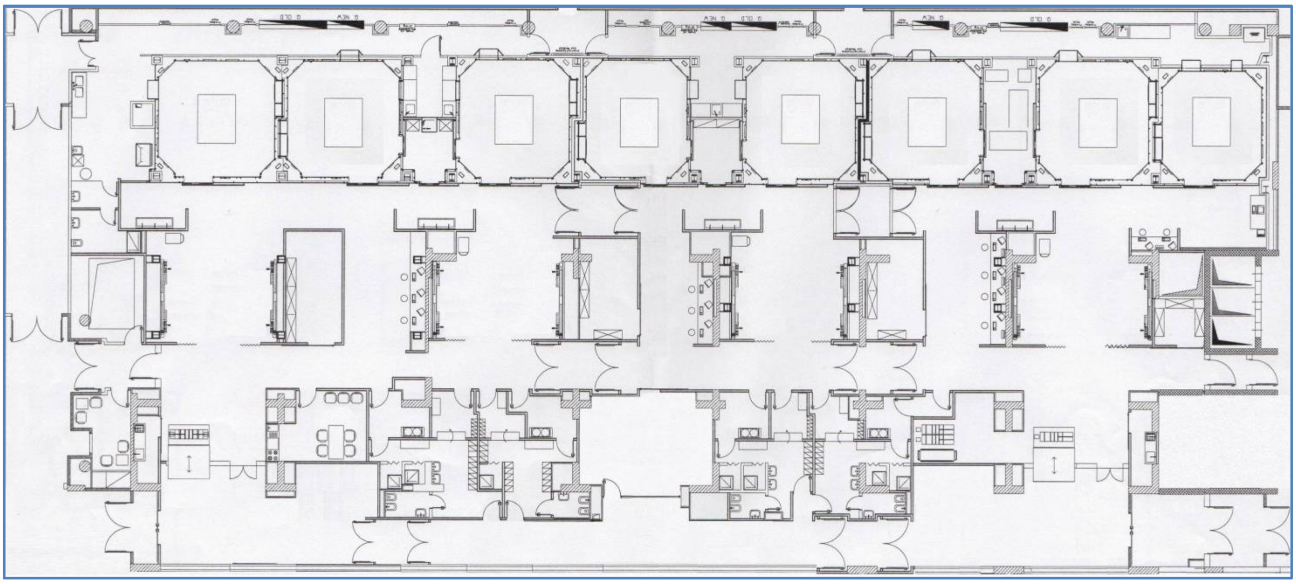

Figure 3.3: Operating Block layout

Operating rooms require the improvement of performance by making better use of its available resources. The interdependencies with other hospital functions are numerous and complex. The creation of a schedule that indicates the times of surgeries contains a multitude of constraints, preferences and objectives to take into account. The schedule has major consequences for performance on the operating room department in terms of waiting time, of overtime and the performance of interrelated departments. The hospital management wishes to improve operating room performance in general terms of resource utilization, production volume and cost reduction. Other stakeholders perceive different problems in and around the operating room, for example:

- The operating room personnel addresses a high variability of duration of surgery leading to varying daily workloads;
- Some surgeons complain about not being able to perform the amount of surgeries they want;
- Surgical wards deal with large fluctuations in patient flows, which leads to low average bed utilization and frequent overstaffing as well as understaffing;
- The operating room planners deal with daily changes due to lists of patient not received or not correct;
- ; Scheduling surgeries is often tightly constrained by limited availability of additional equipment as well as limited availability of sterile surgical instrument sets or anaesthetist physicians

During our analysis, we observed non-functional methods of planning. This creates organizational difficulties regarding the allocation of human and material resources to each operating room. It is natural to think that uncertainty does not generate efficiency much less improvements. Poor planning, leading to vacant Operating Rooms, prevents surgery from being cost-effective.

CHAPTER 4: Simulation Model & Lean Management in a Public Healthcare Facility

4.1 Introduction

This chapter presents the results of a simulation study that has involved a public Facility Healthcare, in particular an operative unit of intensive care and a block operating. These unit represent 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 two units; 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, the 5S method and Pull System. To this end, for each unit two simulation models 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).

4.2 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 labelling 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 4.1, attached to the paper, the actions to be undertaken during the implementation of the method 5S are shown.

Phase	Description	Action
SORT (*SEIRI*)	Separate necessary and unnecessary, eliminating the unnecessary	- Initial assessment and awareness of waste - Detect anomalies by tags - Rating of objects according to the frequency of use - Deleting unnecessary items
STRAIGHTEN (*SEITON*)	To order the materials in well-defined positions to eliminate the search time	- Determination of the most ergonomic position for medical equipment, medical materials medicines - Clearly define the individual positions and facilitate the maintenance of the new location
SCRUB (*SEISO*)	Clean and systematically order the various areas of work, discover the problems	- Regular cleaning and periodic - Identification, analysis and elimination of sources of dirt and confusing - Introduction of temporary standards of cleanliness and order to maintain the results achieved
STANDARDIZE (*SEIKETSU*)	Define and formalize new standards for location, cleanliness and order	- Definitive standards of cleanliness and order to consolidate the improvements - Checklist for preparation and control of equipment
SUSTAIN (*SHITSUKE*)	Maintain and improve the standards and the results achieved	- Periodic audits to verify compliance with the standards - Training continuous to spread the rules - Continuous monitoring of performance - Identification of new goals for continuous improvement

Table 4.1: 5 S method and its application phases

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.

4.2.1 5-S Method in the Intensive Care Unit

Innumerable benefits accompany 5S. When the workplace is organized and clean, it is more productive. More time is available for patient care, fewer errors occur, a more professional image is projected, and work is more efficient. The results of 5S application in Intensive Care Unit are pictured in Figures 4.1A and 4.1B.

Figures 4.1B: ICU after 5S method

In the frame 4.1.A there are some photos of interiors intensive care unit providing storage medications and medical equipment before 5S. In the frame 4.1.B you can see how the equipments and drugs have found a logical arrangement according to the rules of the 5S method. In the frame 4.1.A you can see how the equipments and drugs have found a logical arrangement according to the rules of the 5S method. In addition they were designed "ad hoc" containers and are labeled with a description of the item and the part number.

4.2.2 Data collection in the Intensive Care Unit

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 4.1), 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.

DATE :	**Start Time :**	**Name:**	**Surname:**
No. Observation:	**End Time :**	**SHIFT** Morning ☐ Afternoon ☐ Night ☐	
Key-Personal : Physician ☐	Nurse ☐	Technical Operator ☐	

DATA COLLECTION

PROCESS	**ACTIVITY**	**START TIME** [hh:mm]	**END TIME** [hh:mm]	**CRITICALITY**

Figure 4.2: Data collection template

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 2 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.

Criticality description	**Frequency measuring in 12 weeks**	**Percent on 90 observations**
Interrupting therapy administration for physician assistance	16	18%
Interrupting therapy administration due to urgency intervention on broken machinery (absence of preventive maintenance)	36	40%
Patients waiting for TAC	10	11%
Picking material in the warehouse operative unit	44	49%
Missing material in the ICU	64	71%

Intensive care unit with only two nurses (undersizing)	8	9%
Lack of information	20	22%
Dressing carts lacking material	28	31%
Work overload : little time / patient	20	22%
Poor knowledge medical electrical equipment	32	36%

Tab. 4.2 : Criticalities description and frequencies

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;
- 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.

4.2.3 The Intensive Care Unit Simulation Model

The main idea behind our research work was to develop a discrete event simulation model able to recreate the complexity of the ICU. 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 ICU (see figure 4.2) 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.

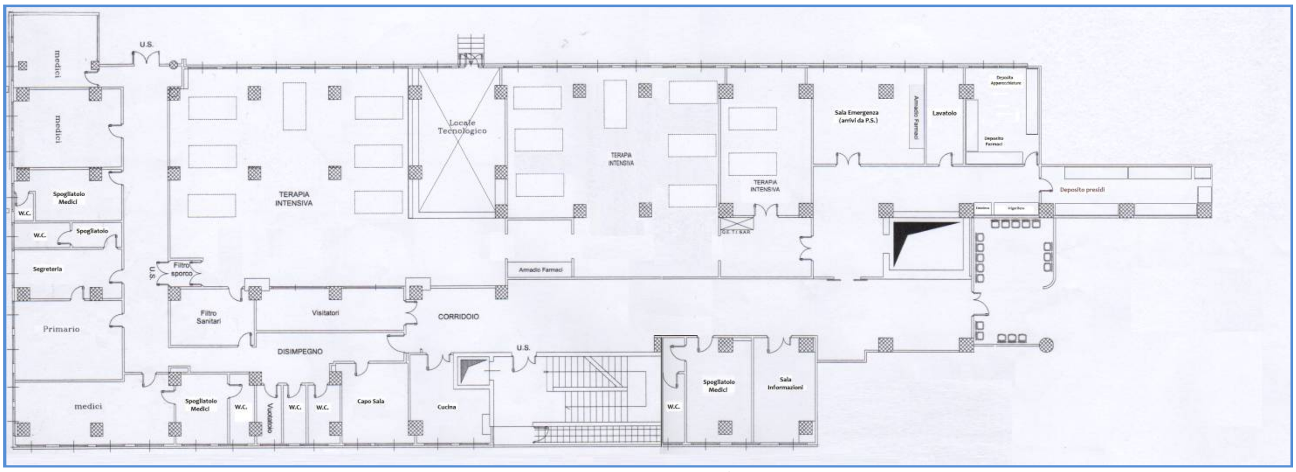

Figure 4.2: 2D layout of the ICU

- **2st Step - Defining the network resources pool**

According to the AnyLogic Library, the resources network (see figure 4.3) 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.

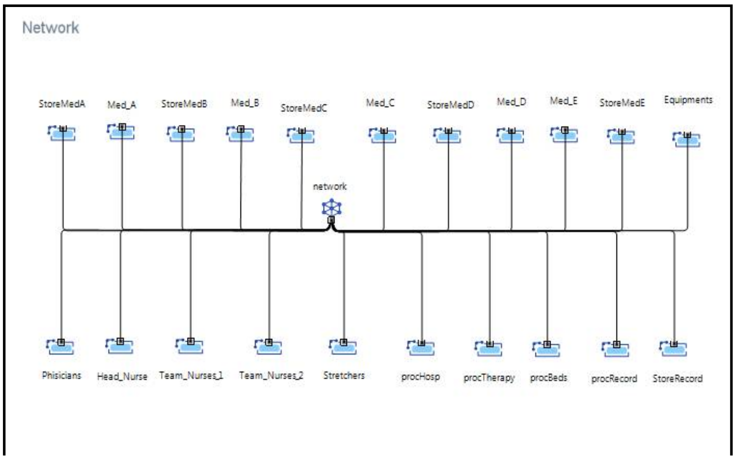

Figure 4.3: Simulation Model network and resources objects

- **3st Step - Animating Patients and Resources**

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

- **4st Step - Creating a Flowchart for each process**

This model has been built considering five fundamental processes:

- *Patients' Arrival process:*

Only serious patients with disease that involve vital organs are admitted into the ICU. 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 4.4also shows the Patient record creation process).

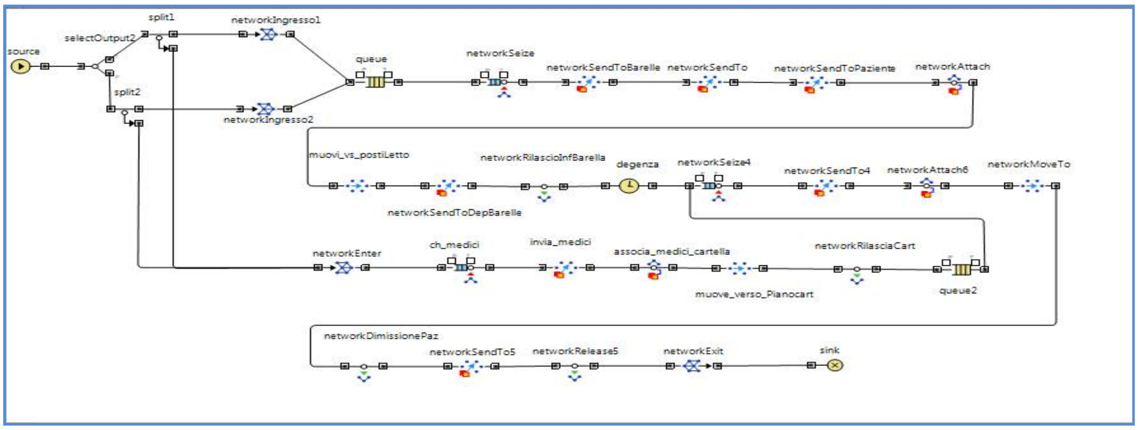

Figure 4.4: Simulation model Flow Chart: Patient Arrival Process and Patient record creation process

- *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 4.5 depicts the flow chart of the hygienic care process.

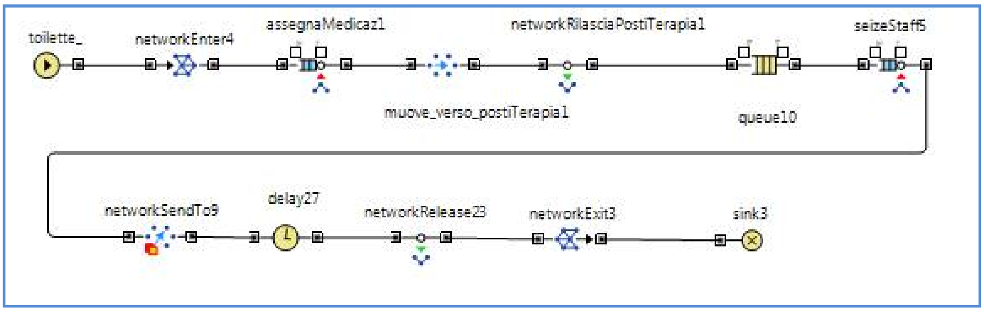

Figure 4.5: Simulation model Flow Chart: Hygienic care process

- *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 4.6 depicts the flow chart of the Medication and Monitoring Process.

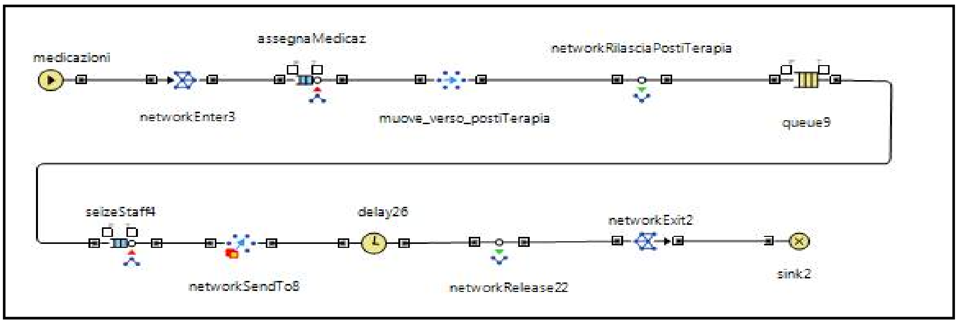

Figure 4.6: Simulation model Flow Chart: Hygienic care process

- *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 4.7 depicts the flow chart of the therapy administration process.

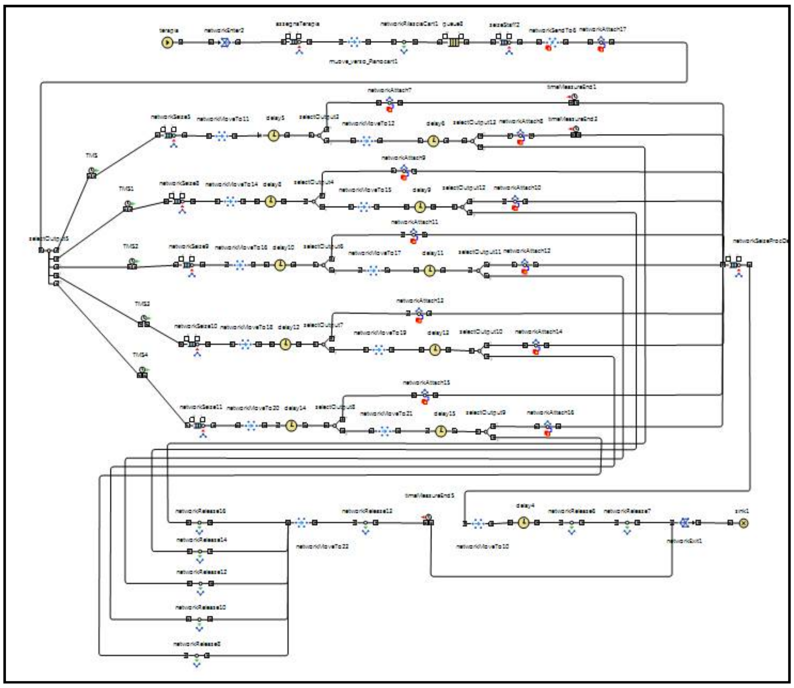
Figure 4.7: Simulation model Flow Chart: Therapy administration process

The five processes described above have been implemented as part of the simulation model that seeks to recreate the ICU 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.

4.2.4 Analysis and simulation results in the Intensive Care Unit

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 4.2) 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 4.8 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.

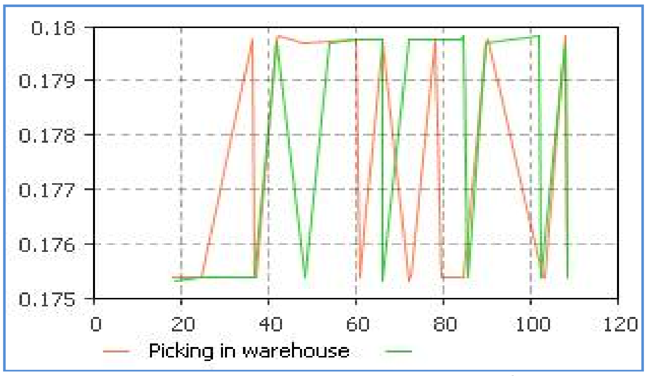

Figure 4.8: average therapy administration time for scenario 1

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 4.9).

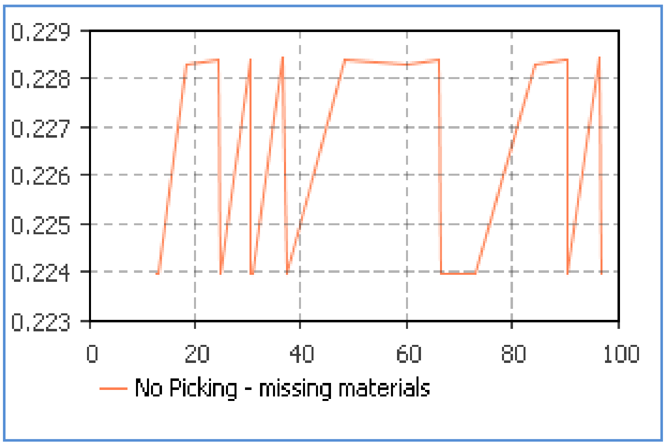

Figure 4.9: average therapy administration time for scenario 2

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 4.10 we can note that the average time that elapses between the medical record reading and the therapy administration is about 9.9 minutes.

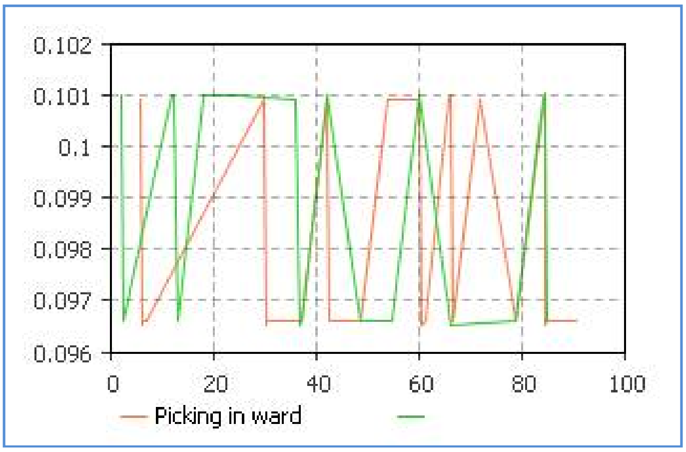

Figure 4.10: average therapy administration time for scenario 3

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 4.3 summarizes the simulation results for the three scenarios.

Scenario	Time to picking [minutes]	Add Value to 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

Tab. 4.3 : Simulation results for the three scenarios

4.3 Lean Tools applied in Operating Rooms

Lean approach, with its emphasis on lower costs but higher quality and customer service, is surely an interesting research area to studying. In this section we deal of the improvement effects resulting from the application of lean principles, in particular “pull technique”, in the management of Operating Rooms through simulation. We can say clearly what are the fundamental goals for the management of operating rooms: improving productivity and efficiency while maintaining high quality of care at all times. Improving efficiency mean to have: cases of shorter durations, rational scheduling of various types of surgeries, minimize non-operative time by reorganizing operating room tasks. The Operating Rooms represent one of the most costly units within a hospital. As the health care economic environment becomes increasingly more challenging, increased Operating Rooms productivity represents a high priority. The administrators of health-care facilities must constantly deal with the difficult task of balancing the achievement of health quality standards with the appropriate allocation of resources. Cutting the waiting lists and the length of stay in hospital is therefore an important managerial goal for modern healthcare systems because it increases the perceived quality of care and frees resources. In elective surgery departments, the external performance indexes are the time and waiting lists. The internal performance indexes are the throughput time (time from arrival to dismissal), bed occupancy, dismissal rate and resources utilization. Those managerial performance parameters only partially measurable when patients arrive in emergency conditions. In this case can't be made schedulation. Our goal is to describe a model of planning to use in Surgery Department. This model consists of two levels of organization and scheduling. The first level covers the activities of planning, upstream, necessary to the execution of elective surgical operations without wasting time or other resources. The second, downstream of the first, concerns the programming activity of the perioperative period of time. To this level will be implemented "Pull technique", own of the Lean Management. In a "Pull system" , the timely transition of work from one step in the process to another is the primary responsibility of the downstream (i.e., subsequent) process. This is in contrast to most traditional “push systems”, in which the transition of work is the responsibility of the upstream (i.e., prior) process. The "pull system" can be created whenever a patient is being moved from one point of care to the next. This is particularly important when the patient is being transferred from one care setting to another. Communication and cooperation are keys to pull systems for patient transfer. A preoccupation of Lean management is to identify blockages and obstacles that cause delay, and remove them. After describing two levels, we compare the data collected in the Surgery Department (where we spent 12 months), with the results obtained from the simulation model, in which was implemented technique" Pull". In the two levels of planning will be described the improvements obtainable from the application of principles del Lean Management.

4.3.1 Wastes in the Operating Rooms

In a general overview, we can say that a poor planning, leads to downtime of Operating Rooms and prevents surgery from being cost-effective. Patients entering the Operating Block at the wrong time can slow down the whole process, as can patients who cannot leave immediately after surgery due to complications upon wakening. The early closing of one or more Operating Rooms or an Operating Block, when there are fixed overheads and personnel costs and expensive and sophisticated equipment, is regarded as an unrecoverable loss of resources. A classic example of waste is the sudden cancellation of surgeries sometimes for organizational reasons alone. A poor coordination between the services prevents the deployment of the various operators responsible for ensuring the smooth and speedy shift of the Operating Room, between one patient and the next. This process involves the surgeon, who estimates the duration of the procedure but is rarely accurate due to the individual variability of the pathology, as well as the variability of the surgeon, who may be faster on some days and slower on others. Besides any unexpected difficulties encountered by the surgeon, the anaesthesiologist may also come across clinical problems that are hard to forecast. It is important pay attention to nursing staff. This is involved in frontline for all activities of operating room. Their lack of coordination leads to operating rooms being used for longer than necessary; cost efficiency levels vary, as well as wastes between one surgical team and another. In this context, it is also necessary to improve and optimize equipment, but even more human work. Enhancing harmony, coordination and synergy between people who are working, it leads to increase efficiency and reduce wastes. It is amazing how many people wander about hospitals without following a definite schedule, and without the aim of completing their work within a certain time. Finally we consider that facilities that have the latest technology not always also offer the highest quality. A system without errors and waste leads to working in environments in which everything flows smoothly without disruptions or inefficiencies, on time and as scheduled, people are courteous, there are no unsolved organizational squabbles, and results are achieved with whatever resources are available. Efficiency becomes effectiveness when performance matches objectives. Unfortunately almost all operators tend to think that mistakes and inefficiencies are inevitable. However, in view of the error rate in health care, due to organizational problems, rather than human factors, and considering how many improvements can be determined, it is simply impossible to go on ignoring them.

4.3.2 "Pull System" approach

Tools that support strategy and planning as well as those that help solve problems are many, but in this context is need to consider those ones capable to help day-to-day the operations with their execution . In particular, one of these tools that find their basis in Lean theory is "pull system method". The basic idea this method pursues is to take up the operating room only when the patient is ready that is to say pre-operative activities have been carried out and resources (people and materials) are available. In a pull system of service, the timely transition from one-step in the process to the following is the primary responsibility of the downstream (i.e., subsequent) process that, in such a case, is the surgical department. In 'pull' systems rather than pushing patients into a waiting queue for the next step in their care, available resources are requested to 'pull' patients towards them. In this method a smooth communication and cooperation are keys to pull systems for patient transfer. Before to apply "pull system" is need know the way should be (not always observed) planned and controlled a surgical department. Surgical department includes four hierarchical levels of planning: strategic, tactical, operational offline and operational online planning. At the strategic level, the capacity dimensioning of the surgical department is determined and capacity is divided over specialties. At the tactical level, slots of operating room time are assigned to a specific specialty or surgeon and surgical staff is planned. At the operational offline level, elective patients are scheduled in advance, and staff is assigned to a specific operating room. This results in an operating room schedule. At the operational online level, planning becomes control and day-to-day disturbances are dealt with, such as unexpected delay or the arrival of emergency surgeries (Van Houdenhoven et al., 2006). This research focuses on the operational offline level of operating room planning, that concerns in detail the scheduling of activities since patients enter in surgical department to their exit. At this level, resource capacities are already determined and allocated. The problem consists of assigning actual patients to operating rooms and determining the start of every surgery without times waiting through implementation of "pull system". From a patient's perspective, the process starts the moment the decision is made to perform surgery. This decision is an agreement between physician and patient. The medical specialist fills in an admission registration form, which provides information required for planning the patient. This involves short description of the treatment, expected duration of surgery, expected length of stay in the hospital, indication of urgency, some additional information relevant for preoperative preparation. This form is processed at the central department of planning surgical , where it is completed with additional of patient information. The future admission/operation is then placed on the waiting list, which is kept both digitally and physically. This continuous process covers the arrival process of elective patients requiring surgery. A surgery involves a number of other preceding and succeeding activities that also need to be planned, such as the admission at the surgical ward. Planning surgery and admission are linked by a required length of stay before and after the operation. In practice, surgeries and admissions are just planned on basis of expected length of stay information supplied at registration. This means that an operating room schedule implies a certain admission schedule and a certain level of bed occupancy at the surgical wards. Creating an operating room schedule is a repetitive process, of which every cycle consists of planning operations for a single week. This process should be carried out centrally by operating room planners, who work in the surgical department. Figure 4.11 shows the scheduling process.

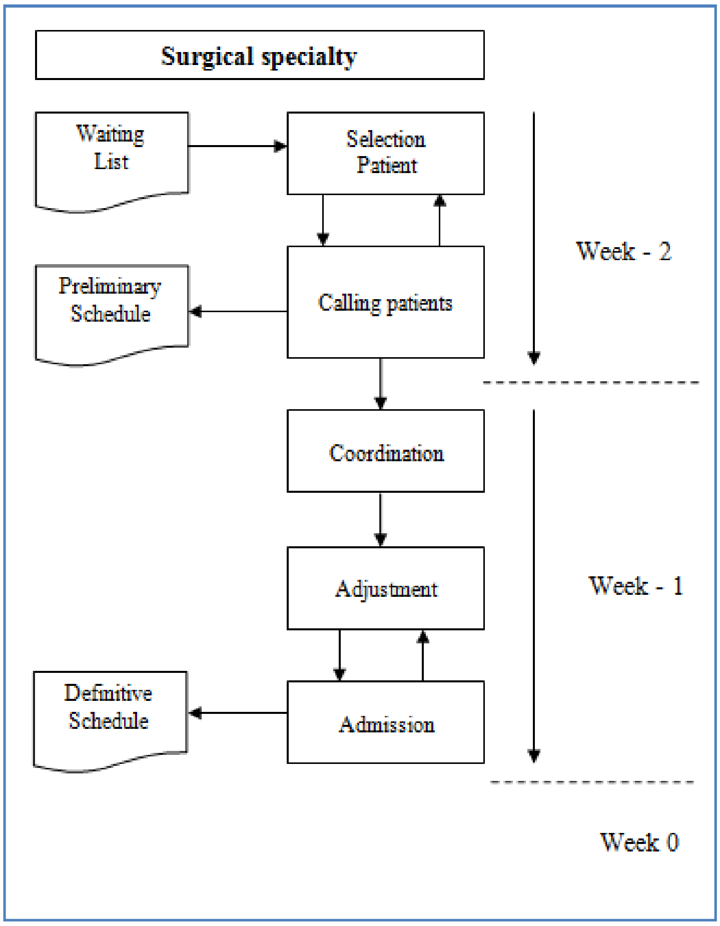

Figure 4.11: Flowchart process scheduling

- ***Patient Selection* :**

Patients selection occurs two weeks ahead of the surgery week and is based on the information reported on the waiting list. This phase comes up with a preliminary operating room schedule where patients are randomly sequenced within a session. The planned duration is based on the information supplied by the surgeon.

- ***Calling patients:***

After patients selection, planners inform the anesthesiology department since each patient requires a preoperative screening by the anesthesiologist before surgery. Screening are carried out in the week before the surgery is expected and if a patient is not fit for surgery, the surgery is cancelled and another patient from the waiting list is selected. Then the preliminary operating room schedule is updated accordingly.

- ***Coordination:***

In the week before surgery is scheduled, the preliminary operating room schedule is sent to the operating room managers, the surgeons involved, the surgical wards and the radiology department to check and establish the right surgeries.

- ***Adjustment:***

Communication with some actors may bring about the need to adjust the preliminary schedule, because of several reasons. Estimates of operation durations may be adjusted, surgeons may want to add patients to the schedule (e.g. in case of high urgency), surgical wards may foresee problems with accommodating all patients, etc. Such reasons require adjustment of the preliminary schedule, by shifting patients between wards, assigning patients to another day in the same week or removing patients from the week , etc. Adjustments can be done until Thursday (morning) in the week before surgeries. After this deadline, the operating room schedule is definitive.

- ***Admission:***

After finalizing the operating room schedule, the operating room planners call the patients involved and inform them about the planned date and time for surgery providing details about preparation and time for check-in at the hospital.

However, changes are likely to occur. Indeed, it can happen that the patients in the definitive schedule cannot come at the planned time and therefore have to be immediately replaced by other patients from the waiting list. There can be also internal reasons (i.e lack of tools and medical products) that do not allow fulfilling the schedule. As a consequence, many last minute changes can occur. In this process can happen that patients indicated in the definitive schedule they cannot come at the planned time and therefore are immediately replaced by other patients from the waiting list or lack of tools surgical and medical products do not permit perform the surgery. Consequently, this results in many last-minute changes and increases discussion about the operating room schedule. On a operational offline level , "pull system" seek to provide the information necessary to control and to accelerate the flow of patients throughout the surgical process. Changing the scheduling from "push system" , without rules or well criteria defined, to a patient-based "pull system" will result in significant reductions in time wait with simultaneous increases in customer service. In other word, for each surgical specialty and on base of definitive scheduling, the patient will be called only when the resources are available and everything is set for surgical process. Increasing effectiveness will require the imposition of more specific and focused scheduling rules as well as the possible redesign of supporting processes. It will increase the responsibility of everyone involved in the day to day operation of surgical department. This will necessitate minimize delay cases , ensuring possible reconfigurations in staff utilization and they composition. All staff, surgeons and nurses, must know and take part to definition:

- Scheduling rules and regulations;
- Consistent monitoring of processing times;
- Monitoring continuous all surgeries , to report possible corrections to phases of operating process;
- Establishing quality indicators, such as start time, operating room utilization, analyze cases exceeding assignment time, etc.;

Before the pull system begins, the actual organization of operating rooms must be re-engineered in the processes. Streamlining activities must also include the supply of medicines and surgical devices required for each surgery. Responsibilities should be assigned, and procedures documented for operating the system day-by-day, for monitoring performance of the system, taking corrective action. The operating room department analyzed consists of eight operating rooms. For each operating room there is location for preparation and recovery after surgery. Before describing our model is important to say which approach is needed for this implementation, highlighting also weaknesses. The approach of an organisation is to align its processes, control them and study them as part of the flow of value from patient perspective. The weakness is that for most important processes lack a written and shared definition. Another weakness is not fully identifying value in the process. The third is not timing the speed of the process but not seeing the flow. Main processes of operating block have been detected and mapped with procedural flowcharts that have been referred to as conceptual model. In particular, process "pull system" before to build the simulation model is been analyzed.

4.3.3 Conceptual Model in OR

Conceptual model is built to highlight the logical flow of activities within the simulation model. The process under investigation and the respective conceptual model is discussed below. The building of this conceptual model is based on the roles that each operator performs in the operating block. Surgeries entail lots of different activities involving professionals that are required to cooperate with a high degree of synergy and coordination sharing risks and responsibilities. As depicted in Figure 4.12,for each surgery are employed Physicians Specialist, Professional Nurses, the Anesthetists, the operating room Planners, the Surgeons. Below we analyze the activities of each professional:

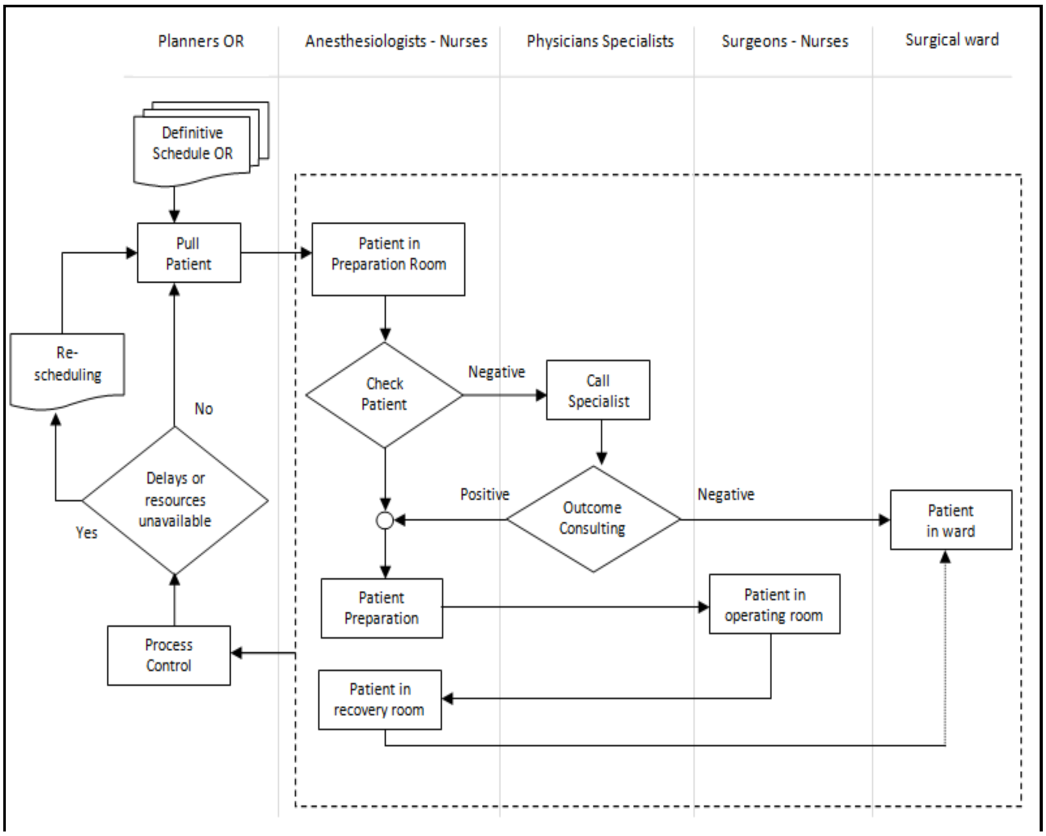

Figure 4.12: “Pull system” conceptual model

Planner OR: The strategic role is assigned to team planners of the activities of the block, which, after defining the program of surgeries and coordinates all preparatory activities upstream of surgery. The task of the planner is to call patients from the ward, according to definitive schedule, check the availability of material resources and the presence of the surgical and nursing staff required to single surgery. Check the duration of the surgery, verify possible delays and if necessary reschedule the subsequent intervention for that specific operating room.

Anesthesiologists: In pre-surgery phase, Anesthetist get patient in preparation room, where starts a check on general conditions. In the case of negative check, comes called one or more specialists to do a detailed analysis about opportunity to continue with the surgical phase. If is positive the consulting outcome, the patient is prepared for surgery. After surgery, the Anesthetist is committed to monitor patient vital functions until the patient is ready to leave the recovery area. In all these activities the Anesthetists are supported from the presence of nurses specialist in anesthesia techniques.

Physicians Specialists: During the preoperative control, some patients require additional consults or examinations before surgery. The anesthesiologist calls one or more medical specialists, depending on the type of diagnosis. Specialist Physician carries out a visit and decides together the Anesthetist and the Surgeon, if the intervention can be performed. In case of negative outcome, the patient is brought back in the ward. Conversely, for outcome positive, continues the preoperative preparation.

Surgeons : Surgeons are medical doctors with additional training to perform general or specialized types of surgeries. While surgeons spend time preparing for procedures, reviewing records and meeting with patients, their most critical role is to perform accurately and efficiently in the operating room. During a procedure, the surgeon carries out the steps outlined with the patient in pre-surgery appointments. Specific actions vary based on the type of surgery, but the surgeon typically uses standard equipment and tools to perform operations. In addition, he is responsible for quickly identifying problems and working to correct them during the procedure.
Nurses circulating: In the operating block, circulating nurses remain in the unsterile field.

These nurses are not scrubbed, and do not wear gloves or a gown. Their role is to monitor and document the procedures taken during the surgery. They inform operating room staff of anything that may cause contamination. In addition, are of support to patient during preoperative and postoperative phase.
Nurse anesthetists: Nurse anesthetists provide anesthesia and related care before and after surgical, therapeutic, diagnostic and obstetrical procedures. They also provide emergency services, such as airway management. They provide anesthesia in collaboration with surgeons and anesthesiologists. In addition, they carry out checks specific to ensure that the operating room is properly fitted out with medicines and medical supplies, that the operating room records are updated, that tools from sterilization unit are correctly placed and materials traceability is monitored.
Nurses Scrub: Nurses scrub remain in the sterile field of the operating room and follow the designated scrub procedure, wear gloves, a mask and gown. Scrub nurses aid surgeons by handing them equipment, sponges and other necessary instruments during the operation. They also help the surgeon by monitoring the patient's condition during the procedure.
Generally, all nurses are an integral part of improved management in the operating room. They can help manage changes related to reduction in product duplications, to define supply storage areas throughout the operating room. Are concerned with having the correct products the surgeon or anesthesiologist needs to deliver quality patient care. They are fundamental to improve management of inventory and activities of support in the operating room.

4.3.4 Data analysis and current performances in OR

A common indicator for measuring performance of an operating room department is utilization. Although precise definitions differ in the literature, utilization is a measure for the fraction of resource use against resource capacity. In case of operating rooms, the goal is often to reach the highest possible utilization. In general, a utilization of less than 100% may have three components: starting late, finishing early or having idle time between operations. In our research to evaluate the performance indicators, we use data from the period of January 1, 2014 until December 31, 2014, a period of 52 weeks. The datasets contain data on surgeries and sessions. A first observation was made on the timing of daily use of operating rooms. These have a utilization rate far below the daily standard. Moreover, since our focus is on elective surgery, we noted that the scheduling of operating rooms is practically nonexistent. Despite waiting lists, the opening days of operating rooms vary each week with a logic based on the presence or not of the surgeons and / or anaesthesiologists. These analyses provide information on which areas of operation scheduling need special attention, and thus provide input for designing alternative scheduling systems. Table 4.4 shows the current values of average time process, average time surgeries, pre-surgery and post-surgery average time, average waiting time for each surgical specialty. Process time we can identify as sum of three time frames: the first of the pre-operative timeframes is that spanning the period from a patient's entrance into Surgical Department until pre-operative room. The second timeframe spans the period from the surgical incision (or the beginning of the surgical procedure in lieu of an incision) to the application of the surgical dressing (or final washing from the surgical procedure). In this second timeframe, the main event is the surgical procedure and activities undertaken the surgical team to maintain the patient's hemodynamic, temperature, and fluid status. The final stage is the interval between the conclusion of the surgical procedure and transport of the patient out of the surgical suite until recovery room. In all these activities, we found several inefficiencies due to lack of organization of the department operative. As can be seen from the ratio between the non-surgical time and the process time for each surgical specialty, there is a high time idle percentage respect to surgery time. From Table 4.5 we can see the utilization time, as the number of hours, that every surgical specialty carried on average daily basis each month. This means that an operating room is open for only one scheduled surgery to day. Indeed, the monthly number of surgeries shows how lack the productivity of the department, especially for certain surgical specialties. Also in this case, we have found that, despite the long waiting lists, is never used the time available.

Surgical specialty	Average Process Time [min]	Average Time Surgery [min]	% ATS on APT	Average Time pre - surgeries [min]	Average Time post - surgeries [min]	Sum Non-Surgical Time [min]	% NST on APT
Neurosurgery	270	150	56%	80	40	120	44%
General Surgery	210	110	52%	75	25	100	48%
Vascular Surgery	165	80	48%	50	35	85	52%
Ortho Surgery	150	60	40%	60	30	90	60%
Ear-Nose-Throat Surgery	120	50	42%	40	30	70	58%
Gynaecology Surgery	170	90	53%	55	25	80	47%
Urology Surgery	180	95	53%	60	25	85	47%

Tab. 4.4 : Average times analysis

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Neurosurgery	4,20	6,50	6,50	5,20	7,00	6,40	7,50	6,30	7,50	7,40	6,40	7,50
n°surgeries	9	15	16	13	8	11	19	14	12	17	18	22
General Surgery 1	8,00	7,50	8,00	5,30	3,30	5,40	5,30	7,30	7,40	6,30	9,30	7,30
n°surgeries	30	37	35	27	8	23	33	29	33	41	48	32
General Surgery 2	7,40	6,00	6,40	4,00	4,30	4,00	4,40	8,00	7,40	6,40	7,40	7,40
n°surgeries	23	12	14	6	1	1	11	15	17	23	23	17
Vascular Surgery	2,30	4,40	4,40	3,30	2,40	3,30	5,40	5,30	5,00	4,40	6,50	4,40
n°surgeries	8	22	12	11	4	19	36	27	22	25	23	21
Ortho Surgery	6,30	6,00	5,40	3,40	4,30	5,40	6,30	7,00	6,20	7,40	6,20	5,40
n°surgeries	48	50	52	37	34	46	57	60	41	61	50	49
Ear-Nose-Throat Surgery	4,00	5,40	4,20	4,00	-	3,50	3,10	2,40	3,50	4,10	4,30	2,20
n°surgeries	22	26	31	24	-	17	20	18	20	25	20	15
Gynaecology Surgery	3,20	3,20	4,20	6,10	5,40	2,10	3,50	4,10	4,20	4,20	5,50	6,00
n°surgeries	5	1	4	2	1	3	6	9	11	4	17	14
Urology Surgery	4,50	4,50	5,20	5,30	3,10	5,30	5,20	7,00	4,50	5,30	6,40	5,50
n°surgeries	31	42	37	39	22	51	41	43	41	45	47	46

Tab. 4.5 : Average Time Utilization Daily

Another important point concerns the days of use monthly for each operating room, that annually are to below standard level (see figure 4.13). For example, some surgical specialties using the operating room 3 days out of 5, for a time less than 5 hours. Indeed, each specialty surgical is typically formed as a cluster of autonomous resources, planning is also often functionally dispersed.

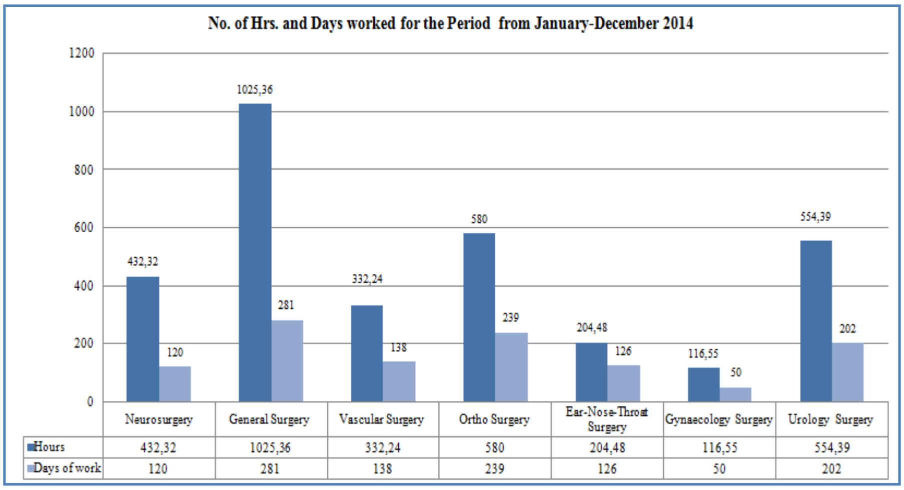

Figure 4.12: No. of Hrs. and Days worked

The effectiveness and efficiency of health care delivery in Department Surgical is not only determined by how the various planning functions are addressed; this is also determined by how they interact. The inefficiencies encountered refers to the time that the patient spends during the perioperative waiting to get medical treatment. Utilization of the Operating Rooms was computed through an assessment of the hours of surgery elective performed from each speciality surgical for the period from January-December 2014. If it is assumed that on average 1500 hours yearly are available for each specialty of the operating room (6 hours a day for 250 days per year), considering the actual hours of surgeries we can deduce that the utilization rate is very low (see Tab.4.6).

Operating Room	**Total hours of surgery / year**	**% of Utilization**
Neurosurgery	432,32	29%
General Surgery 1	712,16	47%
General Surgery 2	313,2	21%
Vascular Surgery	332,24	22%
Ortho Surgery	580	39%
Ear-Nose-Throat Surgery	204,48	14%
Gynaecology Surgery	116,55	8%
Urology Surgery	554,39	37%

Tab. 4.6 : % Utilization OR

The operating room assigned to gynecology in the operating block, is particularly unused because in the health facility there is another operating room that is most widely used in the gynecology ward. Therefore this operating room could also be used for other surgical specialties. Regarding the other operating rooms we observed the following:

OR Neurosurgery: Generally the operating room is opened for only one case per day. The weekly program undergoes constant movement and almost always is used 3 days a week.

OR General Surgery: At the General Surgery is assigned two operating rooms. In the scheduling of surgical activities it is used only one, the other in a few days of the week. The average of surgery is two a day.

OR Vascular Surgery: Vascular Surgery has the same trend of Neurosurgery. Both specialties have a greater complexity of the process but neither has a productivity economically viable for the health facility. Indeed, surgical implants purchased for patients are not always are used due to the cancellation of surgery.

OR Orthopedic Surgery: Orthopedic Surgery is the surgical specialty that works more days a year and with an effective time of utilization approximately 40%. The actual time is related to the hours of surgery in the operating room. Indeed on 6 hours of availability, the time current level setting of the operating room is 2.4 hours; the remaining hours refer to the stages pre-operative and post-operative. The daily average of surgeries is three. The margins of improvement are high.

OR Ear-Nose-Throat Surgery: The operating room assigned to surgery Ear-Nose-Throat has a very low utilization rate. In average it is used for 4 hours per day and 10 days per month. Still, the number of surgeries exceeds other surgical specialties. Also in this case the optimization of the operational programming can bring an increase in productivity.

OR Gynecology Surgery: As mentioned earlier the operating room assigned to gynecology is very rarely used because most of the surgeries of gynecology and obstetrics are performed in the operating room in the hospital ward.

OR Urology Surgery: As regards the urological surgery, the analyzed data relate to the programming elective. However, for this specialty the surgeries are performed for most of cases with day hospital way. The definitive schedule is performed by internal staff at ward and not by planners the operating block. For this reason many surgical interventions are not elective surgery. We can therefore say that the percentage of utilization of the operating room is, considering the performance in day hospital, higher.

In addition to the above described, we can say that to improve the activities of the operating block analyzed are required the following actions:

- Define scheduling processes that will support improved operating room use (under decrease, overused times);
- Ensure appropriate preoperative patient checking and evaluation, complete all steps as possible before the day of surgery, and reduce redundancy of activity;
- Improve the efficiency of the non-operative processes and patient flow;
- Reduce redundancy of patient information;
- Improve employee engagement and satisfaction of all surgical service;

A key finding was that daily operating room capacity was not adequately matched to demand. Daily volume lack was attributed to insufficient operating room capacity information provided to the surgeons as they plan their operative schedule. This lack of coordination within a specialty interfered with developing an appropriate operating room allocation strategy. To improve planning, information on the cases set, durations estimated cases, the percentage of use of the operating room, and staff absences must be made available to improve the decision-making process when planning elective cases. Scheduling Surgery Elective involves the coordination of several activities in an uncertain environment. Due to the very customized nature of surgical procedures there is significant uncertainty in the duration of activities related to the patient calling process, surgical procedure, and recovery process. Furthermore, there are information which must be traded before surgical treatment. Considering the complex schedule procedures that include possible cases where there is patient waiting, operating room team waiting, operating room idling, and overtime for the surgical suite. Uncertainty combined with the need to tradeoff many criteria makes scheduling a complex task for operating room planners.

4.3.4 Simulation Model Flow Chart

The processes above described have been analyzed in order to explore the range of enhancement possibilities and detect operational targets based on quantitative performance indicators that can lead to increase the Operating Block effectiveness and service levels. To come up with an effective and easy to deploy solution for monitoring the operating rooms performances as well as analyzing and testing the impact on alternatives of programming and scheduling based "Pull System" , a simulation model has been developed. The simulation

model is designed to aid a Surgical Department in evaluating the current efficiency of surgical suites, the potential maximum capacity of the operating rooms, and how either changing resources, changing the way to define the definitive scheduling and applying "pull system" method would affect performance improvement. The simulation model flow chart is centered on flows of patients scheduled ahead of time for elective surgery. The available types of surgeries include Neurosurgery, General Surgery (two operating rooms), Vascular Surgery, Orthopedic Surgery, Ear-Nose- Throat Surgery, Gynecological and Urological Surgery (one operating room for each). The Operating Block that has been modeled as part of the simulation model consists of eight pre and post-operating rooms and eight operating rooms. While preparation rooms can be used by patients of any type, operating rooms are distinct for each specialty and come equipped with special instruments enabling particular types of surgery. The simulation model takes as input the final schedule that is used to evaluate which resources (humans and
machines) are required to comply with all the activities in it. To this end, human resources in the operating block have been modeled. In greater detail, the simulation model includes two teams dealing with four operating rooms each. As depicted in figure 3, each team, includes:

- Anesthesiologists
- Nurses anesthetists
- Operating Block Nurses (or Circulating Nurses)
- Operating Room Nurses (or Scrub Nurses)
- Surgeons (for each specialty surgical)

By default assignments are as follows: an anesthesiologist for two operating rooms, a sterilized nurse (or scrubs) for each operating room, a scrub nurse for each operating room, a anesthetist nurse for two operating rooms. In addition, the number of health workers can be chosen in the initial settings of the simulation
while surgeons are in a fixed number that is a first surgeon and an assistant surgeon for each operating room. In addition, we have considered the cleaning staff that intervenes at the end of each surgery. From figure 4.13 we see the hierarchical dependence of each operating room on the resources allocated.

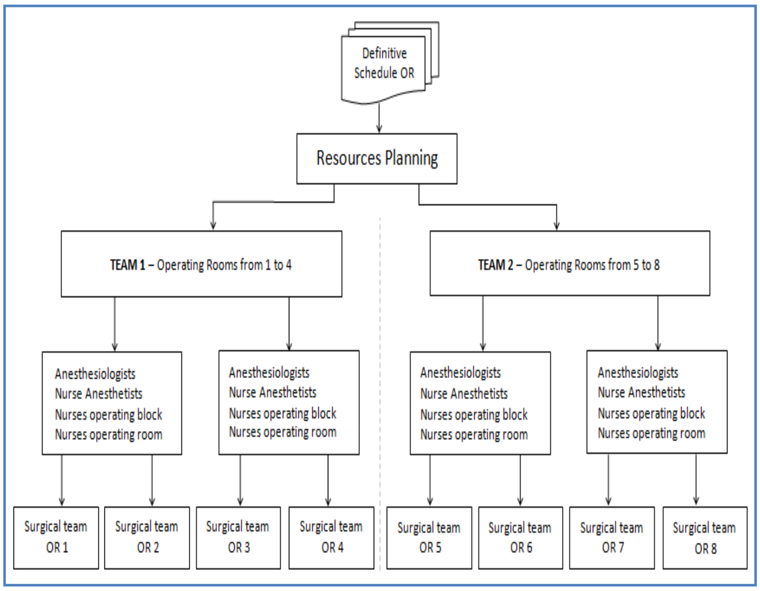

Figure 4.13: Simulation Model Resources Organization

The first process implemented is the operating rooms preparation and checklist control process that starts every day at 7:00 AM and lasts one hour. In this process, which is shown in figure 4.14, are involved nurses in the operating room (sterilized, assistant surgeon) and nurses of operating block (non-sterilized).

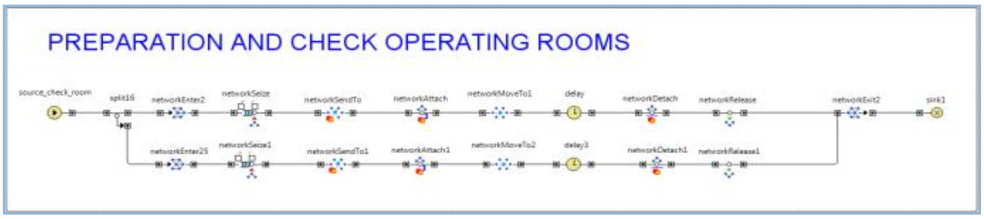

Figure 4.14: Simulation model Flow Chart: Preparation and Check Operating Rooms

The simulation model is also equipped with a dedicated output section showing the main performance measures of the operating rooms; for each operating room is implemented the "Pull System" method, for patient calling , and perioperative process that concerns the stages pre-operative, surgical, and post-operative. In figure 4.15 is shown the simulation model flow chart of the Neurosurgery preoperative process. Nevertheless similar models have been built for the other specialties.

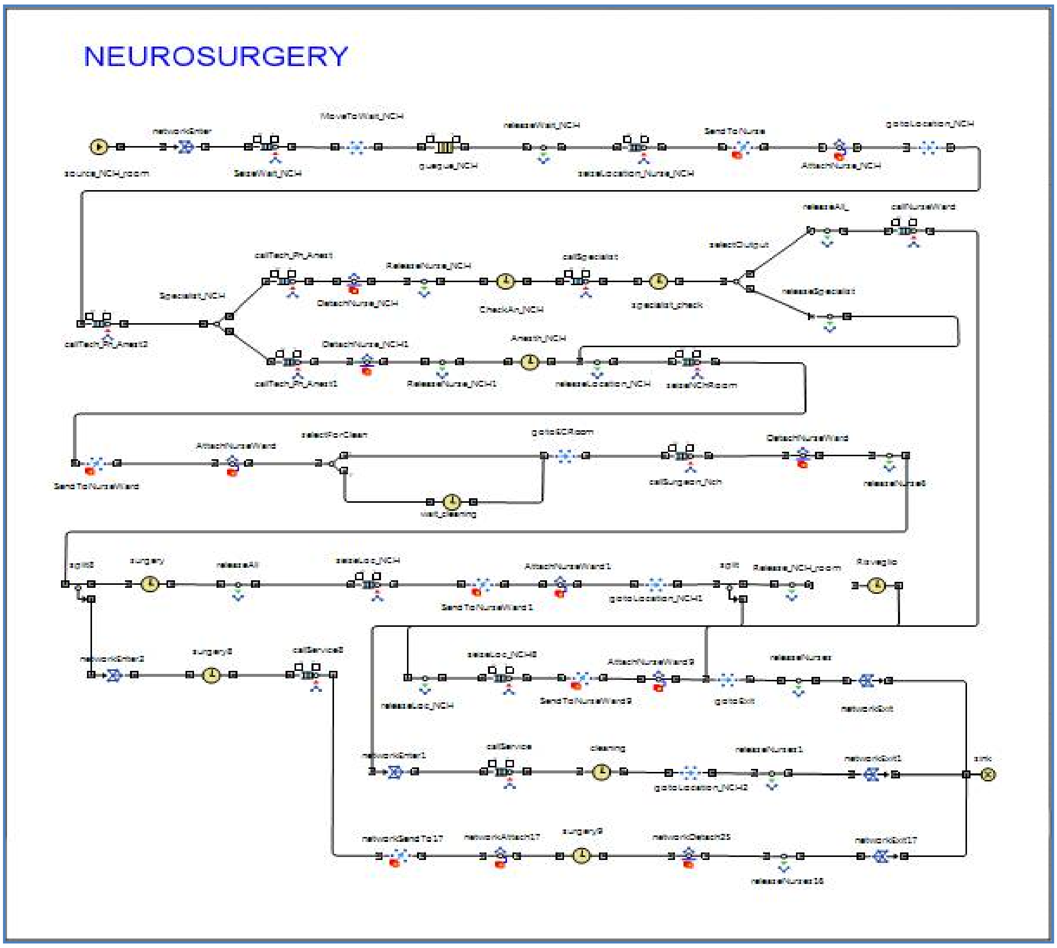

Figure 4.15: Simulation model Flow Chart: Pull System for Patient and perioperative process

The pull method has been implemented within the simulation model. Hence, when the patient entity is generated some build-in controls are carried out. Such controls, have been implemented from scratch in Java and include:

- Checking for the operating room availability from the definitive schedule;
- Reading the start time and end time of regular working shifts for each operating room;
- Checking if there is an anesthesiologist ready to start the pre-operative stage;
- Comparing the remaining time before the operating room closes to the surgery estimated time.

This comparison is necessary to prevent overtime. Indeed, if overtime occurs the system pulls another patient with lower estimated surgery time and postpones the patient that may cause overtime to the day after. After

such controls, the patient is treated (pulled) only when resources are available (as it happens in manufacturing systems where the pull method is applied). The advantages are the reduction the waiting time in the operating block, reduction of overtime work (and related costs), optimization of elective surgeries.
Furthermore, as the simulation model is meant for what if analysis, several scenarios can be investigated changing the parameters in the input dialog window shown in fig. 4.16. Some of the basic parameters include:
- numbers of operating rooms nurses
- number of operating block nurses (for each team);
- number of anesthetists nurses (for each team);
- number of anesthesiologists doctors (for each team);
- choice of weekly opening days for each operating room;
- time opening daily for each operating room;
- define the estimated time for each type of surgery (for each operating room);

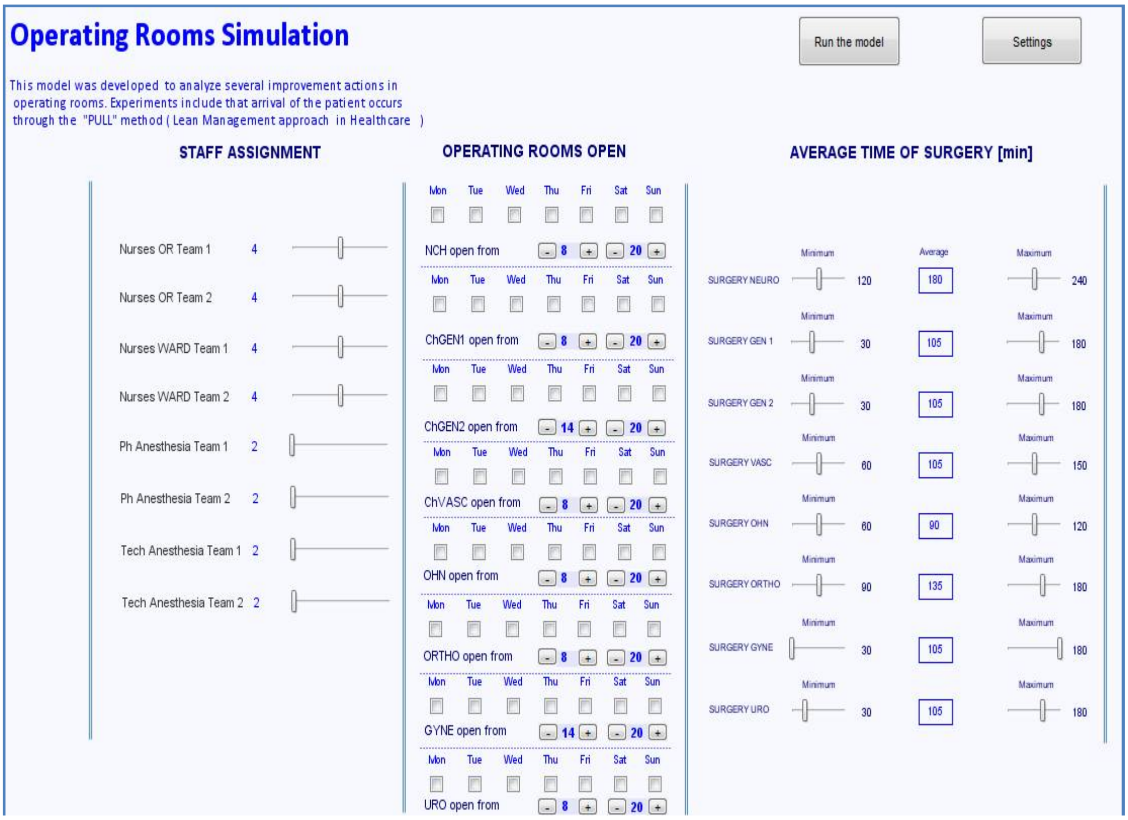

Figure 4.16: Parameters input window

In addition, times for anesthesia induction vary according to the surgery type based on real data provided by the Department of Anesthesiology and Intensive Care of the Hospital. It is worth mentioning that along the development process the simulation model has been extensively tested with real data about the estimated time of surgery, time of preparation of patients, the arrival times of the patients in the surgical unit, the time required for patients awakening after anesthesia, time for operating rooms preparation and cleaning. In addition, the model has been also validated with the Sanitary Direction.

4.3.5 Simulation Analysis and Results Comparison

The simulation model can be considered an accurate representation of the operating block, especially for the purpose of testing ideas and concepts. This model explores the dynamics of patients flows and of all healthcare operators involved in operating rooms processes. In order to facilitate the use of the simulation model, a graphic user interface has been added to provide the user with the possibility to monitor performance evolution during the simulation (see figure 4.17).

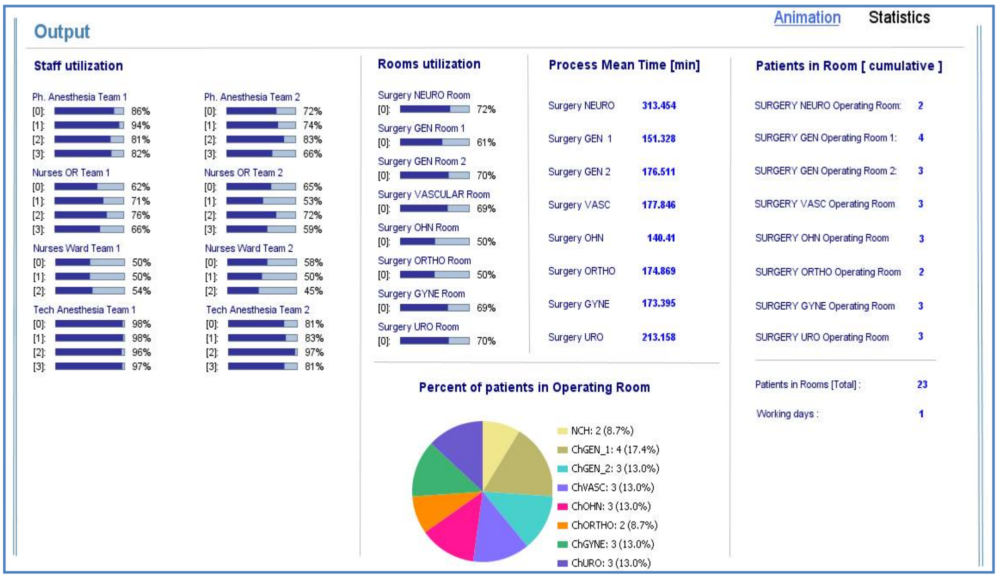

Figure 4.17: Output of the simulation model

In particular, the output section includes the measure of the following output parameters:

- operating rooms daily, monthly and yearly level of use (for each room and average value);
- waiting time before surgery (for each room and average value);
- waiting time after surgery (for each room and average value);
- circulating nurses level of use (for each nurse and average value);
- scrub nurses level of use (for each nurse and average value);
- auxiliary workers level of use (for each worker and average value);
- anesthetist nurses level of use (for each nurse and average value);
- anesthesiologist doctor level of use (for each doctor and average value);
- average process time (for each operating room and surgery type)
- patients rate for each operating room;
- daily , monthly and yearly number of patients for each operating room;

For the analysis that have been carried out as part of this research work and that will be discussed in the sequel, some basic settings include:
1. operating rooms standard opening times include: six hours in the morning
assigned to four rooms and six hours in the afternoon assigned to the remaining four rooms;
2. Health care professionals assigned as shown in table 4.7.

Healthcare operators	**Assigned** [from 8:00 am to 2 pm]	**Assigned** [from 2:00 pm to 8 pm]
Anesthesiologist	2	2
Nurses anesthetist	2	2
Nurses circulating	4	4
Nurses scrub	4	4
Cleaning staff	1	1

Tab. 4.7 : Staff assigned to perioperative process

Simulation results allow ascertaining that compared to the actual performances, significant improvements can be achieved thanks to the “pull method implementation”. Indeed, as shown in figure 8, comparing 2014 performance levels calculated in section 4 with those obtained in the simulated scenario, it results that the productivity is greatly increased. Some surgical specialties double the number of surgical procedures, such as Ear-Nose-Throat Surgery and General Surgery, while other specialties benefit from significant increases in productivity ranging from 20% to 40%.

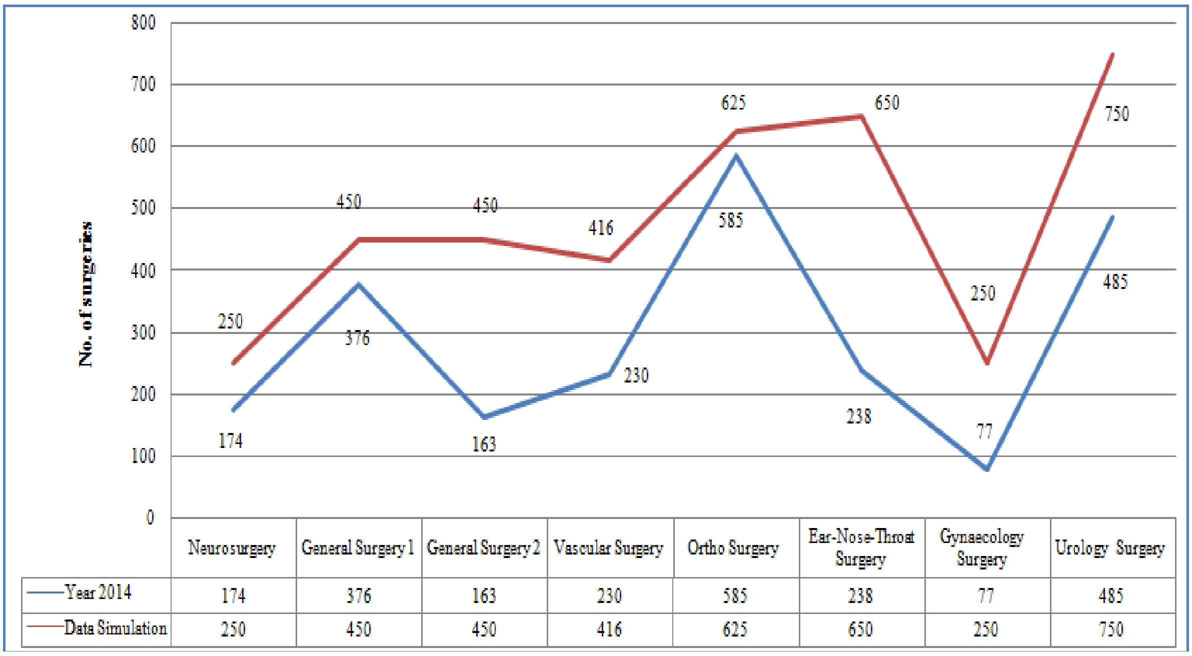

Figure 4.18: Comparison number of surgeries (Year 2014 – Simulated Data)

The simulation results reported in table 4.8, inparticular, those reported in the third column of the table, provide an overall picture of operating rooms efficiency in the simulated scenario compared to the efficiency levels of the real facility.

Operating Room	**Hours Utilization actual**	**OR Utilization actual**	**OR Utilization simulated**
Neurosurgery	6,00	41%	82%
General Surgery 1	6,30	55%	83%
General Surgery 2	6,30	55%	83%
Vascular Surgery	4,46	45%	68%
Ortho Surgery	6,00	58%	77%
Ear-Nose-Throat Surgery	3,52	33%	76%
Gynaecology Surgery	4,40	47%	70%
Urology Surgery	5,12	52%	78%

Tab. 4.8 :Utilization rate operating rooms

The first column of the table shows the average daily time utilization of operating rooms. It may be noted that many operating rooms are open for an unproductive time, such as Vascular Surgery, ENT Surgery, Gynecology and Urology. The reasons are mainly of an organizational nature and managerial. The simulation results were obtained considering the estimated time of surgery. Therefore we can assert that with these times, an increase of working hours, the technique "pull", and correct assignment of resources can be achieved an increase of utilization of the operating rooms. The kernel of the simulated scenario is represented by the improvement in waiting times of patients before surgery. Furthermore another important outcome of the simulated scenario is the substantial reduction (60%) of patients waiting times before surgery. This result, that is analytically shown in table 4.9, is in line with the essence of the pull method. It is worth noticing that waiting times in the simulated scenario cannot be further reduced due to the activities that are required before the pre-anesthesia phase for preparing the surgery. Table 4.10 reports the simulation results for staff utilization. These simulated data compared with actual data calculated by using the historical records available in the healthcare facility clearly show that the current level of use of Doctors and Professional Nurses (as well as other workers) are pretty low. It is easily understood that this level of use is due to the low productivity of the operating rooms. However we can say that, on the basis of interviews with operators of operating rooms, many hardships are due to lack of information about daily activities to be carried out. Consequently operators directly concerned, such as anesthesiologists and nurse anesthetists, some days are in an overload of work and rather underused in other days. To compound this condition we found a undersizing of staff requiring perform the activities intraoperative, and outpatient visits needed for planning interventions.

Operating Room	**Average waiting time [min]**	**Average Waiting Time Simulated [min]**	**% of Improvement**
Neurosurgery	70	15	78,6%
General Surgery 1	70	10	85,7%
General Surgery 2	70	10	85,7%
Vascular Surgery	45	15	66,7%
Ortho Surgery	50	15	70,0%
Ear-Nose-Throat Surgery	40	10	75,0%
Gynaecology Surgery	50	10	80,0%
Urology Surgery	55	10	81,8%

Tab. 4.9 : Waiting time improvement

Observing the simulated data we note that all health care increase the utilization rate as a result of increased productivity of operating rooms. A consideration regarding nurses circulating (*) is that 65% of utilization can be increased up to 90% by removing a unit, for this simulation scenario.

Healthcare operators	**% Utilization actual**	**% Utilization simulated**
Anesthesiologist	65%	97%
Nurses anesthetist	50%	95%
Nurses circulating	25%	65% (*)
Nurses scrub	65%	97%
Cleaning staff	52%	85%

Tab. 4.10 : Staff utilization

A further improvement is possible with a reduction of the times in the procedures and an increase of health personnel specialized. We also simulated another scenario with the use of the operating theater for 12 hours instead of 6, assigning two additional units of anesthesiologists and nurse anesthetists. During creation, the simulation model has been continuously tested with real data about the estimated time of surgery, time of preparation of patients, the arrival times of the patients in the surgical unit, the time required for awakening of patients after anesthesia, time of preparation of operating rooms and cleaning. In addition, this model has been validated with the Sanitary Direction

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5.1 Introduction

This chapter presents a simulation study carried out within a private healthcare facility with the aim of understanding whether or not it is able to handle a greater flow of incoming patients as well as the related impact on the overall efficiency. As a result, the simulation outcomes have pointed out the need for an internal work re-organization that has been devised through Lean Management tools and methodologies. The simulation model has, then, been used to predict the intended changes effects as well as their feasibility. The proposed research work is grounded on an in dept analysis of the main processes and activities taking place in the healthcare facility as a starting point for the simulation model development. Afterwards, simulation has been used for "as-is" analyses and, in combination with Lean Management approaches, for "what-if" studies whose results and findings are discussed.

5.2 Process mapping

Process mapping has been the preliminary step of the study. This stage has been crucial since most of the healthcare facility operational processes were undocumented. Therefore, it has been the groundwork for clarifying how things get done and how resources (man and machines) are committed to achieve operational and organizational goals creating a common reference framework for all the stakeholders involved in the simulation model development.

As a matter of facts, the simulation model accuracy relies on the ability to recreate the system under investigation faithfully and with a suitable level of detail. To this end, a thoroughly analysis of current procedures, processes and resources has provided meaningful insights for setting the goals of the simulation study and modeling the healthcare facility core processes. In this perspective, the healthcare facility value chain has been investigated according to Porter's Model (Porter, 2008) distinguishing between primary and support processes. Thus the relevant specific value creating processes have been identified as shown in figure 5.1. Due to their close linkage, both primary and secondary processes have been considered. Recalling that primary processes affect patients' outcomes while secondary processes are needed to accomplish the formers, substantial advantages may be achieved optimizing and coordinating interrelated processes. Therefore the modeling effort has been mostly focused on:

- Reservation and Patient's Reception;
- Diagnosis, Therapy and Rehabilitation
- Patient's Discharge
- Outpatients' Ambulatory Care
- Purchase and Inventory Management process

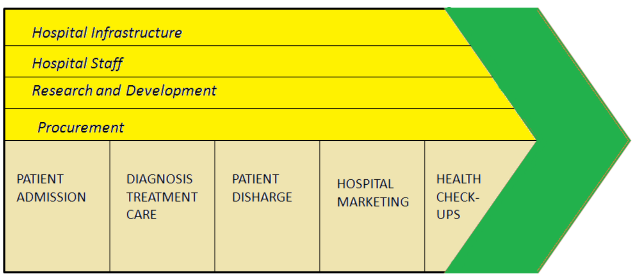

Figure 5.1: Porter's Value Chain in Healthcare (Gehmlich, 2008)

Indeed particular attention has been paid primary processes, as detected in the value chain model, but not only. As a matter of facts, the procurement process has a significant impact on the healthcare facility efficiency and as a consequence it has been considered as well. Moreover, sourcing processes entail an area of spending where proper inventory policies can provide a substantial contribution in reducing wastes and ensuring a high service level. Once the processes to focus on have been detected, a structural analysis of each process flow has been carried out. This way, the main activities, information flows, interconnections and professionals involved have been identified and reported on preliminary process maps that have been validated by the healthcare facility hospital staff and updated according to their suggestions so as to rely on a real operational picture. The processes under investigation have been mapped with procedural flowcharts that have been used as conceptual models for the simulation model development.

5.3 Conceptual Model

As mentioned before, the healthcare facility main processes have been detected and mapped with procedural flowcharts that have been referred to as conceptual models. Indeed, as suggested by Banks (1998), in a simulation study the activity of abstracting the real system with conceptual models is unavoidable. Conceptual models are built to highlight the logical flow of activities and relationships to be recreated within the simulation model. The processes under investigation and their respective conceptual models are discussed in the sequel.

5.3.1 Patient's admission

Patient's admission process is based on pre-booked appointments that are scheduled ahead of time by the Head Nurse of each unit. In other words, patients with an official admission request issued by their general practitioners get through to the admission desk and undergo a scheduling process handled by the Head Nurse where admission dates and times are settled. After the patient's arrival at the hospital, pre-admission checks are carried out to verify the documentation formal correctness. As a result, the admission request may be accepted or denied. In case of acceptance the patient is sent to the ward he/she is intended for, where preliminary examinations are done by the Head Physician and by the Head Nurse. The final decision on the patient hospitalization is taken by the Head Physician that fills the patient's case history out and sends it back to the reception desk where the data reported on it are used to fill the main log out. Such data are also uploaded on the Hospital Management Software that is always kept updated on the Hospital resources availability and levels of use so as to monitor the facility efficiency and make statistical analysis. Furthermore, such data are even sent to the Local Health District (that is part of the National Healthcare System). Figure 5.2 depicts the conceptual model of the reservation and patient's reception.

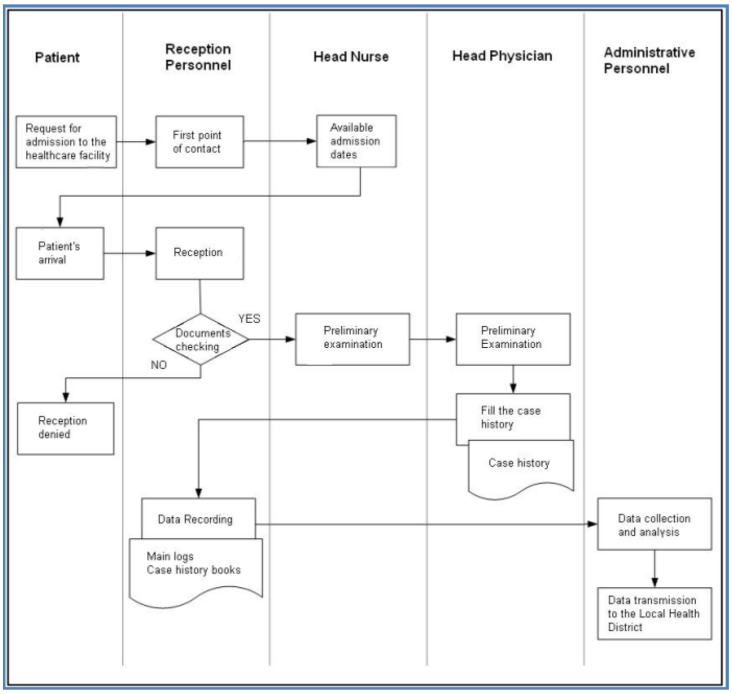

Figure 5.2: Conceptual Model of Patient's admission process

5.3.2 Diagnosis, Treatment and Care

Hospitalized patients follow different pathways depending on a number of factors that are strongly affected by randomness and uncertainty. To this end, past data collected over a 1 year period have been retrieved and analyzed. It has been a crucial step to shape the main features of the simulation model including service time distributions and transitions between clinical conditions. Particular attention has been paid on surgeries that often are part of the therapeutic process. Indeed, surgery entails lots of activities involving different professionals that are required to cooperate with a high degree of synergy and coordination sharing risks and responsibilities. As depicted in Figure 5.3 each surgery includes three different phases: before surgery, surgery and after surgery where a number of Physicians, Professional Nurses, the Operating Room Responsible and the Anesthetist are committed. Basically the pre-surgery starts when the Head Physician draws up a surgery note that is delivered to the Operating Room. Here, the person in charge gets the O.R. ready and, together with the Anesthetist, undertakes specific controls to ensure that the room is properly fitted out with medicines and medical supplies, that the O.R. records are updated, that slips on sterilization processes and materials traceability are correctly placed. Moreover, the O.R. Responsible coordinates with the unit staff for the patient preparation and transfer to the O.R. Finally, the pre-surgery phase ends with the pre-anesthesia administration by the Anesthetist. At this stage the surgery phase starts and it involves a team of Physicians, Professional Nurses and the Anesthetist. After surgery, the Anesthetist is committed to monitor patient vital functions until he/she deems the patient ready to leave the recovery area.

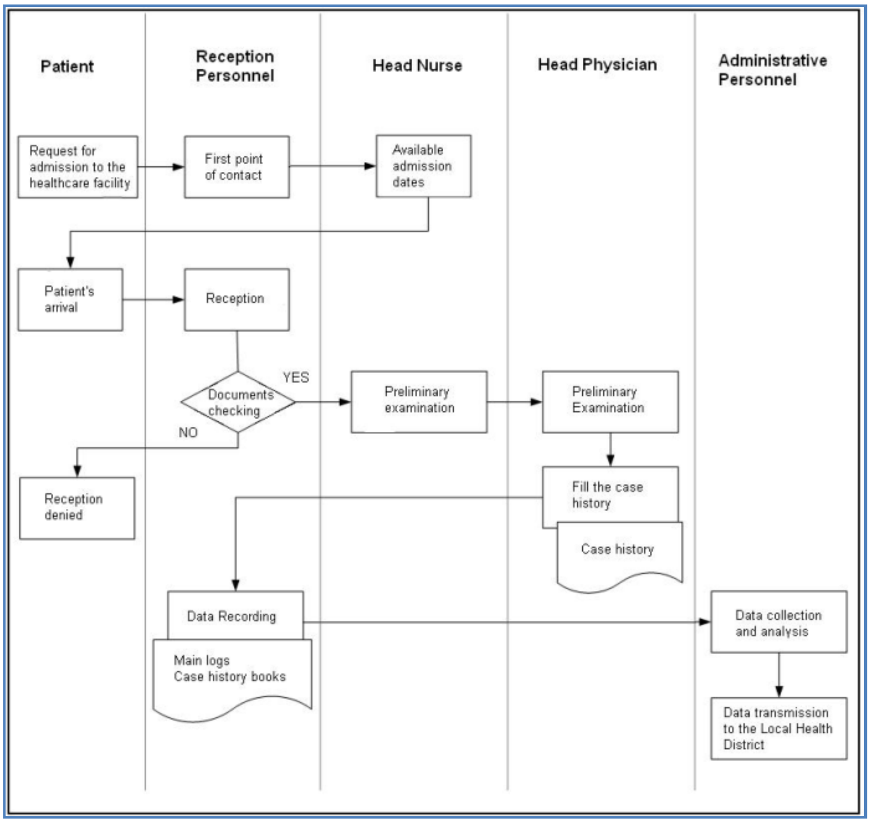

Figure 5.3: Conceptual Model of Patient's admission process

5.3.3 Patient's Discharge

The patient's discharge process implies that patient treatment and care is concluded, the patient can release the resources he/she has been allocated to and leave the healthcare facility. Since the discharge process entails resource availability for new patients, it directly affects the entire patients' flow and therefore it could not have been overlooked in the hospital simulation model. The process conceptual model is shown in figure 5.4. Basically the trigger for the process is the Physician decision based on the patient's health conditions. Therefore, after checking that all the requirements for discharge are met, the patient's case history is closed and sent to the Administration Department where all the data about patients' pathways are collected. Such data include: name of the patient, date of birth, date and time of arrival, preliminary diagnosis, discharge date, main diagnoses, secondary diagnoses and complications, major surgical intervention (if any), minor operations and procedures, case history ID, department in which the patient has been located, exit date and time, etc.Such information is sent also to the Local Health District. It is worth noticing that each patient's pathway enables an information flow toward the administrative structure and therefore most of these data have been then redefined within the simulation model as attributes of the dynamic entity "Patient".

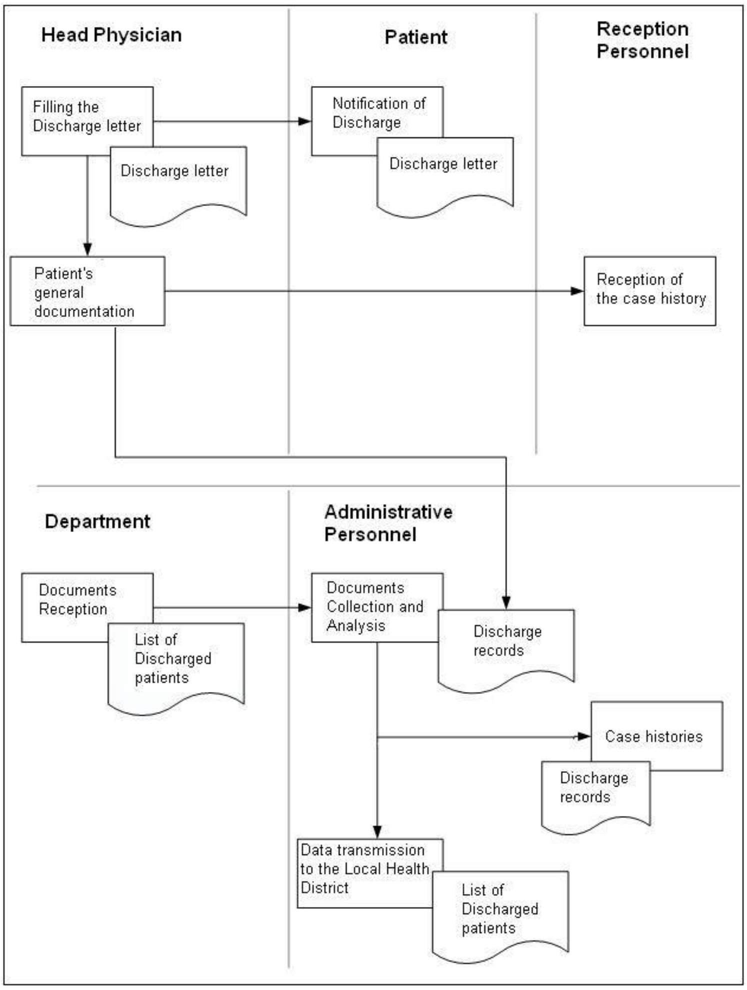

Figure 5.4: Conceptual Model of the patient's discharge process

5.3.4 Outpatients' Ambulatory Care

The Healthcare facility also provides outpatients' ambulatory care including different types of services: echocardiography, echocolordoppler, computed axial tomography, blood analysis, etc. These services are delivered using the same resources (medical staff, machines, tools and materials) that are used for inpatients. Therefore, due to resources sharing, inpatient and outpatient services affect each other and exert a relevant influence on the facility service level. Outpatient's services are provided based on pre-booked appointments arranged by the reservation center upon patients' requests. Therefore, the outpatients schedule including patients' data, arrival time, type of examination, etc is sent to the reception unit daily. Each incoming patient has to check in at the reception desk for documents validation and wait for the service to be delivered. After service delivery patients check out paying and getting the invoice that is issued by the reception desk as depicted in Figure 5.5.

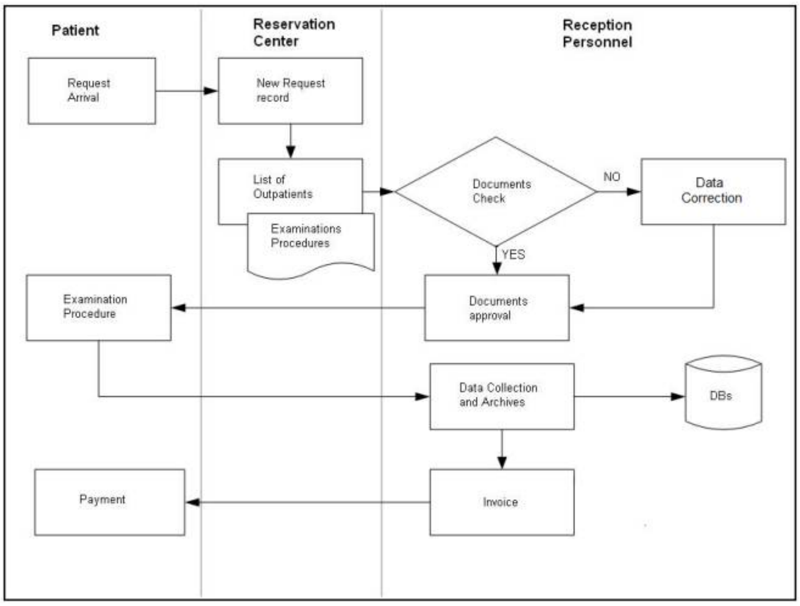

Figure 5.5: Conceptual model of the outpatients' ambulatory care

5.3.5 Purchase and Inventory Management process

Although procurement is not classified as a primary process according to the Porter's Value Chain Model depicted in Figure 5.1, its role is crucial to comply with the intended targets in terms of service levels, effectiveness, and efficacy. As it happens in industrial plants, Inventory management policies are established in order to ensure the availability of the right quantity at the right time. However, for a hospital unit, inventory shortage is not tolerated since materials and drugs availability is crucial to save human lives. Therefore procurement processes are carried out by the Purchase Area that is required to issue purchase orders, upon approval of the Administration area, in order to fulfill the department's needs. Purchase orders may refer to open contracts when there is a formal agreement signed with a specific supplier, but, when no supplier contract exists, the purchase area asks a list of qualified suppliers to submit a tender and addresses the purchase order to the supplier that offers the best price. The inventory management is carried out according to an (s,Q) inventory control policy where s is the Order-Point and Q is the Order-Quantity. The inventory is continuously reviewed and a new purchase order is issued every time the inventory position drops below the Order-Point s; the quantity ordered is Q. s and Q are defined according to specific laws and regulations that impose (for some medicines/materials) the inventory levels and also according to the experience of the Head Physicians. The storage area includes a central warehouse and satellite warehouses located in each department. Figure 5.6 depicts the conceptual models of the Purchase and Inventory Management process.

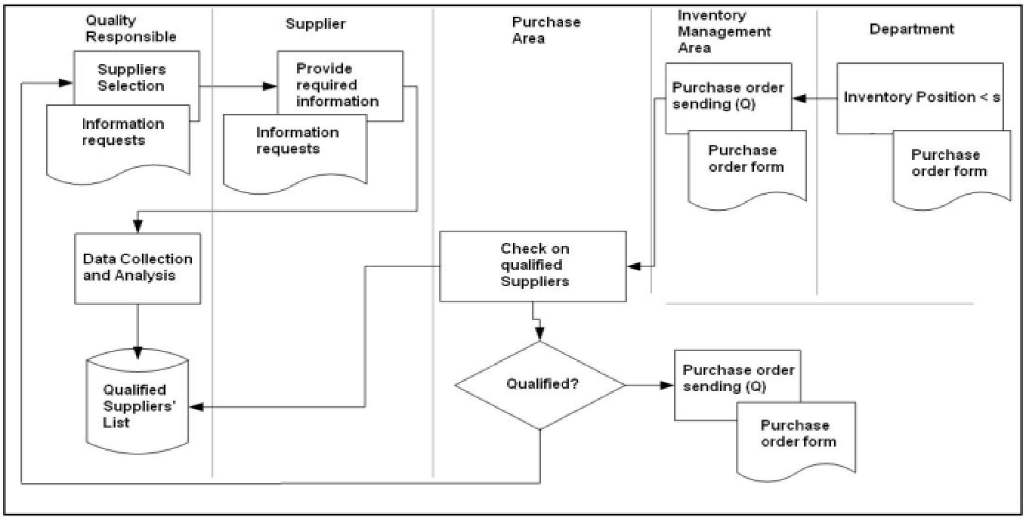

Figure 5.6: Conceptual model of the purchase and inventory management process

5.4 Process analysis and simulation development

Processes mapping through functional flow charts has been the groundwork to improve the acquaintance with the system operational modes and the main professionals involved in it. At this stage the processes above described have been analyzed in order to explore the range of enhancement possibilities and detect operational targets based on quantitative performance indicators that can lead to increase the healthcare unit effectiveness and service levels. To come up with an effective and easy to deploy solution for monitoring the healthcare facility performances as well as analyzing and testing the impact of operational alternatives, a simulation model has been developed. The simulation model hinges on two logistics flows: patient pathways and goods flows. In other words the simulation model has been devised so as to mirror both primary value added processes such as admission, treatment and discharge and key support processes such as procurement. Due to the inherent complexity of such processes the simulation model development has required a relevant effort. Indeed, several variables have to be taken into account and some of them are out of control (such as the way each patient responds to a treatment, complications, etc). Needless to say that stochasticity and variability are deemed the main system's attributes. Therefore the simulation model has been developed to capture the inherent system nature striving to ensure reliable results over a wide range of possibilities. In particular, from a purely engineering perspective the main room for improvement has been detected in the overall system planning, scheduling and control so as to have an optimal resources' deployment maximizing resources' level of use and minimizing idle times. Thus the simulation model is meant to provide an operational picture of the system under different allocation policies. For instance, considering the admission process, the main bottlenecks have been identified in late arrivals, patients' no-show and short notice cancellations. Further to these troubles that may cripple the hospital efficiency it is useful to investigate how different admission policies (such as short processing times, dynamic admission, priority assignments) can affect both the system efficiency and patients' service levels. On the simulation side this ambition has been put into effect by using a discrete event simulation tool: Anylogic. The reason why Anylogic has been chosen is the possibility of writing Java code to define and customize the main classes and objects that are part of the simulation model. Therefore it results in a very flexible tool providing the user with the opportunity to model the system with the degree of accuracy he/she deems suitable for the purposes of the study. As a matter of facts patients' flows have been modeled through a transportation network whose topology has been drawn over the facility layout. Network nodes include hospital offices, rooms and departments, patients are dynamic entities flowing over the network while equipment, medical and paramedical staff are modeled as network resources. In particular the staff members are moving resources while mobile devices are portable resources. In addition, the healthcare facility network includes static resources bound to particular network nodes such as Operating Rooms, Laboratories, Wards, beds, etc.

The procurement process has been modeled as a transportation network as well. Therefore it has its own resources but even regular resources (i.e. equipment and drugs) that can be conveyed from this network to the other; it happens when satellite warehouses ask the central warehouse for stock replenishment.
The animation main frame includes entities and resources flow across the network based on the simulation model flow chart depicted in figure 5.7.

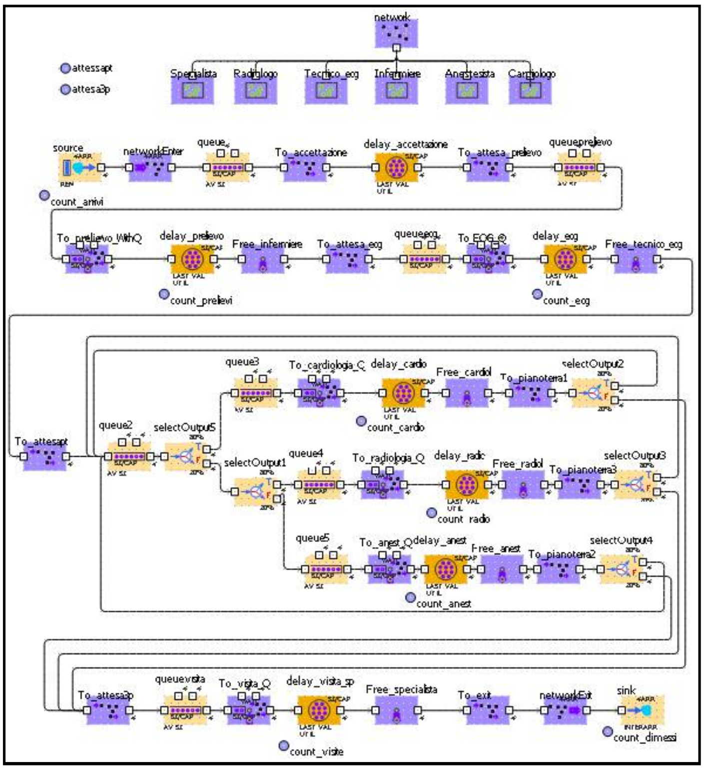

Figure 5.7: Simulation model Flow Chart: hospitalization process

The simulation model is also equipped with a dedicated output section showing the main performance measures of the healthcare facility, including (see figure 5.8):

- urology rooms level of use (for each room and average value);
- day surgery and day hospital rooms level of use (for each room and average value);
- oncology rooms level of use (for each room and average value);
- first aid rooms level of use (for each room and average value);
- head physicians level of use (for each doctor and average value);
- professional nurses, healthcare workers and auxiliary workers level of use (for each nurse/worker and average value);
- head nurses level of use (for each head nurse and average value);
- level of use of C.A.T lab, blood analysis lab, x-ray lab, ultrasound lab, operating rooms and urodynamic lab;
- queue size at C.A.T lab, blood analysis lab, x-ray lab, ultrasound lab, operating rooms and urodynamic lab.

5.5 Simulation analyses and results

As already mentioned the main idea is to see to which extent the healthcare facility is able to handle a greater flow of incoming patients and to point out if the current work organization can be improved. Therefore the simulation model has been used as a decision support tool for evaluating how the healthcare facility can maximize its operational efficiency subject to limited resources and capacity. It can be can be done thanks to the simulation model capabilities that allow the most important factors affecting the healthcare facility efficiency (i.e. patients' and outpatients' arrival rates, number of available Head Physician, Head and Professional Nurses, hospitalization procedures, etc.) to be set at each simulation run.

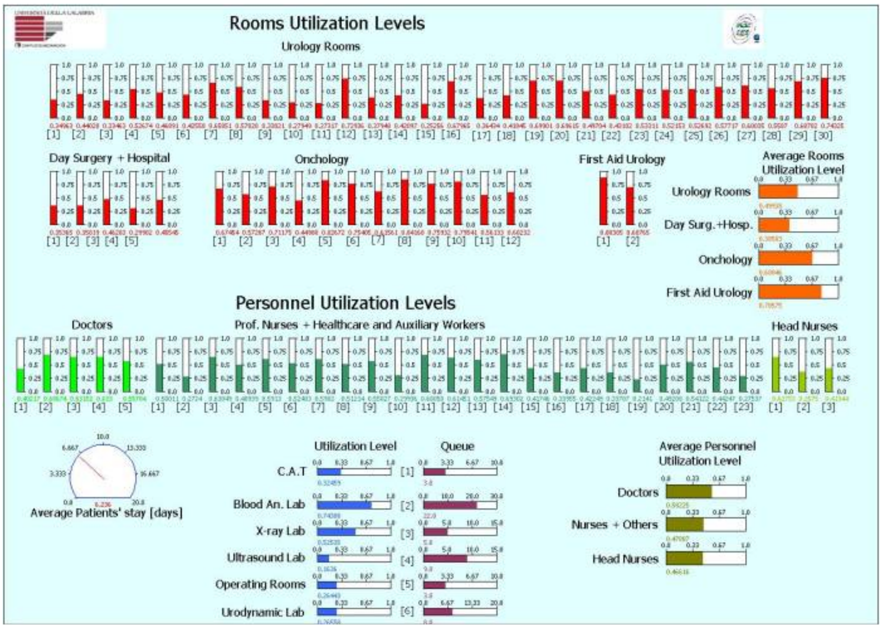

Figure 5.8: Output of the simulation model during

In order to facilitate the use of the simulation model, a graphic user interface has been added to provide the user with the possibility to change some of the factors affecting the healthcare facility performance (see figure 5.9). The factors that can be changed from the graphic user interface are:

- patients' arrival rate;
- outpatients' arrival rate;
- number of available urology doctors;
- number of available broncho-pneumology doctors;
- number of oncology doctors;
- number of available head nurses;
- number of available professional nurses;
- number of healthcare workers and auxiliary workers;
- efficiency multiplier for C.A.T lab, blood analysis lab, x-ray lab, ultrasound lab, operating rooms and urodynamic lab.

However it is worth saying that – in order to test additional scenarios – changes can be made directly in the simulation model (i.e. admission procedures, patients' scheduling, etc.).

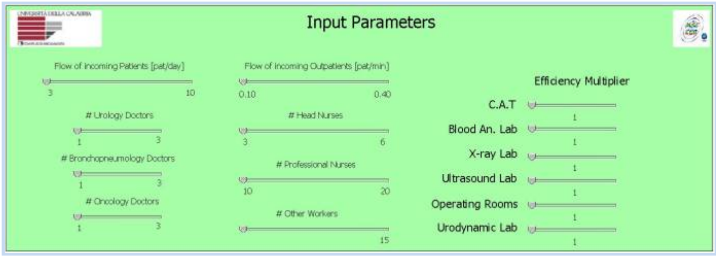

Figure 5.9: graphic user interface

The simulation model potentials have been exploited over different scenarios. First and foremost, "what-if" analyses, based on resources availability and efficiency, have been carried out. To this end, the healthcare facility performances have been investigated under two conditions: increase in patients' inter-arrivals and increase in labs efficiency by using efficiency multipliers. In the first analysis multiple performance measures are considered, including Doctors, professional Nurses and other workers level of use, labs level of use and average patients waiting time for using labs services. In the second analysis only the average patients waiting time for using labs services is considered.

	Low Patients Inter-arrival Time	**High Patients Inter-arrival Time**
Avg. Doctors level of use	0.20	0.39
Avg Prof. Nurses level of use	0.26	0.46
Avg. Other Workers level of use	0.24	0.40
Avg. X-ray Lab level of use	0.15	0.26
Avg. CAT Lab level of use	0.08	0.18
Avg. Ultrasound Lab level of use	0.46	0.95
Avg. Operating Rooms level of use	0.09	0.20
Avg Waiting Time for labs services [min.]	173.42	1082.42

Table 1: Simulation results when changing the patients' inter-arrival time

Table 1 reports the simulation results for the first analysis. The low value of the average patients' inter-arrival time corresponds to the actual inter-arrival time (calculated by using the historical records available in the healthcare facility) while the high value corresponds to 150% of the actual value. The simulation results clearly show that the current level of use of Doctors and Professional Nurses (as well as other workers) are pretty low if compared to the incoming flow of patients and therefore even a 50% increase of the patients' flow would result in a more than acceptable level of use for the healthcare facility personnel. However while most of the labs show a very low level of use and therefore they can potentially accept a greater flow of patients, this is not the case of the ultrasound lab that seems to reach its full utilization level. It is interesting to note how the additional flow of incoming patients causes a substantial increase of the average waiting time for labs utilization. This is mostly due not only to the increase of equipment level of use but, above all, to the increase of the work needed to provide the patients with the final results of their analyses.
The simulation results reported in table 1 (in particular those reported in the first column of the table that provide an overall picture of the simulated healthcare facility efficiency) are comparable with the efficiency levels of the real facility. Indeed by giving a look to the statistics provided by the Italian Ministry of Healthcare (that on a yearly base provides statistics on the level of use of all the Italian Healthcare facility) we discovered that currently the healthcare facility considered in this paper is characterized by low level of use.
The second analysis focuses on the average waiting time for labs services and aims at understanding if an increase in the labs efficiency would result in a reduction of the average waiting time for labs services.
The increase of the labs efficiency has been simulated by introducing within the simulation model an efficiency multiplier (see figure 5.10); a reduction in the efficiency multipliers means an increase in the efficiency level (i.e. a reduction of the efficiency multiplier from 1.0 to 0.8 means a 20% decrease of the procedures times). A reduction in the procedures times can be obtained by a better organization of the work.This analysis has been carried out keeping the flow of the incoming patients at 125% of the real value.

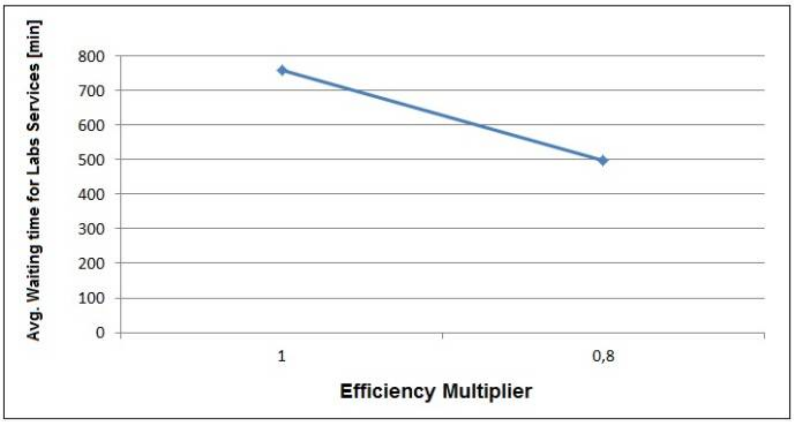

Figure 5.10: Effect of the Efficiency Multipliers on the Avg. waiting time for labs services

The figure 5.10 shows how a reduction of 20% of the procedures times (efficiency multiplier from 1.0 to 0.8) results in a reduction of the average waiting time for labs services from 760 minutes to 500 minutes (34% reduction). The results of this analysis have pointed out that a reorganization of the work together with a better use of the available resources could considerably improve the healthcare facility efficiency. Indeed the personnel level of use (Doctors, Nurses and other workers) is currently low (as it is the labs utilization level, except the Ultrasound lab). This means that there is no need for new resources (both personnel and equipment) but for a better organization of the work. Recalling that Lean Management is focused on the most effective means of producing value for their patients, Lean management principles and tools have been referred to minimize wastes and improve the work organization. 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 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 so as to make resources available easily and quickly with a smooth workflow. The information collected revealed a clear situation of non-organization. Each process presented problems mostly dependent on the hospital management policies (e.g. too stressful shifts), 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.). 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;
- pharmacy or in other operative units;
- the warehouse 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 have been

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). The 5S method, the kanban method, layout optimization, etc.) have been applied to ensure that medications, medical materials and machineries could be always available (Longo et al., 2014). The simulation results on the impacts of changes suggested by Lean Management tools and methodologies, clearly show 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 the intended work reorganization may result in a 100% increase in the patients' value. 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 assigning more patients to one nurse (workload optimization). Thus simulation results confirm that Lean methods and tools can be successfully transferred to the real system with a relevant increase of the overall performances.

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CHAPTER 6: Other Research Insights - Conclusions

6.1 Introduction

This chapter is devoted to illustrate a related research line that has been followed together to the main research stream illustrated in the previous chapters. Indeed, further research activities have been focused on Lean Management and its applications in healthcare facilities. The tests of this application have been made through simulation models constructed "ad hoc". During the analysis carried out in health facilities it was found to lack of information systems for the management of patients and pharmaceutical logistics. Therapeutic treatments are the main processes in a hospital. They comprehend patient reception, diagnosis, cure, possible staying in hospital and, finally, discharge. These processes are also supported by a number of services ensuring products and materials to guarantee their execution. Nowadays, there is an ever growing demand for qualitative improvements of health care services. This implies transformations not only in therapeutic treatments, but also in their support activities. Among the last one of the most important is logistics, whose aim is providing patients with a high service level at a reasonable cost. Health care organizations are now starting to conform to the new requirements, thus increasing their managerial complexity and the number of transactions taking place within them. Therefore, a deep reengineering of health care logistic processes is needed and specific logistic goals have to be settled. In this chapter possible future scenarios for health care logistics are proposed, according to different parameters like complexity, consistency with organizational processes, personnel skills and, of course, costs. Particular emphasis will be given to the computerized management of medicines throughout the healthcare facility.

6.2 The process of management of clinical medicine

The process of medicines management includes all operations from prescription to drugs administered to patients and can be divided into two main components: therapy management and inventory management. The management of treatment starts from the doctor's prescription on the patient's medical record and the transcript of the notebook of therapy and / or nursing record. Daily, the nurse will check the actual presence on the carriage of drug therapy required by the notebook of therapy and pick up from the warehouse ward of the missing ones and finally, before administration, will monitor the correspondence between patient and prescription reference. Inventory management deals instead of periodically determine the need to ward of drugs and medical supplies, to advance the demands for supply to the central pharmacy, specifying eventual products urgent, to control the drugs received and place them in storage peripheral, to take medicines necessary to treatment, to check their expiration dates, and finally of your prized possessions. As you can well understand, the process of clinical management of drug is complex, because it is interfaced with other processes, such as the administration of medications and the business of advising to the Doctors performed by pharmacists of the Hospital. There are numerous types of issues that may arise in the interior. For example, insufficient space at the central warehouses and / or peripheral storage of bulky materials, high number of managed codes, high values in the fixed assets inventory, expired drugs and materials, waste in withdrawal requests and use of materials, resulting in the presence of several packages open, confusion in setting the trolleys and high likelihood of medication errors. The process in question requires an efficient internal organization. The next section analyzes the traditional approach to the clinical management of drug, highlighting the critical issues.

6.3 Process of medicines management

Drugs, like the rest of the hospital supplies, are usually managed in stock, so as to ensure a supply that is in the central pharmacy to the wards. They provided by suppliers at the central pharmacy of the hospitals, are stored in the locations of the warehouse and then taken to be distributed to the wards in the same packaging into which come from pharmaceutical companies. Drugs delivered to departments do not have precise locations, and according to an order: are housed within rooms or areas of clearing used for storage peripheral, on the shelves, but also sometimes in boxes, without an encoding preset. The same product can be in multiple positions, resulting in a use of space that does not guarantee an adequate stock rotation. This last factor increases the likelihood of having expired medicines to department and causes waste of resources. The logic materials management is adopted LIFO, although the constraints of the expiry dates of drugs would make it more appropriate FIFO logic. In general, the flow of drugs within the hospital involves: wards and the pharmacy, which carry out a series of activities interacting.

- **Activities of wards**

  - *Doctor's prescription*: during the tour visit, once or twice a day, doctors prescribe to patients therapies to follow (type of drug, dosage and time of administration) on paper.
  - *Passing information to the doctor-nurse*: doctors communicate on paper or voice information to nurses and to transcribe these on your record, it also paper, adding data relating to health conditions of patients.
  - *Preparation of the carriage of medicines by the head nurse or nurse*: the head nurse or nurses consult the nursing record and verify the presence in the carriage of drugs needed for the next round of administration. In the case of drugs missing, the attendant goes to the warehouse ward and then processes the visual identification and make the picking. The replenishment of the truck can be made simultaneously to the stage of prescription or at the end of the lap of administration.
  - *Preparation of drugs prescribed and administered to patients by the nurse*: the nurse consults the register-nursing and identifies, always visually, the drug by reading the trade name on the package. If the medicine is not present on the carriage, provides to retrieve it. The administration and its outcome are finally noted on paper.
  - *Analysis of the needs ward* : the head nurse or administrative personnel control the amount of drugs in stock ward at intervals which ranges from once a day to once a week and independently by prescription / administration. The check is usually done visually and to determine the volumes to ask the pharmacy does not use logic supply common, but each operator usually relies on its knowledge and experience. Rarely, nurses, during the night, carry out the inventory of materials in the warehouse ward and on the carriage: counting, sorting, deleting any expired materials.
  - *Picking requests or purchase at the central pharmacy*: the officer in the ward issues a request to drugs and medical devices with the necessary quantities, while for new materials is made a purchase request containing an extended description of the item and its technical characteristics. The request for purchase of new drugs or medical devices will be submitted to the administrative office. Both requests for picking and buying are mostly written on paper and transferred directly to the pharmacy.
  - *Check material and storage ward:* The head nurse receives the material sent by the pharmacy and signature for acceptance of the bill of delivery. At this point, the charge nurse or nurses will proceed to storage. The ordering of the packs following criteria is entirely discretionary, which may vary from department to department, for example, the alphabetical order by the date of expiry growing.

- **Activities of the central pharmacy**
  - *Picking warehouse:* Each ward sends a list of drugs or medical devices they need. Pharmacist analyzes requests and authorizes workers to make the picking. At this point, workers of the warehouse verify presence of the required codes and any expired medicines.

  - *Preparation and distribution to the ward*: the drug packages are removed from the closets of the pharmacy according to the pick-lists and are prepared carriages with items ordered from each ward. Next, need unload accounting of drugs. If the hospital is equipped with an information system that gives value to the stock, the material is discharged from the warehouse accounting and simultaneously uploaded to those peripheral (wards). Otherwise, the items are consumed for data, and then are discharged accounting, at the time of distribution from warehouse to the wards. At the end of the picking, the pharmacist verifies the correctness and sign the delivery note. Finally, warehouse personnel, but sometimes even ward, carries a destination carriages with packs of medicines.

- *Analysis of understock* : Periodically, on the basis of picking, the pharmacy performs an analysis of consumption by updating the parameters of minimum stock. The comparison of these parameters with the material inventory in the warehouse are identified items understock which should be ordered. If the hospital is equipped with the information system, the analysis can be performed automatically.
- *Call off / purchase orders and reminders* : For materials with stocks below the minimum stock for which there is a framework supply contract (signed by the purchases or the Administration Hospital), the pharmacy automatically emits a request for reinstatement to suppliers (call off). For other materials, with inventories below the minimum stock, and for new purchase orders, issuance of the purchase order is subject to approval by the Administration. If the ordered material has a delivery delay, the pharmacy will issue a reminder to the supplier. The procedure for supplying through the central pharmacy is sometimes used only for ordinary items, or those of wide use and economic value content. Special products, rarely used and often of high value, can be ordered directly from the wards. In this situation, the pharmacy is responsible only for their transfer.

6.3.1 Critical of the process

During the investigation carried out the stocks held in the warehouse of the central pharmacy and ward stores are far oversized compared that necessary to prevent breakage of the stock. This practice creates inefficiencies that result, directly or indirectly, into a lower level of service and in higher costs for the hospital. Unfortunately, very often workers to warehouse management are not aware of the economic performance of the structure. Another thing worth of consideration is the sometimes excessive involvement of nurses in activities not related to their profession: inventory control ward, preparation of requests to the pharmacy, transport of material from the warehouse of the pharmacy to the ward and its storage. All this reduces the time available for the treatment and care of patients and adversely affect the level of nursing service. Table 6.1 shows critical issues identified during our stay in the healthcare facility.

Critical issues
1. High value of fixed assets of ward warehouses
2. Lack of control of the consumptions in ward
3. Lack of methodologies and tools available to hospital staff for estimating consumption ward (order management is based on experience)
4. High risk of product obsolescence
5. High time spent by administrative staff and sanitary for medicine management (needs analysis, receipt and storage, packaging management, necessity of frequent inventories, etc.)
6. Location of stocks of ward (often does not directly fills a shelf, but you leave everything to the head nurse. Even in cases where there is a shelf, the criteria for its filling are discretionary)
7. Unpredictability of requests for ward
8. High frequency of urgent requests from the wards
9. Risk of error in the phases of associating patient-treatment, preparation and administration of the drug (all controls are visual)
10. Manual transcription of prescriptions from paper medical records to register nursing paper (risk loss of information)

Table 6.1: Critical process of management of clinical medicine

6.4 Applications possible in Process of Medicines Management

The process of corporatization of local health facilities, initiated with the Legislative Decree 502/92 and subsequent amendments, requires the introduction in the public health system of control mechanisms similar to the model of the competitive market. The hospitals must assume the managerial autonomy and economic - financial and, should establish objectives for quality of service and cost management. The actual scenario of the health sector is also characterized by limited resources and a growing spending. The need to rationalize the system of public health, especially in light of a request as to satisfy increasingly demanding quality, requires a profound transformation that involves not only the processes of diagnosis and treatment, but also those of support, including logistics essential for the differentiation processes of the services provided and to improve the quality of the same. The objectives of the logistics must ensure that decision-making process involves several figures and job skills, prepare a gradual plan of action with increasing complexity. In hospitals it is growing awareness of the significant weight that investments in supplies and costs of their management have on the company's balance sheet. Therefore, in order to increase the efficiency necessary to operate in the direction of simplifying the flows of materials and replace the current high level of stocks with a greater amount of information, available in real time and accurate information, about the various stages of the logistics chain. Precisely for this reason, as happens in the industrial environment, hospitals should use innovative systems of inventory management. Unlike what happened in manufacturing companies, in which the supply chain management is a strategic element of the management, the health sector is, unfortunately, anchored, in most cases, to a distribution with the traditional system. To overcome the many problems, described above, they can be applied to some methods used in manufacturing logistics. Five possible applications below are proposed to be implemented in pharmaceutical logistics:

1. Carriage medicines with kanban system;
2. Carriage medicines with kanban system and optical reader
3. Computerized system for prescription and medical records
4. Computerized system for the management of "unit dose" of medicines
5. Computerized system for the management of "personalized doses" of medicines

6.4.1 Carriage medicines with "kanban system"

This application involves the integration of the entire supply chain of the hospital and the review of the management system of the material with the use of logic Kanban, originally applied in the automotive sector. In particular, the system is based on using of "card" accompanying materials (kanban) that allow you to:

- order the material required;
- manage the central warehouse;
- ensure the first in- first out (FIFO) in the internal handling;
- require only the amount necessary;

Medications, delivered by suppliers at the pharmacy healthcare company in the packaging of pharmaceutical companies, are stored in the locations of the warehouse, picked according to a logic of replenishing stocks of ward and distributed to each ward through the use of pairs of carriages locker "twins". Each carriage-locker, equipped with wheels for moving between hospital pharmacy and ward, contains all the medications used from the ward and replaces, in fact, the cabinet of the pharmaceutical ward. In this way, the carriage performs the function of buffer peripheral ward and no more that of simple vector for the transport of materials from the pharmacy to the ward, as in the conventional configuration. The exchange of the two carriages "twins" between pharmacy and wards should occur with varying frequency depending on ward (usually weekly): the hospital pharmacy sends a carriage full of medicines; the ward sends to the pharmacy "cart-locker" half-empty. At half-empty carriage is attached a data sheet containing predefined levels of equipment, reports of extraordinary consumption, the shortcomings and the need to purchase new medicines. This information will be used to replenish the "carriage-locker," according to a FIFO, for subsequent sending to the ward. The described technique determines the best results if preceded by a rationalization of medicines in terms of number and type. It is also appropriate to have a reorganization of medicines according to the concept of the active ingredient.

6.4.2 Carriage medicines with “kanban system” and optical reader

This system ensures that the drug packages, delivered by suppliers at the pharmacy company's health, are labeled with a bar code or RFID tag containing information relating to products, such as production lot, expiry date, coding of the drug, supplier code, location, and the essential elements for monitoring the flow of medicines and control of expired. The packs are stored in the locations of the central warehouse, taken on the basis of the requests and distributed in the cabinets of the ward, and from this to the patients, by means of a carriage provided with laptop computer and an optical reader for barcodes or RFID tags. The endowment of carriage allows the automatic unloading of medicines taken from the closet to the optical ward and helps nurses to administer the right treatment (if the patient has a bangle with barcode). The system described can have several variations, and its implementation involves identification codes allowing access to the warehouses to authorized personnel only, avoiding the danger of manipulation of medicines and ensuring the traceability of medical personnel who perform individual operations.

6.4.3 Computerized system for prescription and medical records

The computerized prescription system differs from the traditional system to the mode of transcription of prescriptions in the side ward: switching from a manual recorded in the appropriate paperwork to an electronic generation of a computerized medical record. The process begins with a prescription by the physician of medicine from administered to the patient. The prescription is recorded on special terminals like PDAs (personal digital assistants or handheld PC) held by the doctor and is associated with the patient reading bangle with barcode. The doctor, through to the electronic identification of the patient, is able to carry out a proper prescription, due to the presence of utilities such as:

- list of drugs in the hospital formulary;
- immediate consultation of therapies, including freshly made (active, suspended or interrupted);
- possibility of creating associations between drugs according to protocols
- automatic control of drug interactions
- compatibility of the prescription with some key elements of clinical pathway of the patient (diagnosis, allergies, diagnostic tests, etc.).
- checking the immediate availability of medicines in the warehouse ward or hospital pharmacy

6.4.4 Computerized system for the management of "unit dose" of medicines

The "unit dose" completely changes the traditional process of inventory management from a physical, technological and informative. Distribution "unit dose" requires that medicines provided by suppliers at the pharmacy healthcare company in the packaging of pharmaceutical companies, are divided into single-dose, using automated machinery. The packages containing a single dose of the drug, labeled with bar codes, are stored in the locations of the warehouse, taken on the basis of requests and distributed at the dispenser manual or automatic. Nurses, with barcode reader, take in the dispenser only single-dose packages required for each round medication administration.

6.4.5 Computerized system for the management of "personalized doses" of medicines

The "dose personalized" allows the automation of the entire process of the clinical management of medicines, introducing computer technology on the entire process. The path logistics of the drug is completely computerized, starting from the prescription until the administration to the patient, with a completely paperless and data management in real-time. The distribution in "personalized doses" is the evolution of the unit dose; it consists of the administration of medicines to the patient in a personalized way: medications, delivered by suppliers at the hospital pharmacy, are divided into single-serve by automated machines, which are then stored in the warehouse locations. On the basis of medical prescriptions received by the various wards, the hospital pharmacy prepares therapy, taking needed medications from warehouse locations and creating custom envelopes for the individual patient. On each envelope is placed a label with a bar code, which are shown on data specific to a single dose (patient name, date, ward, medicines content, route and time of administration). The packages thus obtained are ready to be distributed to the wards. It is important to highlight that not all drugs lend themselves to a customized management (eg, medicines dressing).

6.5 Conclusions

Different configurations described above can be regarded as modules, independent and interacting between them. In this way, in reality it will be possible to activate one or more systems, identifying a plurality of mixed solutions. The interaction of these systems allows a gradually increase starting from computerized prescription, which starts the demand or from the end point of the supply chain, and thus obtaining that efficiency of the system, does not accessible from other modules more or less combined with each other , which are characterized by a prediction and a control based on past data and not on actual usage. The fundamental element on which will be based the future developments of the process of re-engineering of hospital logistics is that these solutions are not independent, but can be implemented in an integrated and modular, depending on various aspects, such as the size of the hospital , the maturity of the child towards the management of the drugs or the willingness to invest. The combination of several tools for optimizing flows hospital creates synergies between its benefits and overcome their weaknesses. The task of future research on the one hand stimulate the adoption by hospitals of innovative methods to improve the management efficiency of drugs and medical supplies, on the other refine the study of integration between these, in order to allow 'dispensing to patients of an increasingly high level of service, taking full advantage of latest possibilities offered by Information and Communication Technology. The current situation of the public healthcare facility analyzed, it requires a simplification of the flow of the material with lower inventory and the speeding up of information the entire logistics system, through a high degree of automation gradually more increasing, for example by increasing the load points and control information. In particular analysis carried out in the Intensive Care Unit and in Operating Block has highlighted how much be the enormous stress of staff. The workload has continues to increase during the last years and this type of environment creates an atmosphere of frustration and anxiety for all staff due to particulars conditions of patients, weighed down by a logistics management and information inefficient. 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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