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Lifecycle analysis for surgery instruments at a hospital

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struments
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Italian abstract

Gli strumenti chirurgici sono importanti “devices” utilizzati come supporto indispensabile nella cura di pazienti negli ospedali.

Essi sono caratterizzati da un intero ciclo di vita che inizia convenzionalmente nello “Store”, dove gli strumenti sterilizzati sono prelevati per essere utilizzati all’interno delle sale operatorie, e termina nuovamente nello “Store”, dove gli strumenti vengono immagazzinati per essere riutilizzati in un nuovo ciclo.

Può accadere che le singole fasi del ciclo subiscano ritardi rispetto ai tempi previsti, non assicurando, pertanto, nelle sale operatorie, il corretto numero degli strumenti secondo i tempi programmati.

Il progetto che vado ad illustrare ha come obiettivo l’ottimizzazione del ciclo degli strumenti chirurgici all’interno di un nuovo ospedale, applicando i principi della Lean philosophy ed in particolare i metodi: “Poke Yoke, 5S e tracciabilità”.

Per raggiungere tale scopo, il progetto è stato articolato come segue.

In un primo momento si è osservato l’intero ciclo di vita degli strumenti nei due principali ospedali di Copenhagen (Hervel e Gentofte hospital). Ciò ha permesso di rilevare gli steps del ciclo, nonché di riscontrare sul campo i principali problemi relativi al ciclo stesso quali: bassa flessiblità, decentramento dei differenti reparti di cleaning e di store rispetto alle operation theatres ed un problema nel sollevamento degli strumenti pesanti.

Raccolte le dovute informazioni, si è passati alla fase sperimentale, in cui sono stati mappati due cicli di vita differenti, utilizzando tre strumenti di analisi:

- Idef0 che consente di avere una visione gerarchica del ciclo;
- Value stream Mapping che permette di evidenziare i principali sprechi del ciclo;
- Simulator Tecnomatix che favorisce un punto di vista dinamico dell’analisi.

Il primo ciclo mappato è stato creato con il solo scopo di mettere in risalto gli steps del ciclo e alcuni problemi rincontrati all’interno degli ospedali visitati.

Il secondo ciclo, invece, è stato creato in ottica Lean al fine di risolvere alcuni tra i principali problemi riscontrati nei due ospedali e ottimizzare il primo ciclo. Si ricordi, infatti, che nel secondo ciclo le principali innovazioni introdotte sono state: l’utilizzo del Barcode e Rfid Tag per identificare e tracciare la posizione degli items, l’uso di un “Automatic and Retrievial Store” per minimizzare i tempi di inserimento e prelievo degli items e infine l’utilizzo di tre tipologie di carrello,

per consentire un flessibile servizio di cura. Inoltre sono state proposte delle soluzioni "Poke-Yoke" per risolvere alcuni problemi manuali degli ospedali.

Per evidenziare il vantaggio del secondo ciclo di strumenti, è stato preso in considerazione il parametro "Lead time"e le due simulazioni, precedentemente create, sono state confrontate. Tale confronto ha evidenziato una radicale riduzione dei tempi (nonché dei costi associati) della nuova soluzione rispetto alla prima.

Alla presente segue la trattazione in lingua inglese degli argomenti oggetto di ricerca.

Buona lettura.

Abstract

Surgical instruments are important devices need to carry out the service of care at a hospital: the right surgical instruments must be provided where it is needed and in the right time, according to lean philosophy.

This project focuses on optimization of the flow of surgical instruments at a hospital. The idea of the project is to propose an optimized lifecycle of surgical instruments which can be implemented in a new hospital.

To make such a proposal, careful consideration of different ideas has been made. The empirical study consists of visiting two hospitals in the capital area (Herlev and Gentofte Hospital) and scouting articles, books and websites. Two solutions are carried out: the first solution represents the main steps of the cycle and it is a draft for the analysis. The second solution puts into practice the principles of the lean thinking.

Three different methods are used:

1) $IDEF_0$: it allows mapping the different steps of the cycle of surgical instruments through a series of hierarchical diagrams; they describe step after step the cycle;

2) Value stream mapping: it allows highlighting, for each phase of the cycle, what the main wastes of cycle and what the main activities that enhance the cycle are;

3) Simulation: the software Technomatix has been applied in order to give a dynamic point of view of the lifecycle.

Precisely the two solutions are compared and the parameter Lead time is taken into consideration. Through the analysis of the two simulations the main beneficial of the second solution are highlighted: the function of the traceability solves the problem to identify the different item in the hospital, the use of the automatic and retrieval store minimizes the times to store the different items and the use of a new organized cycle in order satisfies acute and plan cases.

In other word all information about the theory approach was considered as base to create a new solution.

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1 Problem statement

Well manage the surgical instruments within the hospital is a fundamental requirement if the hospital has to deal with high number of surgical operations and ensure that all instruments are ready at right time.

When it talks about the surgical instruments it refers at entire life cycle that each instrument has to go through; the cycle starts in the warehouse, where the instruments are picked and finishes when the instruments are stored again and re-used to another surgical operation. Waiting, delays, high time to move the items and to carry out some phase characterize the total cycle. After a visit at the hospitals and after have spoken with the workers of Herlev and Gentofte hospital, some causes were identified:

"A big problem is that the wards are decentralized respect the cleaning area: it utilizes high time to move them to one zone to another one (Herlev hospital)";

"It's difficult to insert the box inside the case cart: the lifting of heavy box requires high time (Gentofte and Herlev hospital)"etc.. ;

"The system is not so much flexible";

According these ideas, the goal of this project is to propose an optimized cycle of surgical instruments where principles of Lean philosophy are applied: in other words a cycle where are solved the problems of the two hospitals and a continuous flow of items is guaranteed without waits and wastes.

To achieve this goal, two life cycles are hypothesized and mapped through different tools such as the value stream mapping, Idef$_0$ and simulator "Tecnomatix". The first cycle is mapped following the main information gathered after the visits of the two hospitals; the second cycle, instead, is mapped solving some problem seen in Gentofte and Herlev hospitals and following a lean optical. The main parameter to compare the two simulations is the Lead time: it will be useful to explain the advantages of the second solution compared to the first one.

The chapter below explains the approach utilized in the treatment.

2 Approach

This project is divided in ten sections: they are included in four main parts (figure 1).

The first part is a background of theory for the case study analysis and it uses many approaches. The theory consists of articles and books that provide a description on what the main steps of the life cycle of surgical instruments are and how the lean philosophy is applied in healthcare case. The main articles are important because they talk about the function of the case cart and the usage of the automatic retrieval store that guarantees an automatic storage of the boxes. The last part of the chapter is dedicated to describe the importance of the simulation and its application.

After having briefly touched upon lean philosophy, the second part shows the main steps of the lifecycle observed during the two visits at Gentofte and Herlev Hospital, the two hospitals of the capital. The two visits are important in order to gather idea of the cycle.

Following the empirical study, the third part starts with the description of the first lifecycle of surgical instruments. The first system is mapped using two main tools, $IDEF_0$ and Value Stream Mapping. These tools allow defining a clear overview of the main steps of cycle through two different ways.

After this first solution, the main principles of Lean philosophy are treated in order to focus on Poke Yoke method, 5S method and lingering over the traceability. They will be used in the new system.

To create a network between the first and second system, the description of first simulation is done.

After that a new solution of the system is provided and the traceability, other principles of Poke Yoke and 5S are applied. In this way a new system is proposed also to solve any problem in Gentofte and Herlev hospital. The new system is described through the Value stream mapping and simulation: at the end a parameter Lead time is analyzed in order to compare the two simulations and to highlight the advantage of the second solution in term of times.

The last part of the report is dedicated to the discussion of the obtained results and different recommendations are provided to Herlev and Gentofte hospital.

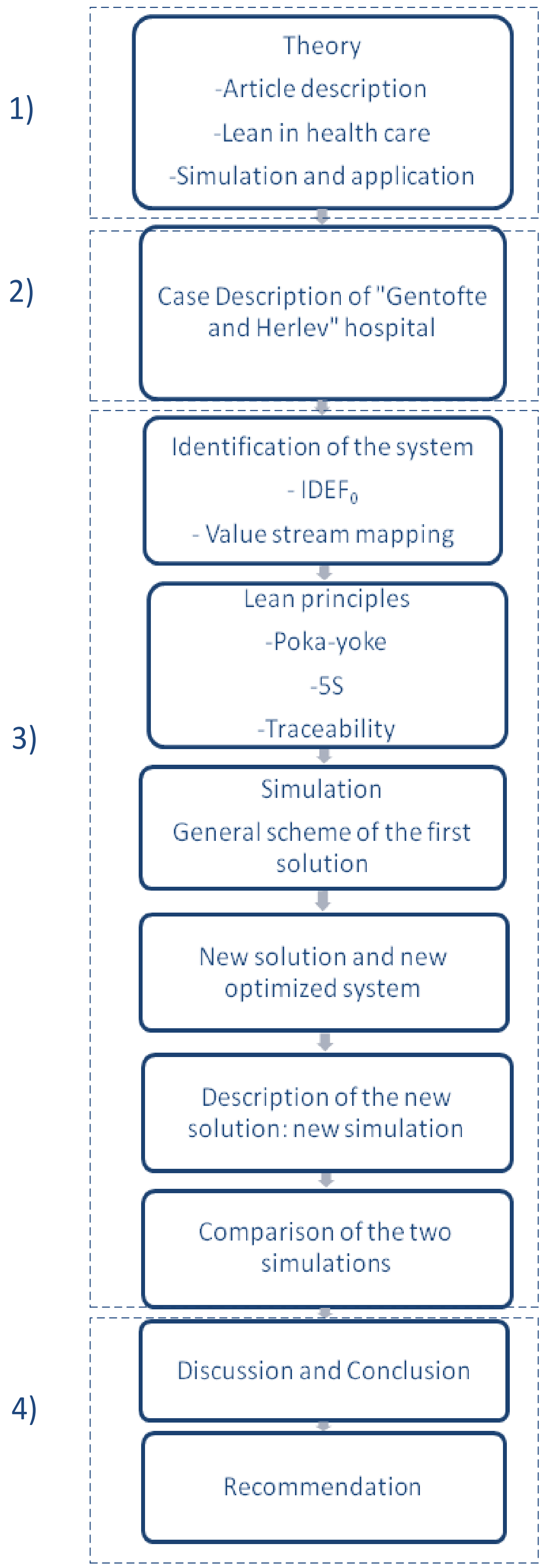


Figure 1 Approach

3 Theory

The treatment starts providing some meaning about the main key words: it thinks about surgical instruments, boxes and case carts, the three main devices mentioned in the lifecycle. This is done in the first part of the chapter.

The second part of the chapter is an overview of article descriptions and books that shows the importance of the case cart (vehicle that is supplied with items designated for a single surgical procedure and transported to the operating room) and of the automatic retrieval store (an innovative store used to pick or store the items).

The third part focuses on description of the main phases of the lifecycle of surgical instruments: each phase is analyzed in order to have a clear description of the step of the cycle.

Following the chapter, the fourth part is a generic background of the lean philosophy: it is important in order to introduce what the main principles of the lean thinking are and what the applications of the lean philosophy in healthcare case are.

The last part of the chapter gives an overview of how the simulation and its application helps to represent the total cycle.

3.1 The management of surgical instruments

The management of medical devices, surgical instruments, supplies and equipment is a critical aspect of the modern health care delivery system and directly impacts patient safety. Before entering in the discussion, it is important to understand the meaning of the main devices used during the cycle of surgical instruments.

"Surgical instruments are tools or devices that perform different function such as cutting, dissecting, grasping, or suturing. Most surgical instruments are made from stainless steel. Other metals, such as titanium, chromium, vanadium, and molybdenum, are also used". (1) They are used in different areas of the hospital and to know their cycle it is important to prevent different problems. The instruments are not utilized without a container; in fact they are inserted in specialized surgical packs, called **boxes** that contain the most common sterilized instruments needed for particular surgeries (figure2).

Figure 2 Box of instrument (2)

These boxes are transported in different areas of hospital through the **case carts (**figure 3). "The case cart is a vehicle stocked with instruments and supplies designated for a single surgical procedure". They are filled using a standard supplies list and preference list specific to the surgical procedure. (3) The function of the case cart, indeed, is to ensure that the right instruments and supplies are available at the right time for the right procedure.

Figure 3 Case cart [4]

3.2 Article Description

After have describing the main meaning of the key word, in this part an Article description is given: it allows informing about the importance to use the case cart in the hospital and what kind of case cart are used in the hospital.

The second part is dedicated to show two ways to handle the instruments in the storage: manual or automatic.

3.21 Why the case cart is important?

The use of the case cart represents a new solution developed the last years. It was invented because the hospitals recognized the drawbacks of the traditional decentralized system for managing surgical supplies.

“Medical/surgical supplies were, for the most part, processed and maintained in the departments and patient care areas in which they were to be used. In this case there was considerable duplication of effort and equipment, and it was difficult to maintain consistently high standards of sterilization technique and product quality throughout the health care facility. During the time there was the necessity to centralize processing and to grew efficiency, economy, and patient safety. This was justified because the number and variety of surgical procedures grew as the types of medical devices, equipment, and supplies. For these reasons the hospital moved toward centralization of supply storage in a central sterile process department (CCSD) instead of in the surgery department.

Several advantages were highlighted: standardized procedures and protocols, elimination of duplicate cleaning and processing of equipment, increase availability of Operation Theatre personnel for patient care and a reduced change of cross-infection by eliminating a decontamination area”. [(5)]

In this perspective the trend to centralize material management allowed the implementation of various way for distributing supplies to one part to another part of the hospital: one of these was the use of case cart.

An exemplification of the case cart has been explained before; in this chapter it wants to show that there are two kind of case carts : opened case cart or closed case cart. The opened carts provide some distinct advantages over enclosed. Opened case Carts are typically used in facilities that have a dedicated process utilizing clean and dirty travel routes to and from the operating room. At the same time they are lighter and allow seeing their content; they. are easy to clean and they are lighter in weight; differently enclosed case carts are used when the items are transported between supply storage and the surgical but they are heavier in weight and have higher costs. They also may need it be used as a black table. [(6)]

3.22 Automatic retrieval store

During the lifecycle of surgical instruments an important phase is the storage of items. In real case there are two types of storage functions. The different instruments can be handled manually or automatically. With handling means stored and retrieval.

The manual storage is done when the different items are inserted inside the shelves by hand. It thinks that the case carts is moved toward the shelves and each boxes is taken and inserted in the store.

Another kind of storage is automatic and it is called Automatic storage and retrieval system. The automated storage and retrieval system (ASRS or AS/RS) involved of a variety of computer controlled methods for automatically placing and retrieving loads from specific storage locations. To achieve their missions, the equipment required for an AS/RS includes a Storage & Retrieval Machine, or SRM, that is used for rapid storage and retrieval of material.

They are typically used in applications where there is a very high volume of loads being moved into and out of storage and can be used with standard loads as well as nonstandard loads.

They are designed for in manufacturing, distribution, retail, wholesale and institutions. They focus on bringing "goods to the man" rather than manual walking and searching. The main benefits are that the space savings, increased productivity/reduced labour, increased accuracy and reduced inventory levels. (7)

These two ways to store the items are important because they are mentioned in the different systems. It thinks that the retrieval system will be used in the new solutions in order to guarantee an automatic picking or storage of the items.

In the following chapter the idea about how is the life cycle of surgical instruments is described. This is important because each step is indicated in order to understand how the lifecycle is.

3.3 Life cycle of surgical instruments

After this brief section about the articles descriptions, it is important to know what is the cycle of surgical instruments through the different information gathered on the website. This chapter, indeed, is dedicated to achieve this goal. The lifecycle of surgical instruments is the main topic of the treatment. (8), (9)

The involved areas during the life cycle of surgical instruments are different. The main areas are linked as follow:

1)Area of warehouse or store: the boxes are stored;
2)Area of Operation theatre: the boxes and instruments are utilized for the surgical operation;
3)Area of cleaning and sterilization: in this area the instruments are cleaned, picked and sterilized.

In these areas the different steps of surgical instruments are carried out and are shown as follows in figure 4.

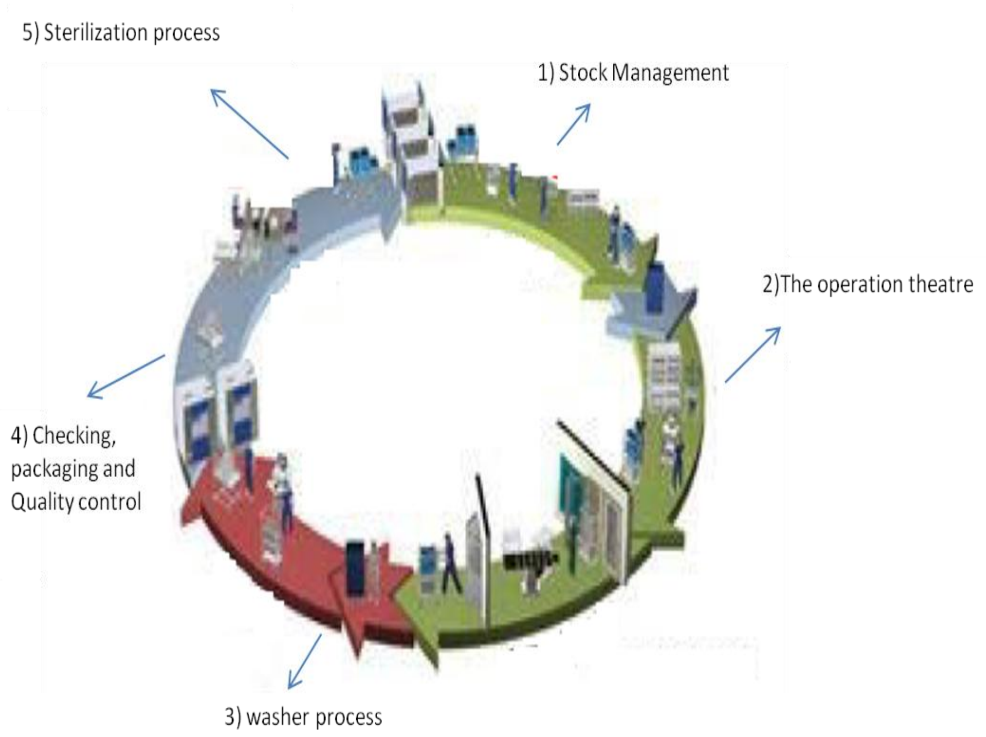


Figure 4 Life cycle of surgical instruments [(10)]

1) Stock management

The stock management is an important phase, carried out in the store. The store, indeed, is dedicated to insert the different boxes coming from the sterilized zone. The sterilized packages/boxes are transported from the point of sterilization to the storage on case carts and later they are inserted in shelving. The storage of instruments is done with care to avoid any kind of contamination and exposure of items to dangerous area of the store (water pipes, sinks, or other area). After the storage the item remains in this area until a new request from Operation Theatre (OT) is ready: the different boxes are ordered and are taken out. Later they are inserted in the case carts that are prepared in advance for all scheduled surgery cases, with the earliest cases of the day prepared first, and transported to the operation room.

2) The operation room

The boxes arrive in the Operation room or Operation theatre (OT), area where a patient is treated: the boxes are opened and the different instruments are used during the surgical operations. When the surgical operation is finished instruments and items are placed in the boxes and/or impervious bags for transport to the decontamination area. The used instruments during the surgical operation are of two kinds: multiple use or single use. The multiple use instruments are inserted in the boxes and transported in cleaning area; otherwise the single use instruments are collected in bins to be disposed off. The boxes are moved in an area of cleaning. In this area, all multiple use instruments arrive to be processed, cleaned and sterilized. The instruments follow precise steps.

3) Washer process

It includes the pre-cleaning phase (Automatic or manual) followed by cleaning in washing machine. The instruments are in the first moment pre-washed manually to ensure that no residual material or organic residue remains on the instrument surface. If the gross soil has been removed properly,it is used an ultrasonic bath that removes the remaining soil. The ultrasonic bath penetrates into the box locks, joints, and screw areas of the instrumentation and deletes the dirt.

After this phase, the instruments should be washed again to remove residual detergent. For this goal it is used a washing machine. It is a machine used to reduce the number of micro-organisms but not usually bacterial spores .

4) Check-in, packaging and quality control

After the washing of the items a visual check for cleanliness and dryness it is made for all items washed as part of the decontamination process. This is done because all non-conforming product should be rejected and returned to the wash area for manual cleaning, followed by the automated wash process (depend from the process request) before continuing through to packaging and sterilization.

4.1) Packaging

Once the instruments are checked, they are inserted again in the boxes: this phase is called packaging because the instruments are inserted in boxes that are wrapped in muslin or nonwoven disposable wrap or in a paper to prevent contact with the hot metallic containers.

“Choice of sterilization packaging material is based on the following general standards of performance:

• Ability to conform to the medical device

• Freedom from toxic ingredients and non-fast dyes

• Strength, durability, and seal integrity during transport and sterilization

• Effectiveness of sterility penetration and removal”.[(11)]

5) Sterilization process

After the phase of packaging, the items are ready to be sterilized. The “Sterilization” is defined as the process of killing the microorganisms that remain on a clean instrument. The absolute definition of sterility is the “state of being free of viable microorganisms.” The sterilization period is dependent on the temperature and size of a load and can range from 10-60 minutes. After sterilization the instruments are taken out and are placed again in the case cart because they should move out the sterilized area. After this phase, the sterilized instruments are ready to be transported again toward the storage area and the cycle.

These phases are only explained in this section and will be treated in the next section of the thesis.

3.4 Lean philosophy and the lean principle in healthcare

In this part of the chapter the lean thinking philosophy is explained: it allows knowing how it works in the case of health care case.

3.41 A history of Lean principle and their application in healthcare

The term lean is based on the production philosophy which evolved in Toyota Motor Sales Company. Toyota was the first company that introduced several innovations during post –World War II Japan. Despite the destructive effects, Toyota Company was the first to be able to understand how to gain recognition in the global world: “its goal was to provide a high quality of the product at a competitive price”. In this perspective was born Toyota Production System (TPS), which today is known as lean manufacturing.(12)

The main goals of lean philosophy are explained in figure 5.

Figure 5 Key goals of lean philosophy [Own creation]

The figure above shows 7 goals followed according lean philosophy. The first goals regards to eliminate or minimize the waste; it means to eliminate the need for the workers to walk, bend, reach, or turn , in other word to eliminate any kind of waste that doesn't bring value to the system;   the second goals regards guarantees a continuous flows in other words to delete the delays that bring high waste in the cycle introducing any kind of devices; the term just in time it intends to reduce inventories by providing the parts when is required instead of stockpiling huge quantities of parts "just in case" to complete an order ; it is important to inspect the phases of the job and spread a new philosophy that focuses on continue improvement and perfection and tries to guarantee the quality of the job; at the end to avoid mistake (6)(7) it is important to implement devices that eliminate mistakes or bring attention before they become defects. (13)

3.42 Lean in healthcare

These principles are included and recalled in the "5 main Lean principles": they are applied in the every sector; it thinks in the world of health and hospitals that puts the patient and his health at the centre of the analysis.

Below the five principles are explained and an example allows understanding them are applying in the healthcare case, precisely referring to a patient who enters in the hospital to have a service. The "Principles of Lean Thinking, Tools & Techniques for Advanced Manufacturing" and "Thinking Lean in Healthcare" describes these 5 principles:

Value: define value precisely from the perspective of the end customer, in terms of a specific product, with specific capabilities, offered at a specific price and time. All thinking philosophy must begin by differentiating value for the customer from muda- the Japanese term of waste.   In healthcare the customer can be a patient, a physician, or an administrator. If the patient waits 30 minutes to see their primary care physician, this tasks add values to the medicals because receive the different information, not for the patient. For the patient this is a waste.

Mapping: the mapping allows the audience to view the big picture and get a general overview of the system. The value stream is the steps required to complete a process or service (or in manufacturing, to create a product). Examining the value stream helps to identify waste within a process.

Returning to the case of patient, the step of being examined by the physician adds clear value to the patient. The step of filling out a medical history from multiple times is a step that could be interpreted as adding no value but it is unavoidable within the hospital. Through the mapping are highlighted two kind of waste.

Type one: it adds no value and can be eliminated immediately.

Type two: it adds no value, but is required for the way things are currently done.

Flow: the flow means working on each design, order, and product continuously from beginning to end so that there is no waiting, downtime, or waste, within or between the steps. The goal of flow is to eliminate queues and waiting in the process because they can produce multiple wait times and interruptions.

Following the example if in the hospital there is a patient who feels sick, he calls his physician and makes an appointment. At the appointed date and time, he arrives at the provider's office and waits to be seen. Upon examination, the doctor may recommend the patient see a specialist, have laboratory tests performed, and even begin taking a prescribed medication. Each step entails waiting for a service or product to be delivered.

Pull: Design and provide what the customer wants only when the customer wants it. This is the opposite of push technology, where a product can be created when there is little or no demand. Push processes can lead to large inventories and related costs to maintain them. For example, if a child should be transferred of a baby from a surgical suite to a neonatal intensive care unit and if the baby arrives at the department and the respirator and the respiratory therapist are not waiting for the patient, there is a problem. The baby has been pushed without the appropriate services and staff on hand to provide appropriate care. In this perspective pull works to ensure that the service is ready when request and waiting is are minimal when the patient arrives in a new department.

Pursue perfection: a lean thinking enterprise sets their sights on perfection. The idea of total quality management is to systematically and continuously remove the root causes of poor quality – with the ultimate goal of achieving Zero defects. Use of the plan-do-study-act cycle helps in the strive for perfection. In any process improvement initiative using lean thinking, a small incremental change is recommended based on study of the process. The recommendation is to use the different principles and determine their impact. If the impact is positive, the change is incorporated in the process, and the cycle begins anew . [14], [15]

3.43 Tools and methods of lean philosophy

In the hospital world the main methods and tool that can be used are described as follows: [16]

1.**Value stream mapping,** a method to describe and map (eg, timing) current and future process steps; it includes the mapping of flow of products, people, information, and materials;
2.**Kaizen**: it represent improvement sessions ;
3.**Work standardization**: based on assessment of the presumed "best way" to do the work (includes standard operating procedures and time-on-task specifications); Work done by multi skilled work teams;
4.**5S**: a method for organizing and standardizing workspaces;
5.**Physical layout improvement**: to minimize travel time and inventory inefficiencies;
6.**5 Why**: Root cause analysis;
7.**Poka-yoke**: Mistake-proofing/failure prevention;
8.**Kanban:** Information systems are used to know when products are ready to be pulled to the next step or when a problem exists.

This instruments has been borrowed from the manufacturing world to healthcare in order to win the challenge of ensuring the best possible service to the patient/citizen at the lowest possible cost . However the success of lean thinking in healthcare can be obtained only if a complex intervention process that incorporates and integrates multiple creation of different type of component can be orchestrated well.

3.5 Simulation and application

In this last part of the chapter the information about the simulation and its application are indicated in order to understand how can be used the simulation in the case of analysis.

"Simulation is a technique, not a technology and helps to replace or amplify real experiences to replicate substantial aspects of the real world in a fully interactive manner". [17]

The simulation allows evaluating, comparing and optimizing alternative designs, plans and policies. It also provides a tool for explaining and defending decisions to various stakeholders. The advantages of the simulation are:

- To help companies to ask many “what if” questions about changes in their systems;

- To know the consequences of a proposed action plan or design if it cannot be directly and immediately observed;

- To understand the current system and explain why it is behaving as it is.

The simulation follows specific steps that allows to the simulation study to be successful. Even if the goal of the simulation changes every time, the process by which the simulation is performed remains constant. The basic phases of the simulation are explained below:[18]

1) Problem Definition

The initial step involves defining the goals of the study and knows to understand what needs to be solved. The first step is important to define the case of study. In this way it determines if simulation is the appropriate and necessary tool for the problem under investigation.

2) Project Planning and system definition

The second step is to divide the project into different work packages. In this way, this schedule is necessary to determine if sufficient time and resources are available for completion.

Later it individuates the part to be scheduled and simulate. Because the system could be very complex, it is important to have an experienced simulator who can find the appropriate level of detail and flexibility.

3) Model Formulation

The actual system can be understood through the determination of the basic requirements of the model. The understanding of what variables are involved and how these variables interact is possible creating a flow chart of how the system operates.

4) Input Data Collection & Analysis

The type of data to collect is determined when formulation of the model is done. In this phase new data is collected and/or existing data is gathered. A theoretical distributions can be used to fit data. For example, the arrival rate of a specific part to the manufacturing plant may can follow a normal distribution curve.

5) Model Translation

The model is translated into programming language. In this perspective can be used different language as Fortran or different programs as Arena, Tecnomatix etc...

6) Verification & Validation

This phase allows verifying if the process follows the expectation. To validate the model through the verification is important because is ensured that no significant difference exist between the model and the real system there. Validation can be achieved through statistical analysis or reviewing the model with an expert.

7) Experimentation & Analysis

Experimentation involves developing the alternative model(s), executing the simulation runs, and statistically comparing the alternative(s) system performance with that of the real system.

8) Documentation & Implementation

At the end a documentation (written report and/or presentation) is done. The results and implications of the study are discussed. At the end the best course of action is identified, recommended, and justified.

3.51 Plant simulation: Tecnomatix

The simulation is important to see from dynamic point of view the case of study.

For this reason, simulation is important in order to model the complex system with lots of interacting parts, with is another common feature of healthcare. The use of simulation is due because one of the challenge in healthcare is how to improve the efficiency of operations. In this case, the model is not defined in terms of a series of equations but in terms of the physical movement of a transaction over time through different facilities or resources. (19)

One of the best ways to obtain results to the simulation is to use a Tecnomatix Plant simulation. This tool was utilized in order to simulate the system treated.

"Plant Simulation Tecnomatix is a tool used to create a digital models of logistic systems (such as production) ;it also can explore a system's characteristics and optimize its performance. The main results that is possible to achieve are bottle-neck analysis, statistics and charts letting evaluate different manufacturing scenar-ios. Through these results fast, reliable, smarter decisions in the early stages of production planning can be implemented. In other word using Plant Simulation Tecnomatix, it can model and simulate production systems and their processes. In addition, it can optimize material flow, resource utilization and logistics for all levels of plant planning". (20)

In this chapter the theory part stops and the main information about the theory are taken into consideration. The next chapter is dedicated to understand how work the real case of surgical instruments in Gentofte and Herlev hospital: the two main hospitals of the city.

4 Case descriptions (Gentofte and Herlev hospital)

After a brief description of the main information gathered on websites previous mentioned, the treatment starts in this section. In this chapter, indeed, is explained different information about how works the cycle of surgical instruments in the area of Copenhagen.

The two visited hospital are Gentofte and Herlev and they are very important in order to understand how the cycle is. The treatment starts with the description of the main differences and finishes with a detailed description of the two hospitals.

Main differences between Herlev and Gentofte hospital

The two visited hospitals are Gentofte and Herlev: they are two of the major hospitals of the city. Even if the two hospitals are intended to carry out a service to care for the patient, the services they provide are different: Herlev hospital deals with both emergency or acute case and planned, Gentofte provides planned surgery. The main distinction reflects on the management of surgical instruments that is handled in two different ways: it refers mainly to packaging and storage of surgical instruments.

In Gentofte, indeed, the instruments are packaged according the request of Operation Theatres (OT) those changes daily. Differently in Herlev hospital a base instruments packaging is provided to different departments. Another difference is a kind of storage: in Herlev the storage of the items is manual, otherwise in Gentofte is automatic. At the end it can say that in Herlev has a decentralized location of the Operation theatre respect the cleaning area (the distances between an area to another one is considerable); in Gentofte hospital Operation theatre are close the cleaning area. Different questions were asked to several employees to clarify the movement of the instruments.

The main differences are shown in figure 6and will be discussed in detail below.

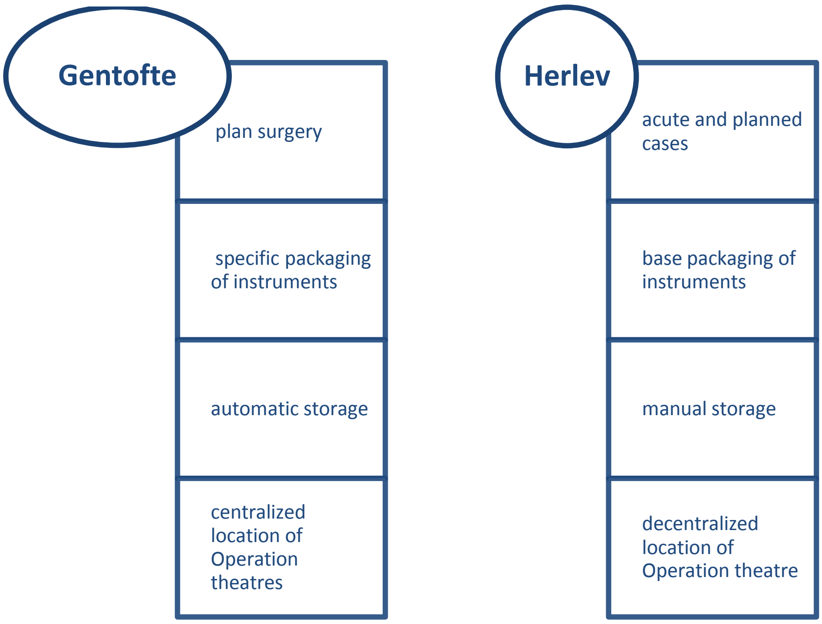


Figure 6 Differences between the hospitals [Own creation]

Gentofte

Gentofte Hospital is located in Gentofte within the Copenhagen area in Denmark (figure 7). This hospital is a part of the hospital service at Region Hovedstaden. It primarily serves the municipalities of Gentofte, Lyngby-Taarbæk, and Rudersdal, with a population of about 175,000. The hospital was opened in 1927.

As one of the university hospitals for Copenhagen University, Gentofte Hospital focuses on research (publication lists) and training facilities. The layout of this hospital is organized with two large medical departments cover gastroenterology, endocrinology, rheumatology, geriatric medicine and stroke rehabilitation. At the same time there are the houses dedicated cardiology and pulmonary medicine departments. The hospital also hosts the regional department for innovation in elective surgery .[21]

Figure 7 Gentofte hospitals [22]

The hospital is composed by different zones: the areas visited were the cleaning area, the storage, the Operation Theatre; in other words the areas covered by the surgical instruments during their lifecycle. In figure 8 a general scheme shows the path of the surgical instruments.

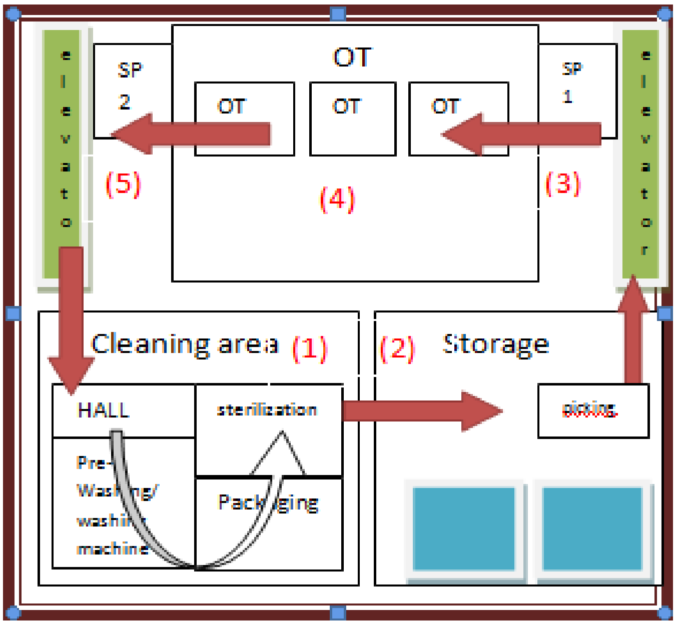


Figure 8 Layout Gentofte [Own creation]

The first area visited was the cleaning area: it is localized at the ground floor (1). This area includes a hall where the case carts are emptied and accumulated, an area dedicated to the pre-washing of the instruments and the cleaning in washing machine and another area dedicated to the packaging and sterilization. Nearby the sterilized boxes are stored in the storage (2): the particularity is the picking and storage of the items is automatic and a computer system keeps track of the instruments. In this way the traceability is assured. The storage and the OTs are in two different floors and are connected by an elevator in the corner of the storage: when the picked items are inserted in the case cart, they are moved by the elevator to the second floor and they wait in a Stopping place (SP1) before to be moved to the OTs (3).A series of hallways lead to the OT (4).

Another stopping place2 hosts the different case carts coming from the OTs, after the surgical operation is done. Here another elevator leads to the ground floor, directly in cleaning area (5). Generally two different elevators are used: one for cleaned instruments and one for un cleaned instruments. This is the general cycle of the surgical instruments. Below each area is analyzed and the main information gathered highlight the two main differences of the hospital.

Cleaning area (1)

The cleaning area is dedicated to wash the dirty instruments. This area is divided into 4 sub-areas dedicated, all with the purpose of cleaning. When the case cart comes from the OT, they are emptied and they stop in a Hall: they wait the end of the process of cleaning of the instruments. As the employees said to us, in this Hall frequent bottlenecks are created because the waiting time of the case cart is longer than the washing of instruments. This was the first identified problem.

The nearby areas are dedicated to the washing of the instruments: the particularity of these areas is that the Washing and Autoclave machine are arranged side by side to minimize movements and take up less time. Generally the washing machine last 30 minutes; otherwise the Autoclave machine time is 40 minutes. During the phase of packaging, the instruments are inserted in a basket and wrapped in a paper. Only a small percentage is inserted in boxes due to their high cost. In this phase standard/pre-packed baskets are created and inserted on the trays of case cart to go to the autoclave machine. Subsequently they are moved to the storage because they should be stored. The transport of the item is a problem when the weight of the trays of the case carts is over a specified limit. The insertion of trays with heavy instruments is not easy when the weight is excessive and the time to prepare the case cart is not enough. In this area the traceability of the items is guaranteed through the use of a computer system and is done through barcode scanning of the boxes. The boxes, indeed, are scanned before the beginning of each process and the information is saved on a software computer T-DOC: this assures that all information of the instruments is memorized and the end time of the process is known.

Storage (2)

The storage contains both single used and multiple used instruments. It guarantees that the request is satisfied.

The cycle starts as follows: the case carts arrive to the storage hall. They contain different sterilized boxes. Before storage, items are scanned: in this way their traceability is guaranteed. Through the scanning, boxes information is saved in T-DOC computer software: this software allows knowing the position and how long boxes are in the storage or in the system. In other words is guaranteed the continuous knowledge of the status of the items whenever is necessary. This represents an important advantage when instruments are needed in emergency case: if they are in the storage or in every part of the system they are picked and delivered, otherwise they are booked and bought through the web system. The particularity of this storage is the automatic system that allows storing or picking the different boxes/basket. There are two ways to pick or to insert the boxes: the first one is automatic and allows withdrawal or positioning through a system that does not require human hands. The other one is manual. These two ways are used in parallel because, despite the high automation that the hospital provides, there is still some time before this automatic system is used. The advantage is that the two integrations help to satisfy the continuous requests of this service.

The packaging/picking of the items is provided in accord to the Operation theatres request. They send a request to a computer; according this request the boxes are taken. In this way the pre-packed boxes are selected and picked and if other single use instruments are needed they are inserted in the case cart. This is a good solution so no time is lost in other parts of the department because the instruments will be ready to be used. Each case cart is prepared for each operation theatre and contains the instruments/boxes that they needs. This is the most important difference with Herlev hospital.

In this area there is an automatic yellow robot that allows transporting the hot boxes coming from the area of sterilization: in this way the items are transported directly to the conveyor and are inserted in the storage.

Stopping places and Operation theatres (3) (4) (5)

The case carts are moved from the cleaning area by the elevator. A stopping place allows the case carts to stop: they are picked up from the different staff coming from the OT.

A series of hallways lead to the OT. In the main hallways a computer/display shows the state of each OT: it allows controlling of the surgical operation, precisely the availability and the time of each surgical operation. This is another way to have track of the instruments. The case carts are placed in a Hall of OT (2/3 case carts in each OT) and not all boxes are utilized. When in the OT there is a necessity for other instruments which are not present in the case cart it is possible to book different instruments in case of an emergency. The future goal is to predict all kinds of emergency instruments, personalizing each box, without having to resort to external. At the end of surgical operation the single use instruments are separated to the multiple uses. The single use are collected and thrown away, the multiple use instruments are collected in the same case cart and moved to the stopping place2 (SP2): here they are transported to the cleaning area by elevator. Outside the OT, another room provides the basic instruments. In this way the extra requests are satisfied. The life cycle ends when the case carts arrive downstairs to be washed again and then restart the cycle; they are transported again by the elevator. One the main advantage of Gentofte hospital is that there is the automatic storage that favourites an automatic storage of the items in few time.

Below the description of Herlev hospital is important in order to give information about the second visited hospital.

Herlev Hospital

“Herlev Hospital was the second hospital visited. Herlev is a hospital in Herlev, Denmark, close to Copenhagen.

It is 120 meters tall and has 25 floors. It is famous for being Denmark's tallest building, and the fifth tallest hospital in the world. Its modern, functional architecture in bright concrete, glass and bronze-colored aluminum gives a unique impression.

Construction began in 1965 and the hospital was finished in 1975. It was opened in 1976” (figure 9). [(23)]

Figure 9 Herlev Hospital [Own Picture]

The situation in Herlev hospital is different because there is not storage to store the different items. The reason is that each department (not OT) delivers the case carts to the area of cleaning: at the end of the cleaning process each case cart contains the same items that are delivered. These departments are not localized close the cleaning or store area but in another area. For this reason there is a decentralization of the item. The process of picking and the packaging of the items in the storage are not done after the cleaning. The items are directly delivered to the different departments. The cleaning area was the only visited zone.

In this area a Hall allows to host the case cart coming from the departments. They are emptied and the boxes and instruments are separated. The boxes are accumulated in an area waiting to be washed in the Cabinet machine. The instruments are inserted in a basket and cleaned in another area: the figure below shows the path of the instruments in the cleaning area (figure 10).

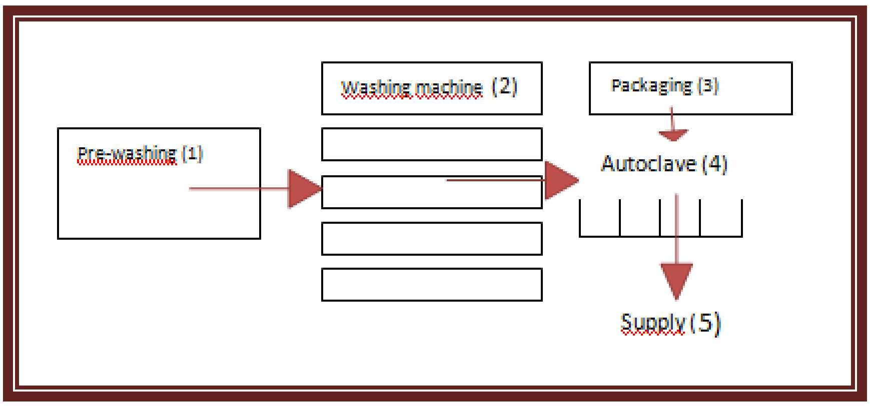


Figure 10 Layout Herlev [Own Creation]

The box and the cart are divided and the instruments are inserted in a basket. In this way they start the process of cleaning explained below. The cleaning area is divided into three sub-areas: decontamination, sterilization and delivering area. Each area is analyzed as follows.

Area of decontamination (1) (2)

The different instruments arrive in this area and are inserted in a basket: the phase of pre-washing is done (1). In this phase the boxes are put on the table and before the washing of the instruments they are inserted in a basket: here the basket is scanned to keep track of the instruments and the information about the pre-washing of the instruments is provided. The advantage of the traceability is the same shown above in the Gentofte case. This is an important phase of the cleaning.

Later each instrument is cleaned by hand and inserted again in a basket. Scanning the baskets the instruments are inserted in another box and later transported to the washing machine available (3). Generally there are 4/ 5 washing machines that work in parallel when they are not broken; in this way they ensure a continue flow. The time of each washing machine is 40 minutes.

For particular instruments (robot surgery instruments) there is another machine that washes and disinfects every item inserted.

In this area bottleneck and waiting are characterized by a trend of peaks and valleys: this is because the hospital deals with acute cases and the arrival time of instruments is not always known. It thinks about 8/9 times per days. Another cause is the failure/repair of the machine (during our visit there was a queue due to a repair of the washing machine). Generally there are 4/5 washing machines (look image) that work in parallel when they are not broken, in this way they ensure a continue flow.

Area of packaging and sterilization (3)(4)

The cycle of instruments continues in the sterile room. This area is divided in different sub- areas: one dedicated to packaging the instruments and one to the phase of sterilization. An important difference with Gentofte is that the packaging is a service furnished for different customers (departments) that paid a quota to have the service of cleaning, packaging and sterilization.

For these reason the label attached on packaged paper keeps track of the information of the customer: information includes name of customer, number of barcode, position of the department etc. (figure 11). The same was done in Gentofte hospital but the information of the barcode regarded directly the OTs, not the department.

Figure 11 Information about customer [Own Picture]

After being packaged the containers are inserted inside an autoclave (about 12 basket in each one) to be sterilized. The time of sterilization is 1 hour and ten minutes. As employees said not all instruments withstand high temperatures: a manual sterilization utilizes the alcohol to disinfect.

Supply (5)

The sterilized items are inserted in the case cart and they are delivered immediately to the customer: for this reason is not present storage that contains the different items, but a big area where the case cart wait to be delivered. This is another difference with Gentofte because there the different items were stored and later picking according the request of the OT; so in Getinge storage has a specific picking and packaging of the instruments. In Herlev, indeed, all instruments/ case carts that enter in the cleaning area are the same that exit at the end of the process. After the process of cleaning/sterilization, the items are indeed in own case cart and delivered directly to the department. The case cart doesn't change after the process of storage because the items are the same. Normally 95% of the instruments follow this cycle.

Consideration

The two described cases show as the hospital manage the surgical instruments in two different ways.

If it thinks about the phase of the storage, cleaning, packaging, sterilization of items, Gentofte hospital has an important advantage because has a Central Sterile Supply department: this department is like a manufacturing plant for sterile items. Soiled items from operating theatres, wards, out-patient and other special departments are collected in this department for processing, and then returned to the end-user. In this way cleaning, disinfection, inspection, packing, sterilization, storing and distribution are carried out so near, assuring a continuous flow of item. Other advantage is that is ensured better control of the items that are not lost and more reliable results. Compared to Herlev hospital, another advantage of Gentofte hospital is the use of an automatic system to carry out or store the different boxes: in this way the fatigue of the employees is avoided and items can be placed very fast on the case cart that are directly designed to the OTs. The only disadvantage is that Gentofte can not to satisfy emergency request: this goal is difficult to provide because there are not storage inside the OT. This could be a problem for Gentofte hospital.

After this brief description the next chapters allow mapping a draft of the life surgical instruments cycle through the use of two methods: IDEF0, Value stream mapping at the beginning and simulation later. These methods will give a clear overview of the main phases of the cycle.

5 Functional description of the system

In this chapter a presentation of the different tools used for describing the life cycle of surgical instruments is given. This chapter, indeed, is dedicated to map a first solution of the cycle and the first used method is the $IDEF_0$.

The $IDEF_0$, indeed, is very important in order to identify the main steps of the cycle using a series of diagrams that create a hierarchical scheme.

Other the first method is used also a second method called Value Stream mapping: it will highlight the tasks under two points of view. Each task, indeed, can be seen as "waste" when it does not take value for the system; otherwise it can be a "value ads" when it takes value for the system. These results will be important to understand what improvements should be implemented in order to create a new cycle that follows lean philosophy.

A short introduction will be dedicated to explain the mean phase of each utilized method.

5.1 IDEF0

The $IDEF_0$ is a technique introduced in 1970 by the U.S. Department of Defence. The acronym stands for Integration Definition for Function Modelling. (24)

The most important goals to employ this technique are shown: (25)

1)To perform system analysis and design at all levels, for systems composed of people, machines, materials and information of all varieties;
2)To produce reference documentation concurrent with development to serve as a basis for integrating new systems or improving existing systems.

This technique uses several tools in order to explain the main function object of exam. The figure 12 represents functions, defined as activities, processes or transformations, goal of the analysis of the treatment.

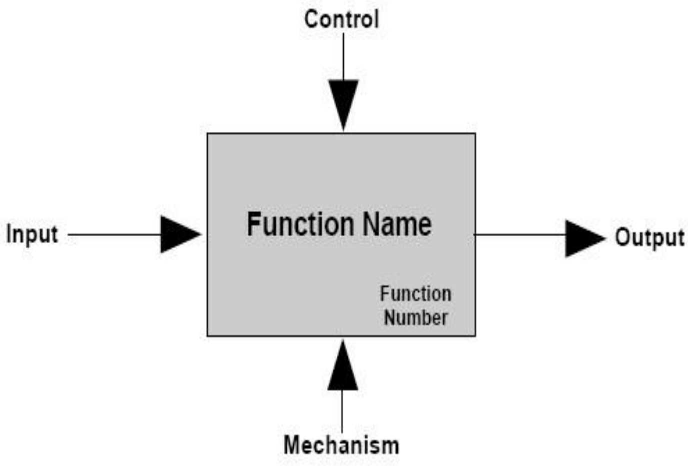


Figure 12 General Scheme [24]

The meaning of the arrows is indicated as follows **:**

1) Input: data needed to perform the function;

2) Output: data produced as a result of the function;

3) Control: influence or direct how the processes work;

4) Mechanism: persons or devices to perform the function.

5.11 Communication by Gradual Exposition of Detail

The main goal of $IDEF_0$ is to highlight the steps of the lifecycle of surgical instruments: the diagram shows the use of a hierarchical scheme that must be followed so that the whole cycle is completed. The first mentioned level is the level 0: it includes the activity box A-0 or “The life cycle in health care case”, the main functions of the $IDEF_0$ analysis (figure 13).

The opening of the level 0 allows knowing the content of the Activities box A-0 that includes all steps of the cycle of surgical instruments. The analysis proceeds to level 3 of detail which is the final level of the hierarchy it will be described later.

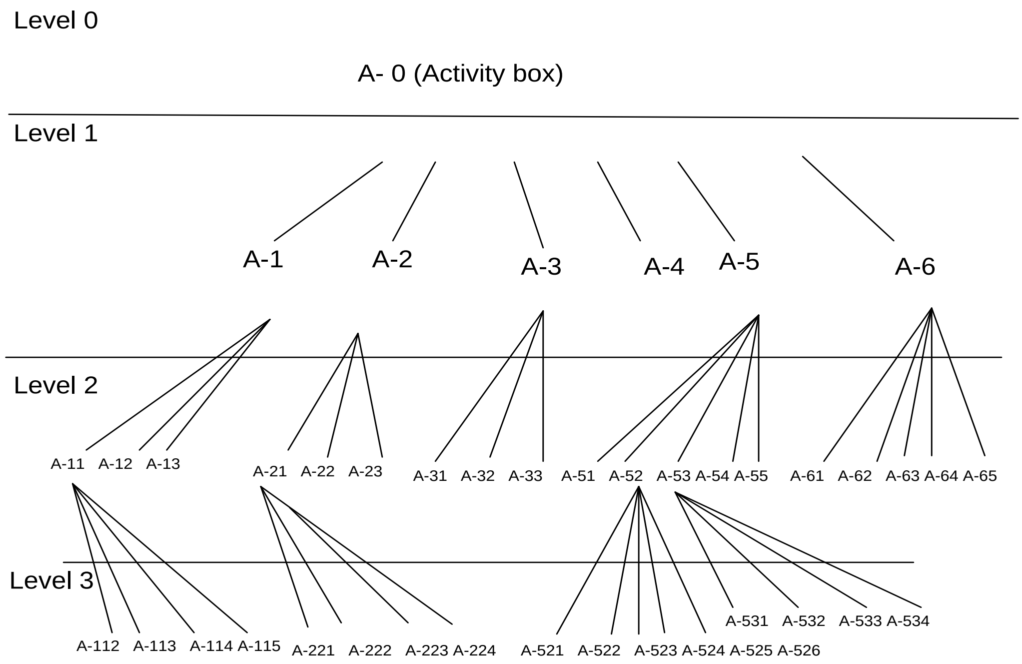


Figure 13 Hierarchical diagram of IDEF0[Own creation]

Below each level is shown and the different tasks are explained.

Level 0

The zero level of the diagram includes the Activity box A-0 called "life cycle of health care case" (figure 14).

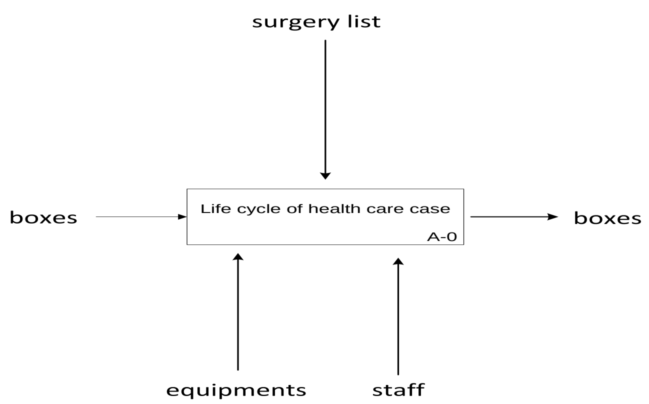


Figure 14 Activity box A-0

The inputs of this function are the boxes, containers of the surgical instruments. They are also the output of analysis.

The lifecycle of surgical instruments is supported through the use of a Surgery list: it represents a control of the function. The arrow below represents the mechanisms of the function. It is very important in order to have two ways: “Staff” which includes all human resources involved during the lifecycle and “Equipment” that includes physic resources as washing machine, cabinet machine, autoclave and case cart. Opening the first Activity box A-0, the level 1 is described in the figure 15.

It includes six Activity boxes: they are the main activities of the cycle.

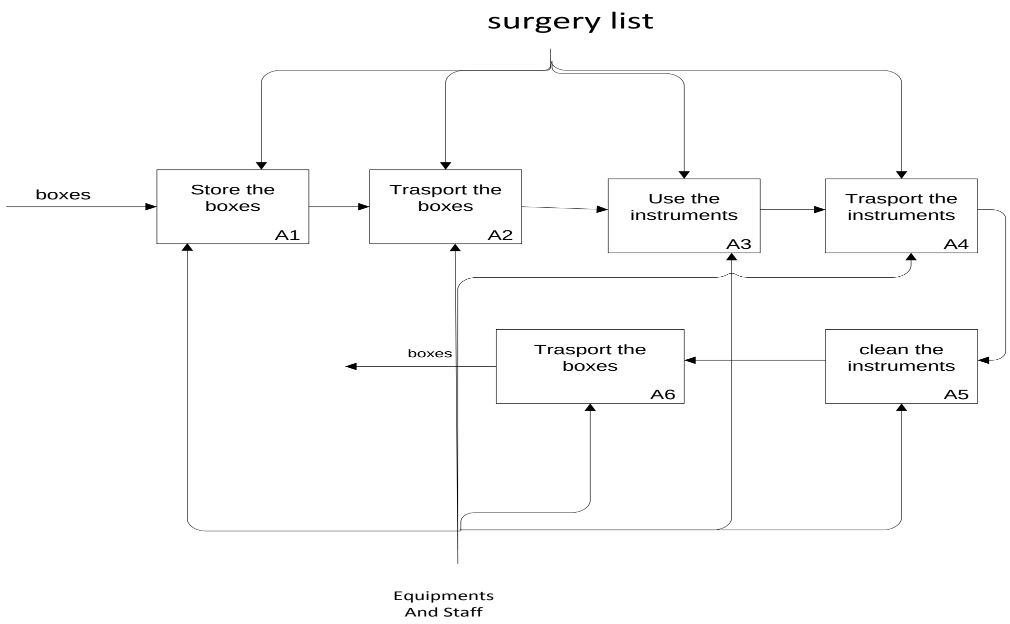


Figure 15 First level IDEF0 (A 0)

In this case of study, the life cycle starts according this idea explained in the Activity box below.

-Activity Box A1: the life cycle starts in the Store, area where the different boxes input of the function, are stored. The boxes, indeed, after being prepared in the area of packaging, they are inserted in a store, area where they wait until a new request is forwarded;

-Activity box A2: the different boxes are selected from the store and later they are put inside a case cart. They are moved close the Operation Theatre, area where the surgical operation is done;

-Activity box A3: in the Activity box A3 the instruments are used in the Operation Theatre for the surgical operation; here they are opened and the different items are created again;

-Activity box A4: after the surgical operation the different items are moved to the area of cleaning; for this reason this activity box represents the transport of the different items;

-Activity box A5: all processes of cleaning are done in the Central Sterile Supply Department, area where the different items are washed;

-Activity box A6: when the sterilized boxes are washed, they are inserted in the automatic store, area where the items are preserved and wait to be taken out again. It is supposed in the first solution, that the different items are stored in a manually way; this is an important differences compared to the other situation.

-

Store box (A 1)

The content of the Activity box A1 is shown in the figure 16.

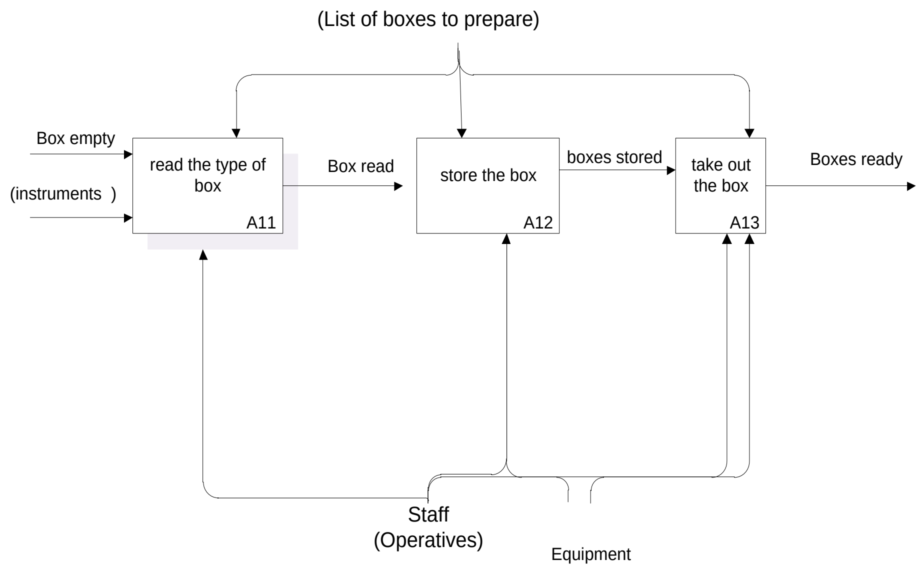


Figure 16 Store the boxes (A 1)

Input is emptied boxes. The boxes are prepared with the appropriate surgical instruments by an operative in the area of cleaning, precisely in the phase of packaging. Later the operatives use a specific list to determine the content of a given box.

Transport of instruments (A-2)

The second Activity box, represented in the figure is the Transport of the boxes. It includes two main Activity boxes and the level of detail of this analysis is the second.

Select the boxes (A 21)

The figure 17 shows the process in exam. The inputs are the boxes, container of instruments that are collected and put inside the case cart. The movement of the case cart is this case of analysis is manual: for this reason, an Activity box A215 is used in order to understand how is the movement of the case cart in the different part of the storage.

This window is indicated through two exits: the exit “yes “indicates that the case cart can remain in the same direction; the exit “no “indicates that case cart has to move to other direction, toward a new position of the box.

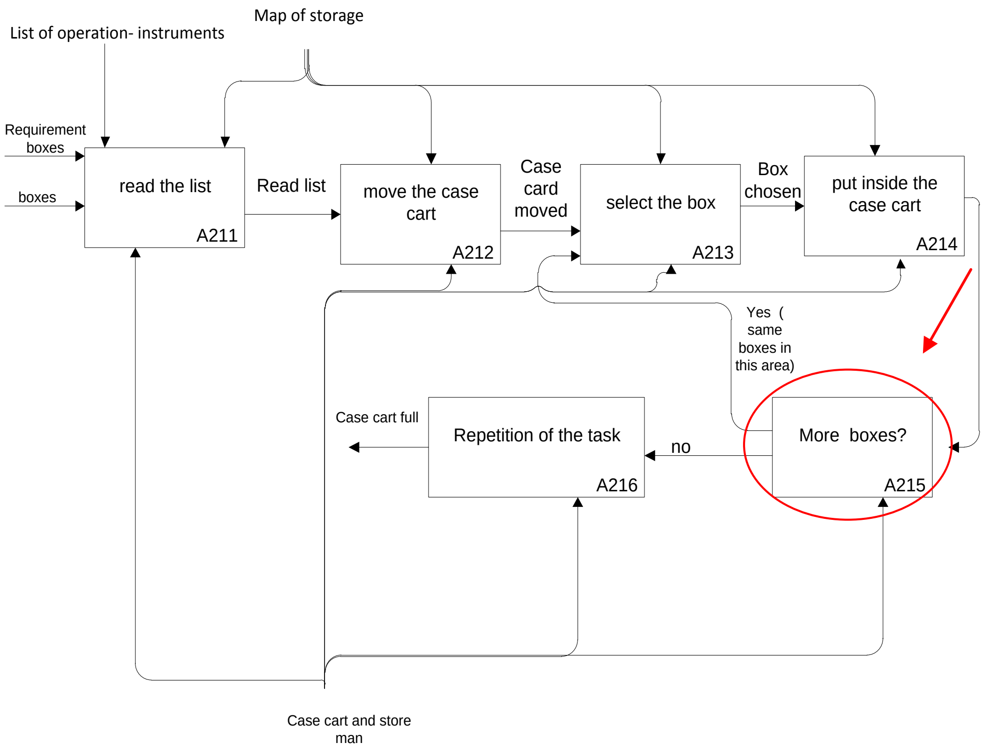


Figure 17 Select the boxes (A 21)

The cycle continues until all boxes are taken out. In this case these tasks are ensured if is known the list of surgical operation- instruments and the map of the store: they represent the Control of the analysis; at the same time the Mechanism are represented by "case cart" and "operatives" because they represent the main utilized resources.

The process of Selection of boxes finishes when all boxes are taken out: for this reason the output of this window is "case cart full".

Move the boxes (A 22)

The second Activity box is the "movement of the case cart to a stopping place": area where the case cart waits before to be used. The figure 18 shows all process. It supposed that the stopping place is in the second floor of the hospital: this condition is supposed because the time to transport the different item is saved.

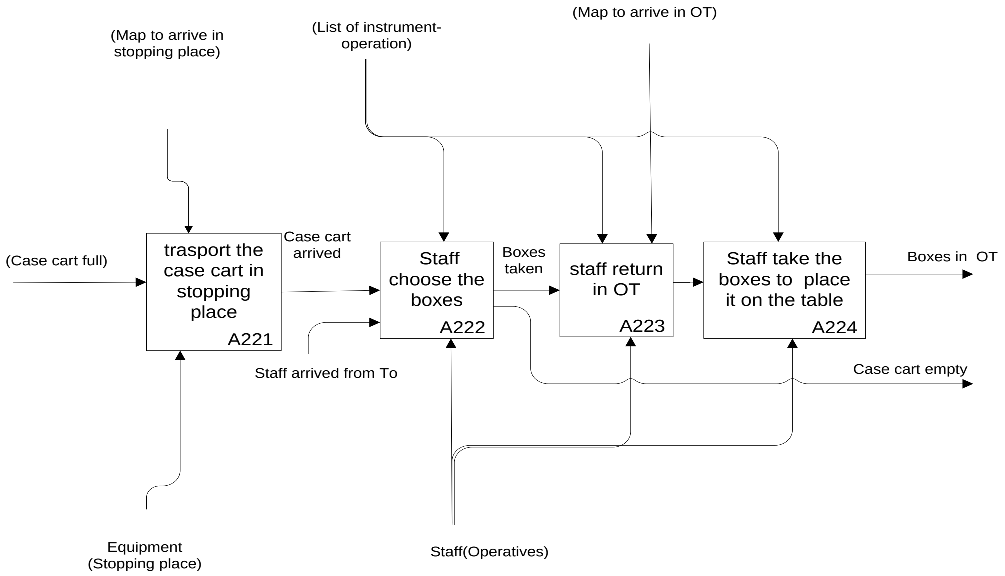


Figure 18 Move the boxes (A 22)

These tasks are possible if the “map to arrive in stopping place”, the “list of instrument-operation” and the map to arrive to operation theatre” are known: they represent the Control of this operation. Otherwise the resources involved in this process are possible only if the stopping place and Operative are available: they are the two Mechanism of the analysis.

At the end of this process the boxes are in the Operation theatre and the case cart waits in the stopping place: for this reason they represent the output. This hypothesis is made only to simplify the treatment: in reality the case carts are used inside the operation theatre.

Use the instruments (A 3)

Now the hierarchical scheme continues with the boxes that are inserted in the area of Operation theatre. The boxes are the main created input: they are positioned on the table and used to the surgical operation (figure 19).

The “medic” is the main human resource involved in this phase: he has to know the name of the boxes to utilize and control that the instruments are inserted inside the box after the surgical operation. The last Activity box represent “the movement of the boxes to a stopping place” that is the area where the boxes are inserted in a case cart again.

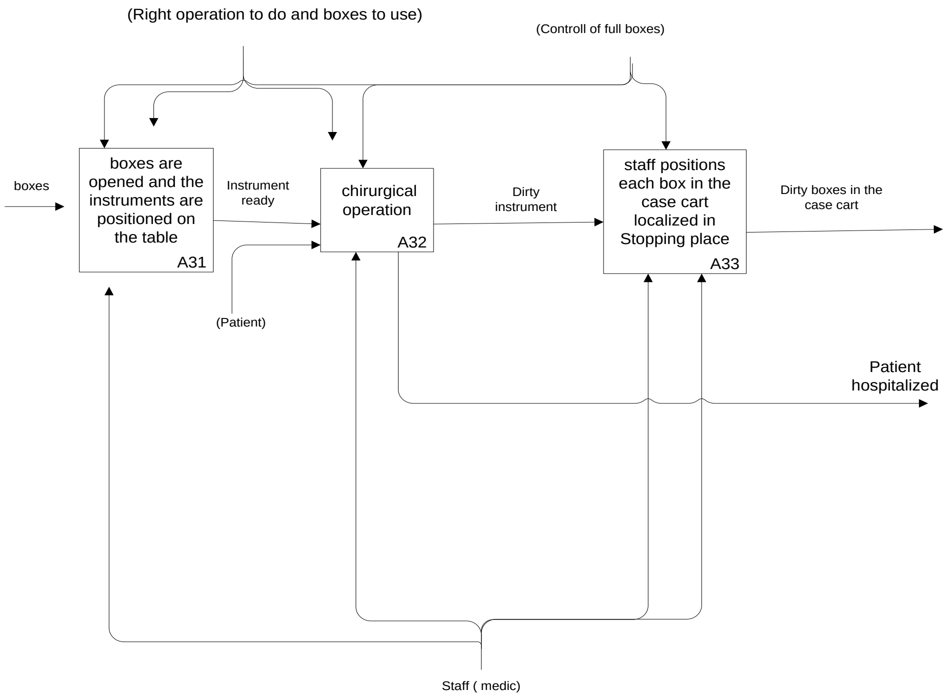


Figure 19 Use instruments (A 3)

At the end of this phase, the boxes are inserted again in the stopping place: area where the dirty box waits before to go in an area of cleaning.

The Activity box A-4 shows the transport from the area of stopping place to the area of cleaning.

Cleaning process (A 5)

The cleaning process is described in the level one of analysis as indicated in the figure 20. It remembers that each Activity box is opened and the cycle of cleaning is described.

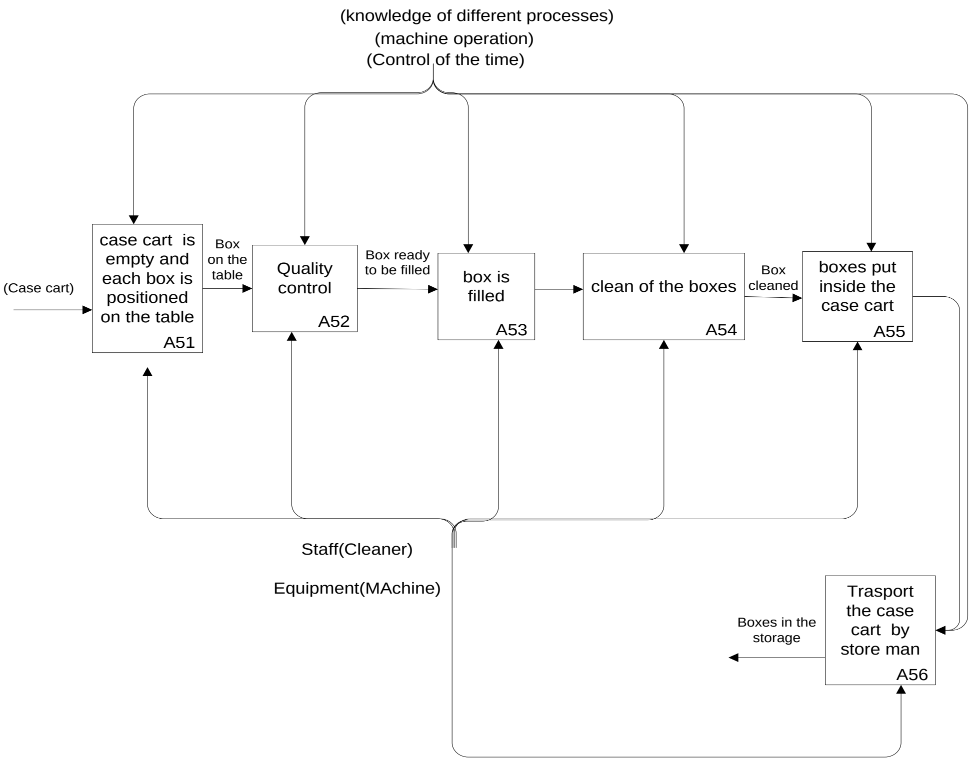


Figure 20 Clean the instruments (A 5)

The beginning of the cycle starts through the emptying of the case cart (Activity box A 51). Later a window Quality Control is opened and the main phases are described in the following window. The level 3 of analysis is used to describe the Activity box "Quality control", "Box filled" and "Clean of the boxes". They represent the main phases of the cleaning of the instruments. These tasks are possible only if the "Control" and the "Mechanism" of the function are respected as shown in the figure.

Quality control (A 52)

The input is the "box on the table "and the exit is "box ready to be filled"; in this case each instruments is checked and is discarded when is single use.

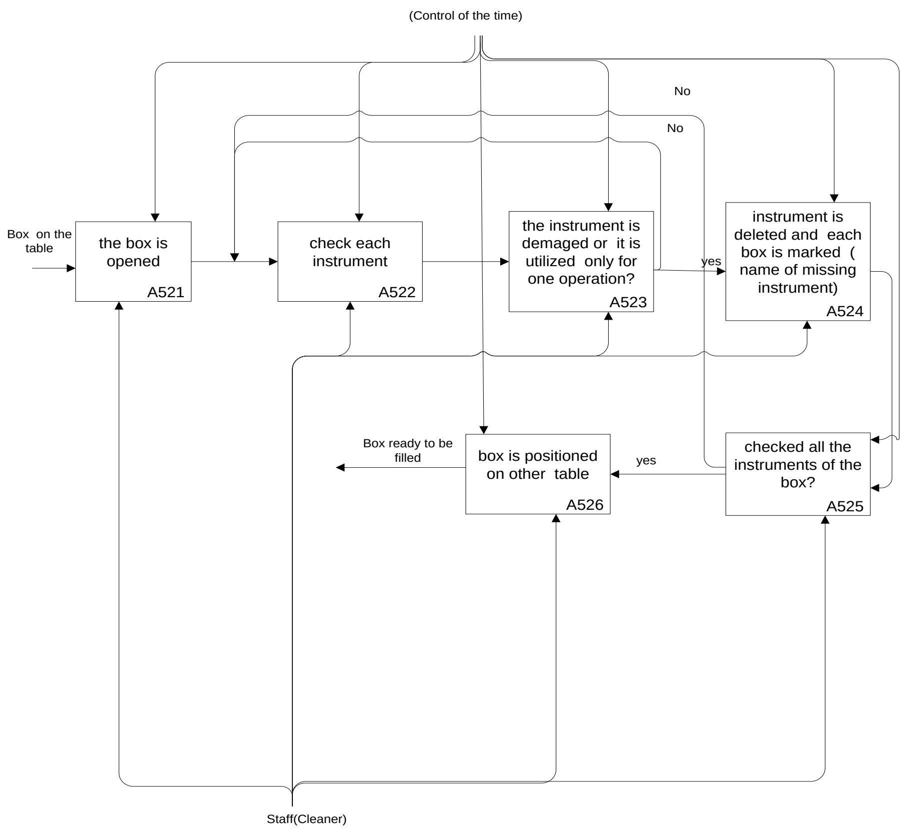


Figure 21 Quality Control (A 52)

The process follows the two different tasks that are represented in the figure 18. They are important in order to indicate the different tasks of cleaning. To achieve this goal is used an interrogative window A523 that has two exits: the exit "yes "indicates that instrument is single use and it is discarded; otherwise the exit "no" indicates that the instrument is multiple uses, and it can remains in the system. To keep track of the single uses instruments, each box is recomposed and it is marked again. This is done only to know what the instruments to insert inside the box are and to guarantee a Kanban solution.

For this reason the mechanism is represented by the cleaner, a human resource who should know the time and the task of each steps of quality control (look Control in the figure). The task continues through the Activity box "Box filled": in this way the boxes are filled again to continue the cycle.

Box filled (A 53)

The process continues with the check-in of the instruments. The instruments, indeed, are moved to the area of cleaning and they checked.

To achieve this goal, the operative reads what is written on the label of the box and they pick up the missing instruments from shelves and insert them in the boxes.

Compared to the reality this is a hypothesis suggested to keep track of the instruments. The instruments, indeed, are inserted in the box immediately and they are moved to be cleaned (figure 22).

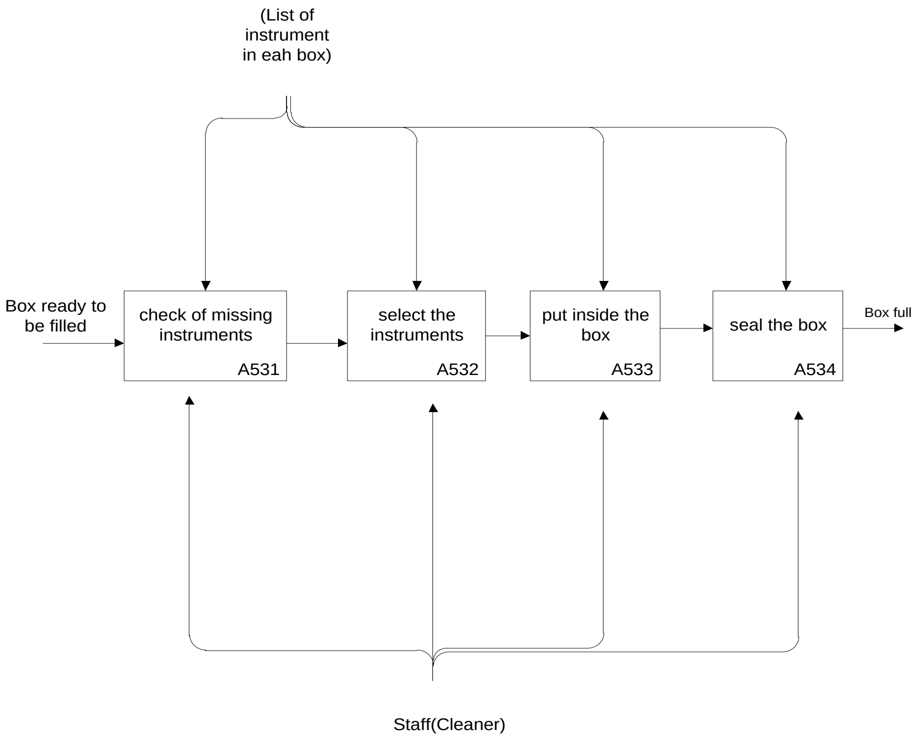


Figure 22 Box filled (A 53)

In this case it is important to take into consideration the mechanism represented by "Staff" and "List of instruments in each box" as Control.

Clean of the boxes (A 54)

The real process of cleaning starts with the Activity box A 54 the separation of the instruments and box because they follow different washing. The input is the "full boxes" that are cleaned, packaged and sterilized. These tasks are possible only if it is known the process to clean the instruments (Control) and the cleaner are available to achieve these tasks. The processes are shown in the figure 23.

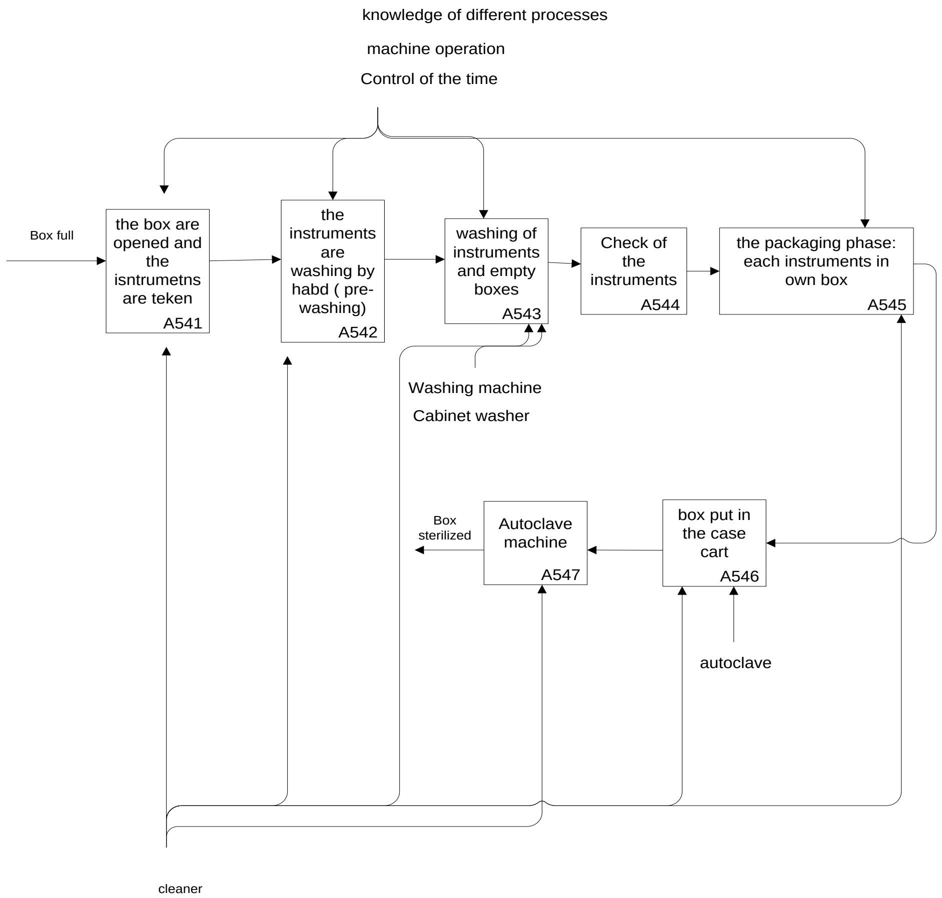


Figure 23 Clean the boxes (A 54)

At the end of this process, the instruments are in the Autoclave machine and later they are inserted again in the area of storage, as is described later.

Transport the box (A 6)

The last step is the storage of the boxes. To achieve this phase the boxes are collected and moved to the store as shown in figure 24. This process is described according the phase indicated in the figure. Even in this case is utilized an interrogative window A65 that shows the movement of the case cart to the position of the shelves.

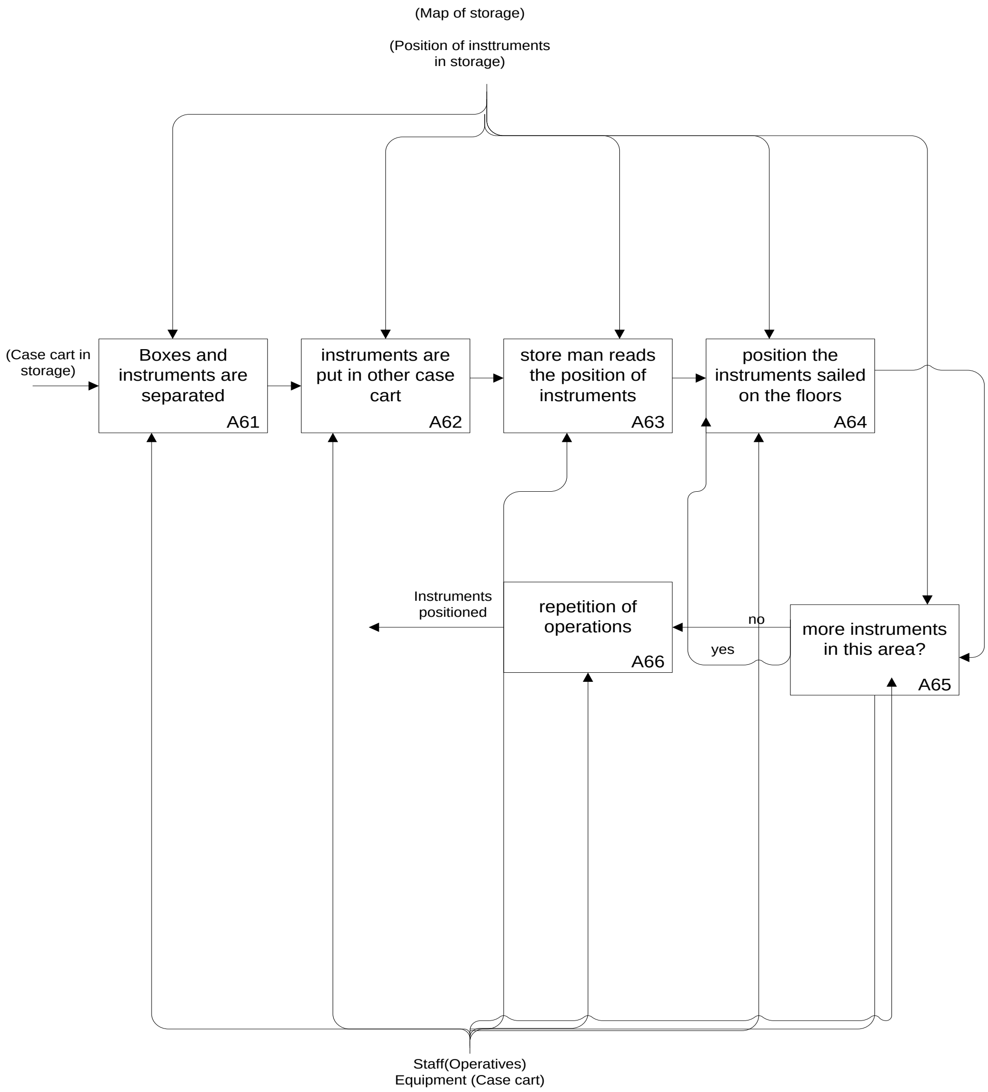


Figure 24 Transport the instruments

These first steps are important in order to understand what the path of the different items is. Otherwise the second method is used in order to understand how can be described the cycle through a new method Value Stream mapping.

5.2 Value Stream Mapping

Until now, $IDEF_0$ has provided an overview of the system through the different hierarchical scheme. Now it is important to analyze the situation through another method: the value stream mapping.

A brief introduction of the method Value stream mapping is shown below.

5.21 Value stream mapping: theory

“Value stream mapping is a lean manufacturing technique used to analyze and design the flow of materials and information required to bring a product or service to a consumer. At Toyota, where the technique originated, it is known as "material and information flow mapping".[26]

This method has several advantages and goals: [27]

- To provide a list all of the steps in a process from beginning to end.
- To identify steps that does not add value to the process such as inspection, test, rework, set-up, inventory buffers, product movement ;in other words any activity that does not improve the form, fit, or function of the product or service
- To add the time in each of the non-value-added processes and to add the time in each of the value-added process. In this treatment the time is not taken into consideration.

This method uses a several common icons that can also be customized to best serve a value stream map. Icons help distinguish different elements of a product line from another. For example, if are considers the arrows, they should be used to distinguish between product and information movement. In this treatment will take into reference only the Time Line (figure 25): the timeline shows value added times (Cycle Times) and non-value added (wait) times.

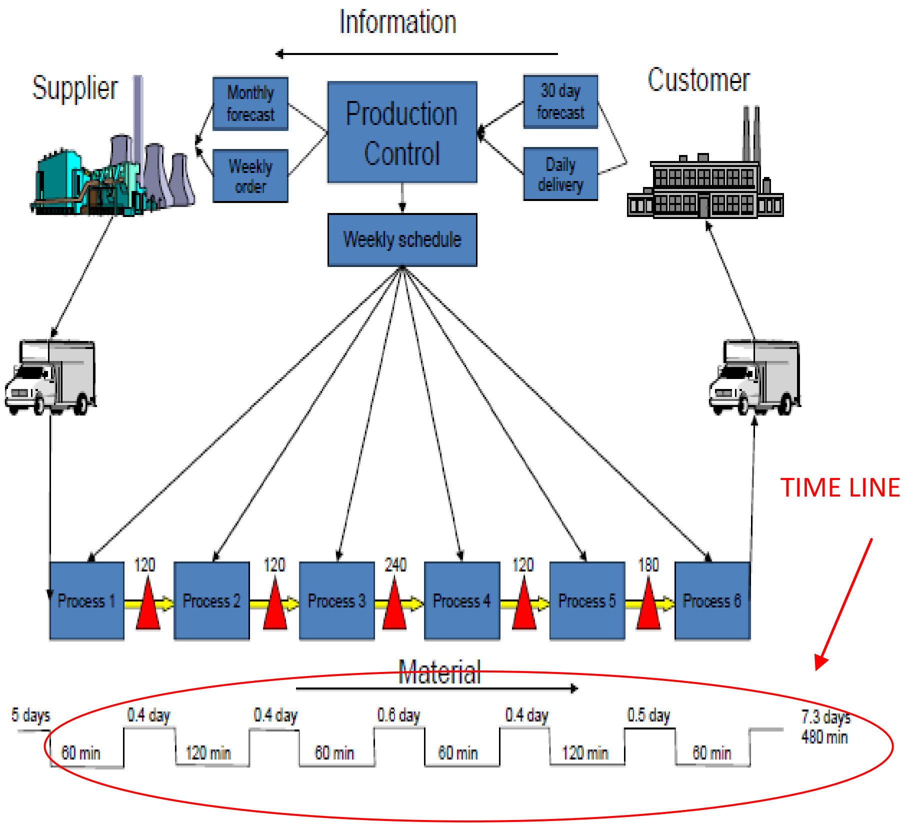


Figure 25 TIMELINE (28)

In this case of analysis the figure above shows all value stream mapping. In Our case of analysis, the time line is taken into consideration and it will show only the task not the time of each task. This is an important hypothesis done.

5.22 Value stream mapping: available resource

In this perspective in the method defines the number of physical and human resources involved in the process such as the number of employers, stopping place, cleaner, operatives.

The main resources are:

-Four operatives: S1,S2,S3,S4;
-Five cleaners (two for each function): C1,C2,C3,C4,C5;
-Nurse/ medic (generic number);
-Two stopping place: SP1 and SP2.

5.23 Deviations

The main deviations are:

1) The movement of the carts and the drawing of the boxes in the storage are described in following way: it is considered a word “OR” (figure 26) to consider the movement of the case cart.

Compared to $IDEF_0$ it was utilized the interrogative window to indicate the movement of the case cart in the storage. This hypothesis is also considered to describe the task Quality Control and to indicate the task to throw the single use instruments. This hypothesis is made only to simplify the treatment.

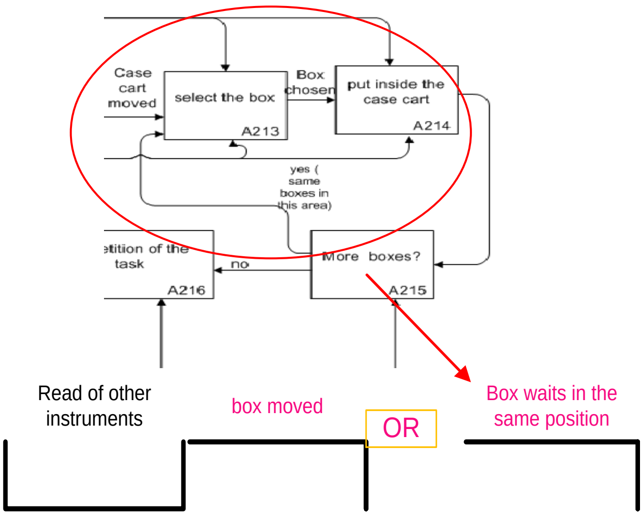


Figure 26 Choice of tasks [Own creation]

3) To manage the parallel tasks, is used a word “SAME TIME”: it is used for example in order to consider the washing of the boxes and the case cart (Figure 27).

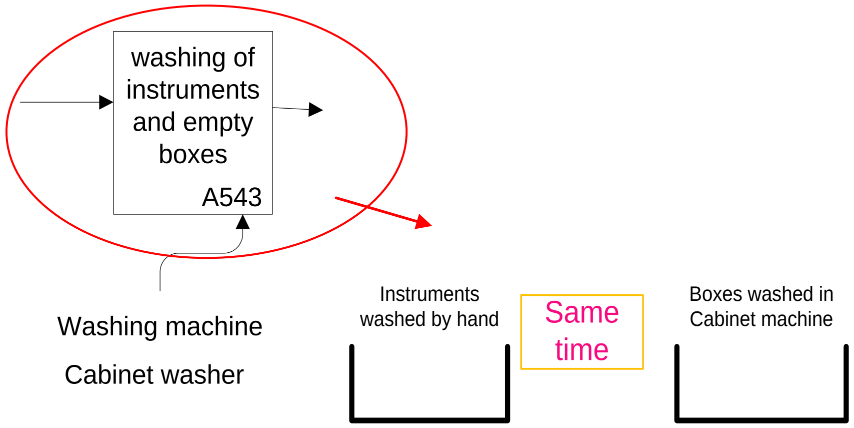


Figure 27 Parallel tasks [Own creation]

5.24 Value Stream mapping

The new Value stream mapping is showed in appendix 1 .

The different steps are explained below as follows:

1)Select the boxes

The first mapped case is the manual movement of the case cart by operatives. In this case the workers are two and they are S1 and S2. They move around the store in order to select the different boxes.

The main waste of the cycle is represented by the manual movement of the case cart in the store. For this reason, it is used a word "OR" in order to indicate the movement of the case cart or the waiting of the case cart.

2)Move the case cart

The subsequent task regards the movement of the case carts to a stopping place. The operative S3 arrives in the store, he takes the case cart and moves it to the stopping place 1. It assumed that each case cart is transported directly in the stopping place to avoid queue in the elevator area.

Even in this case, the tasks "call elevator "and "the movement of the case cart inside the elevator" are obligatory tasks that provide value add to the cycle. Otherwise, the movement of case cart and the waiting of elevator are waste for the cycle.

3) Use the instruments

The instruments, arrived in the stopping place and they wait the arrival of the nurses who have to take the different boxes. This is a value add for the cycle. The boxes are moved to the Operation Theatre because they have to be used. All tasks carried out in the OT represents a Value Add for the cycle because they are necessary.

4)Movement of the case cart to the area of cleaning

The case cart is in a stopping place and a new operative S4 arrives in this area and takes the different item: he moves them to the cleaning area. The movement of the case carts is made in the same way described before. For this reason the waiting and the movement represent the main waste of this cycle.

5) Quality Control

The case cart is in the cleaning area. The employees who work in this area are cleaners. It is supposed that for each typology of cleaner there are two employees who work in parallel way to avoid the stress.

The tasks to check the different instruments add value to the system; otherwise the movement and waiting no. The process is always the same: in this case it is used the word "OR" to indicate the choice to throw the items or no; the tasks end when all instruments are checked and the boxes filled are moved to be cleaned.

6) Cleaning of instruments

The phase of cleaning includes the washing, check-in, packaging and sterilization phase. The involved cleaner are C4 and C5 who take each box from the case cart, separate the box from the instruments because they follow two different paths. Even in this case the movement represents a waste of the cycle; otherwise the separation of instruments and boxes is a Value adds for the process.

At the end the boxes are inserted in Autoclave machine to be sterilized. In this case the main wastes are represented by the waiting and the movement of the items.

7) Store the instruments

The last operation is represented by the "Store the instruments. This process is the same shown in the sub-chapter "Store the box". The operatives, indeed takes the case cart, reads the list of box-position (this is a Value add) and later, after moved the case cart, inserts the box in the direction indicated.

The word "OR" indicates the choice of whether to move the cart in another direction.

Whatever the choice made, the boxes are repositioned and wait a new request.

The value stream mapping is important in this case, because allows understating what the main wastes of the cycle are. They are important because allows understating that these main movement and waiting should be reduced in order to have some benefits' in the future.

The next chapter allows taking into consideration different information about the principles of Poke yoke, traceability and 5S.

6 Poke yoke, 5S and traceability

After the description of the main phases of the cycle is important to understand what the main principles of the lean thinking can be used in order to improve the system. For this reason, the main principles of philosophy are represented by the Poke yoke, 5S and traceability. They are important in order to give some information about what are the techniques used to solve the problem that can happen in the hospital.

6.1 Poke-yoke: mistake proofing

“Poke-yoke is a Japanese term that means "fail-safing" or "mistake-proofing"; it is any mechanism in a lean manufacturing process that helps an equipment operator avoids (yokeru) mistakes (poka)” Its purpose is to eliminate product defects by preventing, correcting, or drawing attention to human errors as they occur”. (29)

To understand the meaning of Poke Yoke method, it is possible only if it is clarified the distinction between a Mistake and Defects.

A mistake, as defined by the institute of Medicine, is the “failure of planned action to be completed as intended or the use of a wrong plan to achieve an aim”. (27 p.88)

Defects are the end result of a mistake.

Both of them cause high costs for the hospital. For this reason it is important to know the main mistakes that happen in the society, as healthcare, and find the right solutions before that the mistakes transform in Defects. The five steps, represented in figure 28, should be following in detail and not by-passed to achieve a quick conclusion.

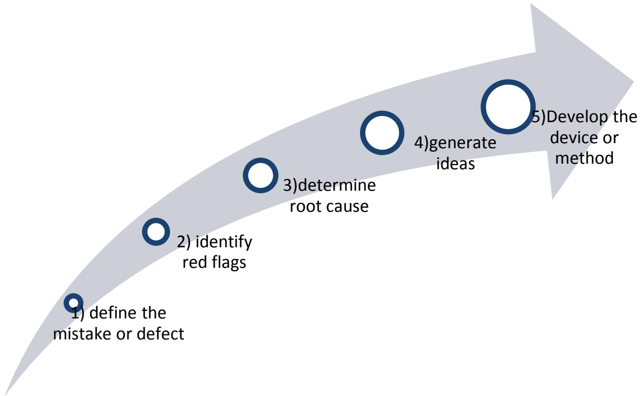


Figure 28 Five steps [Own creation]

Each phase is described as follows: (27 p. 88-92)

:

First step: Define the mistake or defect

The first step is to define the mistake or defect in detail. For this reason a lot of question must be formulated in order to have a clear idea of the situation: “when the mistake occurs or not? Where did they take place and who identified the mistake or defect; if there was a deviation from standard etc.”

Second step: condition of mistake

Defined the mistake or defect in the first phase, the second step allows to identify the condition or causes that provokes the likelihood of a mistake. The different cause of mistakes should be highlighted because is important to understand in which way is possible to attend and to solve the different mistakes.

Third step: root cause of each mistake

This third phase is the most important because allows identifying the root cause of each mistake identified in the previous step. Generally the literature provides several techniques/diagrams that provide detailed results. One of these diagrams is called Cause-and-Effect Diagram.

“The cause and effect diagram is used to explore all the potential or real causes (or inputs) that result in a single effect (or output). Causes are arranged according to their level of importance or detail, resulting in a depiction of relationships and hierarchy of events”. (30) As the figure 29 shows, the problem is divided in different categorized of analysis and for each category are identified the main causes.

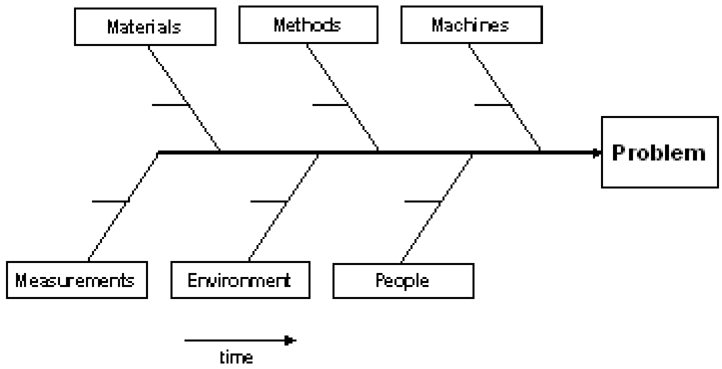


Figure 29 Root cause analysis (27 p. 90)

Fourth step: generation ideas

Gathered the main causes of mistake, the fourth steps is dedicated to the generation ideas: these ideas are found in order to solve the mistake. This phase is also called “the brainstorming”. The phase of brainstorming is composed of two sub-phases: the first one allows gathering of the ideas, even that are not appropriate. In a second sub-phase is dedicated to reject the idea that are not relevant to achieve: this phase is called” list – reduction phase”.

Fifth steps: developing the device or method

At the end the last steps guarantees the development and implementation of the device or method that will detect or prevent the mistake. In this phase often the priorities change and initiatives are forgotten. For this reason in this phase is important to remember the priority and track them. When the steps are terminated, all information are collected on a paper that is placed on the wall so that the team can view the steps in each moment.

The figure 30 shows how the Poke Yoke is applied in the two hospital:

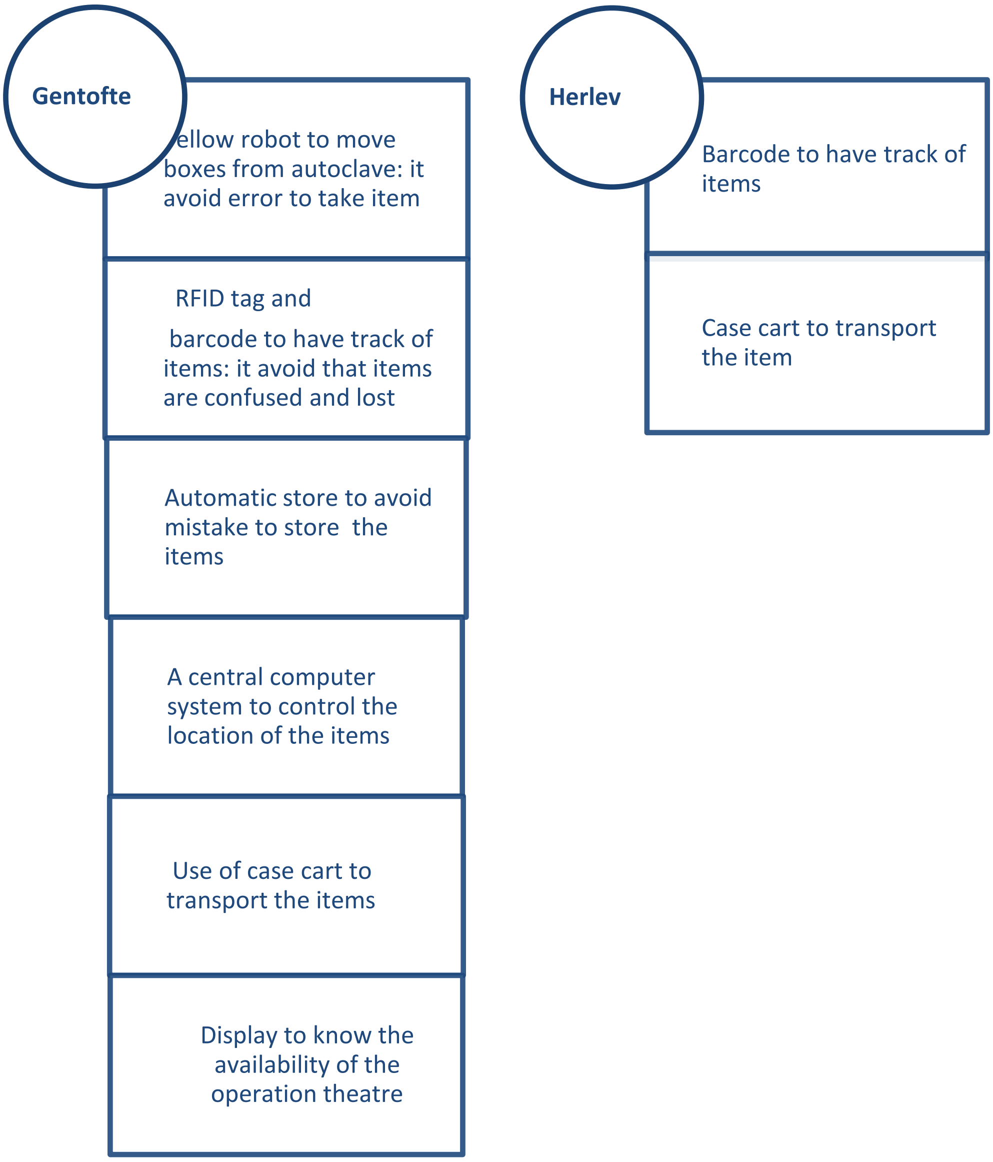


Figure 30 Poke yoke in the two hospitals

6.2 5s

The 5S is another technique of lean thinking that had produced different and important results in healthcare. The 5S are Japanese words that are an integral part of the Lean Healthcare process: it promotes "A Place for Everything and Everything is in its Place". The five words represent at the same time the phases of this method: Sort, Straighten, Sweep, Schedule and Sustain (figure 31) and they provide a series of advantages because eliminate non value-added operations in the workplace.

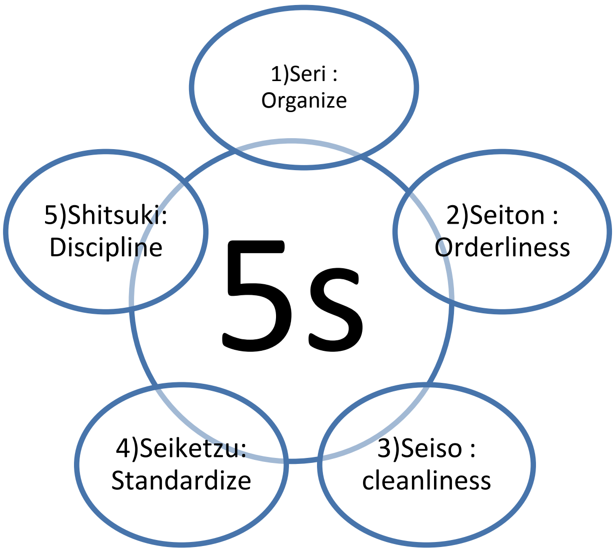


Figure 31 Meaning of 5S [Own creation]

The following sub-chapter shows in detail the 5 steps: precisely the different steps are applied in healthcare case. They are only mentioned in the treatment; in fact they are important in order to give some information about the way to solve any kind of problem in the hospital: (27 p. 74-86)

First S: Seire- organize-Sort

The first step of this method is to eliminate unnecessary items in the workplace. To achieve this goal different technique can be used. The result would be a leaner organization, with redundant positions/staff removed or re-assigned and unnecessary procedures cancelled out.

Second S: Seiton-orderliness-straighten

The first phase allows deleting and sorting the items, otherwise the second phase is dedicated to organize the other items. The items, indeed, are arranged so that they are easy to find, easy to use, easy to return to a designated location. The goal is that each people not familiar in this area should be able to find, use, and return the items.

Third S: Seiso-cleanliness- scrub

Until now the item are organized and straighted (the first two phase): now the goal of the third phase is to clean the work station. This is important because to clean the workspace and all equipment, and keep it clean, tidy and organized ensures that everything is located in the place where it belongs. It thinks to the cleaning of windows, equipment, light fixture, floor, container etc...

Fourth S: Seekers-Standardize-Stabilize

To maintain the gains achieved in the first three steps, the knowledge of the technique and method utilized should be widespread: each employees must be responsible for maintaining the benefits, must be educated regarding the technique utilized. For this reasons the aim of this phase is to standardize the work practices; in other word all work stations for a particular job should be identical; all employees doing the same job should be able to work in any station with the same tools. Everyone should know exactly what his or her responsibilities are for adhering to the first third S.

Fifth S: Shinseki- Discipline –Sustain

Once the previous 4 S's have been established, they become the new way to operate. For this reason, the aim of this phase is to guarantee maintaining this new way to operate and do not allow a gradual decline to the old ways. Sustaining is the most difficult phase of 5S and it is the responsibility of management.

The figure 32 shows the application of 5S in the two hospital:

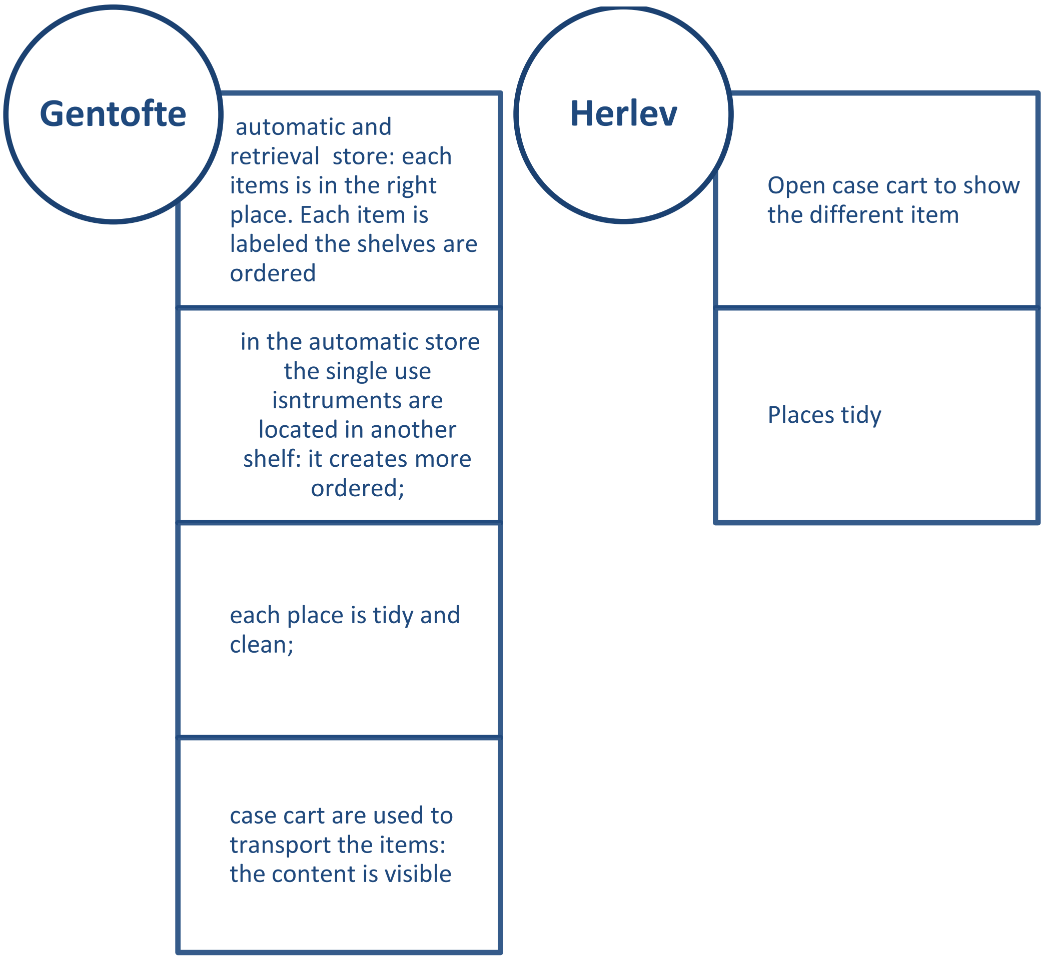


Figure 32 Application of 5S in Gentofte and Herlev hospital

6.3 Traceability

The last tool mentioned is the traceability of the surgical device. It remembers that identification, traceability, control and computer management of instruments are the solve and satisfy hospital needs.. The figure 33 shows the meaning of the solution : (31)

"Traceability allows tracking he movement of the items, in specified steps of the cycle, tracing a backward of the history, application or location of that which is under consideration"

Figure 33 Meaning of traceability [Own creation]

The main advantages of the traceability are: (32)

•Allows controlling of actual use of each instrument and guarantees optimization of usage, cutting down on useless inventories and ensuring efficient maintenance planning.

•Automate the process used to prepare theatre trays and trolleys, thus minimizing the potential for error and the time needed for such preparation.

These advantages represent an important innovation from the point of view of healthcare: the traceability is guaranteed through the use of the main tools that are used in the modern Hospital. They are T-doc software, Barcode and RFID solution.

T-doc solution

The modern way to keep track of the instruments is to use the software: its use facilitates the documentation of the instruments, which move from different departments. Famous software used in this field is called T-Doc and it is provided by the company Getinge. As Getinge Company says (10). the T-DOC can be used to develop the principle of Flow efficiency.

Bar code

“A **barcode** (figure 34) is an optical machine-readable representation of data, which shows data about the object to which it attaches. Originally barcodes represented data by varying the widths and spacings of parallel lines, and may be referred to as linear or one-dimensional (1D). Later they evolved into rectangles, dots, hexagons and other geometric patterns in two dimensions (2D).

Barcodes originally were scanned by special optical scanners called barcode readers; later, scanners and interpretive software became available on devices including desktop printers and smartphones”. [33]

Figure 34 Example of barcode [34]

RFID tag

In sectors like healthcare, RFID tag is an important and innovative solution. It based on combining a microchip with an “antenna” in a “tag” (figure 35), which then responds to signals from a reader or scanner, returning a signal and possibly storing information. These advice takes a number of advantages and the use in healthcare situations is of critical importance.

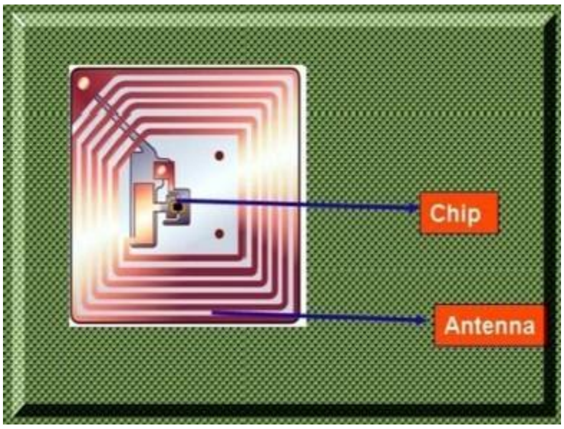


Figure 35 Example of RFID [35]

The RFID tag can be of two types: active and passive. The main difference is the method of powering the tags : active RFID uses a battery internal power within the tag; in this way they have continuously power the tag; Passive RFID relies on RF energy transferred from the reader to the tag to power the tag.

Passive RFID requires stronger signals from the reader, and the signal strength returned from the tag is constrained to very low levels. Active RFID allows very low-level signals to be received by the tag (because the reader does not need to power the tag), and the tag can generate high-level signals back to the reader. Passive RFID is smaller htan Active RFID that is slightly buickly because the battery.

The use of passive RFID tag is advisable then an active tag because the costs are low. [36]

Differences between barcode and RFID

After have explaining the main information about the barcode and RFID any differences between the two technology can be provided. Conceptually, bar coding and RFID are quite similar; both are intended to provide rapid identification and tracking of items. It remembers that bar codes and RFID technologies are not mutually exclusive, nor will one replace the other. The main differences between these two technologies are linked as follows : [37]

1.Barcodes uses a sensor and light to read the data on the tag ;differently RFID uses radio waves to read to distance the information written on tag;
2. Barcode scanners process tags one at a time; otherwise RFID scanners process dozens in a single second at the same time;
3. Barcodes are really simple and can be easily replicated ; RFID is more complex and secure;

4. RFID tags can be hidden to protect against the environment while barcodes need to be exposed
5. Barcodes is very cheaper compared to RFID.

The figure 36 below shows how the traceability is applied in the two hospital.

	Gentofte hospital	**Herlev Hospital**
Traceability	Use of Barcode attached on each boxes; they start to use RFID tag	Use of barcode attached on the boxes

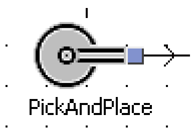
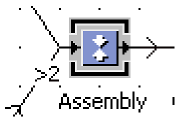
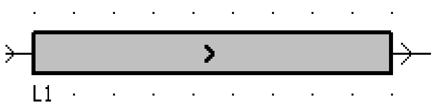
Figure 36 Traceability in the two hospitals

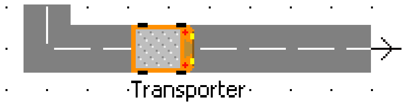
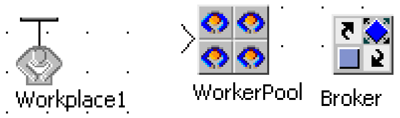
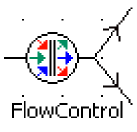
7 Simulation

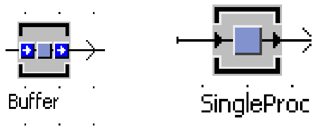
After the brief explanation of the $IDEF_0$, value stream mapping and the main principle of lean thinking, is important to understand how the simulation represents the first idea. The simulation provides a dynamic view of the cycle: the application utilized to do the simulation is “Plan simulation”.

The Table 1 shows the main resources utilized and what their purpose inside the simulation is.

Table 1 General resource

Resource	Function
	Pick and Place selects the box inside the buffer (in $IDEF_0$ this task was made by the employer)
	Assembly inserts component in the boxes or in the case cart (in $Idef_0$ this task was made by employees). The resource disassembly separates the entity.
	Line: to simulate the movement of the input

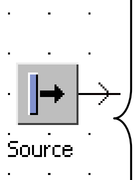
	Track simulates the movement of the elevator. They are supposed two floors to optimize the space of hospital.
	Workers take out the boxes from Operation theatre
	Flow control: to distribute a percentage of input

	Buffer stores the input (box, instruments); Single proc: to simulate OT (hypothesis 3 OT) and other tasks.

Resource: Source

The resource “Source” allows creation of the input for the simulation. These inputs are instruments, boxes, case cart and the elevator. They are created when the simulation and the life cycle needed of them. It is supposed to create a loop in this cycle: for this reason it has established a specific number of inputs.

1) Input



- Surgical instruments: 24 utensils are created;
- Boxes: it considers 4 utensils for each box; the total of box is 6;
- Case cart: in each tray of case cart 1 box is inserted; in total there are 6 boxes in each case cart. The source creates the case cart at a time.
- Elevator: the capacity is 1 case cart for each deal.

2) Boundaries

The main boundaries are described as follows:

•only one typology of boxes exists;
•It is established a precise number of items that should be processed: the loop is created.

7.1 General scheme

The simulation does not follow the $IDEF_0$ to the perfection. A generic overview of the cycle is shown in the figure 37. The name of the six windows is the same shown in the $IDEF_0$.

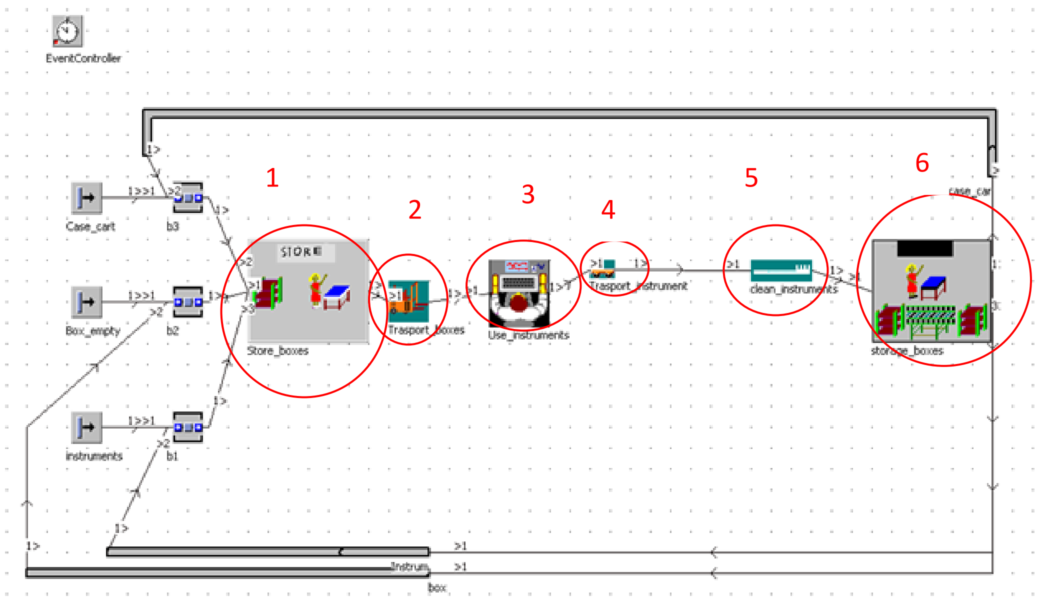


Figure 37 General Scheme

The cycle starts with the creation of the input through the source “Case_cart”, “Box_empty” and “Instruments”. The entities wait in own buffers before the beginning of the cycle. The main tasks are shown as follows.

(1)Store_boxes

First window is “Store_boxes”. This window includes three phases, the same shown in the IDEF0. Precisely the first phase (1) indicates the creation of the box through the Assembly resource “box_filled”: it allows creation of a box with 4 instruments, highlighted with red circle. The first circles is used only to create the box, in fact it is used a resource Assembly “box_filled” that creates the box; the assembly resource inserts 4 instruments in each processed box (figure 38).

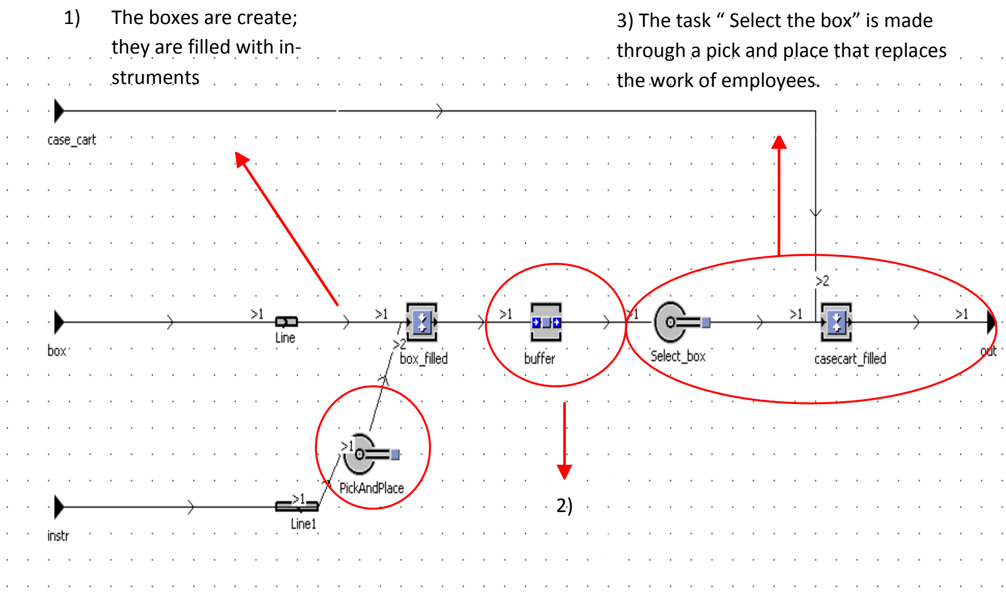


Figure 38 Store_boxes

The second phase (2) indicates the task "Store of the boxes": the boxes are inserted in a resource "buffer" and they stationed several time.

The third phase (3) is the selection of the boxes through a resource "Select_box": it is indicated by a picks and place that allows taking the different boxes and inserting them in a case cart. The assembly resource "casecart_filled" is used to achieve this goal. The figure A1 and A2 show the value inserted in the Assembly resource "Box_instruments" and "Box_casecart".

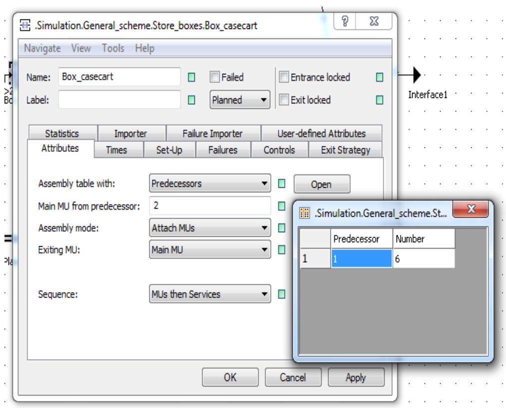


Figure A 1 Resource "Box_instruments

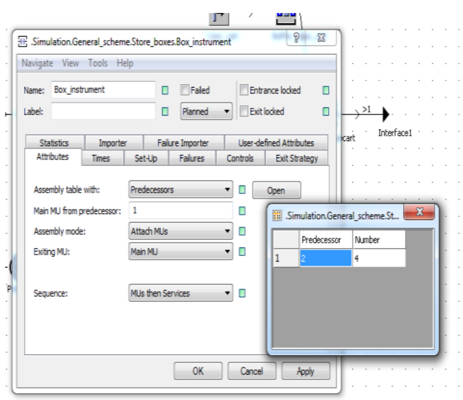


Figure A 2 Resource "Box_casecart"

This situation is explained as follows: six boxes are created and inserted in a case cart.

(2)Transport_boxes

The second window is the "Transport of the boxes"(figure 39).

It includes the movement of the boxes toward a stopping place, area where the boxes wait to be picked. An elevator is created in this phase through a source "el_source". It allows moving the case cart to a stopping place "SP1". The case cart waits in the resource "Area" (1) and later is loaded on elevator through the resource "elevator_casecart" (2). The case cart is moved to the "case-cart_elevator" (3) and later arrives in the stopping place1 (4). The stopping place is simulated with a resource "Buffer" because it contains 6 boxes coming from the elevator.

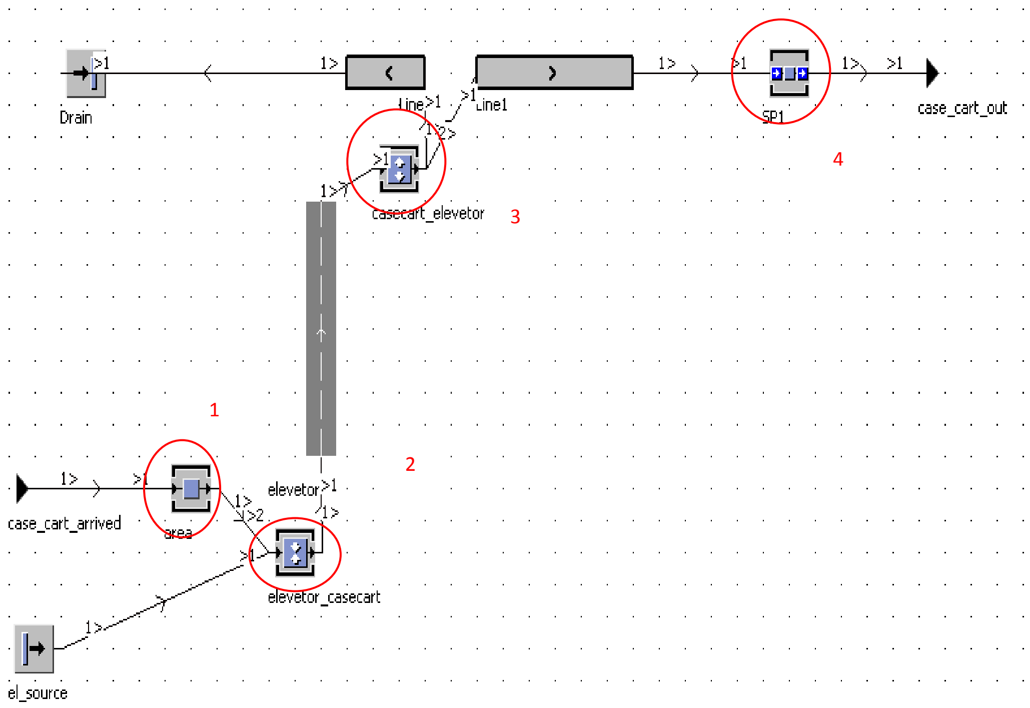


Figure 39 Transport of boxes

(3)Use_instruments

The case cart arrives in a resource “Choice_boxes”. Each box is taken and used in the different operation theatres. Three are the operation theatres and the time to do surgical operation is set as follows: the time of Operation theatre1 is 30 minutes; the time of Operation theatre2 is 45 minutes; the time of the Operation theatre3 is 60 minutes. In this case is supposed to consider the flow control “distribution” to distribute the different boxes (figure 40).

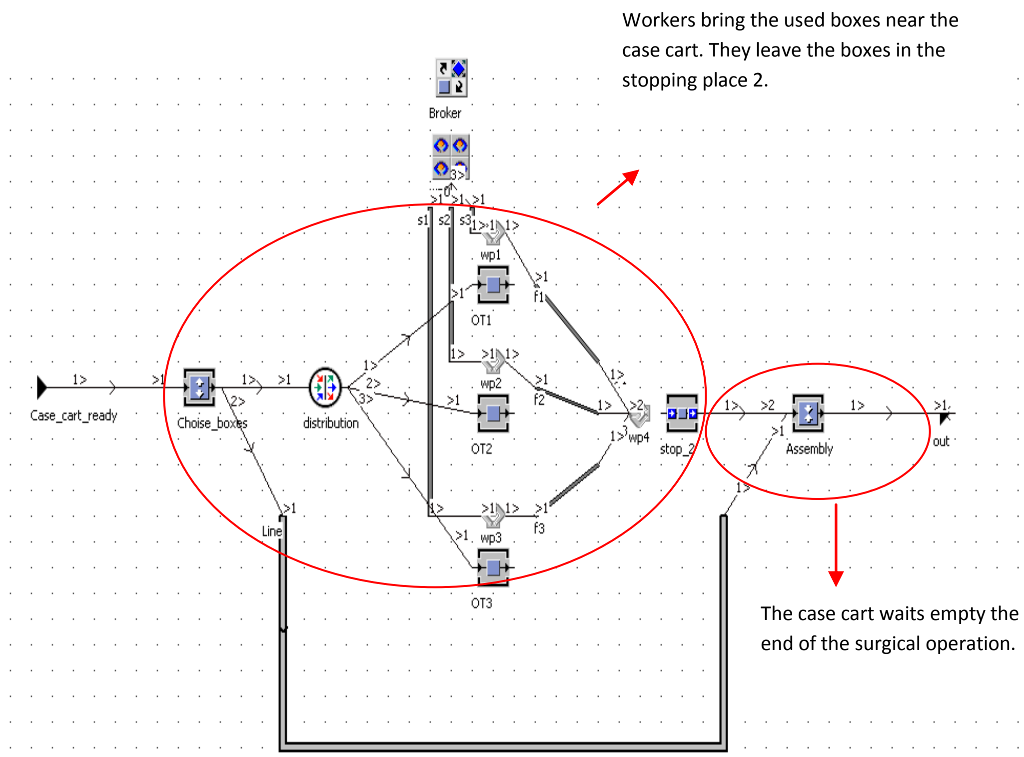


Figure 40 Use_instruments

(4)Transport_ instruments

The instruments are in the stopping place 2 and they are moved to the area of cleaning. The full case cart is transported by elevator to go in CSSD (figure 41).

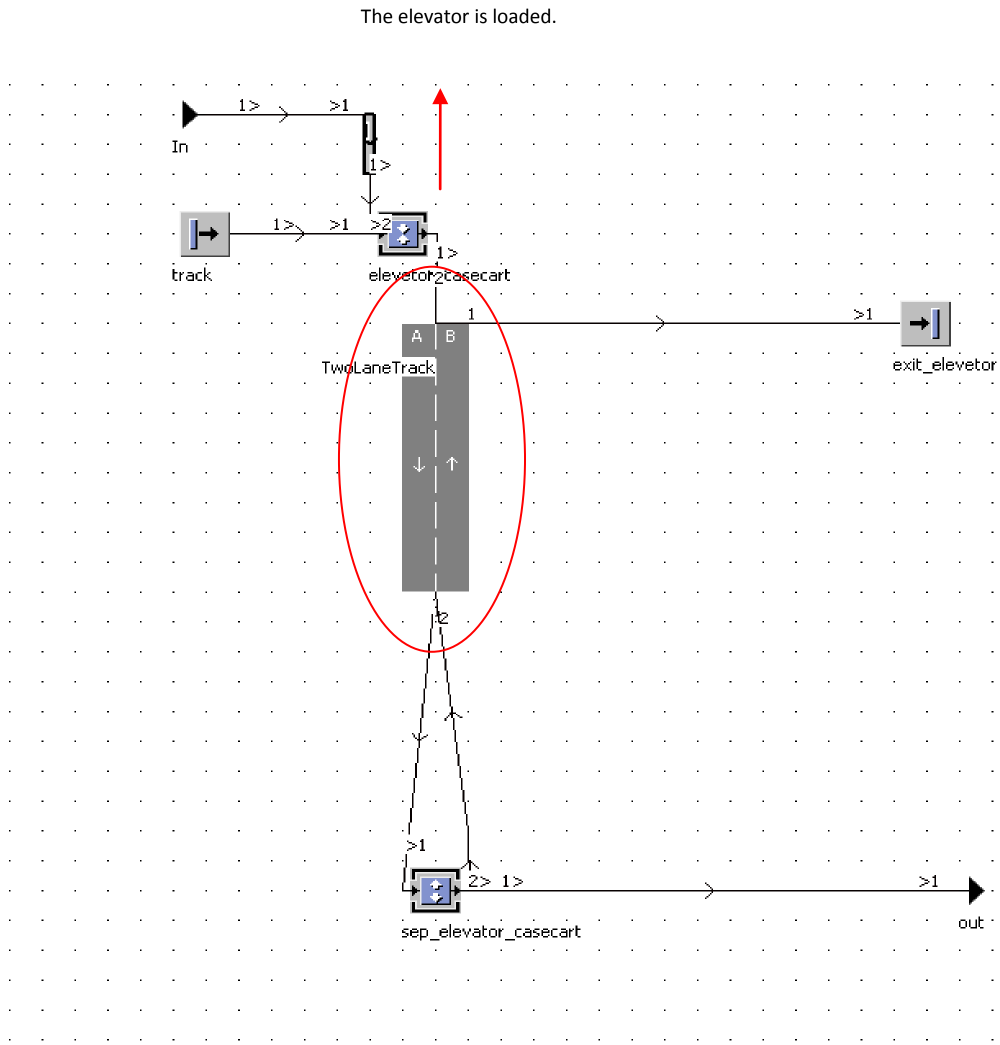


Figure 41 Trasport_instruments

(5)Clean instruments

The case cart is arrived in cleaning area. The phases are the same shown in IDEF0: this step included the phase of pre-cleaning, cleaning, packaging and sterilization. In this macro-window are included two sub-processes: the "Quality Control" where the instruments are checked and the cleaning phase.

These two sub- windows are described as follows.

Quality Control of instruments

The figure 42 shows the process.

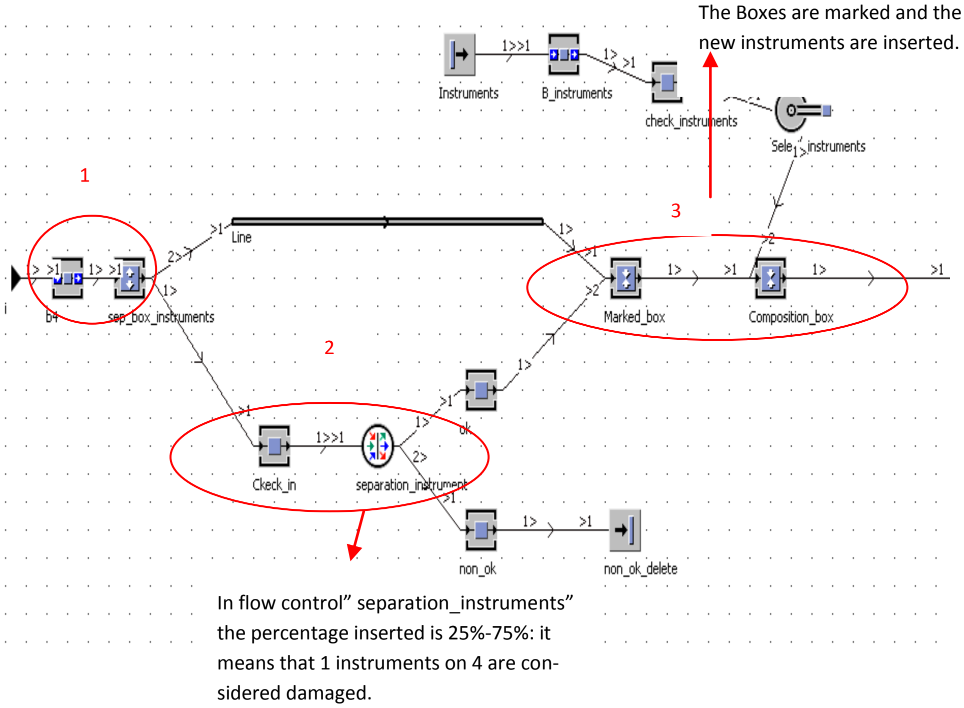


Figure 42 Quality_control

It is supposed that the 6 boxes of each container are processed one at a time: the buffer "b4" is employed to guarantee the waiting for the other box. The process starts as follows: the box and the instruments are divided through the resource "sep_box_instruments" (1).

Later the instruments are checked (2) through the flow control "separation – instruments" the instruments: the 25% of the instruments called "Non-ok" are single use and they leave the system (one on four), the other percentage, called "Ok", is inserted inside the box through the resource assembly "Marked-box" (3).

This resource is called "Marked_box" because allows marking the box. The instruments are inserted in the box through the resource "Composition_box". The operation ends until all the instruments of the six boxes are checked and ready to go to be cleaned.

Clean of boxes: "cleaning1"

The six boxes arrive in the area of cleaning. They are cleaned all together and at the same time. The figure 43 shows the four processes: pre-washing, washing, packaging and sterilization.

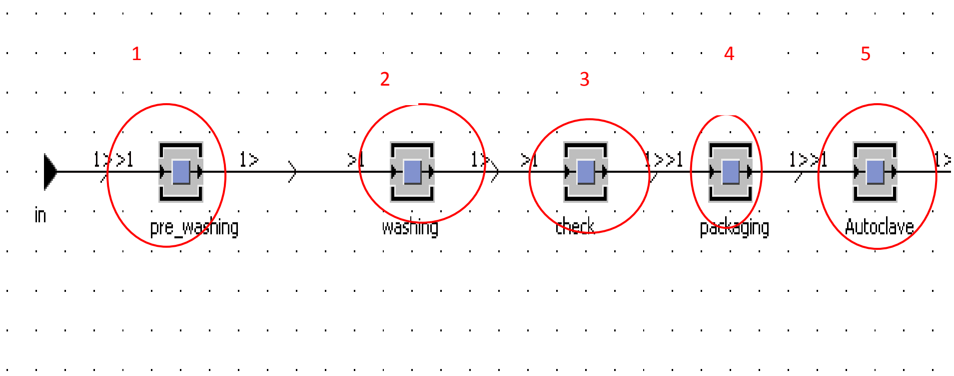


Figure 43 Cleaning1

The first phase is the “pre-washing”; here the instruments are cleaned by hand. In this way they are washed all together. Later they are checked (3) and they pass close a resource “packaging” (4); later they are inserted in Autoclave to be sterilized (5). Here the process of cleaning finishes and the different item are moved to the area of storage to be stored.

(6)Transport the boxes

The last step is the store of the different items as is shown in figure 44.

The process follows the same tasks described in IDEF$_0$. The items are taken through the resource “Sep_case cart”. Later case cart and boxes are stored in the buffer “b_box” and “b_case cart”. Even in this case the pick and place simulates the work of employees.

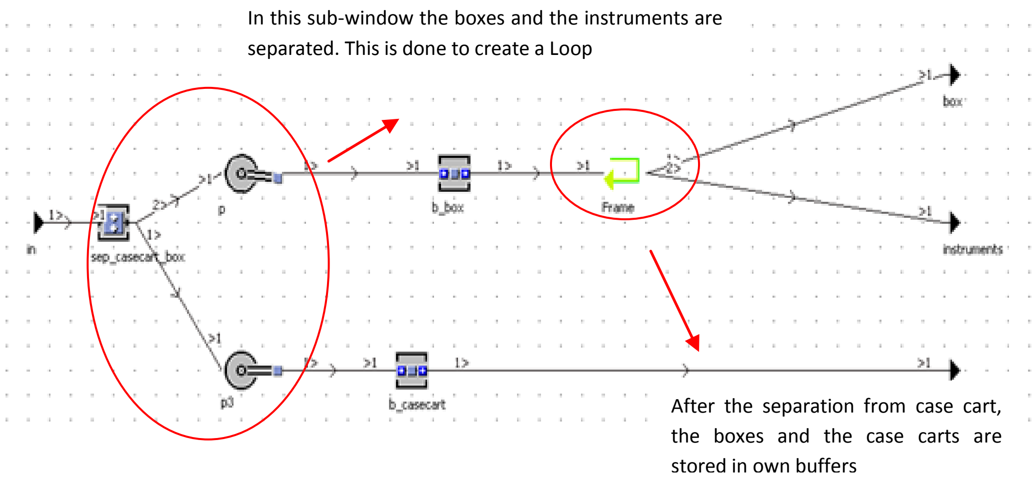


Figure 44 Storage_boxes

The last macro-window “Frame” is not a phase of the cycle but allows dividing the instruments and box: in this way the Loop is created because at the exit of this phase the three entities back to the first steps “Store_boxes”.

In order to introduce the new simulation, it is important to remember what the main characteristic of the first simulation are. The main characteristics are shown as follows:

-6 boxes are contained in one case cart;

-The hospital is composed by two floors connected by an elevator;

-After the surgical operation the items are inserted in the boxes and later they are moved to the cleaning area where there is the phase of Control of the different items called Quality control of the instruments;

-During the phase of cleaning the different boxes are cleaned together and at the same time;

-The phase of storage is made manually.

After this consideration the new solution is explained as follows.

8 New solution

After have to describe what the main characteristics of the first simulation are, this chapter is dedicated to create a new system according the principle of lean philosophy. This goal is achieved through the analysis of each step of the lifecycle. The main ideas are gathered and the new cycle is created.

This chapter is divided in 6 parts: the first part is dedicated to show the main hypothesis of the new cycle: they regards the use of new devices; the second part, instead, shows the three new options to represent the cycle ; these three option of the cycle are describe and through the analysis of the main advantages and disadvantages of options, the new solution is created. The other last parts of the chapter are dedicated to map the new cycle through the method “Value stream mapping” and “the simulator”; at the end the new simulation is compared with the first simulation and an analysis of the parameter Lead time is done.

8.1 Development of a new and optimized system

In this new system is supposed to consider the case to provide two different services: acute case and plan surgery cases. Before to enter in the description of the new lifecycle, three new hypothesis are described below:

1)Traceability of surgical devices;
2)New kind of store: automatic store;
3)A lift elevator and two case carts.

These different hypothesis are considered in order to apply the principle of Lean thinking: precisely to identify the different items in the hospital (traceability) and don’t lose time, to speed picking or storing of the different items inside the store, to avoid the fatigue of employees to transport the different items. Below the different new hypothesis are described.

1)Traceability of the boxes

An important consideration is about the traceability of the different items. Two are the ways to have traceability of the items: the use of barcode for the boxes and RFID tag on the case cart.

The barcode provides a several information when is scanned. An advantage of the barcode is that is cheaper compared to the RFID solution. Because the hospital manages a big quantity of the boxes, the use of RFID helps for different reasons but not from the point of view of the costs. The scanning of a barcode, indeed, is used in order to know the name of the box, instruments contained within the boxes, destination of the boxes, in other word is known the location of the different boxes in the system.

Traceability of the case cart

To have traceability of the case cart is important to use a RFID tag. It is important in order to give information about the place where is the case cart. The amount of cart is lower than the number of boxes. In this way more case carts can be read simultaneously through a reader that sends the information to computer software.

2)Automatic store

Another consideration about the new system is the use of the Automatic store. For the new system it is supposed to consider an automatic storage and retrieval system: the same used in Gentofte hospital. Some information is provided again in this chapter. This automated storage handles the storage of containers, packaging of containers onto case carts and most of the transport of the case carts within the storage area. This suggestion is very important in term of time and fatigue (figure 45).

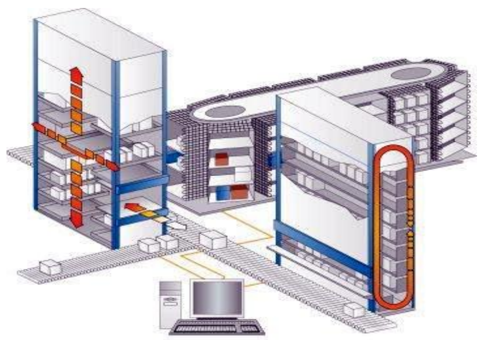


Figure 45 Automatic storage and retrieval system [13]

The integration between the storage and computers ensures that the automatic devices pick automatically the items without the use of human resources. The main benefits of this system are: [38]

•the space is saved;

•the human resources don’t seek the items in the buffer but they only book the items on the system computer; in this way they work more productively and reduce their labour;
•there is increased and reduced inventory levels because is always known the number of the items in the store.

3)A lift elevator and two case carts

The lift of heavy boxes is an important aspect to take into consideration. It remembers that was a problem for Gentofte hospital (figure 46).

To solve this problem it supposes to use a lift elevator where the boxes are loaded.

Figure 46 Lift elevator [10]

It wants to insert this product in order to give a generic idea about the lifting of boxes. It doesn’t want to advertise the product. As main information of the product “The lift elevator or lift trolley (as it is called from Getinge company) offers a major improvement in ergonomics as well as more rational materials handling and it can be used to lift boxes, basket, container and other items where heavy lifting is required.

The lift elevator is made of stainless steel for durability and easy cleaning. The main advantage of this device is ergonomic. It thinks that this product reduces staff operations at non-ergonomic because the height of the lift table can be quickly and easily adjusted to a comfortable working height for each staff member - whether sitting or standing; it also reduces the risk of injury due to strain. This solution has the advantage of avoiding the fatigue of the workers in loading and unloading of boxes”. [10]The boxes are lifted by the elevator and inserted inside the case cart. Technical data are not provided from Getinge.

Two are the kind of proposed case carts to use.

1) Case cart with the basket (figure 47): “it allows loading of baskets. They can be pulled out more than halfway and they then secured in place for easy viewing and picking of individual packs. They trolleys also feature a unique, simple securing device to hold baskets in place during transport and enable loading and unloading from both wide sides” .[39] The figure below shows the main technical data of the product.

Base Unit Supplier SPRI	Units	Models	
		5 Full-sized	10 Half-sized
Length	mm/in.	685/27	
Width		495/19.4	
Height		1535/60.4	1535/60.4

Figure 47 Open case cart [10]

2) Case cart with sloping shelves of some degrees.

Figure 48 Case cart with sloped shelves [40]

This represents only an example. In the reality is called “Angled ESD Wire Shelf Carts. The technical data are:

Height: 72” nominal height;

Unit Includes: Units come standard with (4) Angled Shelves;

Casters: (4) swivel 5” x 1 ¼” Rubber Casters with (2) brakesT”. [41]

The use of case cart with inclined shelves of some degrees, allows sliding the boxes when they arrive at requested high. The shelves should be properly blocked with a safety hook to avoid that the boxes fall in the other side. To pick up the heavy box, the side inclined is opened and the boxes slip for gravity in the direction of the lift elevator. This important solution is made in order to avoid the fatigue of the employees who should be facilitated to insert the different items. The picture is only an idea of case carts with sloping shelves.

In this new solution is supposed to have only one floor where 3operation theatre, a CSSD and an automatic and retrieval store are localized in one floor and not in two floors connected by a elevator (first solution). Another hypothesis is that the new system handles acute and plan cases.

After the description of the main hypothesis three suggested solutions are described in the second part: they describe a new way to organize the new lifecycle of surgical instrument if planned and acute cases are considered. If thinks how handle the request of the case carts to satisfy the two cases.

After described the advantages an disengages of each solution, only one solution is implemented in the new system and is mapped through the Value stream mapping and simulator.

8.2 Three new ideas to satisfy the request of planned and acute cases

Three new ideas are described below: they focuses on management of case cart if acute and plan case are required.

1)It supposed to have three kind of case carts: a "base" case cart that contains basic instruments to use. It is delivered directly to the area of sterilization and it is always inserted in the operation theatre.
When the acute patient arrives in the hospital and the diagnosis is ready, another "additional case cart" is booked through a computer system of the operation theatre and is created immediately in retrieval store. In this case, the surgical operation starts when base and additional case carts are in the operation theatre.
The request of plan surgery case cart is programmed and "the plan case cart" is prepared in the retrieval store and sent in the operation theatre when there is a planned surgical operation.

1)Another solution is represented by the use of 1 "base-additional case cart" that contains basic and additional instruments. It is ordered in the retrieval store only when the acute patient arrives in the hospital and is known the diagnosis.
The planned case are satisfied through the use of the "plan case cart" booked in retrieval store.

2)The last solution predicts the use of a small store close the operation theatre: it contains dif basic and additional instruments. When the stock of the items of this store is not enough, the items are booked in a automatic store and the level is restored again.

The three solutions are similar but only the first is taken into consideration.

Below the advantages and disadvantages of each solution are described:

Table 2 Advantages and disadvantages of three cases

	Advantages	**Disadvantages**
First solution: three case cart	It is ordered additional case cart if is necessary	More complex system
Second solution: one case cart	Only one case cart to track	High waiting time before its arrive
Third solution: small store	Less time to take the instruments	Check each time the level of stock of items; High number of items dislocated in the system

According the advantages and disadvantages of the hypothesis, only the first solution is considered and is described through different methods.

How does it change the cycle if the first solution is implemented?

8.3 The new solution

The new solution included 3 operation theatres: two operation theatres are dedicated for emergency case, one for plan surgery case. In the new solution is supposed to considers the request of additional case cart.

The figure below shows the layout of the new solution.

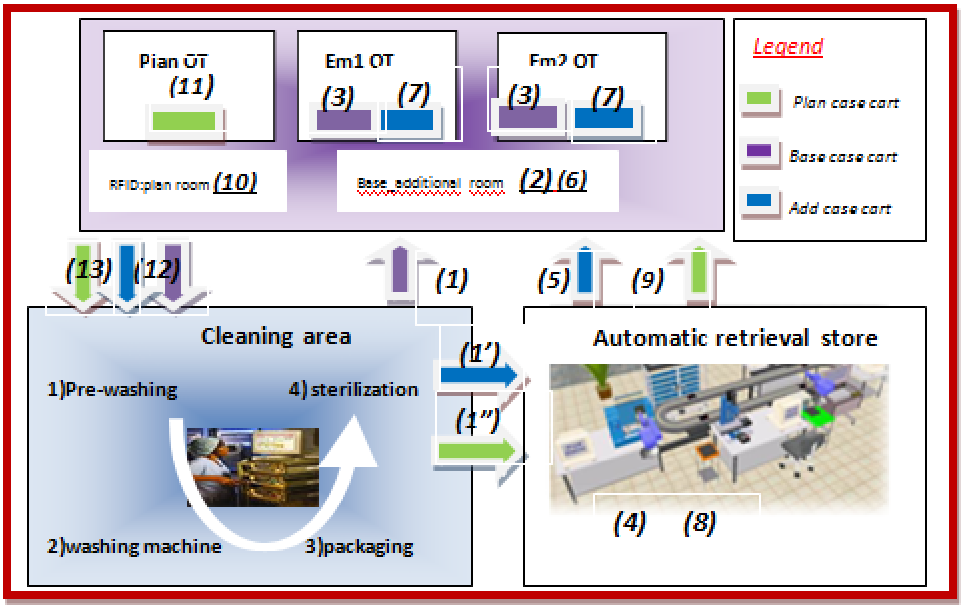


Figure 49 Layout of the new system [Own creation]

As indicated above, three are the evolved case carts:

1) **Base case cart**: it contains two different base boxes that should be used in the emergency case; it is in the operation theatre and contains basic instruments that can be established prior the procedure; they are always the same and they are sent immediately when the sterilization of the instruments is done in area cleaning area;

2) **Additional case cart**: it is used to contain two additional boxes that are required to satisfy the emergency case; these case carts are also required since there are a variety of items that cannot be determined prior to the procedure; e.g., suture, eye, ortho, neuro. For this reason they are booked and sent when there is the request.

3)**Plan case cart**: it contains two plan boxes to use in the plan surgery. The boxes contain different scheduled instruments that are established when is established the surgical operation to do.

How does it change the cycle?

The request of the three case carts is explained in three scenarios below:

1)First scenario : request of base case cart

It supposes that the base case carts are always in the operation theatre: they are created after the phase of sterilization; each sterilized box is taken and inserted in "base case cart" (1). Later it is immediately sent to the area called "base_additional room" where there is a RFID tag (2) and it waits in the operation theatre (3).

2)Second scenario: request of additional case cart

The additional case carts are ordered when the patient arrives in the hospital and is known the type of diagnosis. In the operation theatre, indeed, is established the request of the additional instruments to utilize and immediately the request is sent to the automatic store, area where they are filled. The tasks to do in the operation theatre are shown as follows:

1) The computer system of operation theatre receives the order of additional case cart;

2) The request of the additional case cart is sent to the automatic store;

3) The additional case cart is created and arrives in the operation theatre by the operatives.

Request of additional case cart in the automatic store

The request of additional item arrives in the automatic store (4). Here each box is booked through the computer system and is scanned. A conveyor belt allows moving the boxes close a case cart. After the filling of the case cart, it passes close a RFID reader and the information about the case cart are updated; it thinks about the destination of the case cart and the specific boxes to insert inside.

Base_additional room

After that the case cart is moved (5) to base_additional room: this area dedicated to keep track of base and additional case cart. To achieve this goal they pass close a RFID reader (6) and the information about the case cart is shown on the displays: in this way is known the destination of case cart, their content. The status of case cart is updated.

The additional case cart is immediately taken and put inside the operation theatre to be used.

Operation theatre

In the operation theatre the additional and base case cart are used for surgical operation (7).

3)Third scenario: request of a plan surgery case cart

The request of a plan case cart is programmed according the established plan of the operation theatre. In this case, indeed, the request of the base case cart is directly sent to the retrieval store, where the computer receives the different request of the different case cart (8) . In this way the different case carts are created and sent (9) directly to another room called "plan room" (10). Later they go to the operation theatre (11).

How does it change the phase of cleaning?

Cleaning of the plan case cart, additional case cart and base case cart

The base and additional case carts are sent together to the area of cleaning (12). Otherwise the plan case cart is transported when the planned surgical operation is ended (13). The steps of the total process are explicated as follows:

1)Pre-washing: each box is scanned; a display shows the name of instruments and the arrangement for washing. After the washing, each instrument is put inside another box and it is attached a label that identifies the number of instruments inside, the name of boxes etc..;

2)Washing machine: each box is inserted in the washing machine to be cleaned again. In this way a parallel washing is done;

3)Packaging: each box is again pre-packed. The process is always the same. They are inserted in a wrapped green paper and subsequently a barcode is attached on the paper. According this process, a conveyor belt transports the wrapped boxes inside the autoclave machine. A display shows all process and the time of each step;

4)Sterilization: at the end of this process each box is scanned again and each case cart is filled. To achieve this goal the base case carts are filled and later they are sent directly to the base_additional room (1). Otherwise the plan and additional case carts are directly moved to the automatic store where they are stored (1') (1'').

Below a new value stream mapping is created according the new ideas.

8.4 The new Value stream mapping

Each scenario explained below is shown in the new value stream mapping (Appendix 2). It allows identifying the different scenarios through the time line: compared to the first solution, in this case the traceability and lean principles are taken into consideration. It remembers that the use of the two kind of case carts (case cart for heavy box and normal case cart) is not indicated in the value stream mapping. It considers only one generic case cart.

The value stream mapping starts with the description of the second scenario.

8.5 The new simulation

According this situation, the simulation to do in this case is completely different compared to the first solution. It remembers that the new simulation takes into consideration six windows: the names of the windows are the same but the content is different. The second scenario of analysis is only an improvement of the first scenario and it is important in order to create the different items.

A General scheme shows the different treated steps (figure 50):

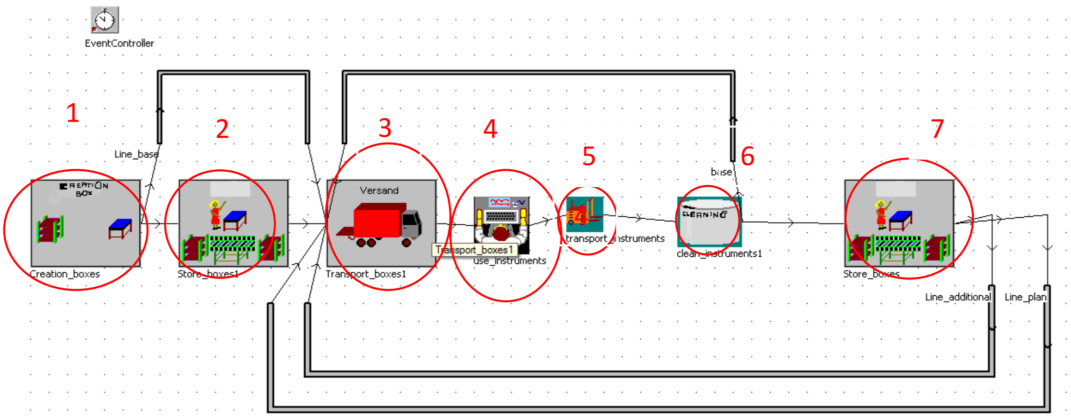


Figure 50 General scheme

The table 3 shows the differences:

Table 3 Main differences with the first solution

Scenario1	***Scenario 2***
1 case cart to satisfied the request of 3 operation theatres	3 case carts: additional, plan, base to satisfy the request of 3 operation theatres

6 boxes in one case cart (2 for each operation theatre)	2 boxes inserted in each case cart

Three are “additional”, “base” and “plan”. At the same time three case carts are created.

According these boundaries each window is examined as follows.

Creation_boxes (1)

The first analyzed window is “Store boxes” and is described in figure 51. Here the boxes are created and inserted inside the case cart.

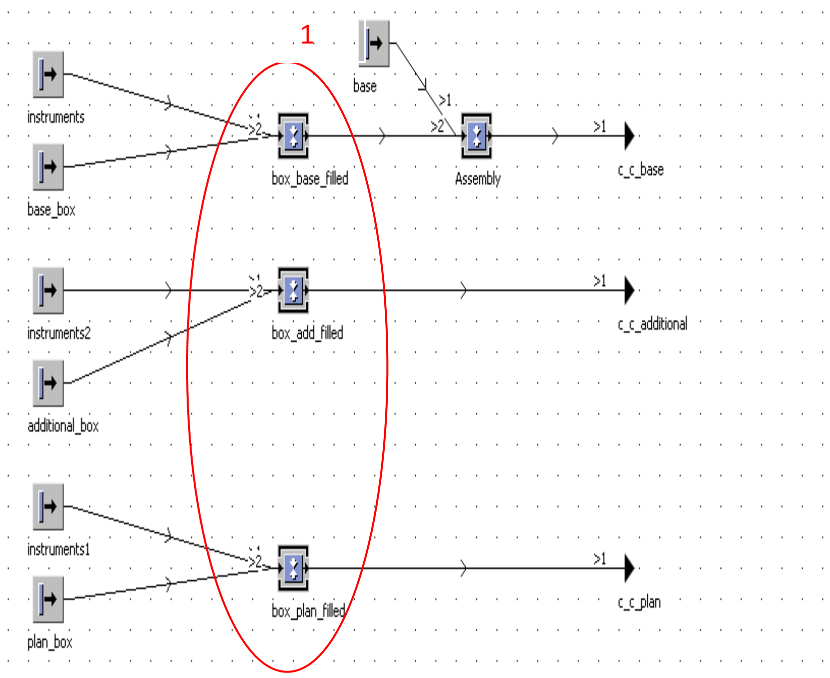


Figure 51 Creation Boxes

The resources “box_base_filled”, ”box_add_filled” and “box_add_filled” (1) allow filling 4 instruments in each box. Only the base boxes are inserted inside the case cart through the resource “Assembly” because it supposed they are coming from the cleaning area and they are not moved to the automatic store. In this case the times are set to 0 minutes because this window is used in order to create the boxes.

Store_boxes1 (2)

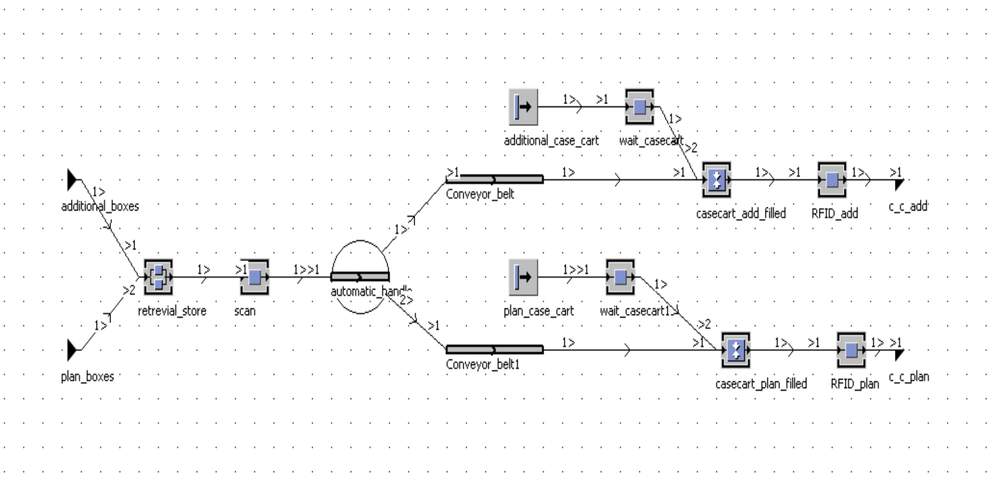


Figure 52 Store boxes1

The figure shows the picking of the case cart ; precisely when there is the additional and plan request of boxes. the table below shows the times of each resource:

Table 4 Store_boxes 1

Process or line	**Times & Capacity**
Retrieval _store	Processing Time: 5:00
Scan	Time: 1:00
automatic handling	Time: 1:00
Conveyor_belt/ belt1	Time: 0:05

Casecart_add_filled	Processing time: 2:00
Casecart_plan_filled	Processing time: 2:00
RFID_add/ plan	Time: 1:00

The figure below shows the first hypothesis: the circle 1 indicates the creation of boxes (the times of each resources are set 0 minutes) , otherwise the circle 2 indicate the “Store_boxes”. In this case the resource “select of boxes” indicated the manual filling of case carts.

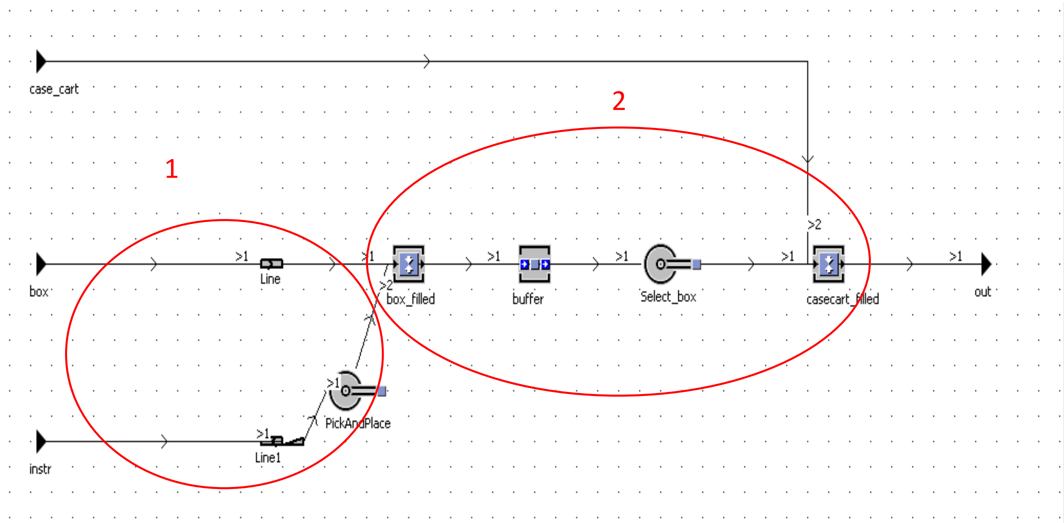


Figure 53 Store_boxes_ first_ solutions

Transport _boxes1 (3)

The third window shows the transport of the case cart in the different rooms (1): areas where there is a RFID reader to scan to keep track of the case carts. One room is used to keep track of additional and base case cart, another one to insert plan case cart.

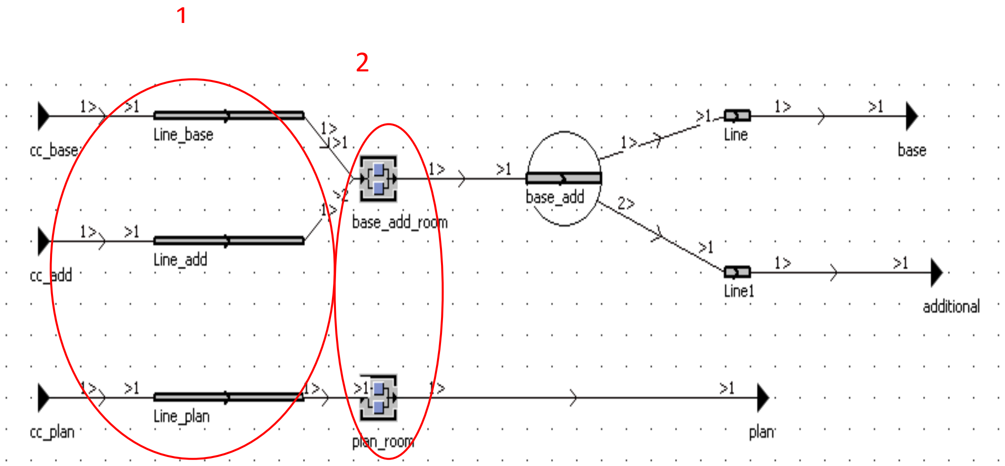


Figure 54 Transport _boxes

The three different case carts arrive there in different times.

Table 5 Transport_boxes

Process or line	Times & Capacity
Line_base	Time: 3:00
Line_add	Time: 3:00
Line_plan	Time: 5:00
base_ additional_room	Capacity: 2 Processing time: 3:00
Plan_room	Capacity:2 Processing time: 3:00
Line/ Line 1	Time: 1:00

In the new solution the different case carts are transported by hands and the time is different compared to the first solution where an elevator connects the two floors.

Use_instruments (4)

The case carts arrive in the area of operation theatre under the window “Use_instruments. In the circle (1) is supposed to consider the Emergency rooms. In each emergency room are inserted the two case carts, base and additional through the resource “base_additional”. The plan surgery (2), instead, describes the plan boxes .

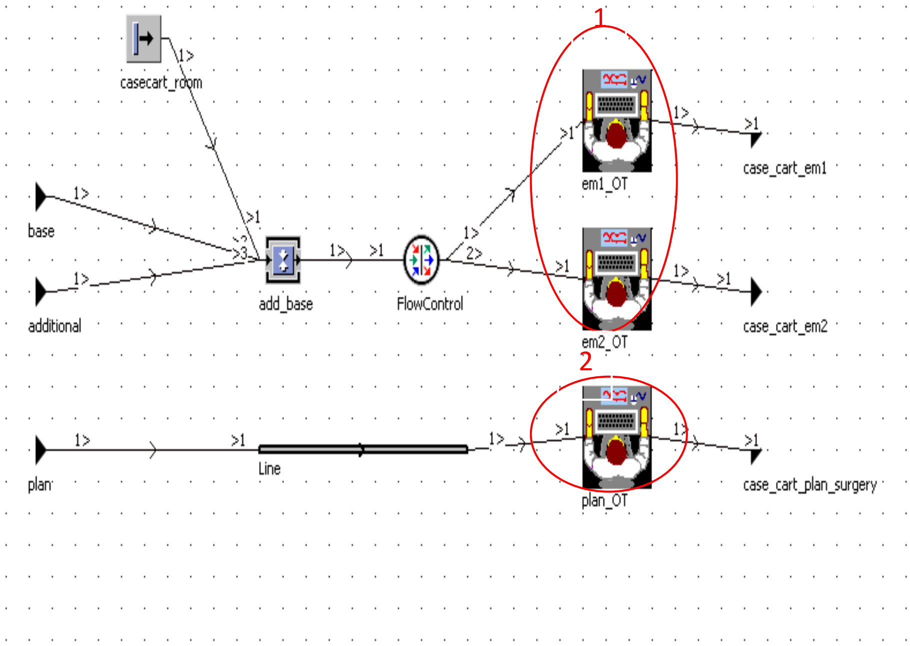


Figure 55 Use_instruments

In this case, the time indicated in the table 6.

Table 6 Use_instruments

Process or line	**Times & Capacity**
Base_additional	Time: 1:00
1) Em_OT1 **2) Em_OT2**	Total time: 35:00 Total time: 55:00
3) Plan_OT	Total time: 65:00
Line	Time: 1:00

Opening each window the content is shown as follows:

1) Emergency operation theatre

The first emergency room is indicated in the figure 56: here base and additional case cart are processed at the same time.

In this case is considered the task to throw the different single use instruments (3).At the same time the multiple use instruments continue their path. This is an important difference between the first and the second solutions. In the first solutions, indeed, the operation to throw the single use instruments was made in the window Quality Control.

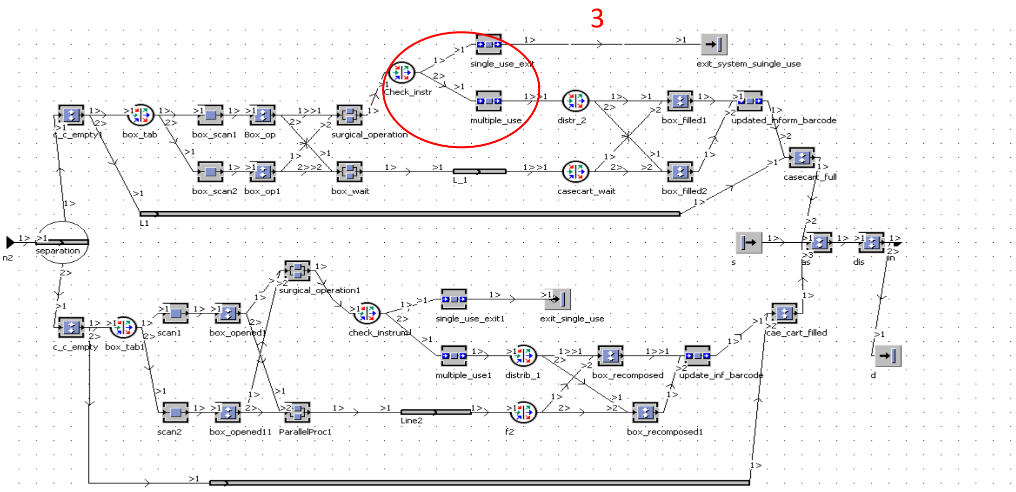


Figure 56 Emergency operation theatres

2) Plan surgery

The case of Plan surgery is different compared to the first solution. It remembers that in this case only one base case cart enters in the operation theatre. The tasks are indicated below: (figure 57).

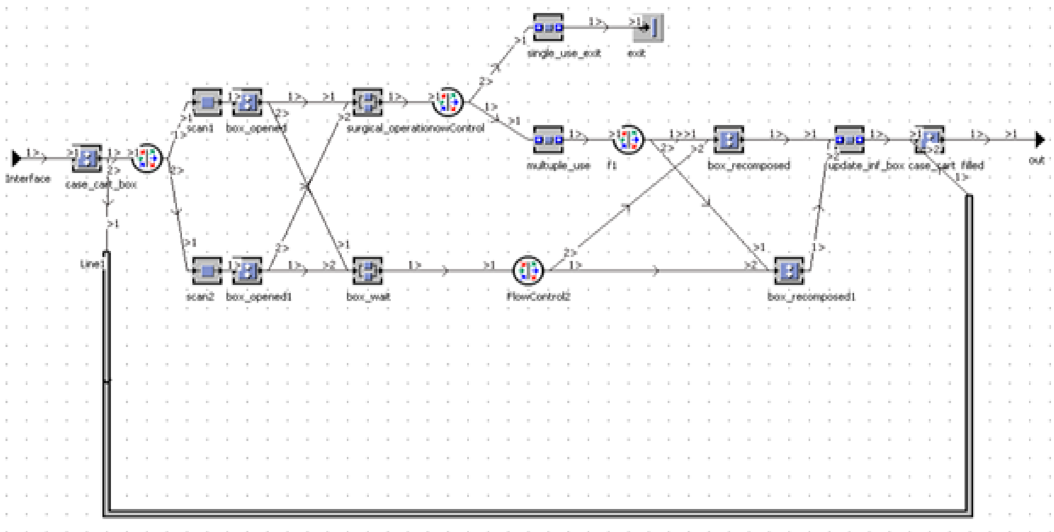


Figure 57 Plan surgery

In both cases are not indicated the times: it refers to the table 5 above.

Transport_instruments1 (5)

The case carts are transported to the area of cleaning. The different case carts are divided according their attribute and they are sent immediately to the area of cleaning (figure 58).

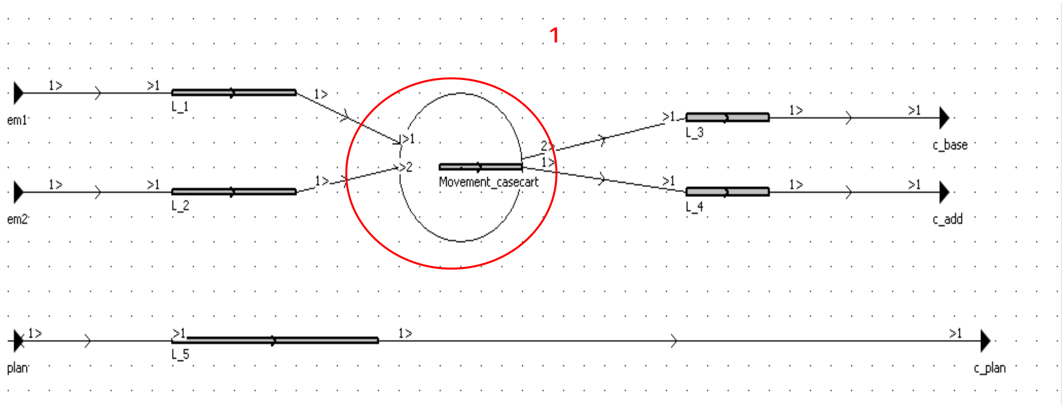


Figure 58 Transport instruments

In the first solution a elevator connected the two floors.

The times of each resource are indicated as follows:

Table 7 Transport_instruments

Process or Line	Times & Capacity
L_1	Time: 1:00
L_2	Time: 1:00
L_3	Time: 3:00
L_4	Time: 2:00
L_5	Time: 3:00

Clean_instruments1 (6)

The window 6 shows the Cleaning of instruments. Each case cart crosses the resource “sep_1”, “sep_2” and “sep_3 and the time is 1 minute. In this way all boxes are inserted to the area of cleaning where the process of cleaning is done (figure 59).

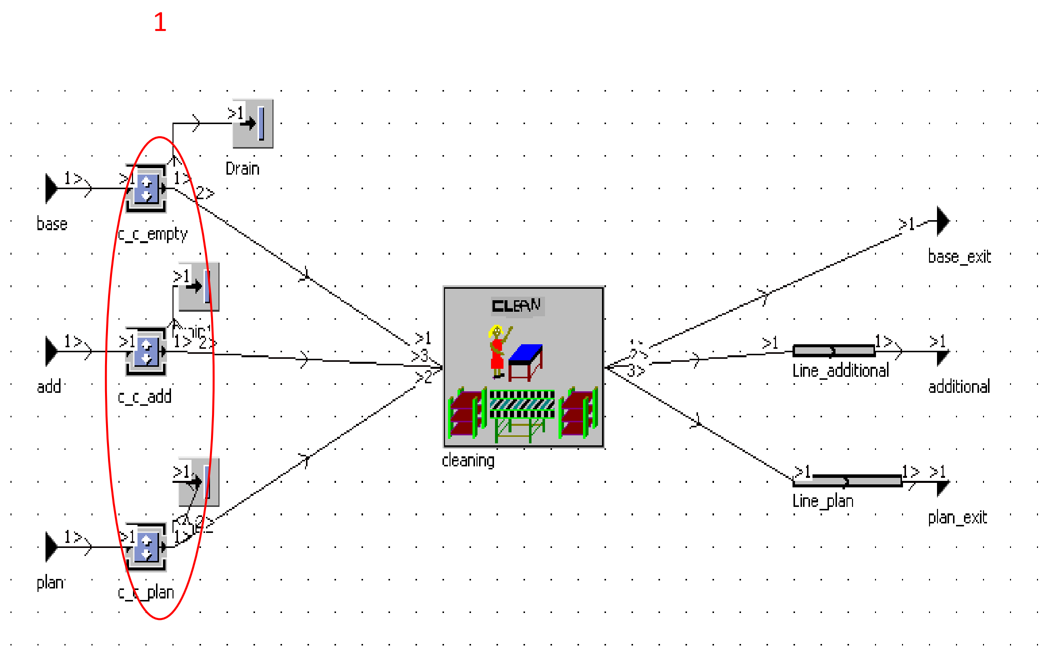


Figure 59 Clean_instruments

In this case of analysis the three case carts arrive in different moment and later they are processed in the area of cleaning.

Table 8 Clean instruments

Process or line	Time & Capacity
Line_additional/ Line_plan	Time: 3:00

The figure 60 shows the area of Cleaning and all processes that there are in this case of analysis. The process of cleaning is described as follows: in this section arrive the boxes that are cleaned according the parallel resource.

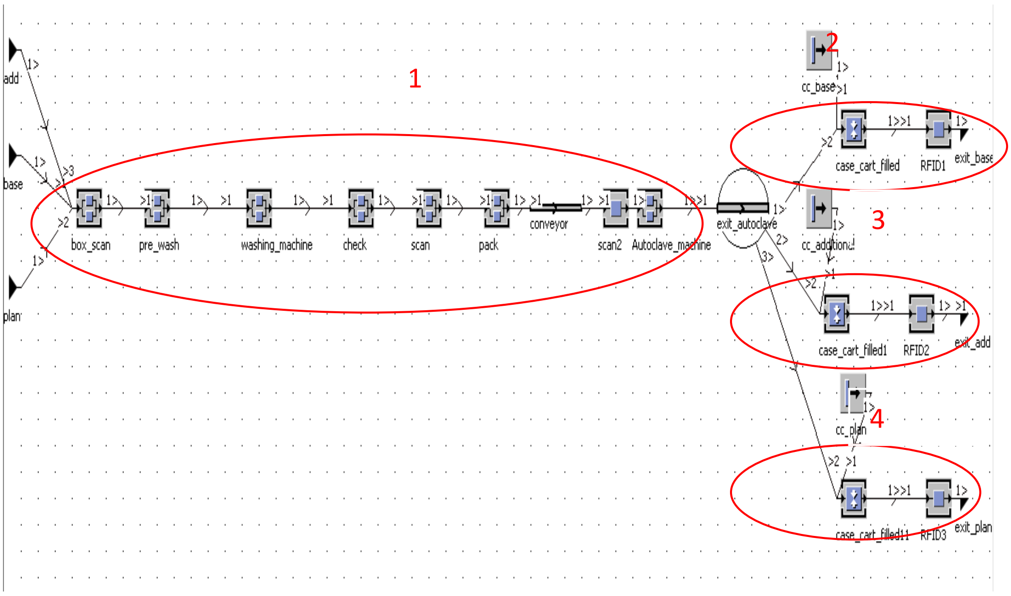


Figure 60 Cleaning1

In the circle 1 are considered all task that happen in area of cleaning: they represent a new process of cleaning. In this case the capacity of the resources is set at 6: in this way there isn't queue: The time of each task is described in the table below:

Table 9 Cleaning1

Process or line	**Time & Capacity**
box_scan	Capacity 6 Processing time: 1:00
pre_wash	Capacity 6 Processing time: 3:00

washing_machine	Capacity 6 Processing time: 30:00
Check	Capacity 6 Processing time: 2:00
Scan	Capacity 6 Processing time: 1:00
Pack	Capacity 6 Processing time: 3:00
Conveyor	Time 1:00
scan2	Time: 1:00
autoclave_machine	Capacity 6 Processing time: 45:00
exit_autoclave	Recovery time: 0:00
case_cart_filled	Processing time : 1:00
RFID1/2/3	Processing time: 1:00

The different case cart are moved in different area: the base boxes goes to the operation theatre where they wait long time. Later the box goes out to be inserted in the case cart. This is done in the first window Store_boxes. The additional and plan boxes are inserted inside the area of the retrieval storage where they are stored. Below the window 7 shows all processes.

Store_boxes (7)

The figure below shows the process of additional and plan case cart: they are inserted in the store boxes. The base boxes are moved to the area of operation theatre where they start again their path.

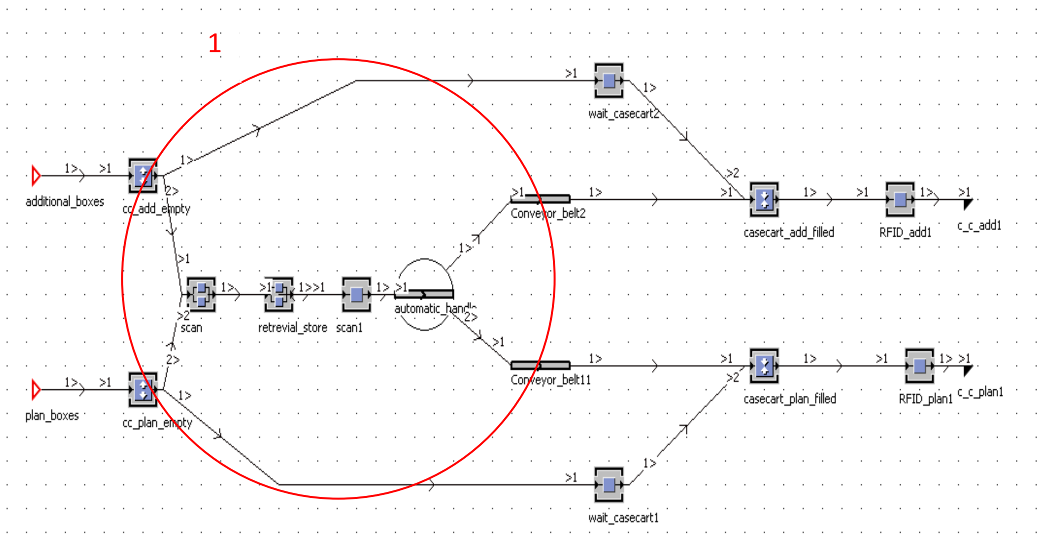


Figure 61 Retrieval _store

In the table below the different resources are taken into consideration and the times are set as follows:

Table 10 Retrievial_store

Process or line	Times & Capacity
cc_add_empty/cc_plan_emty	Processing time: 1:00
scan	Processing time 1:00
retrieval _store	Processing Time: 5:00
scan1	Time: 1:00
automatic handling	Time: 1:00
conveyor_belt/ belt1	Time: 0:05
casecart_add_filled	Processing time: 2:00
casecart_plan_filled	Processing time: 2:00
RFID_add/ plan	Time: 1:00

Later the plan and additional case carts are moved to the “Transport_boxes” where they restart the cycle again.

The key indicator to use to do the comparison is the Lead Time: it is important in order to understand how the cycle works if is taken into consideration this parameter. A lead time is the latency (delay) between the initiation and execution of a process. It is important in order to identify the main characteristic of the new system, if are considered the reduced time s of transport of item,

8.6 Lead time of the new solution

The main results about the Lead time are taken into consideration in this chapter. It remembers that each window is analyzed. In this analysis the different items are processed as follows. The table below shows the content of each window:

Table 11 Automatic store of additional case cart

	Start time	**Time to process all input**	**End time**
Retrieval _store	0	5:00	5:00
Scan	5:00	1:00	6:00
automatic handling	6:00	1:00	7:00
Conveyor_belt	7:00	0:05	7:00
Casecart_add_filled	7:00	2:00	9:00
RFID_add	9:00	1:00	10:00

In this section the total time to put the different item inside the additional case carts is 10 minutes.

Table 12 Transport_boxes1

	Start time	Time to process	End time
Line_ad	10:00	3:00	13:00
base_ addtional_room	13:00	2:00	15:00
Line 1	15:00	1:00	16:00

The additional boxes goes to the operation theatre where base case cart is arrived at minutes 7.

Table 13 Use_instrument: Operation_theatre

	Start time	Time to process	End time
Base_additional	7:00/16:00	2:00	18:00
Emergency Operation theatre 1	18:00	35:00	53:00

Both case carts are taken and later they are brought to the other window Transport_instruments: they are transported to the area of cleaning

Table 14 Transport_instruments

	Start time	Time to process all input	End time
L_1	53:00	1:00	54:00
L_3	54:00	3:00	57:00
L_4	55:00	2:00	57:00

The different items are moved to the area of cleaning to be moved through the resource “sep_1” and “sep_2” (Time 1:00), the different items are cleaned in the cleaning area. The times are set in this way.

Table 15 Cleaning area

	Start time	Time to proc-ess all input	End time
box_scan	58:0	1:00	59:00
pre_wash	59:0	2:00	61:00
washing_machine	61:0	30:00	1h 31
check	1h31	2:00	1h 33
scan	1h33	1:00	1h 34
pack	1h 34	3:00	1h 37
conveyor	1h 37	1:00	1h 38
scan2	1h 38	1:00	1h 39

autclave_machine	1h39	45:00	2h 24
exit_autoclave	2h24	1:00	2h 25
case_cart_filled	2h 25	1:00	2h 26/ 2h 28
RFID1/2	2h27/ 2h 28	1:00	2h 28/ 2h 30

After these tasks the base boxes are taken and moved to additional_base room: they across again the window Transport_boxes to restart the cycle again. For this reason the Lead time of base boxes is 2h 30 minutes. Otherwise the additional boxes are inserted in the Automatic Store. They are moved in 3 minutes "Line_additional" of the window "Cleaning".

Table 16 Store_boxes

	Start time	Time to proc-ess	End time
cc_add_empty	2h 30	1:00	2h 31
scan	2h 31	1:00	2h 32
retrieval _store	2h 32	5:00	2h37
scan	2h 37	1:0	2h 38
Automatic/handling	2h 38	1:00	2h 39
conveyor_belt/ belt1	2h 39	0.00	
casecart_add_filled	2h 40	2:00	2h 42
RFID_add	2h 42	1:00	2h 43/ 2h 45

The Lead time of the additional boxes is 2h 45. The additional case cart arrive there and restart the cycle again.

The situation changes when is involved the case of plan case cart. It is important because the path of the case cart is different compared to the other additional and base case cart. The time of each resource is explained as follows.

Table 17 Store_boxes

	Start time	**Time to process all input**	**End time**
Retrieval _store	0	5:00	5:00
Scan	5:00	1:00	6:00
automatic han-dling	6:00	1:00	7:00
Conveyor_belt1	7:00	0:05	7:00
Case-cart_plan_filled	7:00	2:00	9:00
RFID_plan	9:00	1:00	10:00

At this point the different items are moved to plan room. In this case the time to arrive in this room is higher the base_additional room if is followed the layout.

Table 18 Transport_boxes

	Start time	Time to process	End time
Line_plan	10:00	5:00	15:00
Plan_room	15:00	3:00	18:00

After this situation the different items are moved to the area of operation theatre: they arrive at different times and later they are moved to the other area. The times are shown as follows:

Table 19 Use_instruments_plan_boxes

	Start time	Time to process	End time
Line_plan	18:00	1:00	19:00
Plan_OT	19:00	61:00	1h 20

At this point the different item goes directly to the area of cleaning where they are processed:

Table 20 Transport_ instruments

	Start time	Time to process	End time
L5	1h 20	3:00	1h 23

The different items go directly to the area of cleaning where they are processed.

Table 21 cleaning area

	Start time	Time to process all input	End time
box_scan	1h 24	1:00	1h 25
pre_was	1h 25	3:00	1h 28
washing_machine	1h 28	30:00	1h 58
check	1h 58	2:00	2
scan	2	1:00	2h 01
pack	2h 01	3:00	2h 04
conveyor	2h 04	1:00	2h:05
scan2	2h 05	1:09	2h 06
autoclave_machine	2h 06	45:00	2h 51
exit_autoclave	2h 51	1:00	2h 52
case_cart_filled	2h 52	1:00	2h 53

RFID1/2	2h 53	1:00	2h 54

The plan boxes are moved to the area of Automatic store: here the boxes are processed and in 3 minutes arrives in Automatic store in 2h 57 minutes.

Table 22 Store_boxes

	Start time	**Time to process**	**End time**
cc_plan_empty	2h 57	1:00	2h 58
scan	2h 58	1:00	2h 59
retrieval _store	2h 59	5:00	3h 04
scan	3h 04	1:00	3h 05
automatic handling	3h 05	1:00	3h 06
conveyor_belt1	3h 06	0.05	
casecart_plan_filled	3h 06	2:00	3h 08
RFID_add	3h 08	1:00	3h09/ 3h10

The Lead time of plan boxes is 3h 10.

When the second operation theatre is used, the lead time incremented of 15 minutes: for this reason the lead time of “Base boxes” becomes 2h 45 and of “Additional boxes” 3h.

In the table below, they are shown the times of the first solution. The times of main resources are explained as follows.

Table 23 First solution

Resource	Start time	Time to process input	End time
STORE_BOXES			
Buffer	0	6	6
Select_box	6	12	18
Case_cart_filled	18	2	**20**
TRANSPORT_BOXES			
Area	20	1	21
Elevator_case_cart	21	1	22
Elevator	22	2	24

Case_cart_el	24	1	25
SP1	25	5	**<u>30</u>**
<u>USE_INSTRUMENTS</u>			
Choice_box	30		
OT1		35	
OT2	Parallel tasks	45	
OT3		60	
Stop_2		1	
Assembly	1h 36	3	**<u>1h 39</u>**
<u>TRANSPORT_ INSTRUMENTS</u>			
Elevator_casecart	1h 39	1	1h 40
twoLane_track	1h 40	4	1h 44
sep_elev_case_Cart	1h 44	5	**<u>1h 49</u>**
<u>CLEAN INSTRUMENTS</u>			
Hall_CSSD	1h 49	5	1h 54
Sep_case_cart	1h 54	0	1h 54

<u>QUALITY CONTROL OF THE INSTRU-MENTS</u>			
Process_quality contol	1h 54	30	2h 24
<u>CLEANING1</u>			
Pre-washing	2h 2	115	2h 39
Washing	2h 39	30	3h 9
Check	3h 9	5	3h 14
Packaging	3h 14	15	3h 29
Autoclave	3h 29	45	4 h 14
<u>STORAGE_BOXES</u>			
Sep_case_cart	4h 14	2	4h 14
b_box	4h 14	6	4h 20
b_casecart	4h 14	6	4h 20
TOTAL TIME			**<u>4h 20</u>**

The total time to do the different task is 5 hour. It represents the lead time of the cycle or the time to the latency (delay) between the initiation and execution of a process.

At the end of this analysis the Lead time are explained as follows:

Table 24 Lead time

	Lead time
First solution	4h 20
New solution	
Base boxes	2h 20
Additional boxes	2h 45
Plan boxes	3h 10

As is possible to see in the table above the reduced Lead time reflects the optical Lean of the new system. It remembers that in this new solution is considered the idea to have a maximum capacity of the resource: it think in cleaning area the capacity of each resource is 6 (it reflects the number of boxes inside the system). It also remembers that the choice to considers the times of resources is due to satisfy a request of operation theatre: it supposed that 5 surgical operation are required per day. Any considerations about the Lead time and the main improvement of the new solution, are explained below in the chapter Discussion.

9 Discussion

I n the following section, a discussion of the new solution is done. The chapter will be hence focused on analyzing the effects brought if the lean principles are applied in the new system.

Before to enter in the treatment, it is important to highlight the hypothesis done.

In the new solution the acute and plan demand s is satisfied and reflects the real case that happens in the hospital. To achieve this goal, three case carts (“base”, “additional”, “plan”) are supposed. In this way the importance of the case cart is underlined because represents a small store to contain a right number of items to utilize and to transport very fast the items from one area to another one. Compared to the first solution, only one case cart has been considered: 1 case cart is dimensioned to host the boxes to utilize for 3 surgical operation.

Another consideration to do is the use of two kinds of case carts to decrease the fatigue of employees to lift the heavy boxes and to guarantee a reduction of time; the use of a lift elevator tries to facilitate the lift of the item in both case carts reducing the time. This is an important innovation introduced to solve the problem in Gentofte and Herlev hospital.

Other this main hypothesis, the use of barcode and RFID to keep track of the items is another aspect highlighted in the new solution. It thinks about RFID reader, to have track of the case cart and the barcode label attached on the boxes. The use of these devices helps to keep track in every moment of the items and guarantees that the information s are always updated. It thinks about the content of the boxes in each phase and the the position of the boxes in the system. These important hypothesis represent an improvement of the first solution.

Before to enter to describe the benefits of the simulation ,through the analysis of the parameter Lead time, the two Value Stream Mapping could be compared as follows. This is done to highlight the decreasing of the waste in the second solution.

It preferred to compare three phases of the cycle: “the selection of the box in the store”, the “transport of the case cart toward the operation theatre or cleaning area” and “the cleaning of the instruments “.

The phase “Select of boxes in the store”, includes a several waste in the first solution. All that because in the first solution is considered a manual movement of the case cart in the store. The use of retrieval store ,indeed, allows saving the time to search of items, decreasing the waste due to movement of case cart and the fatigue of employees. Through the retrieval store the request directly on a computer: in this way is saved the time and the only physical operation to do in this case are the scan of the movement of case cart close RFID reader.

About “the movement of the case cart toward the operation theatre”, in the new solution, it is not considered an elevator to transport the items, but the case cart is directly sent to the different area because there is only one floor. Certainly this hypothesis was done only to decrease the time to transport additional case cart: they should arrive in the operation theatre in short time. In this way the tasks “call elevator”, ”wait elevator” are avoided and replaced with a direct movement of the case cart toward the different area. In this case of analysis, the Value add task are replaced with the traceability is guaranteed when the case cart are moved close the RFID reader. Certainly the use of elevator facilities, in term of fatigue, the movement of case cart, but allows high time to transport the item.

In the cleaning area it supposes to reduce the waste eliminating is the Quality Control (the control to throw the single use instrument) and introducing new value add task to track the items: they represent the new value add task.

These consideration reflects on Lead time of each case cart. A table below shows the principle changing in term of time:

Table 25 Time saved

	Lead time first solution	**Lead time second solution**
Select box	20’ (Manually)	10’ (Automatic)
Movement case cart	10’	5/6/7’
Cleaning phase	2h 25	1h 30
Quality control	30’	During surgical operation

According these data the new hypothesis reflect on the total Lead time of the three case carts and underline how the lean principle help to guarantee the advantages on times: the base carts have a Lead time of 2h 30 and it is moved directly to operation theatres without to be stored to the retrieval store.

Otherwise the Additional case cart has time 2h 45 because it supposed to consider a store in retrieval store; the plan surgery case cart has a lead time of 3h 10. It remembers that these times are supposed to guarantee 5 surgical operation per day.

To guarantee that this system works, another consideration is that 5S should be applied: firstly it should eliminate all unnecessary tools, parts, and instructions and keep only essential items in the system. It advices to do this task in the store where the item could increase; each items should be identify in the system without problem. The places should be clean, tidy and organized. In this case all work stations for a particular job should be identical. All employees doing the same job should be able to work in any station with the same tools, maintaining and re-viewing standards.

10 Conclusion

The beginning of the project was directed at observation of the two real lifecycle of surgical instruments in the two hospital of the capital: Herlev and Gentofte hospital. According the gathered information a first mapping of an ideal cycle was done through the method $IDEF_0$ (an important tool to show the phases of the cycle in a hierarchical scheme), the Value stream mapping, the tool to highlight the main Muda of the cycle and a simulator Tecnomatix to underline a dynamic point of view of the cycle.

In this perspective in the first solution 1 case cart with 6 boxes was dimensioned in order to satisfy the request of 3 operation theatres. In each operation theatre 2 boxes were utilized. The idea to use one case cart was done in order to satisfy 6 Surgical operations per day. Another hypothesis was a manual store of the boxes and the movement of the boxes through an elevator that connected the store , cleaning area and Operation theatres. In other words was supposed a layout similar to Gentofte hospital.

The tool “Value stream mapping” highlighted the main wastes of the cycle in particular phases: precisely during the manual store of items (it thinks the manual movement of the case cart in the store and the tasks to search the items to pick up) , a high number of tasks to move the case cart toward the Operation theatre and several tasks during the cleaning phase (it was supposed the Quality Control-phase to throw the single use instruments, during the phase of cleaning).

Later a new cycle was created exactly applying Lean thinking principles. It was applied the Poke Yoke method and was introduced the traceability of the items. The Poke yoke method was applied proposing the utilization of two types of case carts (one case cart for heavy boxes and one normal one) and a lift elevator to facilitate the insertion of the tray inside the case cart. At the same time, in the new solution was proposed the traceability of the different items: it thinks the use of a barcode of the boxes and a RFID reader . In the new system was also considered acute and plan cases to describe a real cases that happen in the hospital. For this reason, it was supposed the use of three case carts to satisfy the request of the item: a base case cart (it was always available in the operation theatre and it contained basic instruments) and additional case cart (it contained the additional instruments required when was available the diagnosis of the patients) and a plan case cart to satisfy the request of plan surgery. To eliminate the main wastes highlighted in the first Value stream mapping, another improvement regarded the use of a retrieval store to guarantee an automatic store or picking of the boxes.

In this perspective the new system was mapped through the Value stream mapping and the simulator Tecnomatix.

An analysis of the Lead time of the three case carts was done : it highlighted the main advantages of the new solution. The main advantages in term of time were identified in three main areas:

- Store: the operation of picking and storage of boxes was done in 10 minutes in the second solution; in the first solution was done in 20 minutes;
- The movement of the case cart from store to operation theatre (all of these located in one floor) was supposed in 5/ 6 minutes; in the first solution 10 minutes were hypothesized (an elevator connected store and operation theatres located in two different floors);

- The cleaning phase was reduced at 1h 30 compared to 2h 30: all that because the phase quality control (the phase to throw single use instruments) was included during the surgical operation.

These advantages were reflected on total lead times of the three case carts. To make the system more efficient, it also was suggested to use 5S method of lean thinking in order to guarantee a new organization of work station.

Other actions could be undertaken in order to better handle surgical instruments: increase or de-crease the number of input, increase or decrease the resources, accelerate some process, render the system more flexible.

Before deciding what actions undertake in order to render the system more efficient, is fundamental to start defining base actions that can help to identify a new way to manage the instruments: for example to decide to utilize three kind of case carts to satisfy acute and plan cases, some device to solve some real problems and speed some phase of cycle (case cart for heavy box, normal case cart, lift elevator, RFID reader ,barcode, automatic store) etc.. in other words provide a base back-ground of necessary improvements, valuated in terms of time, that help better handle the life cycle of surgical instruments.

11 Recommendation

In this last chapter some recommendation is provided to Herlev and Gentofte hospitals:

During the visit at the hospitals, few things were noticed:

- The problem of lifting and insertion of heavy trays inside the case carts (Gentofte and Herlev hostpial);
- High decentralization between central cleaning area and departments/ Operation theatres (Herlev hospital);
- Low traceability of the items in Herlev hospital during the movement of the case carts;
- The system is not so much flexible.

The first step to solve the problem of heavy box is the use of two kind of case carts and a lift elevator to lift the tray. In this way the fatigue of employees is avoided and is decreased the time to insert the different boxes in the case cart.

Another advice to Herlev hospital is the use of RFID reader : it helps to track in each moment the location of the case cart and avoids the loss of them during its path.

In order to speed up the request of case cart to emergency room, it advices at both hospitals the use of a base case carts. It should be always in emergency operation theatre created directly in cleaning area in order to decrease the waiting time of operation theatre (Just in time).

Because it is not simple to introduce these advices, the first step consists in understanding the need of these changes. It is important to point out that this changing will bring huge advantages to the hospital in the medium long period and make their daily work easier. The manager should be convinced before to introduce and train the other workers and explain the effects of these devices. After that he can train the workers and show the new way to manage the cycle of surgical instruments. Only when the workers have been educated, the new system can be implemented. In this phase each workers has to performed the procedures in a certain way and respect the new working rules.

The workers can propose new solutions to a commission composed of people with different background, skills and experience. In this way several idea can be proposed and an information flow can be guaranteed.

It is possible to conclude that these innovations can better handle of surgical instruments and to solve the problem of the Herlev and Gentofte hospital only if they are implemented through these actions.

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